MTO DESIGN SUPPLEMENT

FOR

TAC GEOMETRIC DESIGN GUIDE (GDG) FOR CANADIAN ROADS

JUNE 2023

STANDARDS and CONTRACTS BRANCH
HIGHWAY DESIGN OFFICE

DISCLAIMER

The information provided in the MTO Design Supplement (DS) should not be relied upon as grounds for establishing civil liability.

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MTO Design Supplement
Preface

Background

In 2017, the Transportation Association of Canada (TAC) released the Geometric Design Guide (GDG) for Canadian Roads, replacing the previous 1999 iteration, which contains updated design guidance information, standards including the addition of human factors and emphasizes on the safety in design.

The GDG for Canadian Roads originally released in June 2017 consists of ten chapters, with future chapters planned. Later in spring of 2020 chapter 11 was added. While TAC GDG was developed with MTO participation, it is difficult to develop guidance and standards that are equally applicable across Canada due to differing limiting factors and design demands across the nation. As a result, jurisdiction-specific supplements may be required. With this in mind, there exist certain aspects of the TAC GDG which may not be suitable for roads and highways under MTO jurisdiction or where additional guidance is required.

To address these areas of the TAC GDG, MTO reviewed the guide and compared it against pre-existing manuals, guidelines and policies (e.g., Geometric Design Standards for Ontario Highways (GDSOH), Capacity Analysis Manual, Highway Corridor Management Manual, Illumination Policy, Ontario Traffic Manuals, Roadside Design Manual and various Design Policy Memos etc.) to determine if there was conflicting, missing or repetitive guidance between TAC GDG and MTO. If any conflicting or missing information was found, proper guidance, standards or policies were provided, and compiled in this document, being the MTO Design Supplement (DS) for the TAC GDG for Canadian Roads.

Each Chapter of the TAC GDG has been reviewed and supplemental design guidance on each chapter is provided in this document, being the MTO DS. The MTO DS is intended to be read in conjunction with the TAC GDG to aid designers in completing the design of provincial highways or roads crossing or constructed within the right-of-ways of provincial highways. Anywhere that conflicting information between the TAC GDG and MTO DS exists, the MTO DS takes precedence.

Organization of the Design Supplement

The MTO DS consists of 16 Appendices. Appendices 1 to 8, 10, and 11 correspond to chapters 1 to 8, 10, and 11 of the TAC GDG respectively. While Appendices 9 and 9A correspond to chapter 9 of the TAC GDG. Appendix 12 is developed by the ministry for providing guidance on “Managed Lanes” which is not currently available from TAC. Appendix 13 is a place holder for a chapter on “Work Zones”. This chapter is being developed by the ministry and currently under review. Once review is completed the chapter of Work Zines will be implemented. Appendices A and B are for the comprehensive Glossary and MTO Geometric Design Standards Summary Tables respectively.

How to use the Design Supplement

By default, the TAC GDG is the Guide to be used for geometric design of provincial highways unless otherwise stated in the MTO DS.

Two chapters of the TAC GDG *Chapter 5 – Bicycle Integrated Design and Chapter 7 – Roadside Design* are Not Applicable for design guidance of provincial highways. These Chapters are replaced with the Bikeway Design Manual (originally issued in March 2014) and Roadside Design Manual (originally issued in December 2017 and subsequent editions of 2020 and 2023). The user shall ensure they are referring to the latest version of each manual and this supplement.

Some individual Sections, Figures, and Tables in all chapters of the TAC GDG are either fully or partially Not Applicable and should not be used for design guidance.

Some individual Sections, Figures, and Tables in all chapters of the TAC GDG are Not Applicable and are replaced with substitute guidance. The substitute guidance should be used.

Some individual Sections, Figures, and Tables in all chapters of the TAC GDG are Applicable with additional guidance. This additional guidance should be read and applied in conjunction with relevant Sections, Figures, and Tables.

Some individual Sections, Figures, and Tables in all chapters of the TAC GDG are Applicable with slight modification. The modified guidance should be read and applied in conjunction with relevant Sections, Figures, and Tables.

While TAC originally published ten new chapters in June 2017 all with the same release date, they were published as individual chapters and are being updated separately. In addition, Chapter 11 was added in 2020. The MTO DS Appendices 1 through 10 are developed to apply to the release date version of June 2017 while chapter 11 for Mar 2020 of the TAC GDG.

MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 1 for Chapter 1

Design Philosophy

June 2023

MTO Design Supplement
Appendix 1 for Chapter 1
Design Philosophy

The following design supplements are applicable to *Chapter 1 – Design Philosophy* of the *TAC Geometric Design Guide for Canadian Roads - June 2017:*

Section 1.1.2 – The Use of Standards and Guidelines

- This section is Applicable with the following additional Guidance:

  Policy
  In various places the designer will see reference to "policy". Policy is specific direction given for ministry projects. Policy may be related to the specific application of a standard or guideline or relate to a design approach. Policy may be specifically outlined in this supplement or may be issued in the form of a *Directive* or a *Provincial Engineering Memorandum*. It is the designer's responsibility to be familiar with current policy and its application.

  Any policy in Provincial Engineering Memorandums issued after the date of the last update of this document supersedes what is contained in this document and shall be followed.

Section 1.1.7 - Rehabilitation Design

- This section is Applicable with the following additional Guidance:

  Policy
  The following policy provides direction on the scope of work that is to be included in rehabilitation projects to assist the regions with the delivery of their Major and Minor Capital Programs and ensure a consistent provincial approach. Work performed under the Minor Capital and Day Labour program shall also follow the direction of this policy. This direction also applies to Contracts and Maintenance resources that may be required to consider additional work beyond the original design of the project.

Project Focus

- All commitments of the Northern and Southern Ontario Highways Programs (N/SOHP) must be delivered as scheduled. Additional work beyond the commitments of the N/SOHP, including warranted improvements to these projects, shall only be considered on an exception basis.
- Existing highways and bridges will maintain their present configuration.
- Projects shall focus expenditures on bridges and pavements.
- A cost-effective pavement structure suitable for the expected volumes and loading and corresponding drainage system shall be maintained.
- Structural integrity of the pavement should not be compromised – shoulder construction, subgrade improvements, frost heave repairs, and a sound drainage system are required to ensure pavement integrity.

Standard Application

- Many highways function well with their current geometrics and non-standard elements. The intent is to improve the structural integrity of the highway by maintaining the existing shoulder and lane platform.
- Other Major Capital improvements, including cost-shared improvements with developers and municipalities shall only be considered by exception and upon agreement by the Integrated Deliver Team (IDT) to ensure provincial consistency.
- All improvements that have been deferred shall be recorded and retained for future programming.

Section 1.1.8 - Value Engineering

- This section is Applicable with the following additional Guidance:

Policy

Mandatory Studies

Value Engineering studies are required on the following project types, unless exempted:

- Route Planning Studies
- Preliminary Design Studies for expansion projects over $20 million
- Preliminary Design or Detail Design projects of individual structures over $10 million, when they meet one or more criteria in the Recommended Projects for Consideration for a VE Study

Where an individual work project meets the mandatory requirements for a VE study, it can only be exempted on the approval of the responsible Manager, Engineering.

Recommended Projects for Consideration for a VE Study

Value Engineering Studies should also be considered for projects with technical challenges, complicated functional requirements, or complex external issues. These projects provide the greatest opportunities for improved value. Examples of candidate projects for consideration are:

- New interchanges
- High complexity reconstruction
- Complex (multi-span) bridge rehabilitation
- Projects involving multiple construction contracts
- Projects involving complex or conflicting stakeholder issues, where a workshop could support communication and decision making
- Projects with significant environmental, utility, geotechnical or foundations requirements
- Projects over $10 million that involve significant infrastructure modifications such as:
    - Complex intersections
    - Significant storm drainage works
- Design-Build Major projects over $20 million
- Projects with unique safety challenges
- Multi-modal and multi-use projects
- Major policies, standards, procedures, and business processes

Annual VE Program

Each Region must prepare and submit an annual program for VE projects during the third fiscal quarter. The responsible Manager must approve and sign the program. The program will list projects where a VE study is to be scheduled over the subsequent two-year period. The Program is to be submitted to the Highway Design Office.

Exemption of Mandatory Studies

On an annual basis, mandatory studies must be documented on the VE Projects Annual Program to indicate those projects that will have a VE study completed, and those projects exempted from a VE study.

VE Study Finalization

For each study, a VE study implementation meeting shall be held. The responsible Manager will make the final decision on the disposition of all VE study recommendations. The VE study recommendation decisions and study finalization form shall be forwarded to the Highway Design Office.

Application of Value Engineering Concepts and Tools in Day-to-Day Project Management

In addition to VE studies on projects, there are a variety of creative and analytical procedures used in VE workshops that can also be used within projects, meetings, and other day-to-day activities to support project analysis and decision-making. Information and assistance on these methods are available on the MTO Technical Publication website, and through Regional Value Engineering Coordinators.

Timing of VE Studies

Guidance for the timing of VE studies is available through the Highway Design Office.

VE Study Duration and Independence

Guidance for the duration of VE Studies and the importance of team independence is available through the Highway Design Office.

Section 1.2.3 Design Decisions

- This section is Applicable with the following additional Guidance:

  Designers should note that “standards” do not necessarily mean “best” nor are standards intended to be a substitute for engineering judgement and context-specific considerations to ensure that designs address the needs of all road users and the overall operation and safety of the facility.

Nominal Versus Substantive Safety

Nominal safety refers to ensuring that the design features meet minimum design standards, however this does not examine the actual or expected safety performance of a highway facility. Substantive safety refers to the expect and/or estimated long-term average safety performance of the highway. This takes into consideration the following quantitative measures:

- Collision Types,
- Collison Frequency
- Collison Severity

This is done to aid designers in making appropriate design decisions to addressing operational and safety issues pertaining to a specific section of the highway facility.

When making design decisions, it is important to consider both nominal and substantive safety of the facility.

Design Exemptions

A design exemption is a documented decision related to design elements of a highway facility to a degree that does not meet minimum standard values or ranges. The purpose of design exemptions is to permit deviations from normal design standards based upon project specific conditions and constraints making typical standards not practical and/or appropriate. A design exemption may be considered for a variety of reasons including but not limited to:

- Environmental Impacts
- Construction or Right of Way Costs
- Social Impacts

Please refer to Section 1.5.3 Design Exception Process of the *TAC Geometric Design Guide for Canadian Road – Chapter 1* as well as the additional guidance provided in Section 1.5.3 Design Exception Process of this *TAC Geometric Design Guide for Canadian*

Road – MTO Design Supplement, for more information on how to handle design exemptions and the approval process.

Performance-Based Design

Performance can be an important factor in establishing the purpose and needs of a given project. The performance-based design approach can help focus a designer on addressing the needs of a project and limiting the project scope to focus on documented performance improvement needs.

The data that may be available for performance-based design includes:

- Past performance data (typically from collision reports); and,
- Forecasts of future performance.

Performance-based design can be taken for granted as on the surface it can be perceived as part of the regular design process. However, the designer, particularly on re-construction projects, should specifically consider performance in major design decisions. Performance is also a factor in the Design Exception Process (see Section 1.5.3).

The assessment of performance is not an exact science and available tools often need some engineering judgement applied.

Some jurisdictions or designers may also refer to this as "Practical Design".

For more information on performance-based design please refer to Section 1.2 of the *American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, 2018 "The Green Book" (AASHTO – Green Book)*.

Desirable Versus Acceptable Design

For operational and safety considerations, the design speed should desirably be 20 km/h greater than the posted speed. An acceptable relation is one where the design speed equals the posted speed.

The decision for desirable versus acceptable, usually depends on the economics of achieving the additional margin of safety and capacity normally associated with the desirable design. Of course, a “desirable” design is always preferred over an “acceptable” design if economics are not a consideration. There are circumstances, however, where conditions warrant the use of the acceptable design speed. Acceptable design speeds may be appropriate where the highway is a minor link in the system. For these types of roads, operating speeds are in the low to medium range, and traffic volumes are expected to remain at low levels for the foreseeable future. Although the highway fulfils a provincial mandate in terms of public service, the low speeds and traffic volumes justify consideration of the “acceptable” design standard. A similar analogy can be drawn for the values chosen for other geometric design parameters.

Every effort should be made to use the desirable standard on freeways, arterials and major collectors which are generally important links in the highway system. These roads normally carry significant traffic volumes at medium to high speeds. Considering the service life and function expected of these highways, desirable standards are the preferred alternative. However, achieving the desirable standard is not always practical or realistic when faced with terrain, urban development, and economic factors. Sound engineering judgement is required.

Whether design speed or another design parameter is under debate, the highway designer must never lose sight of the overall objective – to create a safe, efficient, and economical transportation system. Several concepts for improved design have been developed which directly support this goal. These include design consistency and uniformity as well as context sensitive design and performance-based design.
Design consistency has been defined as the condition which exists when the geometric features of the roadway are consistent with the operational characteristics as determined by what the driver expects of the roadway ahead and what they are willing to accept in terms of operational quality.

The concept of operational uniformity is similar in nature to that of consistency. It refers to a consistent arrangement of geometric features, exists and entrances that reinforce the driver’s confidence or expectancy.

Consistency and uniformity of design standards place the driver in an environment which is fundamentally safer because it is more likely to compensate for the driving errors that are inevitably made.

Guidelines for Geometric Design of Municipal Roadways within Provincial Highway Right-of-Ways

Policy

For planning and geometric design of municipal roadways crossing provincial highways within (and immediately adjacent to) provincial highway right-of-ways:

- For new municipal crossing roads and bridges, and widening of existing municipal roads and bridges, design should be in accordance with the *TAC Geometric Design Guide for Canadian Roads* and the *MTO Design Supplement.*
- In constrained areas consideration may be given to using alternative design standards or aspects at the lower end of our design domain.
- For rehabilitation of existing municipal crossing roads and bridges, consideration may be given to using the local municipal road design guidelines issued by the municipality's engineering department or the *TAC Geometric Design Guide for Canadian Roads*.
- For new municipal crossing roads and bridges, and widening of existing municipal roads and bridges, consideration may also be given to using the local municipal road design guidelines issued by the municipality's engineering department or the *TAC Geometric Design Guide for Canadian Roads*. This would be appropriate in the situation where certain geometric features, such as lane width, are consistent at the other standard for a reasonable distance on either side of the provincial project.
- Where the municipality proposes to use their design guidelines or the *TAC Geometric Design Guide for Canadian Roads* for design of the municipal roadway within the provincial highway right-of-way, formal request in writing shall be submitted to MTO along with indemnification.
- Where MTO proposes to use parameters from within the design domain in the *TAC Geometric Design Guide* indemnification is not required.

Guidance for Choice of Municipal Design Parameters

In applying engineering judgement to choose the design parameters for rehabilitation of existing municipal crossing roads and bridges, the following considerations should be applied in this order:

1. Use design parameters in accordance with the *TAC Geometric Design Guide for Canadian Roads* and the *MTO Design Supplement*.
2. If width is an issue, look at reallocation of road space as follows:
    a. Consider narrowing features such as centre islands and shoulders as much as possible.
    b. Consider narrowing sidewalks to the minimum allowed by AODA standards.
    c. Considering narrowing lanes to meet widths in the *TAC Geometric Design Guide for Canadian Roads.*
    d. Consider eliminating shoulders and gutter pan offsets.
3. For all features consider using the local municipal road design guidelines issued by the municipality's engineering department.
4. Consider design parameters from standards or guidelines published by another North American jurisdiction with similar climate and operating characteristics.

Section 1.3.2.4 - The Cost of Collisions

- This section is Applicable with the following additional Guidance:

  The collision costs used for calculations on Ontario highway projects shall be as per the Traffic Office Memo for "Collision Costs in Engineering Analyses Updated" August 3, 2012, and shown in **Exhibit-1A**.

  Currently, Provincial Traffic Office is updating the collision cost in consultation with the ministry's Transportation Safety Division. The designer should contact the Provincial Traffic Office for the latest figures for collision cost analyses.

Exhibit- 1A

Collision Cost for Engineering Analyses

Collision Severity	Updated Values (2011$)
Fatal (K)	$1,582,000
Disability / Major Injury (A)	$142,000
Evident / Minor Injury (B)	$53,000
Possible Minimal Injury (C)	$36,000
Injury (A/B/C)	$59,000
Property Damage Only (O)	$8,000

Section 1.3.3 – Environmental Impacts and Aesthetics

- This section is Applicable with the following additional Guidance:

Climate Change

It has become more important in recent years to consider climate change impacts in design standards. In a previous approach to highway design, designers relied on climate factors being consistent for a given area, and while this approach worked for many years, changes in climatic patterns have resulted in extreme weather events occurring more frequently and at increased severities. Due to climate change, historical climate is no longer a reliable predictor of future risk. Highway designers should be aware of these predicted changes and take the factors and risks into consideration when making decisions.

Types of Extreme Weather in Ontario

Ontario is a large province; the weather can vary greatly depending on the season and location. Summers in southern Ontario can be extremely warm and humid with high temperatures. The northern part of the province has longer and colder winters than southern Ontario. Climate change is expected to have a fundamental impact on the transportation system in northern Ontario through severe weather and unsuitable conditions for winter roads. Climate change is expected to have a disproportionate impact on the far north and its many remote communities.

Ontario experiences a wide variety of weather hazards across the province including:

- extreme rainfall, freezing rain, hail
- tropical storms and hurricanes

- floods and flash floods
- mudslides
- permafrost degradation
- melting snow / ice jams causing flooding
- extreme heat / extreme cold including temperature fluctuations
- droughts
- forest fires
- damaging winds and tornadoes

Extreme Weather Impacts on Highway Infrastructure

Highway designers should be aware that weather patterns are shifting, and events are becoming more extreme. These factors and risks should be taken into consideration when making design decisions. It is important to consider the resultant impacts on the road network and its users. Extreme weather and prolonged impacts from climate change can:

- damage infrastructure, shortening the life expectancy of highways, bridges, and other roadside features
- disrupt the continuity of the road network and make routes impassable
- cause delays in the movement of people, services, and goods
- increase collision risk and driver frustration from hazardous conditions – poor visibility and slippery conditions, etc.
- increase the frequency of maintenance and rehabilitation resulting in increased costs
- overwhelm the capacity of drainage infrastructure
- weaken or wash out soil and culverts that support roads, tunnels, and bridges
- limit and delay construction activities

Challenges for Climate Change Consideration in Provincial Highway Management

The development of climate change solutions requires the consideration of several economic, environmental, and social factors to ensure that ideas can proceed effectively. This involves bringing attention to several challenges including:

- economic viability of measures
- industry capacity to respond to new requirements
- development of new specifications and contract requirements
- stakeholder consultation
- building public awareness

- retraining staff
- quantification and tracking of greenhouse gases

To combat climate change, it is important to take an approach that includes both mitigative and adaptive approaches.

Climate Change - Adaptation

Adaptation means managing the impacts of the changing climate. This includes:

- Ensuring transportation infrastructure is resilient and able to adapt to the effects of climate change including extreme weather events
- Avoiding or withstanding climate impacts
- Designing, constructing, and operating facilities for future weather trends (beyond historical)

Adaptation is important:

- To ensure the continual movement of people and goods safely, efficiently, and sustainably to support a globally competitive economy and a high quality of life
- To minimize health & safety risks
- To extend the longevity of infrastructure and offset future rehabilitation
- To minimize financial impacts

An example of adaptation could be designing an interchange to have the primary road go over the secondary road in an area prone to flooding.

Climate Change – Mitigation

Mitigation is important in the fight to slow down the impacts of the greenhouse effect. For the purposes of highway infrastructure management, mitigation can include (but is not limited to) using recycled, alternative, or extended life-cycle materials, and renewable resources. Additionally, mitigation practices can include congestion reduction measures which can be achieved through better geometric layouts and more efficient construction staging. Carbon sinks such as trees and other landscaping measures in the highway right of way can also lead to the absorption of greenhouse gases and can improve aesthetics.

Mitigation is important:

- To minimize the work and money needed for future adaptation efforts

- To reduce the incidence of extreme weather events that threatens transportation infrastructure in the future
- To minimize the disruption of climate change on the ecosystem.

Section 1.4.2 - Applying the Design Domain Concept

- This Section is Applicable with the following additional Guidance:

  Policy
  For guidance in interpreting the design domain values during the design of Ontario highways, the designer shall follow the guidance provided in the *MTO Design Supplement* to the *Geometric Design Guide for Canadian Roads*.

Section 1.5.3 Design Exception Process:

- **Step 5: Document, Review and Decide (Approve or Reject);**
- **Table 1.5.2;**
- **Figure 1.5.2;** and
- **Step 6: Monitor and Evaluate In-Service Performance**

The above noted Steps, Table, and Figure are Not Applicable and replaced with the following:

Policy
Certain elements on highway and bridge rehabilitation and reconstruction projects are required to have a formal exception approval. Specific direction is given for some highway elements.

Highways are built to the standard that exists at the time of their design and construction. There is not an expectation or requirement to bring all highway elements up to the current standard when repair or rehabilitation work is completed on the highway.

The policy in Section 1.1.7 (Rehabilitation Design) and this Exception Operating Policy apply to all capital rehabilitation and reconstruction projects, including but not limited to, those with environmental assessment approvals, included in a published N/SOHP, works funded by others, and projects with other commitments.

Any highway element changed from its present configuration is to be in accordance with policy. Exception approvals shall be completed as soon as possible in the design process, and preferably, before the start of detail design on the highway element. All exception decisions, with supporting documents, shall be retained in the project file. The project Design Criteria is to have all exception approvals stated under Remark 1.

The Annual Prioritized Provincial Improvement List (APPIL) scoring, and analysis is prepared by the Provincial Traffic Office.

1. All capital projects are required to comply with this Exception Operating Policy.
2. Any deviation from **Exhibit-1E** requires exception approval.
3. Any highway element not in the following tables requires exception approval to be changed from the existing configuration.
4. Exception approvals shall be completed as soon as possible in the design process, and preferably, before the start of detail design on the highway element.
5. Preliminary designs and environmental assessments that could lead to improvements covered by this policy are required to have exception approval, prior to public commitments made and the documents being finalized.
6. Exception decisions, with supporting documents, shall be retained in the project file.
7. The project Design Criteria is to have all exception approvals stated under Remark 1.
8. Exception Approval Process for **Exhibit-1B** Highway Elements:

PART A: Group Approval Process

Provincial Traffic prepares APPIL analysis and scoring for **Exhibit-1B** highway elements.

a. Traffic Office presents the APPIL analysis and scoring for **Exhibit-1B** highway elements to the Integrated Deliver Team (IDT).
b. IDT develops a provincial prioritised list based on APPIL scoring.
c. IDT approves highway elements for construction based on available funding.

d. An individual approval is not required for provincial prioritised list approved **Exhibit-1B** elements.

e. IDT decisions for **Exhibit-1B** highway elements are to be documented in the IDT minutes and communicated to Asset Management Branch, Standards and Contracts Branch, and Regional Offices.

PART B: Individual Approval Process

a. An individual approval is required for **Exhibit-1B** highway elements not on the provincial prioritised list approved highway elements.

b. Exception Submission and Approval Form is completed and is to include APPIL analysis and scoring.

c. IDT exception decisions are to be documented in the IDT minutes and shall include the reason when an exception is not approved.

d. Exception decisions are to be documented on the Exception Submission and Approval form and the signed form is retained in the project file in the region.

9. Exception Approval Process for **Exhibit-1C** Highway Elements:

   a. Exception Submission and Approval Form completed for all approvals.

   b. Project GWP program value $10 million or less.

      - The responsible Manager may approve **Exhibit-1C** highway elements up to $500,000 cumulative construction cost for the entire project.

   c. Project GWP program value greater than $10 million.

      - The responsible Manager may approve **Exhibit-1C** highway elements up to $1,000,000 cumulative construction cost for the entire project.

   d. IDT approval is required for all exceptions greater than the cost limits above.

      - The responsible Manager approves the first $500,000/$1,000,000 in project exceptions and IDT approves all other project exceptions.
      - IDT does not re-visit the Manager decisions for approvals.

   e. The responsible Manager may not delegate their approval authority for **Exhibit-1C** highway elements.

f. The responsible Manager or the MTO project manager is to present the exception information to IDT, as decided in the program area.

g. IDT exception decisions are to be documented in the IDT minutes and shall include the reason when an exception is not approved.

h. Exception decisions are to be documented on the Exception Submission and Approval form and the form is retained in the project file in the region.

10. Exception Approval Process for **Exhibit-1D** Highway Elements:

a. Exception Submission and Approval Form completed for all Regional approvals.

b. The responsible Manager is responsible to approve **Exhibit-1D** highway elements.

c. The responsible Manager may not delegate their approval authority for **Exhibit-1D** highway elements.

d. Exception decisions are to be documented on the Exception Submission and Approval Form and the form is retained in the project file.

Exhibit-1B

Highway Elements for APPIL Analysis and Integrated Deliver Team Approval

Highway Element
Horizontal curve alignment change
New left-turn lane
New right-turn lane
Convert from single left-turn lane to double left-turn lane
Left-turn lane/right-turn lane extension
Speed change lane extension
New passing lane
New truck-climbing lane
New roundabout
New illumination
New overhead beacon
New traffic signal
Median – installing a median barrier (concrete, steel or cable), or install median (remove left turn movements)

Exhibit-1C

Highway Elements for Integrated Deliver Team Approval

Highway Element
New signature bridges on existing highways
Existing bridge widenings: greater than 1.0 m on any side, or beam, or abutment changes are required
New non-highway use underpasses/overpasses/culverts (includes, but is not limited to snowmobile, recreational, bicycle, pedestrian, agricultural, wildlife)
New noise barriers, including extensions to existing noise barriers
New permanent changeable message signs – when not on ITS approved and funded list
New/expanded ITS/ATMS plant – when not on ITS approved and funded list
Curve widening, when the platform width changes
Lane width increases, when the platform width changes
Shoulder width increases (applies to granular and paved shoulders), when the platform width changes
Horizontal spiral alignment changes, when the platform width changes
Vertical alignment changes, when the change is more than a minor grade change dictated by the structural or pavement design
Rock removal for clear zone
New bicycle and pedestrian facilities/trails/alternative transportation facilities
New fully paved shoulders for bicycles

Exhibit-1D

Highway Elements for Responsible Manager Approval

Highway Element
Horizontal spiral alignment changes, when the platform width does not change
Vertical alignment changes, when the change is only a minor grade change dictated by the structural or pavement design
Extensions to turning-lane tapers
Extensions to passing lanes, truck-climbing lanes, and associated tapers
Lane width increases, when the platform width does not change
Shoulder width increases (applies to granular and paved shoulders), when the platform width does not change
Short term pavement markings – painted (minimize use)
Short term pavement markings – continuous edge line (minimize use)
Temporary pavement markings – painted (minimize use)
Clearing for sight lines at intersections
Clearing for icing areas, sight lines
Commercial entrances changes
Residential entrances changes

New ramp closure gates
Highway fence – new or replacement
Chain link fence – new or replacement
Trees and shrubs
Sod
New snow plow turnarounds with passing lane/truck-climbing lane
Snow plow turnaround with passing lane/truck climbing lane – paving a granular turnaround or paving a new turnaround
Median crossover – new
Median crossover – paving existing or paving a new crossover
Upgrading traffic signals
Upgrading existing illumination, including changes to electrical poles and bases
Upgrading to ATMS plant
Upgrading to noise barriers
Replace existing permanent changeable message signs
New loop detectors – traffic counting stations
Temporary work, detours, temporary bridges
Bridge widenings done with barrier wall replacements: -up to 1.0 m widening on each side if no beams or abutment changes
Bridge aesthetics
New fully paved shoulder, when the platform width does not change and they are not due to bicycles
New partially paved right-lane shoulders
Turning-lane tapers
Rock removal for hazard
Removal of invasive plants and species from the right of way

Exhibit-1E

Other Highway Elements Operating Policy

Highway Element	Operating Policy
Cross-fall correction, superelevation correction	All non-selective resurfacing projects: Follow TAC Geometric Design Guide for Canadian Roads and MTO Design Supplement. Selective resurfacing projects of one lift pavement: Follow TAC Geometric Design Guide for Canadian Roads and MTO Design Supplement if possible. Note deviations in Design Criteria and reasons for not complying with MTO Supplement.
Culverts, centreline	Replace, line or repair if estimated remaining culvert lifespan is less than the expected next resurfacing date.
Culverts, entrance	Greater than 500 mm: replace, line or repair if estimated culvert lifespan is less than the expected next resurfacing date. 500 mm or less: replace, line or repair if drainage is compromised.

Culvert, extensions	As required to maintain the drainage system and for other approved work.
Curb and gutter	Maintain existing configuration unless changes due to other work or if estimated curb and gutter lifespan is less than the expected next resurfacing date.
Curve widening	Apply standard widening when existing platform allows. Exception required when the platform width changes.
Ditching and dich clean out	As required to maintain the drainage system.
Durable pavement markings – lines, stop blocks, symbols	A per CDED.
Erosion control	As per standard treatment processes.
Frost heaves	As per standard treatment processes.
Granular sealing	As per design policies.
Guide rail – all types and situations	In compliance with ministry policy documents issued for province wide use.
Paved shoulder – highways with a functional classification of freeway and four or more lanes	In compliance with ministry policy documents issued for province wide use.
Pavement	As per standard pavement design processes
Rumble strips centreline and shoulder – all highways	As per standards, if shoulder pavement exists. If pavement is not present, see partially/fully paved shoulder policy.
Sign replacement	Replace if condition requires replacement within two years of construction completion.
Storm sewers	Changes are required to maintain drainage. Replace line or repair if estimated remaining storm sewer lifespan is less than the expected next resurfacing date.
Traffic counting stations – replace existing	Replace only if required for future traffic counts.
Traffic loop detectors – replace existing	Replace only if required for future traffic counts.

Exception Submission and Approval Form

One (1) page maximum per highway element, plus attachments.

Region: GWP No: Highway No.: Type of Project:

Location: Length:

Exception Number: (start at 1 for each GWP) Highway Element:

Highway Element Cost: Cost of Exception Approvals to Date:

Technical Considerations: (include APPIL score if **Exhibit 1-B** element)

Other Considerations:

IDT Approval Date: or

Regional Approval by:
(printed name, signature and date):

Reason Not Approved:

Attachments: At responsible Manager request (such as location map, photos and drawings).

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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 2 for Chapter 2

Design Controls, Classification and Consistency

June 2023

MTO Design Supplement
Appendix 2 for Chapter 2
Design Controls, Classification and Consistency

The following design supplements are applicable to *Chapter 2 – Design Controls, Classification and Consistency* of the *TAC Geometric Design Guide for Canadian Roads June 2017*:

Section 2.3.6.1 – General Application Heuristics

- This Section is Applicable except the second bullet point which should be as follows:
  - The overall range in design speeds is 40 km/h to 130 km/h.

- The following additional Guidance is also Applicable:

  Criteria for Selection of Design Speed
  Many factors influence and constrain the selection of the appropriate design speed for a given highway facilities, which include:
  - traffic conditions, such as volumes, composition, expected greenhouse gas emission and trip length
  - character of terrain
  - socio-economic-political characteristics of the area, i.e., population density and land development and travel habits of the local residents
  - environmental quality and aesthetics
  - future projected weather hazards for a given area because of climate change
  - economics

  Application of these criteria applied only to the selection of a specific design speed within the logical range of values pertinent to the classification type selected. The ranges for each classification are illustrated in **Exhibit-2I** and **Exhibit-2J**.

  Traffic volumes are instrumental in the selection of the appropriate classification from the eight basic types, as well as in the selection of road cross-sectional features and intersection/interchange design which affect the capacity and level of service.

The effects of terrain types, socio-economic characteristics, environment and economics are not immediately obvious.

The typical driver can recognize or sense a logical operating speed for a given highway based on knowledge of the system, appraisal of the ruggedness of the terrain, and the extent, density, and size of development. Based on this judgement, the driver will adjust speed to be consistent with the conditions expected to be encountered. The driver's initial response is to react to the anticipated situation rather than to the actual situation. In most instances, the two are similar enough that no problems are created. When the initial response is incorrect, operation and safety may be severely affected.

Design speed should be chosen to be consistent with the speed a driver is likely to expect. Where a difficult condition is obvious, drivers are more inclined to accept lower speed operation then where there is no apparent reason for it.

An emerging factor to consider is inclement weather and worsening storm events, because of climate change. In these types of events, the driver's visibility, perception-reaction time, and stopping sight distances (SSD) may be hindered.

All other things being equal, it follows that a highway in level or rolling terrain justifies a higher design speed than one in mountainous terrain, and a highway located in a rural environment calls for a higher design speed than one situated in an urban area.

A highway carrying a large volume of traffic may justify a higher design speed than a less important facility in similar topography, particularly where the savings in vehicle operation and other operating costs are sufficient to offset the increased costs of right-of-way and construction. A low design speed, however, should not automatically be assumed for a secondary highway where the topography is such that drivers are likely to travel at high speeds. Drivers do not adjust their speeds to the importance of the highway but to its physical limitations and the traffic thereon.

When appropriate highway classification division is selected from **Exhibit- 2G**. The design speed can be chosen from the range of values provided in **Exhibit-2I** and **Exhibit-2J**.
When designing a substantial length of highway, it is desirable, although it may not be feasible, to assume a constant design speed. Changes in terrain and other physical

controls may dictate a change in design speed on certain sections. Each section, however, should be relatively long length, compatible with the general terrain or development through which the highway passes. The justification for introducing a reduced design speed should be obvious to the driver. Moreover, the introduction of a lower or higher design speed should not be affected abruptly but over sufficient distance to permit drivers to change speed gradually before reaching the section of highway with the different design speed.

Differences in design speed from one segment to another should not be more than 20km/h. Even so, drivers may not perceive the slower condition ahead, for which they should be warned well in advance. A transition section allowing for speed reductions, as from 100 to 90 to 80 km/h should be provided. Thus, the changing condition should comprise extra-long (anticipatory) sight distances, speed-zone signs, curve speed signs, and so on.

Design speed should be greater than or equal to the legal posted speed. Generally, the desirable practice of selecting the design speed for new construction and reconstruction is 20 km/h greater than the proposed legal speed, unless circumstances warrant a reduction.

A design speed equal to the maximum posted speed is accepted where warranted by such factors as low traffic volumes, rugged terrain and economic considerations. This practice would be more appropriate for minor collector and local roads. A design speed equal to the legal posted speed is the normal practice for Secondary highways.

Where a highway section warrants only resurfacing to remove pavement structure deficiencies, the general practice is to limit construction costs by removing only critical deficiencies as identified by the accident and maintenance records. The existing alignment is generally retained. In these situations, the proposed and the existing design speeds should be the same.

Horizontal and vertical alignment geometry should be consistent with the selected design speed. In practice, because of numerous constraints often encountered, minimum acceptable values for alignment standards are recognized and used. Minimum acceptable standards are based on the allowable reduction in the design speed of isolated curves from the overall design speed of the highway.

The reduction should preferably be no greater than 10 km/h and never greater than 20 km/h.

Where higher than average accident rates can be attributed to geometric design deficiencies, corrective measures should be considered. Isolated deficiencies should be improved if signing alone proves to be ineffective and costs are acceptable.

Where a low volume secondary highway has a generally substandard alignment and advisory and warning signs have proven ineffective, consider:

- Where no improvements are warranted - reducing the legal posted speed to be consistent with the overall highway design speed; or
- Where improvements are warranted – selecting a design speed and corresponding legal posted speed commensurate with the topography and with a realistic balance between improvement costs and user benefits.

The implications of employing substandard curvature are more fully explained in *Chapter 3 – Alignment and Lane Configuration* and *MTO Design Supplement* for *Chapter 3. See also Chapter 1 Section 1.2.3 – Design Decisions.*

Design speeds have been established in 10 km/h increments, usually ranging from 40 km/h for local roads, to a maximum of 130 km/h for design of rural freeways. Maximum and minimum design speeds have been established for each major classification of highways. The resulting functional classification system is presented in **Exhibit-2G**.

Additional Guidance for Design Speed – 130 km/h

It is desirable that newly constructed freeway have posted speeds of 110 km/h and therefore will be designed with a design speed of 130 km/h in the Design Criteria. This can be achieved because new highways can typically be constructed with features that meet or exceed the highest design speed standards without constraints typically encountered on existing highways. New freeways may be constructed in existing urban areas where acquisition on land to accommodate rights of way for high design speeds is impractical for financial, social, or environmental reasons. In these cases, it may be required to use reduce design and posted speeds, however this scenario is expected to be a rare occurrence for new construction. Design aspects of freeways currently being designed should be reviewed and upgraded to 130 km/h where this would not cause extensive changes and delays to delivery. If significant property, drainage, environment, or other impacts would result from a design speed increase to 130 km/h, such an increase may be deferred.

Existing highway segments with posted speeds of 110 km/h that are rehabilitated or reconstructed should be done with a design speed of 130 km/h in the Design Criteria. Certain existing elements such as horizontal and vertical geometry, interchange geometry, stopping sight distance and clear zone may not meet the design requirement during design and any decisions to defer such improvements documented and justified.

Policy

On newly constructed divided freeways, including extensions to existing freeways, where design has not commenced prior to issuance of this Design Supplement, the default design speed shall be 130 km/h.

On highway segments that have had (or are planned to have) the posted speed raised from 100 km/h to 110 km/h, which undergo major capital rehabilitation or reconstruction, the desirable design speed of such projects shall be 130 km/h. Locations identified as not meeting 130 km/h design speed and where upgrades are being deferred shall be documented in the Design Criteria with appropriate justification. Existing roadside safety installations including guiderail, steel beam energy attenuating terminals and crash cushions for which the ministry does not have current standards shall be replaced with systems for which current standards are available. Guidance is provided in the next section.

Current design projects for new or rehabilitated freeways located within sections proposed to be posted at 110 km/h speed, should have the Design Criteria revised to reflect 130 km/h design speed standards. Alternatively, if design has advanced too far, 120 km/h design speeds can be maintained in the Design Criteria, with enhancements to 130 km/h design speed (if any) noted where easily obtainable/achievable. This should apply to all impacted projects that have not yet undergone the 30% detail design completion meeting (for design-bid-build delivery) or where tendering process has not been completed (for design-build and alternative delivery) as of the date of this Design Supplement, unless otherwise exempted by the Manager, Engineering Program Delivery to revisit design on projects that have advanced further and bring it in line with a 130 km/h design speed.

For design-build projects, which have been awarded as of the date of the ministry memorandum: *SCB-HDO-2022-02 dated June 27, 2022*, reasonable efforts should be made to negotiate obtainable enhancements to the design speed if the project has not progressed to a point where the Manager, Engineering Program Delivery deems negotiations impractical. For all other alternative delivery models, where the tendering process has been completed as of the date on this Design Supplement, the proponent should be made aware of this policy change and any changes will be optional for those projects. The assessment for changes to the design speed of alternative delivery projects, should be based on factors such as funding and schedule impacts as assessed at the local-level and approved by the responsible director for each project.

Design parameters for 130 km/h design speed from the *TAC Geometric Design Guide for Canadian Roads, MTO Design Supplement* and the *MTO Roadside Design Manual* shall be used.

Guidance

Design elements including stopping sight distance, horizontal and vertical curvatures, grades, ramp gores, lane widths, shoulder widths and rounding and median widths should be reviewed as part of the detail design projects. Existing elements that do not meet 130 km/h design speed should be identified in the Design Criteria. In many cases, there will be no operational or safety issues identified with such locations and as such, improvements may not be justified. Decisions not to make improvements shall be noted in the Design Criteria. These should be monitored on an ongoing basis between capital contracts and localized improvements considered if safety or operational issues are identified. The following are additional design parameters for 130 km/h design speed:

- The desirable horizontal curve radius shall be 2,300 m.
- The cross slope shall be 2% on tangent sections. Acceptable design tolerances for resurfacing shall be 1.7% to 2.5%. Section 3.5.3.1 of the *TAC GDG - Design Domain: Quantitative Aid* shall also be applied.
- All left shoulders should be paved in accordance with the ministry policy.
- Narrow medians 10 m to 15 m in width should be protected with appropriate barrier according to the ministry *Roadside Design Manual.*
- Designer should ensure that signs meet the retro-reflectivity requirements as per the *Ontario Traffic Manuals* and *Ontario Provincial Standard Specifications.*

Maintenance staff should be contacted to obtain this information. Designers should also consider implementing enhanced signing and pavement markings whenever possible and based on recommendations of the regional Pre-Contract Traffic Office.

Section 2.4.2 – Vehicle Classifications

- This Section is Applicable including the following three additional vehicles operating in Canada:
  - WB-15: Tractor-semitrailer combination; this design vehicle is not representative of most large tractor-semitrailers. A round axle spacing dimension of 15.2 m.
  - WB-17.5: Tractor-semitrailer combination; the axle spacing of 17.5 m.
  - WB-20.5: Tractor-semitrailer combination; the axle spacing of 20.5 m.

Section 2.4.3.1 – Length, Width, and Turning Radius

- This Section is Applicable including the following three Exhibits (**Exhibit-2A, Exhibit-2B** and **Exhibit-2C**)

Exhibit-2A

WB-15 Tractor-Semitrailer Dimensions

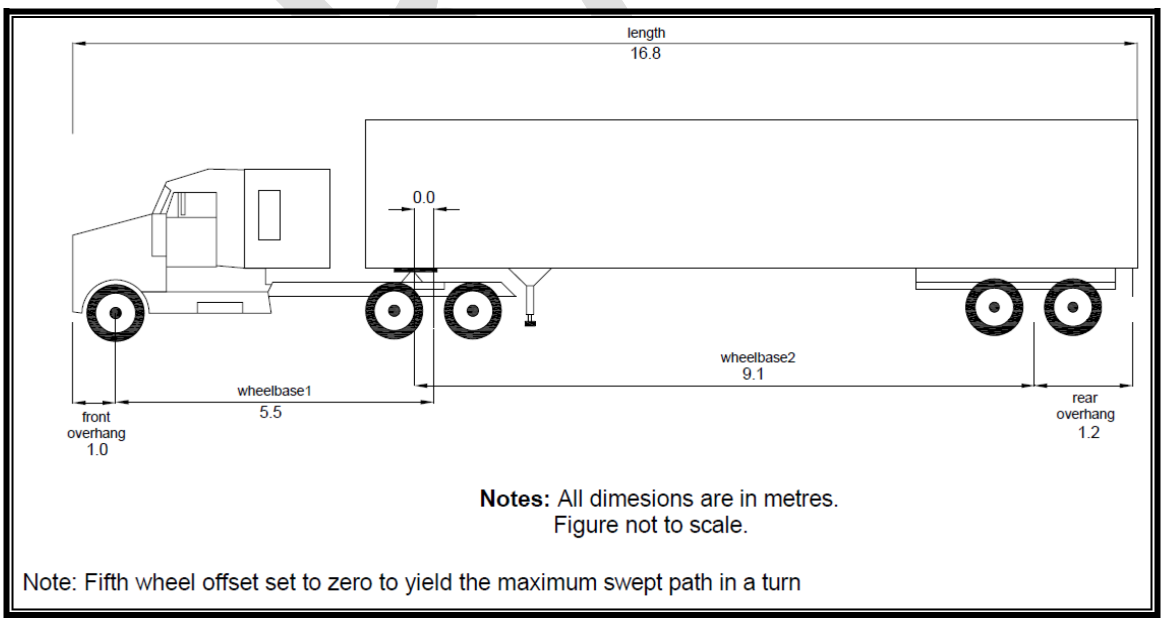


Exhibit-2B

WB-17.5 Tractor-Semitrailer Dimensions

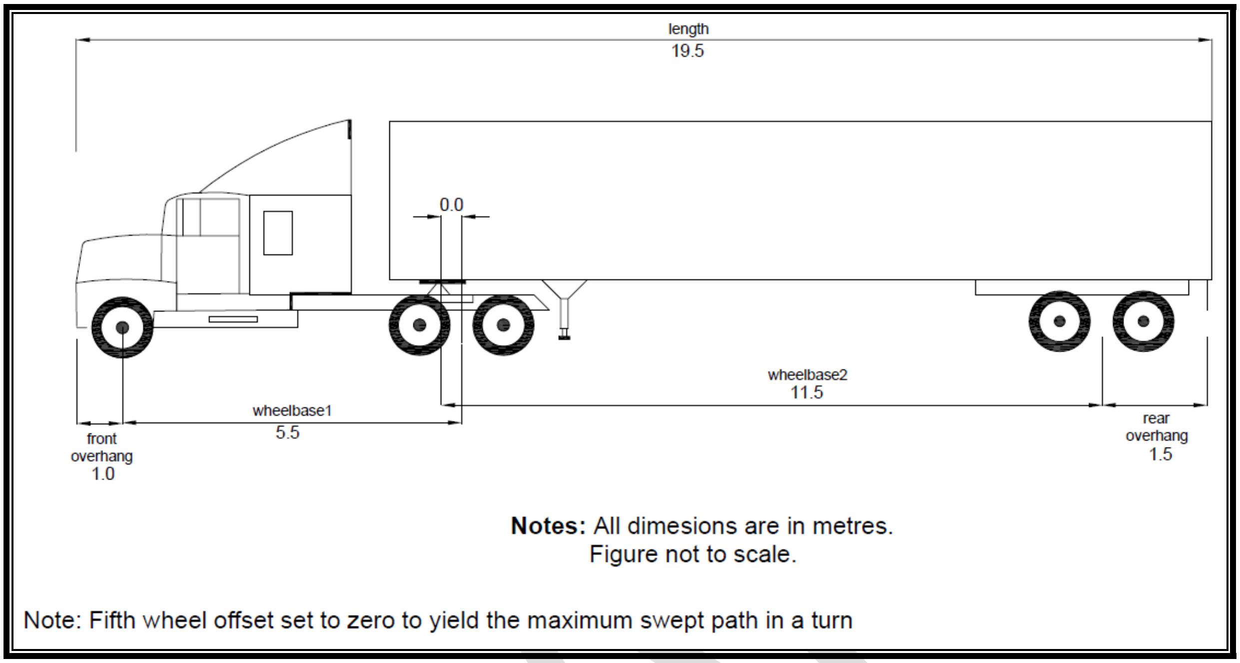
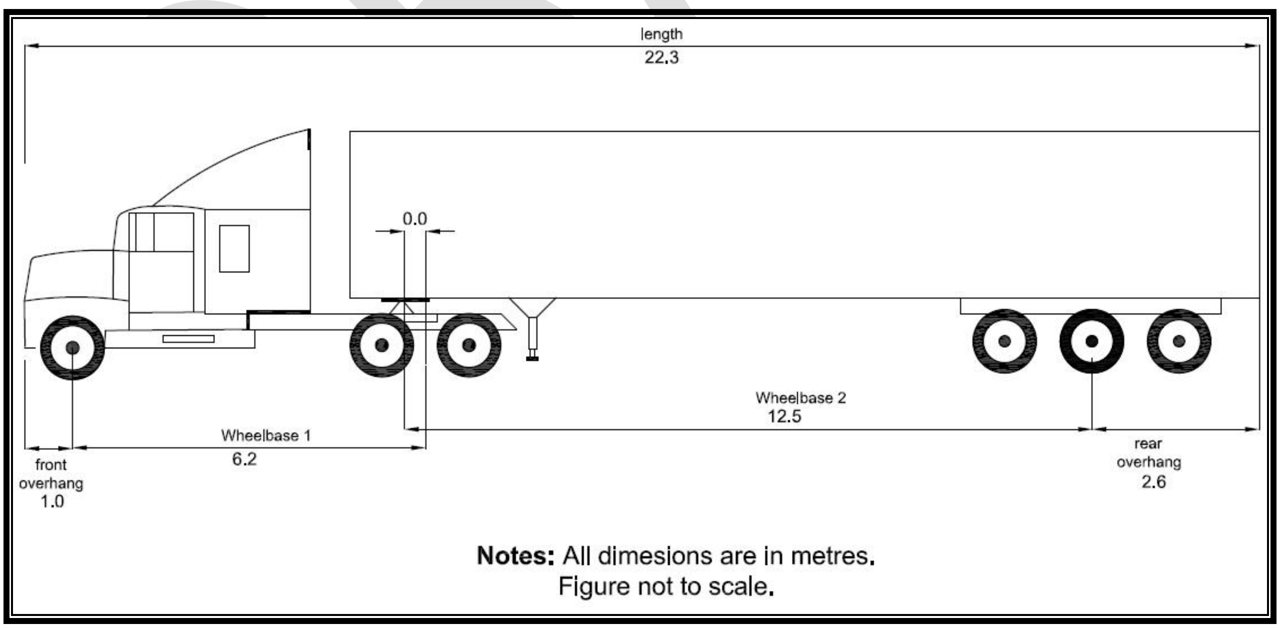


Exhibit-2C

WB-20.5 Tractor-Semitrailer Dimensions



Section 2.4.5 – Selecting a Design Vehicle

- This Section is Applicable including the following additional Guidance:

  The dimensions of design vehicles include maximum values of dimensional trends in motor vehicle manufacture and the design vehicle sizes are greater than those for nearly all vehicles belonging to the corresponding vehicle type category that are expected to be in use several years in the future.

  The Heavy Single-Unit (HSU) design vehicle characteristics are suitable for all single unit trucks and smaller buses. A separate bus design vehicle is required because of the trend toward buses with longer wheelbases. The geometric design requirements for trucks and buses are much more severe than they are for passenger vehicles. Trucks and buses are wider, have longer wheelbases and require more space for their turning maneuvers than passenger vehicles.

  In the design of any highway facility the largest design vehicle likely to use that facility is selected. A design vehicle with special characteristics that must be considered in dimensioning the travelled roadway is used to determine the critical features such as radii for the inner edge of pavement at intersections and on turning roadways.

- For further additional Guidance on selection of design vehicle, refer to Section 9.13.2 – *Corner Radius Considerations and Design* of Appendix 9 – *Intersections* of this Design Supplement.

Section 2.5.2.1 – Object Height

- This Section is Applicable with modification in the last paragraph that object height for determining passing sight distance should be 1.08 m.

Table 2.5.1 – Object Height Design Domain

- This Table is Applicable with modification in the last row that object height for determining passing sight distance should be 1.08 m which is equivalent to driver's eye height.

Table 2.5.2 – Stopping Sight Distance on Level Roadways for Automobiles

- This Table is Applicable for Rural King's Highways and Secondary Highways.
- For Freeways and Divided Highways, designer should use **Exhibit 2-E**.

Section 2.5.4 – Passing Sight Distance

- This Section is Applicable with modification in the second last paragraph that object height for determining passing sight distance should be 1.08 m which is equivalent to driver's eye height.
- The following are additional assumptions in driver's behavior when applying research model (*1, 2*):
    - Passing and opposing vehicle speeds are same and it is design speed of highway,
    - The speed differential between passing and passed vehicles is 19 km/h,
    - The passing and passed vehicles are passenger vehicles and length is 5.8m,
    - The perception-reaction time of passing vehicle to abort passing maneuver is 1 sec and deceleration rate is $3.4 m/s^2$
    - The space headway between the passing and passed vehicle is 1 sec.

Table 2.5.4 – Minimum Passing Sight Distance – 2004 AASHTO Methodology
Table 2.5.5 – Minimum Passing Sight Distance – 2006 MUTCDC (marking) Methodology

- These Tables are Not Applicable and is replaced with **Exhibit-2D** which is taken from *AASHTO's A Policy on Geometric Design of Highways and Streets, 7th Edition (2018).*

Exhibit-2D

PASSING SIGHT DISTANCE FOR DESIGN OF TWO-LANE HIGHWAYS

Design speed (km/h)	Assumed Speeds (km/h)		Passing Sight Distance (m)
	Passed Vehicle	Passing Vehicle	Rounded for Design
40	21	40	140
50	31	50	160
60	41	60	180
70	51	70	210
80	61	80	245
90	71	90	280
100	81	100	320
110	91	110	355
120	101	120	395
130	111	130	440

Passing Sight Distance for Design

Minimum passing sight distances for use in design are based on the minimum sight distances provided in MUTCD or OTM Book 11 as warrants for no-passing zones on two-lane highways. Design practice should be most effective when it anticipates the traffic controls (i.e., passing, and no-passing zone markings) that will be placed on the highways. The potential for conflicts in passing operations on two-lane highways is ultimately determined by the judgments of drivers in initiating and completing passing maneuvers in response to driver's view of the road ahead as provided by available passing sight distance, passing and no-passing zone markings. Research (*3, 4*) has shown that the MUTCD or OTM passing sight distance criteria result in two-lane highways that experience very few crashes related to passing maneuvers. The passing sight distance values provided in **Exhibit-2D** are consistent with field observations of passing maneuvers (*4*).

Passing sight distance for use in design should be based on a single passenger vehicle passing a single passenger vehicle. While there may be occasions to consider multiple passings, where two or more vehicles pass or are passed; it is not practical to assume such conditions in developing minimum design criteria. Observations have shown that longer sight distances are needed when passing or passed vehicles are commercial motor vehicles. Longer sight distances occur in design, and such locations can accommodate an occasional multiple passing maneuvers or a passing maneuver involving a commercial motor vehicle.

Additional Guidance on Passing Sight Distance

Effect of Grade on Passing Sight Distance
Grades may affect the sight distance needed for passing. If the passing and passed vehicles are on a downgrade, then the opposing vehicle is on an upgrade, or vice versa, and the effects of the grade on acceleration capabilities of the vehicle may offset. Passing drivers generally exercise good judgement whether to initiate and complete passing maneuvers. Where frequent slow-moving vehicles are present on a two-lane highway upgrade, a climbing lane may be installed to provide opportunities to pass the slow-moving vehicles without limitations due to sight distance and opposing traffic.

Frequency and Length of Passing Sections
The frequency and length of passing sections for highways depends on topography, design speed, and cost. It is not practical to directly indicate the frequency with which passing sections should be provided on two-lane highways due to the physical constraints and cost limitations. Designs with infrequent passing sections may not provide enough passing opportunities for efficient traffic operations. Providing frequent passing sections may have effect on level of service of the highway. Traffic analysis procedure provided in MTO's *Capacity Analysis Manual* or in *Highway Capacity Manual* is based on two measures of effectiveness – percent time following and average travel speed. Both criteria are affected by the lack of passing opportunities. There is a similar effect on the average travel speed. As the percent of no-passing zones increases, there is an increased reduction in the average travel speed for the same demand flow rate.

Table 2.5.6 – Decision Sight Distance

- This Table is Not Applicable and is replaced with **Exhibit-2E** which is taken from *AASHTO's A Policy on Geometric Design of Highways and Streets, 7th Edition (2018).*

Exhibit-2E

DECISION SIGHT DISTANCE

Design Speed (km/h)	Decision Sight Distance (m)				
	Avoidance Maneuver				
	A	B	C	D	E
50	70	155	145	170	195
60	95	195	170	205	235
70	115	235	200	235	275
80	140	280	230	270	315
90	170	325	270	315	360
100	200	370	315	355	400
110	235	420	330	380	430
120	265	470	360	415	470
130	305	525	390	450	510

NOTES:

Avoidance Maneuver A: Stop on rural road --- t = 3.0 s

Avoidance Maneuver B: Stop on urban road --- t = 9.1 s

Avoidance Maneuver C: Speed/path/direction change on rural road --- t varies between 10.2 and 11.2 s

Avoidance Maneuver D: Speed/path/direction change on suburban road--- t varies between 12.1 and 12.9 s

Avoidance Maneuver E: Speed/path/direction change on urban road --- t varies between 14.0 and 14.5

Section 2.6.2 – Design Classification System

- This Section is Applicable except the last sentence which is replaced with the following:

  The design classification system has eight primary divisions.

Table 2.6.1 – Urban and Rural Design Classification in Canada

- This Table is Not Applicable and is replaced with **Exhibit-2F**.

Exhibit-2F

HIGHWAY CLASSIFICATION – MAJOR DIVISIONS

RURAL	URBAN
Freeway	Freeway
Arterial	Arterial
Collector	Collector
Local	Local

Table 2.6.2 – Design Classification

- This Table is Not Applicable and is replaced with **Exhibit-2G**.

Section 2.6.3.2 – Service Function

- This Section is Applicable with the following additional Guidance:

Rural Freeways

Rural arterial roads are intended to move large volumes of traffic at high speeds under free-flow conditions. Rural freeways connect the larger cities, industrial concentrations, and recreational areas. They also serve as the major highway routes through intensely developed areas and serve larger international and interprovincial travel movements. The need for unrestricted traffic movement on these facilities justifies the elimination of direct property access. Ultimate development will require grade separation at all crossing roads.

Rural Arterial Roads

Rural arterial roads are intended to move large traffic volumes at high speeds. The major distinction between this classification and the freeway classification is in the full control of access. Roads that have full control of access should normally be in the freeway classification. Rural arterial roads, together with freeways, serve as the major routes in a network connecting the major economic regions and centres of large cities, industrial concentrations, agricultural areas and recreational facilities. In areas where freeways are not warranted by the traffic service required, rural arterials are the highest type of road. Because arterials carry large traffic volumes moving at high speed, direct access to abutting lands may be restricted or even eliminated. This applies particularly in areas of intensive development and in undeveloped areas where the lack of other road service would encourage strip development.

Exhibit-2G

THE FUNCTIONAL HIGHWAY CLASSIFICATION SYSTEM

Design Speed Km/h	Freeway	Arterial	Collector	Local
RURAL				
130	RFD 130			
120	RFD 120			
110	RFD 110	RAD 110 RAU 110		
100	RFD 100	RAD 100 RAU 100	RCU 100	
90		RAD 90 RAD 90	RCU 90	
80		RAD 80 RAU 80	RCU 80	RLU 80
70			RCU 70	RLU 70
60			RCU 60	RLU 60
50				RLU 50
URBAN				
120	UFD 120			
110	UFD 110	UAD 110 UAU 110		
100	UFD 100	UAD 100 UAU 100		
90	UFD 90	UAD 90 UAU 90	UCU 90	
80		UAD 80 UAU 80	UCU 80	
70			UCU 70	
60			UCU 60	ULU 60
50			UCU 50	ULU 50
40				ULU 40

Legend of Abbreviations

FIRST LETTER: R – Rural
U – Urban

SECOND LETTER: F – Freeway
A – Arterial
C – Collector
L – Local

THIRD LETTER: D - Divided
U - Undivided

NUMBER: Design Speed

Example: RFD 120 means Rural, Freeway, and Divided with Design Speed of 120 km/h

Rural Collector Roads

Rural collector roads collect traffic from local roads and feed it to arterials or distribute it from arterials to locals. They generally form an integrated network throughout all developed areas of the province and provide direct traffic service for development such as tourist areas, mining areas and the small towns and villages. Rural collector roads have a land service function in that they directly serve the adjacent properties.

Rural Local Roads

The main function of rural local roads is to provide land access. The only traffic service function of a local road is to allow vehicles to reach the frontage of properties from the main highways. Development roads that serve natural resource areas may be considered as local roads until volumes and function justify reclassification.

Urban Freeways

Urban freeways are intended to accommodate heavy volumes of traffic moving at high speeds under free-flowing conditions. Urban freeways connect major points of traffic generation and may serve as urban extensions of principal rural highways. They are intended to service traffic between large residential areas, industrial or commercial concentrations and the central business district. To provide optimum mobility for through traffic, service to adjacent lands is completely eliminated. No parking, unloading of goods or pedestrian traffic is permitted.

Urban Arterial Roads

Urban arterial streets are intended to carry large volumes of all types of traffic moving at medium to high speeds. These streets serve the major traffic flows between the principal areas of traffic generation and also connect to arterials and collectors. In urban areas without freeways, arterial streets provide the best quality of traffic service. Urban arterial streets should limit the amount of direct private access to adjacent development. Desirably, this access should be confined to local and collector road connections, but utilizing such treatments as reverse road frontages, side road access and so on.

Urban Collector Roads

Urban collector streets provide both traffic service and land service. The traffic service function of this type of streets is to carry traffic between local and arterial streets. Full access to adjacent properties is generally allowed on collectors.

Urban Local Roads

The main function of local streets is to provide land access. Direct access is allowed to all abutting properties. Local streets are not intended to move large volumes of traffic. The local street primarily carries traffic with an origin or destination along its length. It is not intended to carry through traffic other than to immediately adjoining streets. Local streets may be residential or commercial. Residential developments may carry appreciably higher traffic volumes and may, therefore, be multi-lane but they are seldom divided.

Section 2.6.3.3 – Traffic Volume

- This Section is Applicable with the following additional Guidance:

The design hour volume (DHV) and the annual average daily traffic (AADT) in the design year are only two factors to be considered in the classification. The volume range for each class is wide and oversleeps that of other classifications. For more details about DHV and AADT, refer to *Provincial Engineering Memorandum HSBM DCSO 2016-05 dated March 31, 2016* for *Capacity Analysis Manual.*

Rural Freeways

A freeway might be required when traffic volumes are 10000 AADT and greater. While a relatively high volume is generally a prerequisite for a freeway, the need for high speed movement under free flow conditions must also be present.

Rural Arterial Roads

The annual average daily traffic (AADT) volumes on rural arterials vary from 1000 to 20000 vehicles. This wide range occurs because arterials in the sparsely populated regions have relatively low traffic volumes while providing an important inter-regional traffic service. Average daily traffic volumes of 20000 vehicles occur on arterial highways in very densely populated areas.

Rural Collector Roads

Average daily traffic volumes on rural collector roads may vary from 200 to 10000 vehicles depending on the population density.

Rural Local Roads

Traffic volumes on rural local roads are generally low but could be several hundred vehicles per day, depending on the density of development along the sides of the road.

Urban Freeways

Freeways may be required when traffic volumes reach 75,000 AADT.

Urban Arterial Roads

Urban arterial streets normally experience average daily traffic volumes of 5000 to 50000. Urban arterials may be divided or undivided, depending on the amount of traffic to be served.

Urban Collector Roads

The average daily traffic in the design year normally ranges between 1000 and 20000 vehicles. Collector streets can have more than two traffic lanes and may be divided.

Section 2.6.3.4 – Flow Characteristics

- This Section is Applicable with the following additional Guidance:

Rural Freeways

On rural freeways, traffic flow should be uninterrupted and unrestricted. Opposing traffic lanes must be separated. Access should be controlled with grade separations or interchanges provided at all road, rail or pedestrian crossings. Parking should be prohibited by regulations on all controlled access highways.

Rural Arterial Roads

Rural arterial roads carry large traffic volumes at high speeds and should be designed for uninterrupted flow of traffic except at controlled intersections with crossing roads. However, intersections on high speed roads controlled by traffic signals or stop signs can be hazardous and should be avoided if possible. In some cases, grade separated interchanges are warranted by traffic volumes. Bicycle and pedestrian traffic are sometimes prohibited by regulation on controlled access arterial roads.

Rural Collector Roads

Traffic flow on rural collector roads is often interrupted by stop conditions or signalized intersections with arterials or other collector roads. Traffic flow is also impeded by vehicles leaving and entering the highway directly from adjacent properties. Bicycle and pedestrian traffic are not restricted.

Rural Local Roads

Traffic flow on rural local roads is normally interrupted by stop conditions at all intersecting roads and is affected by traffic moving to and from adjacent properties. Pedestrian traffic is not restricted.

Urban Freeways

To move high volumes at high speeds, it is necessary to have uninterrupted flow conditions on urban freeways. These conditions can only be provided by grade-separated crossings and interchanges. Parking and pedestrian access is prohibited. Urban freeways are generally constructed on new alignments, because of difficulty of providing the desired service and operating conditions on existing streets.

Urban Arterial Roads

The traffic flow is, desirably, uninterrupted except at signalized intersections and crosswalks. Where signals are closely spaced, they should be interconnected and synchronized to minimize the interference to through movements. Parking and unloading should be prohibited where they might affect through movement of traffic, particularly at rush hours. Pedestrians should be permitted to cross only at intersections or designated cross walks. Public transit loading stations should be designed to minimize interference with through traffic movements. Turning lanes may be provided at intersections.

Urban Collector Roads

The traffic flow on urban collector streets, in and near the central business district, is interrupted frequently by signalized intersections. In residential areas, simpler forms of traffic control are generally used. There are few parking restrictions except during peak hours when traffic movement may be the most important consideration. There are generally no special pedestrian crossing restrictions, but special cross walks might be provided where traffic volumes are high. To improve traffic flow, particularly at peak hours, it is sometimes desirable to provide collector streets with bus bays or turning lanes similar to those provided on arterial streets.

Urban Local Roads

Local streets have stop, yield or signalized controls where they intersect more important streets. Parking may be prohibited or restricted to one side on narrow streets. Pedestrian traffic is unrestricted.

Section 2.6.3.5 – Operating Speed

- This Section is Applicable with the following additional Guidance:

Rural Freeways

The average operating speed under most conditions is between 90 and 120 km/h on rural freeways.

Rural Arterial Roads

The average operating speed is between 70 and 100 km/h. The higher values are found on those sections of rural arterial roads having some control of access.

Rural Collector Roads

The average operating speed on rural collector road varies between 60 and 90 km/h.

Rural Local Roads

Depending on the condition of the surface, the average operating speed on rural local roads varies from 50 to 80 km/h.

Urban Freeways

The normal operating speed under free-flow conditions varies between 80 and 110 km/h.

Urban Arterial Roads

Operating speed under free-flow conditions normally ranges from 60 – 90 km/h with the higher values prevailing in suburban areas.

Urban Collector Roads

The normal operating speed under free-flow conditions varies between 40 and 70 km/h, with the higher value prevailing in urban fringe areas.

Urban Local Roads

Operating speed under free – flow conditions is generally 40 – 60 km/h.

Section 2.6.3.6 – Vehicle Type

- This Section is Applicable with the following additional Guidance:

Rural Freeways

Rural freeways carry all types of vehicular traffic, commercial motor vehicles normally amount to between 20 and 30% of the total volume. Rural freeways are constructed to connect large cities or heavily developed areas. The total length of these roads is normally less than 5% of the total length of rural roads

Rural Arterial Roads

Rural arterial roads link the major regions of a province and serve all types of vehicles. Up to 20% of traffic is commercial motor vehicles. Rural arterial roads normally make up from 5% to 10% of the total rural road length depending upon the extent of rural freeway development in the area.

Rural Collector Roads

Although rural collectors carry all types of vehicles, commercial traffic consists mainly of single unit trucks. In agricultural areas these are normally farm trucks carrying produce such as milk, feed and livestock. These commercial motor vehicles amount to as much as 30% of the volume of traffic using these roads. Few heavy transport trucks use the class of road except when the road serves mining and resource land uses.
Rural collector roads make up from 10 to 20% of the total length of rural roads**.**

Rural Local Roads

In agricultural areas, hauling is done by light and medium single unit vehicles with occasional heavy commercial motor vehicles. In mining and forestry areas, heavy units will predominate. The number of commercial motor vehicles depends upon the adjacent land use and ranges up to 50% of the total vehicular volume. Local roads normally make up approximately 75% of the total length of rural roads.

Urban Freeways

Urban freeways are expected to carry all types of vehicles including a relatively high percentage of commercial motor vehicles, amounting up to 20% of the total volume. Only express bus service with no stop if permitted on urban freeways. The total length of unban freeways is normally less than 10% of the total length of urban roads.

Urban Arterial Roads

All types of vehicular traffic use urban arterial streets. Commercial motor vehicles of all sizes may comprise as much as 20% of the total traffic volume. Both express and local buses are generally routed on arterial streets. The combined length of urban collectors and urban arterials may be as much as 30% of the total length of urban streets.

Urban Collector Roads

In commercial and industrial areas, all types of vehicles use urban collector streets, including commercial motor vehicles moving to and from arterials. In residential areas, collectors will carry a low percentage of commercial motor vehicles composed mainly of service vehicles. The combined total length of arterial and collector streets may amount to 30% of the total length of urban streets.

Urban Local Roads

The type of vehicles using local streets will vary. Residential streets carry predominantly passenger vehicle and the occasional transport. Industrial streets carry a high percentage of commercial motor vehicles. Bus operations rarely occur on residential streets.

The length of local streets amounts to about 70% of the total length of urban streets.

Section 2.6.3.7 – Connections

- This Section is Applicable with the following additional Guidance:

Rural Freeways

Rural freeways should interchange traffic only with other freeways, arterials and collectors. The interconnection of freeways with local roads is not a desirable practice.

Staged Construction

All rural freeways should normally be planned and designed as multi-lane, divided, controlled access facilities even though they may be developed by staged construction. In the plans for each stage of development, provision should be made to adapt each stage to the next or ultimate stage. The transition should be made with minimum waste of the exiting plant and minimum interference to traffic.

Rural Arterial Roads

Rural arterials roads connect with all other classifications of rural roads.

Rural Collector Roads

Rural collector roads connect with all other classifications of roads except freeways.

Rural Local Roads

Rural local roads connect with collector and arterial roads.

Urban Freeways

Urban freeways are directly connected to intersecting or adjacent freeways and to most intersecting or adjacent arterial streets. Some direct connections to collector streets may be provided in the central business district.

Staged Construction

All urban freeways should normally be planned and designed as multi-lane, divided, controlled access facilities even though they may be developed by staged construction. In the plans for each stage of development, provision should be made to adapt each stage to the next or ultimate stage. The transition should be made with minimum waste of the existing plant and minimum interference to traffic.

Urban Arterial Roads

Urban arterial streets connect with freeway, arterials and collectors.

Urban Collector Roads

Urban collector streets are connected to freeways are rarely found except in the central business district.

Urban Local Roads

Local streets connect to other local streets and collector streets. It might be necessary to have industrial or commercial local streets connect directly to arterials.

Table 2.6.3 – Connections by Classification

- This Table is Not Applicable and is replaced with **Exhibit-2H**.

Exhibit-2H

Desirable Highway Classification Connections

Classification	Connects to (Classification)
Freeway	Freeway Arterial
Arterial	Freeway Arterial Collector
Collector	Arterial Collector Local
Local	Collector Local

Figure 2.6.2 – Relationship of Urban Road Classifications

- This Figure is Not Applicable.

Table 2.6.4 – Characteristics of Rural Roads

- This Table is Not Applicable and is replaced with **Exhibit-2I**.

Table 2.6.5 – Characteristics of Urban Roads

- This Table is Not Applicable and is replaced with **Exhibit-2J**.

Exhibit-2I

CHARACTERISTICS OF RURAL ROAD CLASSIFICATIONS

FUNTIONAL CLASSIFICATION	RURAL FREEWAYS	RURAL ARTERIALS	RURAL COLLECTORS	RURAL LOCALS
Traffic Services	Optimum mobility	Traffic movement Primary Consideration	Traffic movement & land access equal importance	Traffic movement Secondary Consideration
Land Service	No access	Land access Secondary Consideration	Traffic movement and land access equal importance	Land access Primary Consideration
Range of Traffic Volume AADT	More than 10000	1000 – 20000	200 – 10000	Not applicable
Traffic Flow	Free flow	Uninterrupted flow Except at signals	Interrupted flow	Interrupted flow
Design Speed	100 – 130 km/h	80 – 110 km/h	60 – 100 km/h	60-80 km/h
Average Operating Speed Off-peak Conditions	90 – 120 km/h	70 – 100 km/h	60 – 90 km/h	50-80 km/h
Vehicle Type	All types Commercial motor vehicles Average 20-30%	All types Up to 20% commercial motor vehicles	All types Up to 30% commercial motor vehicles Mostly single unit type	Predominantly Passenger cars And light to medium, and occasional heavy commercial motor vehicles
Percentage of Total Length	Up to 5	5 - 10	10 – 20	75 approx.
Connects to	Freeways Arterials Collectors	All classifications	All classifications	Arterials Collectors locals

Exhibit 2-J

CHARACTERISTICS OF URBAN ROAD CLASSIFICATIONS

FUNCTIONAL CLASSIFICATION	URBAN FREEWAYS	URBAN ARTERIALS	URBAN COLLECTORS	URBAN LOCALS
Traffic Services	Optimum mobility	Traffic movement Primary Consideration	Traffic movement & land access equal importance	Traffic movement Secondary Consideration
Land Service	No access	Land access Secondary Consideration	Traffic movement and land access Equal importance	Land access Primary Consideration
Range of Traffic Volume AADT	More than 75000	5000 - 50000	1000 -20000	Not applicable
Traffic Flow	Free flow	Uninterrupted flow except at signals and cross walks	Interrupted flow	Interrupted flow
Design Speed	80 – 120 km/h	80 – 110 km/h	60 – 90 km/h	60 – 80 km/h
Average Operating Speed Off-peak Conditions	80 – 110 km/h	60 – 90 km/h	40 – 70 km/h	40 – 60 km/h
Vehicle Types	All types up to 20% commercial motor vehicles	All types Up to 20% commercial motor vehicles	All types	Passenger And Service vehicles
Percentage of Total Length	Up to 10	Up to 30	Up to 30	70 approx.
Connects to	Freeways Arterials	Freeways Arterials Collectors	Arterials Collectors Locals	Collectors Locals

REFERENCES

1. Glennon, J. C. New and Improved Model of Passing Sight Distance on Two-Lane Highways. In *Transportation Research Record 1195.* Transportation Research Board, National Research Council, Washington, DC, 1998.

2. Hassan, Y., S. M. Easa, and A. O. Abd El Halim. Passing Sight Distance on Two-Lane Highways: Review and Revision. *Transportation Research Part A,* Vol. 30, No. 6, 1996.

3. FHWA. *Grade Severity Rating System Users Manual,* FHWA-IP-88-015. Federal Highway Administration, U.S Department of Transportation, Washington, DC, August 1989.

4. Harwood, D. W., D. K. Gilmore, K. R. Richard, J. M. Dunn, and C. Sun. *National Cooperative Highway Research Program Report 605: Passing Sight Distance Criteria.* NCHRP, Transportation Research Board, National Research Council, Washington DC, 2007.

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MTO Design Supplement

For
TAC Geometric Design Guide for Canadian Roads

Appendix 3 for Chapter 3

Alignment and Lane Configuration

June 2023

MTO Design Supplement
Appendix 3 for Chapter 3
Alignment and Lane Configuration

The following Design Supplements are applicable to *Chapter 3 – Alignment and Lane Configuration* of the *TAC Geometric Design Guide for Canadian Roads - June 2017:*

Section 3.1.1 – The Importance of Alignment and Lane Configuration Design

- This Section is Applicable with the following additional Guidance:

  Fuel economy can be improved by minimizing/flattening vertical grades. This may be considered in design if it does not compromise safety, drainage, sightlines, stopping sight distances, and economy. Providing a flatter driving surface can result in less frequent braking, lowered speed variability, and reduced accelerations/decelerations, therefore, reducing greenhouse gas emissions. With that in mind, it is necessary to be cognizant of the emissions associated with minimizing/flattening vertical grades that could potentially counteract the emissions savings (e.g., disrupting land, truck hauling, and material usage during construction).

Section 3.2.1.2 – Horizontal Alignment: Design Domain Control

- This Section is Applicable with the following additional Guidance for bullets 3 and 5:

  3. Designer should consider future conditions such as rain and snowfall when using predictive models for design. Additional information can be found in MTO's highway drainage policy: *Implementation of the Ministry's Climate Change Consideration in the Design of Highway Drainage Infrastructure – October 2016.* Land composition and prevalence of landslides should be considered when determining road alignment. Areas prone to landslides and soil movement should be avoided or correctly reinforced to ensure safe conditions and avoid future maintenance costs.

5. Providing free flow traffic conditions can help minimize congestion and associated emissions.

Section 3.2.2.4 – Maximum Superelevation: Design Domain

- This Section is Applicable with the following additional bullets:
  - Drainage
  - Soil properties
  - Local rain and snowfall patterns

Section 3.2.2.6 – Minimum Radius: Design Domain

- This Section is Applicable along with **Exhibit-3A** which provides a set of 77 standard circular curve radii for use in design and construction. Using the standard circular curve radii provided in **Exhibit-3A** is no longer necessary. These are for general guidance and consistency in the standards as past provincial infrastructure has been built based on these radii. Since the integration of computer programs in highway design, designers are deviating from these radii. However, for consistency and driver's expectations, selection of radii should be as close as possible to these radii in **Exhibit-3A.**

Exhibit-3A

STANDARD CIRCULAR CURVES

Radii in Meters						
45	100	180	340	600	1150	2500
50	105	190	350	650	1200	3000
55	110	200	380	700	1250	3500
60	115	210	400	750	1300	4000
65	120	220	420	800	1400	4500
70	125	230	450	850	1500	5000
75	130	240	475	900	1600	6000
80	140	250	500	950	1700	7000
85	150	280	525	1000	1800	8000
90	160	300	550	1050	2000	9000
95	170	320	575	1100	2200	10000

Section 3.2.2.7 – Distribution of "E" and "F" Over a Range of Curves: Design Domain
Urban Roadways: Design Domain Quantitative Aids

- This Section is Applicable. In this Section, a Subsection "*Urban Roadways: Design Domain Quantitative Aids"* discusses using alternative methods for providing superelevation rates for urban high speed values. It references using values provided in Table 3.2.8 and Table 3.2.9 for maximum superelevation of 4% and 6% respectively. Whenever a designer uses this alternative method and values provided in Table 3.2.8 and Table 3.2.9, the designer should provide justification and document this in the design package.

Table 3.2.7 – Superelevation and Minimum Spiral Parameters, e_{max} = 0.08 m/m

- Design speed 60 and radius 500 m: the spiral parameter 235 m is incorrect, and it is replaced with 135 m.

Section 3.2.3.5 – Spiral Parameter: Design Domain Application Heuristics

- This Section is Applicable along with **Exhibit-3B** which provides standard spiral parameters for use in design. Using the standard spiral parameters provided in **Exhibit-3B** is no longer necessary. These are for general guidance and consistency in the standards as past provincial infrastructure has been built based on these spiral parameters. Since the integration of computer programs in highway design, designers are deviating from these radii. However, for consistency and driver's expectations, selection of spiral parameters should be as close as possible to these spiral parameters in **Exhibit-3B.**

Exhibit-3B

STANDARD RANGE OF SPIRAL PARAMETERS A (meters)

25	65	110	175	240	325	550	1100
30	70	120	180	250	350	600	1200
35	75	125	190	260	375	650	1300
40	80	130	200	270	400	700	1400
45	85	140	210	275	425	750	1500
50	90	150	220	280	450	800	1600
55	95	160	225	290	475	900	1700
60	100	170	230	300	500	1000	1800

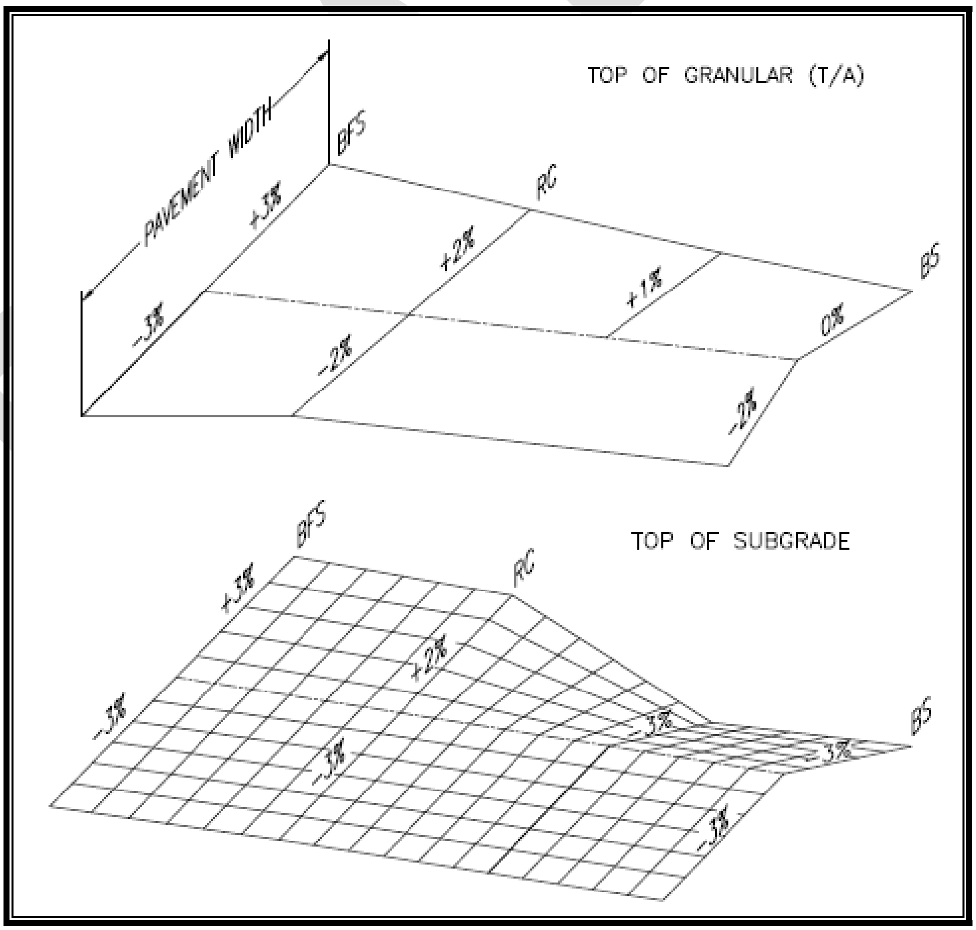
Note: Values above 700 m are beyond the normal range of application

Section 3.2.4.5 – Superelevation Development: Design Domain General Application Heuristics

- This Section is Applicable including the following additional Guidance:

  Subgrade Transition into Superelevation
  On tangent alignment, the subgrade should be prepared having a 3 percent crown. When a tangent section meets with a horizontal curve, transitioning of the subgrade in superelevated sections starts from the Beginning of Superelevation (BS) to where it is parallel with the top of pavement as illustrated in **Exhibit-3C**. For more detail the designer may refer to *InRoads Preference* and *Standards Manual and MTO Customization Document.*

Exhibit-3C
SUBGRADE TREATMENT IN SUPERELEVATION



Section 3.2.4.6 – Methods of Developing Superelevation: Best Practices

- This Section is Applicable with the following additional Guidance for Divided Roadways:

  Divided Roadways
  On divided roadways with wide medians, the median pavement edges are usually maintained at the same elevation as shown in **Exhibit-3D** and, each pavement is revolved about the median edge as illustrated in *Chapter 3 - Alignment and Lane Configuration, Figure 3.2.8*.

  On divided roadways with narrow medians consisting of a median barrier and paved shoulders, the median barrier edges at the two shoulders desirably should be at the same elevation, as shown in **Exhibit-3D**.

  On divided roadways where additional lanes are being added to the median and provision for the above treatment was not made in the original design, median shoulder edges will not be at the same elevation. This difference in elevation can be taken up with an asymmetric concrete median barrier, as shown in **Exhibit-3D**. The use of curb and gutter with any guide rail system is not recommended. For further guidance regarding use of curb and gutter refer to the ministry's *Roadside Design Manual.*

  Smooth Profile of Traveled-Way Edges
  Divided highways warrant a greater refinement in design and greater attention to appearance than compared to undivided two-lane highways because divided highways usually serve much greater traffic volumes at higher design speeds. The cost of refinement is insignificant compared with the construction cost of divided highway. The diagrammatic profile shown in *Figure 3.2.8 – Three Methods of Superelevation Development on Divided Roadways* of *Chapter 3*, the tangent profile control lines result in angular breaks at various cross location of superelevation development denoted as '1' in the same Figure, for clarity it is also illustrated in **Exhibit-3E**. For general appearance and safety, these breaks should be rounded in final design by insertion of vertical curves. Angular breaks will be particularly noticeable where hard surfaces, such as concrete barrier or retaining wall, follow the edge of pavement profile. Even when the maximum relative gradient is used to define runoff length, the length of vertical curve does not need to be large to conform to the 0.67 percent break at 50 km/h design speed and 0.5 percent break at design speeds of 80 km/h and higher. Where the traveled way

is revolved about an edge, these grade breaks are doubled to 1.33 percent for 50 km/h design speed and to 1.00 percent for design speeds of 80 km/h and higher. Greater lengths of vertical curve are obviously needed in these cases. Specific criteria have not been established for the lengths of vertical curves at the breaks in the diagrammatic profiles. For an approximate guide, however, the minimum vertical curve length in meters can be used as numerically equal to 0.2 times the design speed in kilometers per hour. Greater lengths are desirable where practical as the general profile condition may determine.

A second method uses a graphical approach to define the edge profile. The method essentially is one of spline-line development. In this method, the centerlines or other base profile, which usually is computed, is plotted on an appropriate vertical scale. Superelevation control points are in the form of the break points shown in *Figure 3.2.8* of *Chapter 3*. Then by means of spline, curve template, ship curve, or circular curve, smooth-flowing lines are drawn to approximate the straight-line controls. The natural bending of a spline nearly always satisfies the need for minimum smoothing. Once the edge profiles are drawn in the proper relation to one another, elevations can be read at the appropriate intervals for construction.

<u>Exhibit-3D</u>

APPLICATION OF SUPERELEVATION ON DIVIDED ROADWAYS

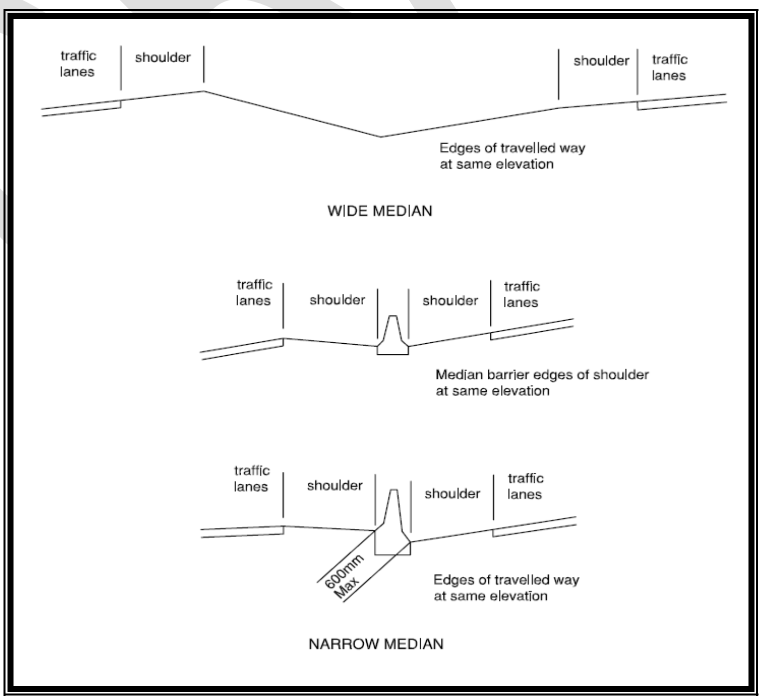
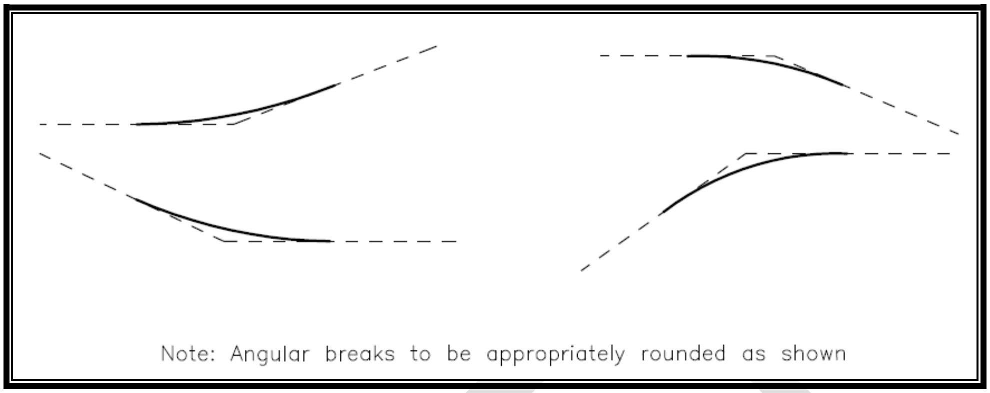


Exhibit-3E

ANGULAR BREAKS IN DEVELOPMENT OF SUPERELEVATION ON DIVIDED ROADWAYS



Note: Exhibit 3-E should be read in conjunction of Figure 3.2.8 of Chapter 3

Section 3.2.5.3 – Lane Widening: Design Domain
Application Heuristics

- This Section is Applicable. Pavement widening values on curves for few common design vehicles such as Heavy Single Unit, Tractor Semi-Trailer (WB-20), and B-Train are provided in **Exhibit-3F**, **Exhibit-3G**, and **Exhibit-3H** respectively by using the formula provided in *Figure 3.2.9* of *Chapter 3*. For other design vehicles, pavement widening values should be calculated using the same formula.

Table 3.2.14 - Pavement Widening Values on Curves for Heavy SU Trucks

- This Table is Not Applicable and is replaced with **Exhibit-3F.**

Exhibit-3F

PAVEMENT WIDENING VALUES ON CURVES FOR HEAVY SINGLE-UNIT TRUCKS

PAVEMENT WIDTH 7.5 m									
Design Speed (km/h)									
W (m)	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**
	Range of Radii (m)								
1.75	50-55	55-60	-	-	-	-	-	-	-
1.50	60	65-70	-	-	-	-	-	-	-
1.25	65-75	75-80	90	-	-	-	-	-	-
1.00	80-95	85-105	95-115	-	-	-	-	-	-
0.75	100-120	110-130	120-150	130-160	-	-	-	-	-
0.50	125-170	140-190	160-210	170-240	190-250	250-300	340	-	-
0.25	180-250	200-300	220-350	250-400	280-450	320-525	350-575	420-650	525-700
PAVEMENT WIDTH 7.0 m									
2.00	50	55	-	-	-	-	-	-	-
1.75	55-60	60-65	-	-	-	-	-	-	-
1.50	65-70	70-80	-	-	-	-	-	-	-
1.25	75-90	85-100	90-110	-	-	-	-	-	-
1.00	95-115	105-125	115-140	130-150	-	-	-	-	-
0.75	120-150	130-170	150-200	160-220	190-250	250-280	-	-	-
0.50	160-240	180-280	210-320	230-350	280-400	300-450	340-500	-	-
0.25	250-475	300-550	340-650	380-750	420-900	475-1000	525-1150	-	-
PAVEMENT WIDTH 6.5 m									
2.00	50-60	55-65	-	-	-	-	-	-	-
1.75	65-70	70-75	-	-	-	-	-	-	-
1.50	75-85	80-95	90-105	-	-	-	-	-	-
1.25	90-110	100-120	110-130	130-150	-	-	-	-	-
1.00	115-140	125-160	140-180	160-200	190-230	-	-	-	-
0.75	150-220	170-250	190-280	210-320	240-350	-	-	-	-
0.50	230-400	280-475	300-550	340-600	380-700	-	-	-	-
0.25	420-1300	500-1600	575-2000	650-2200	750-2500	-	-	-	-
PAVEMENT WIDTH 6.0 m									
2.00	55-65	55-75	-	-	-	-	-	-	-
1.75	70-80	80-90	90-100	-	-	-	-	-	-
1.50	85-105	95-115	105-125	-	-	-	-	-	-
1.25	110-130	120-150	130-170	-	-	-	-	-	-
1.00	140-200	160-230	180-250	-	-	-	-	-	-
0.75	210-350	240-400	280-450	-	-	-	-	-	-
0.50	380-950	420-1150	475-1400	-	-	-	-	-	-
0.25	1000-10000	1200-10000	1500-10000	-	-	-	-	-	-

Table 3.2.15 - Pavement Widening Values on Curves for WB-20

- This Table is Not Applicable and is replaced with **Exhibit-3G.**

Exhibit-3G

PAVEMENT WIDENING VALUES ON CURVES FOR TRACTOR-SEMI-TRAILER (WB-20) VEHICLES

PAVEMENT WIDTH 7.5 m									
Design Speed (km/h)									
W (m)	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**
	Range of Radii (m)								
2.00	50-105	55-110	85-110	-	-	-	-	-	-
1.75	110-120	115-125	115-125	130-140	-	-	-	-	-
1.50	125-140	130-140	130-140	150-160	-	-	-	-	-
1.25	150-160	150-170	150-170	170-190	190-200	-	-	-	-
1.00	170-200	180-210	180-210	200-240	210-250	250	-	-	-
0.75	210-250	220-250	220-250	250-300	280-320	280-350	340-380	-	-
0.50	280-340	280-350	280-350	320-420	340-450	380-500	400-425	420-575	525-600
0.25	350-525	380-575	380-575	450-650	475-750	525-800	550-900	600-950	650-1050
PAVEMENT WIDTH 7.0 m									
2.00	50-115	55-120	90-130	130	-	-	-	-	-
1.75	120-130	125-140	140-150	140-150	-	-	-	-	-
1.50	140-150	150-160	160-170	160-180	190-200	-	-	-	-
1.25	160-190	170-200	180-210	190-230	210-240	250	-	-	-
1.00	200-240	210-250	220-250	240-280	250-300	280-320	340-350	-	-
0.75	250-320	280-340	280-350	300-400	320-420	340-450	380-500	-	-
0.50	340-375	350-525	380-550	420-600	450-650	475-700	525-800	-	-
0.25	500-850	550-950	575-1100	650-1200	700-1300	750-1500	850-1600	-	-
PAVEMENT WIDTH 6.5 m									
2.00	50-130	55-130	90-140	130-150	-	-	-	-	-
1.75	140-150	140-160	150-170	160-180	190	-	-	-	-
1.50	160-180	170-190	180-200	190-220	200-230	-	-	-	-
1.25	190-230	200-240	210-250	230-280	240-300	-	-	-	-
1.00	240-300	250-320	280-350	300-350	320-400	-	-	-	-
0.75	320-420	340-475	380-500	380-550	420-600	-	-	-	-
0.50	450-750	500-800	525-900	575-1000	650-1100	-	-	-	-
0.25	800-2200	850-2500	950-2500	1050-3000	1150-3500	-	-	-	-

Table 3.2.16 - Pavement Widening Values on Curves for B-Train

- This Table is Not Applicable and is replaced with **Exhibit-3H.**

Exhibit 3-H

PAVEMENT WIDENING VALUES ON CURVES FOR B-TRAIN VEHICLES

PAVEMENT WIDTH 7.5 m									
	Design Speed (km/h)								
W (m)	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**
	Range of Radii (m)								
2.00	50-95	55-100	90-105	-	-	-	-	-	-
1.75	100-105	105-110	110-120	-	-	-	-	-	-
1.50	110-125	115-130	125-140	130-140	-	-	-	-	-
1.25	130-140	140-150	150-160	150-170	-	-	-	-	-
1.00	150-180	160-190	170-200	180-220	190-230	250	-	-	-
0.75	190-220	200-240	210-250	230-280	240-300	280-320	340-350	-	-
0.50	230-300	250-320	280-350	300-400	320-420	340-450	380-500	420-525	525-575
0.25	320-475	340-525	380-575	420-600	450-700	475-750	525-800	550-900	600-1000
PAVEMENT WIDTH 7.0 m									
2.00	50-105	55-110	90-115	-	-	-	-	-	-
1.75	110-120	115-125	120-130	130-140	-	-	-	-	-
1.50	125-140	130-150	140-160	150-170	-	-	-	-	-
1.25	150-170	160-180	170-190	180-210	190-220	-	-	-	-
1.00	180-210	190-230	200-250	220-250	230-280	250-300	-	-	-
0.75	220-280	240-300	280-340	280-350	300-400	320-420	340-450	-	-
0.50	300-420	320-475	350-500	380-550	420-600	450-650	475-750	-	-
0.25	450-800	500-900	525-1000	575-1100	650-1250	700-1400	800-1500	-	-
PAVEMENT WIDTH 6.5 m									
2.00	50-115	55-120	90-130	130	-	-	-	-	-
1.75	120-130	125-140	140-150	140-160	-	-	-	-	-
1.50	140-160	150-170	160-180	170-200	190-210	-	-	-	-
1.25	170-200	180-220	190-230	210-250	220-250	-	-	-	-
1.00	210-250	230-280	240-320	280-340	280-350	-	-	-	-
0.75	280-380	300-420	340-475	350-500	380-550	-	-	-	-
0.50	400-650	450-750	500-850	525-950	575-1050	-	-	-	-
0.25	700-2000	800-2200	900-2500	1000-3000	1100-3500	-	-	-	-

Section 3.2.5.4 – Application of Widening on Curves: Best Practices

- This Section is Not Applicable and is replaced with the following Guidance:

The pavement widening values provided in **Exhibit-3F** to **Exhibit-3H** represent the total amount of widening required.

For new construction and reconstruction projects, curve widening should be applied by adding half of the total requirement to each side of the highway. When widening values ending in 0.25 or 0.75 and equal division of the widening is not practical. A preferred treatment is to round the total widening value to a higher even digit before dividing in half. The normal shoulder width should be maintained over the length of curve widening.

Since the amount of pavement widening is a function of the curve radius, the widening should be applied over the length of the spiral in such a fashion that a smooth edge of pavement is produced. For un-spiraled curves the widening should be applied over the corresponding spiral length had the spiral been applied. The two methods illustrated in **Exhibit-3I** and **Exhibit-3J** may be applied to attain the pavement widening. For details refer to *Ontario Provincial Standards Drawings.*

Pavement widening may be warranted on several successive horizontal curves such that a significant length of highway has a continuous variation in pavement width. In such a situation, a wider pavement over the total section of highway should be considered. The amount of widening should be representative of the required widening on individual curves and not necessarily the widening required by the smallest radius curve. Alternatively, less widening could be applied over the total section with additional widening on the smaller radius curves.

Each situation should be assessed independently considering how closely the warrants are met, the length of the highway section under consideration, the frequency of curves and the amount of widening required for each curve. A uniform pavement width is desirable but may not always be economically practical.

For guidance on the placement of edge line pavement marking in areas of curve widening, refer to *Ontario Traffic Manual (OTM) Book 11*.

EXHIBIT-3I

WIDENING ON BOTH SIDES OF CURVE WITH OR WITHOUT SPIRAL 213.01

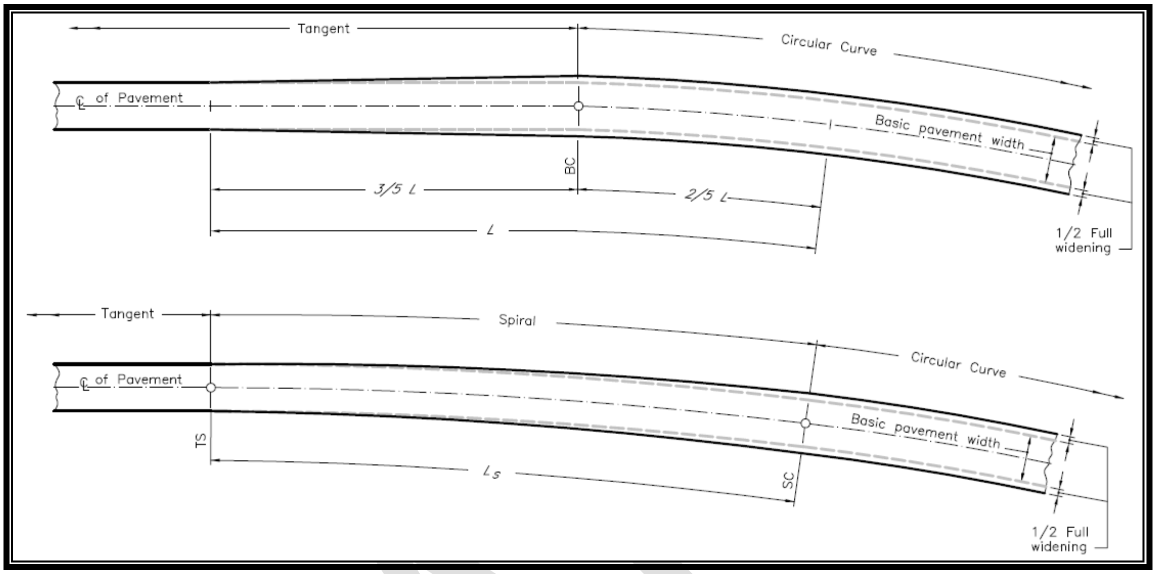
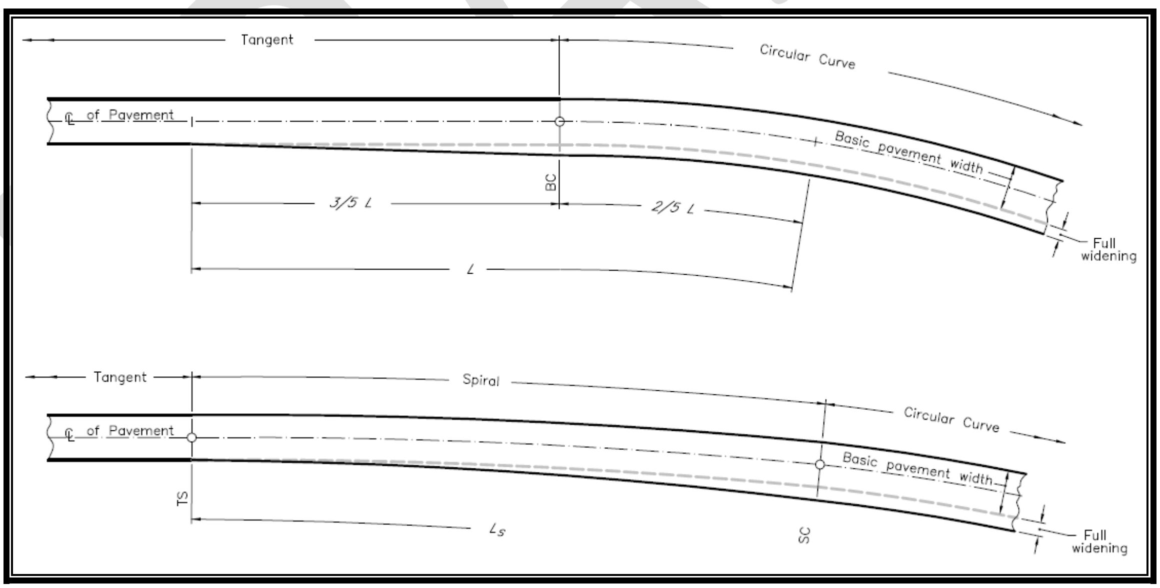


EXHIBIT-3J

WIDENING ON INSIDE OF CURVES WITH OR WITHOUT SPIRAL 213.01



Curve Widening on Resurfacing Projects

Curve widening on resurfacing projects should be carried out with a corresponding reduction in shoulder width to maintain the existing subgrade. A minimum shoulder width of 1.0 m gravel, or 0.5 m paved, must be maintained to provide the pavement with adequate lateral support. Additionally, minimum standards for shoulder widths, shoulder rounding, and clear zones must be adhered to.

An exception to the minimum shoulder width requirement may be considered in the application of resurfacing and curve widening to secondary highways, particularly those with low traffic volumes. Where the required curve widening closely approaches or exceeds the existing shoulder width, an acceptable and cost-effective design alternative to road widening may be to utilize the entire shoulder width to achieve the curve widening.

For resurfacing projects with no recycling, or with partial-depth recycling, widening values of 0.25 m may be ignored. If the widening requirement is 0.5 m or less, the total widening may be applied to the inside of curve to avoid application of a narrow strip of base pavement to both sides of the highway prior to resurfacing.

For resurfacing projects with full-depth recycling, curve widening should be applied by adding one half of the total requirement to each side. Widening values ending in 0.25 or 0.75 should be rounded to a higher even digit before dividing in half. For example, if 0.75 m total widening required, it may be 0.4 m in each side (0.75+0.05)/2=0.4 m.

Section 3.2.6.1 – General Application (Horizontal Alignment: Design Domain Additional Application Heuristics)

- This Section is Applicable with the following additional Guidance:

    - Horizontal curves should lead vertical curves.
    - At the end of a long tangent section, a transition of gradually decreasing radius should be introduced to allow the driver to adjust his speed to the new condition. The additional length provides the opportunity for reducing speed safely.
    - Spirals should be used wherever possible rather than compounding circular curves.
    - The desirable horizontal curve for design speeds of 120 km/h and 130 km/h should be 1,700 m and 2,300 m respectively.

    Deviation from Standards

    For the most part in design, desirable standards should be observed, and minimum standards should be exceeded. However, in isolated instances where other controls pose a severe restraint in applying minimum standards, substandard horizontal geometry may be tolerated where there is no evidence of any geometric deficiency as indicated by the accident record. (See Chapter 1, section 1.2.3) In such cases, curves should have radii and superelevations corresponding to speeds normally of not more than 10 km/h less than design speed, and in no case more than 20 km/h less. The designer should demonstrate with respect to safety and economics that application of substandard curve is the optimum solution and must document this in the design package. In assessing the implications of employing substandard curves, the designer should observe the following principles:

- Substandard horizontal curves are potentially hazardous since limiting values are based on lateral friction values and design speed and, therefore, near-limiting conditions occur frequently.
- Substandard horizontal curves should not be introduced adjacent to areas where speeds might be higher than either posted speed or design speed, for example, following long tangents, or at the bottom of downgrade.

Guidance on Railway Grade Crossing Regulations and Standards
Highway Design Office prepared and issued the *"MTO Railway Guidelines"* in March 2023. This Guideline is available on the MTO Publication website at the following link:
https://www.library.mto.gov.on.ca/SydneyPLUS/TechPubs/Portal/tp/tdViews.aspx?lang=en-US
In the search bar, write "MTO Railway Guidelines" and click search.

Section 3.2.6.3 – Horizontal Alignment and Lateral Clearances: Design Domain Quantitative Aids

- The second paragraph of this Section is Not Applicable which references Figure 3.2.12.

Figure 3.2.12 – Lateral Clearances for Passing Sight Distance

- This Figure is Not Applicable and is replaced with the **Exhibit-3K**.

Exhibit-3K

LATERAL CLEARANCE FOR PASSING SIGHT DISTANCE (m) FOR TWO-LANE HIGHWAYS (m)

(from centerline of inside lane to sight obstruction)

Design Speed (km/h)	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**
Passing Sight Distance (m)	**120**	**140**	**160**	**180**	**210**	**245**	**280**	**320**	**355**	**395**	**440**
Radius (m)	**Lateral Clearance for Passing Sight Distance (m)**										
10000	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.4
7000	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.3	2.8	3.5
5000	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.6	3.2	3.9	4.8
4000	2.0	2.0	2.0	2.0	2.0	2.0	2.4	3.2	3.9	4.9	6.0
3000	2.0	2.0	2.0	2.0	2.0	2.5	3.3	4.3	5.2	6.5	8.1
2000	2.0	2.0	2.0	2.0	2.8	3.8	4.9	6.4	7.9	9.7	12.1
1500	2.0	2.0	2.1	2.7	3.7	5.0	6.5	8.5	10.5	13.0	16.1
1200	2.0	2.0	2.7	3.4	4.6	6.2	8.2	10.7	13.1	16.2	20.1
1000	2.0	2.4	3.2	4.0	5.5	7.5	9.8	12.8	15.7	19.4	24.1
900	2.0	2.7	3.6	4.5	6.1	8.3	10.9	14.2	17.4	21.6	26.8
800	2.2	3.1	4.0	5.1	6.9	9.4	12.2	15.9	19.6	24.3	-
700	2.6	3.5	4.6	5.8	7.9	10.7	14.0	18.2	22.4	27.7	
600	3.0	4.1	5.3	6.7	9.2	12.5	16.3	21.2	26.1	-	
500	3.6	4.9	6.4	8.1	11.0	14.9	19.5	25.4	-		
400	4.5	6.1	8.0	10.1	13.7	18.6	24.3	31.6			
350	5.1	7.0	9.1	11.5	15.6	21.2	27.6	-			
300	6.0	8.1	10.6	13.4	18.2	24.7	32.1				
250	7.2	9.7	12.7	16.0	21.7	29.4	-				
220	8.1	11.0	14.4	18.2	24.6	-					
200	8.9	12.1	15.8	19.9	26.9						
180	9.9	13.4	17.5	22.0	29.8						
160	11.1	15.1	19.6	24.7	-						
140	12.7	17.1	22.2	27.9							
120	14.7	19.8	25.7	32.2							
100	17.5	23.5	30.3	-							
90	19.3	25.9	33.3								
80	21.5	28.7	36.8								
70	24.2	32.2	-								
60	27.6	36.4									
50	31.9	41.5									

Section 3.3.2.3 – Maximum Grade: Design Domain Quantitative Aids
Section 3.3.2.4 – Maximum Grade: Design Domain Application Heuristics

- These two Sections are Applicable except reference to Table 3.3.1 which is Not Applicable and is replaced with **Exhibi-3L, Exhibit-3M,** and **Exhibit-3N.**
- The following sub-bullets added in bullet # 6:
    - Local precipitation - rain and snowfall patterns
    - Drainage and susceptibility of erosion in the surrounding area
- The following additional Guidance is also Applicable in these two Sections:

Trucks on Grades

The effect of grades on truck speeds is much more pronounced than on speeds of passenger cars. The average speed of trucks on level sections of highway approximates the average speed of passenger cars. Trucks generally increase speed by up to 5 percent on downgrade and decrease speed by 7 percent or more on upgrades as compared to their operation on level terrain. On upgrades, the maximum speed that can be maintained by a truck is dependent primarily on the length and steepness of the grade and the truck's weight/power ratio, which is the gross vehicle weight divided by the net engine power. Other factors that affect the average truck speed on a grade are the entering speed, the aerodynamics resistance, icy condition of the road, and skill of the driver.

Exhibit-3L
MAXIMUM GRADES (PERCENT) FOR RURAL ROADS

Design Speed km/h	Traffic Volume					
	AADT					
	>4000	3000-4000	2000-3000	1000-2000	400-1000	<400
	DHV					
	>600	450-600	300-450	150-300	60-150	<60
120	6 - 7	-	-	-	-	-
110	6 - 7	6 - 7	6 - 7	6 - 7	-	-
100	6 - 8	6 - 8	6 - 8	6 - 8	6 - 8	-
90	6 - 8	6 - 8	6 - 8	6 - 8	6 - 8	-
80	6 - 8	6 - 8	6 - 8	6 - 8	6 - 8	8
70	-	6 - 12	6 - 12	6 - 12	6 - 12	12
60	-	-	-	6 - 12	6 - 12	12
50	-	-	-	-	-	12

Exhibit-3M

MAXIMUM GRADES (PERCENT) FOR URBAN ROADS

Design Speed km/h	Traffic Volume				
	AADT				
	>6000	3000-6000	2000-3000	1000-2000	<1000
	DHV				
	>600	300-600	200-300	100-200	<100
80	6 - 8	6 - 8	6 - 8	-	-
60-70	6 - 12	6 - 12	6 - 12	6 - 12	-
50	-	-	8 - 12	8 - 12	-
40-50	-	-	-	-	8 - 12

Exhibit-3N

MAXIMUM GRADES (PERCENT) FOR FREEWAYS

Design Speed km/h	Maximum Grade %
130	3
120	3
110	3 - 4
100	3 – 4
90	4 - 5

Section 3.3.2.5 – Minimum Grades: Design Domain Application Heuristics

- This section is Applicable including the following additional Guidance:

  Standard minimum gradients for curbed roads and ditches are provided in **Exhibit-3O**. In case of any discrepancies between TAC and **Exhibit-3O**, the Exhibit will govern. On roadways with curbs, drainage is generally adjacent to the curb and longitudinal gradients must be set so as to avoid excessive accumulation of water on the pavement. Minimum gradients shown in the table can be used for the normal conditions of rainfall and outlet spacing. In special cases hydraulic analysis should be carried out to determine where water might spread onto the adjacent travel lane.

Exhibit-3O

MINIMUM GRADES

Design Element	**Grade**	
	Desirable Minimum	**Absolute Minimum**
Curbed Roads	0.5%	0.3%
Uncurbed Roads with Adequate Cross-Slope	0.5%	0.0%
Unlined Ditches	0.5%	0.1%

Section 3.3.3.2 – Crest Vertical Curves: Technical Foundation Element

- This Section is Applicable with the following Modifications:
  - Driver's eye height should be 1.08 m for calculating K values for various sight distances.
  - Driver's eye height and object height for passing sight distance should be 1.08 m.

Section 3.3.3.3 – Crest Vertical Curves: Design Domain Quantitative Aid

- This Section is Applicable with the following Modifications:
  - Driver eye's height and object height for passing sight distance should be 1.08 m.
  - Last paragraph of example is Not Applicable and is replaced with the following:

    In order to maximize passing opportunities, K values for crest vertical curves should be chosen to achieve at least non-striping sight distance. Designers should strive to achieve 75% or greater passing opportunities over the length of road. For example, for a design speed of 110 km/h, the non-striping sight distance is 355 m, as provided in **Exhibit 3-P** below. This corresponds to a K value of 146.
    Per the formula (*Equation 3.3.2 at page 3-58 of Chapter 3*):

$$K = \frac{S^2}{200\left(\sqrt{h_1}+\sqrt{h_2}\right)^2} \qquad (3.3.4)$$

$$K = 355^2/\left[200*\left(\sqrt{1.08}+\sqrt{1.08}\right)^2\right] = 146 \qquad (3.3.5)$$

Table 3.3.3 – K Factors to Provide Passing Sight Distance on Crest Vertical Curves

- This Table is Not Applicable and is replaced with **Exhibit-3P**.

Exhibit-3P

K FACTORS TO PROVIDE PASSING SIGHT DISTANCE ON CREST VERTICAL CURVE

Design Speed (km/h)	Passing Sight Distance (m)	Rate of Vertical Curvature (K)
30	120	17
40	140	23
50	160	30
60	180	38
70	210	51
80	245	69
90	280	91
100	320	119
110	355	146
120	395	181
130	440	224

Reference: Table 3-36 –A Policy on Geometric Design of Highways and Street, 7th Edition, AASHTO – 2018

Section 3.3.5.1 – Vertical Alignment Principles: Application Heuristics

- This Section is Applicable along with **Exhibit-3Q**. In design and construction, standard K vertical curves should be selected from one of the values shown in **Exhibit-3Q**. These are for general guidance and consistency in the standards as past provincial infrastructure has been built based on these K-values. Since the integration of computer programs in highway design, designers are deviating from these K-values. However, for consistency and driver's expectations, selection of K-values should be as close as possible to the values in **Exhibit-3Q** while other parameters are also meeting**.**

Exhibit-3Q

K – STANDARD VERTICAL CURVE VALUES

4	5	8	10	12	15	18	20	25	30	35	40	45
50	60	70	80	90	100	120	150	180	200	230	250	300

Section 3.3.5.2 – Drainage: Application Heuristics

- Bulleted point number 5 and 6 are Not Applicable and are replaced with the following:

5. On flat crest and sag curves, storm water might run sufficiently slowly so as to spread onto the adjacent travelled lane. There is a level point at the crest of a vertical curve, but generally no difficulty with drainage on curbed pavements is experienced if the curve is sharp enough so that the minimum gradient of 0.30% is reached at a point about 15 m from the crest. This corresponds to a K value of 50. Where a crest of K value greater than 50 is used, special attention is needed to assure proper pavement drainage near the apex of the curve, for example, the application of more frequent catch basins.

6. For sag vertical curves the same criterion for crest curves applies, that is, the minimum grade of 0.30% is reached within 15 m of the level point. For a sag curve value of K greater than 50, special attention is required. Sag vertical curves normally occur in fill sections. In general, sag curves should be avoided in cut section since they often present drainage problems. If there are compelling reasons for a sag curve to occur in cut, for example, aesthetic considerations, precautions should be taken to ensure adequate drainage can be affected. This might be regarding the downstream side of a watercourse.

Section 3.3.5.3 – Snow: Application Heuristics

- This Section is Applicable with the following additional Guidance for Bullet # 1:

1. Snow drift is becoming even more pressing due to the increased severity and frequency of wind and snowfall due to climate change.

Section 3.3.5.5 – Vertical Clearances: Application Heuristics

- This Section is Not Applicable and is replaced with the following:

New Structures over Roadways

The minimum vertical clearance over the roadway for new structures shall be:

- 4.8 m for solid or cast-in-place concrete slab bridges
- 5.0 m for all other vehicular bridges

- 5.3 m for pedestrian and bicycle bridges
- 4.5 m for small signs
- 4.8 m for railway bridges over roadways
- 5.3 m for fixed attachments, such as large sign panels, of sign support structures
- 5.6 m for the lowest structural members, such as bottom chord, of sign support structures

The minimum vertical clearance over sidewalks, bikeways and snowmobile trails shall be 2.5 m.

Consideration should be given to a higher clearance for snow grooming equipment where required.

These dimensions take into account two resurfacings, live load deflection, foundation settlement, differential heaving of pavement and vehicle bounce.

All structures having a vertical clearance less than that specified above, shall require approval by the jurisdictional authority.

Existing Structures over Roadways

For existing structures where the highway is being resurfaced or reconstructed, the minimum vertical clearance over the roadway should be:

(A) For structures where the existing vertical clearance is equal to or greater than those specified “New Structures over Roadways”, the following shall apply:

- 4.7 m for solid or cast-in-place concrete slab bridges
- 4.9 m for all other vehicular bridges
- 5.2 m for pedestrian and bicycle bridges
- 5.2 m for fixed attachments

(B) For structures where the existing clearance is equal to or less than those specified in (A), the existing clearance shall be maintained

Note: All existing structures with a clearance of less than 4.5 m shall be signed accordingly. Bridges with a clearance less than 4.5 m has historically been recorded in the Ontario Structure Clearance and Load Inventory System (OSCLIS).

Recently, OSCLIS is replaced with a new system known as Bridge Management System (BMS).

Bridges over Railways

Minimum vertical clearance over railways is 7.01 m (23 feet) measured from the top of rail. Allowance should be made for curvature and superelevation of the track. Temporary clearances during construction, both vertical and horizontal, shall be as specified by the railway or railways having jurisdiction over the tracks. For details, designers are encouraged to refer latest edition of *"Standards Respecting Railway Clearances"* of Transport Canada. The current standard is TC E-05 of May 14, 1992

Bridges over Non-Navigable Waterways

Vertical clearance between the lowest point of the soffit and the design high water level shall be sufficient to prevent damage to the structure by the action of flowing water, ice flows, ice jams or debris, and shall not be less than 1.0 m for freeways, arterial roads and collector roads and not less than 0.3 m for local roads. Lower clearances over non-navigable waterways may be used for low volume roads. Lower clearances may also be used, with approval from jurisdictional authority, where it is prohibitive to use this criterion.

The design high water level referred to above include the amount of backwater created by a bridge or culvert and is the higher of the water level corresponding to the design flood discharge under ice-free conditions and the highest recorded water level created by ice jams.

Bridges over Navigable Waterways

Navigational vertical clearance is dependent on the type of vessel using the waterway and should be determined in consultation with the Canadian Coast Guard, Department of Fisheries and Oceans.

Clearance should also conform to the requirements of the Navigation Protection Act of Canada (NPA). The water level used as a basis for measuring navigational clearance should be the maximum likely to occur during the navigation season.

Approach Grade Elevation

Where the geometric and other non-hydraulic considerations permit, freeboard from the edge of through traffic lanes to the design high-water shall be 1.0 m for freeways, arterial and collector roads and 0.3 m for other roads.

Where the geometric and other conditions permit, the approach roadway shall be placed at an elevation that will not be overtopped during the normal design flood but will maximize relief overflow during the regulatory or other extreme flood.

Freeboard for Routes under Structures Crossing Water

Freeboard for highways under bridges that cross water shall be in accordance with the freeboard criteria for the approach grade elevations.

Freeboard for walkways, cycle paths and maintenance access roads under structures crossing water shall be at least 1.0 m above the water level for spans of more than 6.0 m and at least 500 mm for spans of 6.0 m or less. These values shall be increased where high maintenance costs are likely to result from use of the minimum values.

Minimum Vertical Clearances for Aerial Cable Systems

The minimum vertical clearances for aerial cable systems shall be in accordance with the Standard Drawing (OPSD or MTOD).

Airways over Roads

Minimum vertical clearance to airways is as indicated in *Figure 3.3.4* in the *TAC Geometric Design Guide for Canadian Roads – June 2017.* The dimensions are for guidance only and specific dimensions should be approved by the Regional Director of Civil Aviation, Transport Canada.

Construction Clearances

Construction clearances should conform to the requirements of the agency having jurisdiction over the roadway.

The minimum vertical clearances to temporary falsework shall be:

(I) 4.5 m for solid or cast-in-place concrete slab bridges over roadways
(II) 5.0 m for all girder type vehicular bridges over roadways
(III) 4.7 m for pedestrian or bicycle bridges over roadways
(IV) 4.5 m for railway bridges over roadways

Section 3.4.3 – Alignment Coordination: Design Domain Application Heuristics

- This Section is Applicable with the following additional Guidance:

  - Short vertical curvature should not be introduced on horizontal curves and, when possible, vertical curves should be made long with the mid-points of horizontal and vertical coincident.
  - Horizontal curves seen from a distance tend to appear foreshortened and the radius should be made longer to avoid the appearance of a kink.
  - It should be remembered that horizontal and vertical alignments are the most permanent design elements of a highway, and once a facility is constructed, poorly designed combinations will, in all likelihood, remain in operation and be experienced by road users for many years.

Section 3.5.4 – Cross-Slope Arrangements: Application Heuristics

- This Section is Applicable with the following additional Guidance:

Cross-Slope and Superelevation for Resurfacing Projects
On reconstruction and/or re-alignment projects, cross-slope and superelevation desirably should be restored to design standards. However, on resurfacing projects restoration to acceptable standards should only be made if it can be justified. These justifications must be clearly stated in the Design Criteria and documented in detail in the project file. The following justification guidelines are suggested, but should be used with care and judgement on the part of the designer:

Cross-slope
During the preliminary design stage, the costs to restore a section of pavement to both acceptable tolerances and design cross-slope standards must be determined and carefully assessed.

Resurfacing of a pavement is normally undertaken to strengthen the pavement structure and restore ride and/or skid resistance. This resurfacing can be carried out by a conventional overlay on the existing surface with some padding, by partial depth removal, or by an in-place recycling process including hot/cold in-place recycling. In conjunction with resurfacing to improve ride and pavement structure, cross-slope and superelevation correction may be incorporated to improve ride ability and safety. Minimum acceptable standards are provided in *Table 3.5.1: Pavement Cross-Slope for Resurfacing* in *Chapter 3 – Alignment and Lane Configuration.*

Where a conventional resurfacing or in-place recycling project is undertaken, the conventional or recycled binder course must be thick enough to allow for cross-slope correction to an acceptable tolerance. Where partial depth removal of the pavement is undertaken, milling can be utilized to correct cross-slope or superelevation to an acceptable tolerance. The average cross-slope rate selected for a specific resurfacing project must be reasonably consistent throughout and within the acceptable tolerances outlined above.

Restoration to acceptable standards should be justified in terms of the service to high speed traffic, potential reduction in accident experience and anticipated life expectancy of the project.

For example, resurfacing is occasionally programmed as a short-term improvement with the intention of carrying out more extensive work, such as road widening, in 5-10 years.

Restoration to acceptable standards may also be justified where new procedures with limited correction capabilities are being used.

Superelevation

Superelevation on curves may be less than design superelevation shown in *Table 3.2.5, Table 3.2.6,* and *Table 3.2.7 in Chapter 3.* Whenever superelevation is applied which is less than design superelevation, the maximum speed must be based on the acceptable standard for the rate of superelevation and the maximum friction factor ‘f’ for the range of radii as shown in **Exhibit-3R**.

In many cases design speed and posted speed are the same, particularly for low volume roads. To determine the need for superelevation correction, the following data should be obtained for each horizontal curve:

- existing superelevation
- existing radius
- accident experience
- 85th percentile operating speed

- maximum safe speed as determined by *Table 3.2.5 to Table 3.2.7* in *Chapter 3 – Alignment and Lane Configuration.*

The existing superelevation curves may remain less than that shown in *Table 3.2.5 to Table 3.2.7* of *Chapter 3 - Alignment and Lane Configuration* provided the following conditions are met:

- There is no unusual accident experience, such as loss of control type that can be related to inadequate superelevation.
- The maximum speed given by *Table 3.2.5 to Table 3.2.7* in *Chapter 3 Alignment and Lane Configuration* based on the prevailing rate of superelevation and the maximum friction factor is at least 10 km/h higher than the 85th percentile operating speed. (Generally, the 85th percentile operating speed will be close to the posted speed limit but can be significantly higher.)

Where the above conditions are not met, corrections should be applied to make the superelevation as shown in *Table 3.2.5 to Table 3.2.7* of *Chapter 3 Alignment and Lane Configuration* as follows:

- design standard, based on design speed, or
- acceptable standard, based on posted speed, or the 85th percentile operating speed plus 10 km/h, whichever is greater.

The cost of correction based on design and acceptable standards must be determined and taken into account in selecting the course of action to be followed.

Shoulder

On resurfacing projects, the shoulder cross-slope or superelevation should be improved to the design standard regardless of the treatment of cross-slope and superelevation to the adjacent traffic lanes.

For resurfacing shoulders without adjacent curbs, the fill slope or cut side slope should be maintained. The increased depth of shoulder will necessitate a reduction in shoulder width as shown in **Exhibit-3S.**

The resultant reduced shoulder width is acceptable provided both the following guidelines are met:

- The reduction in width is not more than 0.5 m
- The usable shoulder width is not less than 1.0 m

Exhibit-3R

MAXIMUM SPEED (km/h) AT GIVEN SUPERELEVATION FOR RESURFACING PROJECTS

RADIUS	SUPERELEVATION m/m										
m	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08
45	29	31	32	32	34	34	35	35	37	37	39
50	31	32	33	34	35	35	37	37	39	39	41
55	32	34	34	35	35	37	39	39	40	40	42
60	34	35	36	37	37	39	40	41	41	42	44
65	35	37	37	38	39	40	41	42	43	43	46
70	36	38	38	39	41	41	43	44	45	46	48
75	37	40	39	40	42	42	44	46	46	48	49
80	39	41	40	41	43	44	45	47	47	49	50
85	40	42	41	42	45	46	47	48	48	50	51
90	41	43	42	43	46	47	49	49	50	51	53
95	42	43	44	45	47	49	50	50	51	53	55
100	43	44	45	46	48	51	51	51	52	55	56
105	44	44	46	47	49	52	53	52	53	56	57
110	45	45	47	48	50	53	54	53	54	57	58
115	46	46	48	49	51	54	55	54	56	58	59
120	47	47	50	50	52	54	56	55	57	59	60
125	48	48	51	50	53	55	57	54	58	60	61
130	48	49	52	51	55	56	58	57	60	62	63
140	50	50	53	52	56	57	59	59	62	63	65
150	51	51	54	54	57	58	60	61	64	65	67
160	52	53	56	56	59	60	62	63	66	67	69
170	54	55	58	57	60	62	64	65	68	69	71
180	56	57	59	59	62	64	66	67	70	71	73
190	57	59	60	60	64	65	67	69	71	72	74
200	58	61	62	61	66	67	69	70	72	73	75
210	60	62	63	63	67	68	71	72	74	75	77
220	61	63	64	64	68	69	72	74	76	77	79
230	62	63	66	66	70	71	74	76	78	79	81
240	63	65	67	68	71	73	75	78	80	81	83
250	64	66	68	71	72	74	76	80	82	83	85
280	68	69	70	73	75	77	79	82	84	86	88
300	70	72	72	75	77	79	82	84	86	88	90
320	72	75	74	77	79	81	85	86	88	90	92
340	74	76	77	80	82	83	87	88	90	92	94
350	74	77	79	82	84	86	89	90	92	95	97
380	77	79	82	85	87	89	91	93	95	97	99
400	78	81	84	87	89	91	93	95	99	99	101
420	81	83	86	89	91	94	95	98	101	102	104
450	83	85	88	91	93	96	97	101	104	105	107
475	84	87	90	93	95	98	101	103	106	108	110
500	86	89	92	95	97	101	103	105	108	110	113
525	88	91	94	97	99	103	105	107	110	113	115
550	90	93	96	98	101	105	107	109	113	115	117
575	92	94	97	100	103	107	109	111	116	117	119
600	93	96	99	102	101	109	111	114	118	119	
650	96	99	102	105	109	111	114	117	120		
700	98	102	105	108	111	114	117	121			
750	101	105	107	111	115	116	121				
800	104	108	110	114	118	121					
850	107	110	112	117	121						
900	109	113	116	120							
950	111	115	118								
1000	113	117	121								
1050	115	119									
1100	117	121									
1150	18										
1170	119										

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

Where these guidelines are not met the shoulder should be widened to provide either:

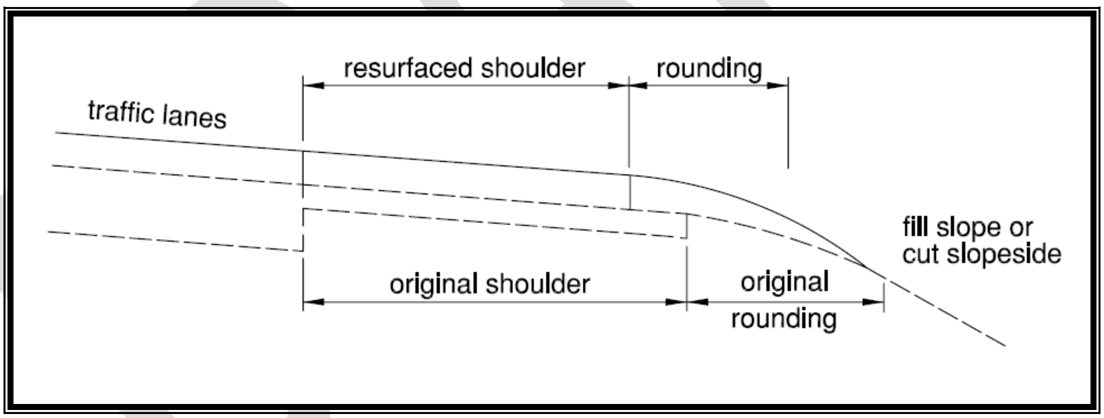
- An acceptable shoulder width equal to the width occurring on most of the project, or
- The standard width noted in the replaced *Section 4.4.2 of MTO Design Supplement*

The cost of widening to either of the above criteria should be compared.

If the shoulder requires widening over more than 10% of the project length excluding intersection improvement, application of the standard width should be considered. Resurfacing of full or partially paved shoulders should be dealt with on a project-specific basis. The cross-slope or superelevation desirably should be as shown in the replaced *Section 4.4.4 of MTO Design Supplement.*

Exhibit-3S

SHOULDER TREATMENT ON RESURFACING PROJECTS



Section 3.5.5 – Cross-Slope Changes: Application Heuristics

- This Section is Applicable with the following additional Guidance:

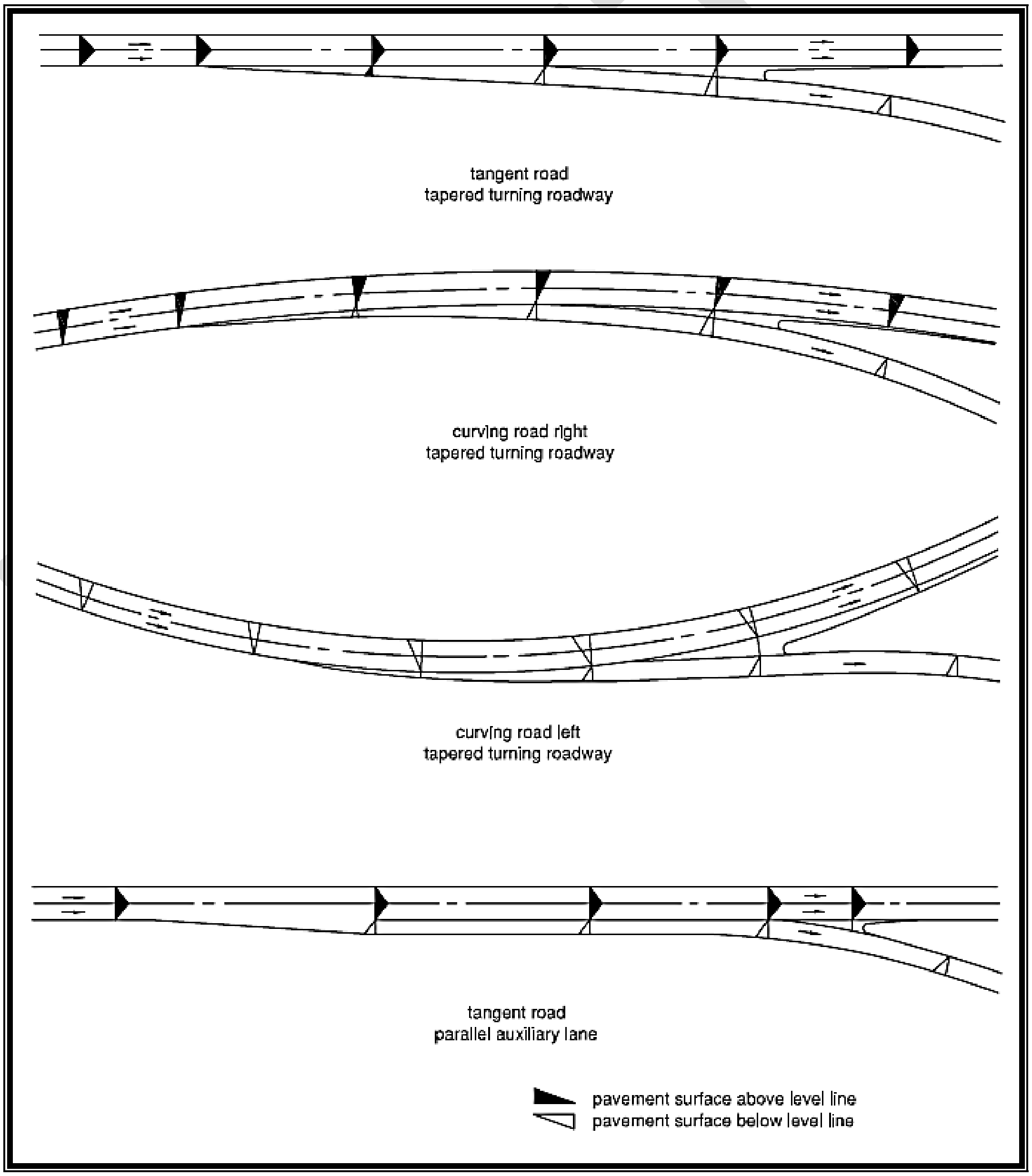
Exhibit-3T illustrates the development of superelevation at a turning roadway exit terminal for alternative alignments and auxiliary lane treatments.

Section 3.6.2.1 – Technical Foundation

- This Section is Applicable with the following additional Guidance:
  Designers should also consider strategies to alleviate congestion, when determining the number of lanes required to best accommodate free-flow traffic conditions, with the goal of minimizing greenhouse gas emissions.

Exhibit-3T

DEVELOPMENT OF SUPERELEVATION AT TURNING ROADWAY EXIT TERMINAL



Section 3.6.3.2 – Application Heuristics

- Last two paragraphs of this section are Not Applicable. Replace with the following:

Where an auxiliary lane is extended beyond an entrance to maintain both lanes balance and basic lanes, the lane should be continued for at least 400 m, as shown in **Exhibit-3U**, to permit entering traffic to disperse into the through lanes. Additional length is warranted if the:

- Ramp traffic volume is high
- Truck traffic on the freeway is heavy
- Roadway is on an upgrade, or
- The lane drop occurs at crest curve

In the case of an auxiliary lane introduced before an exit, the lane should be extended as shown in **Exhibit-3V** to make full use of the capacity of the added lane.

Section 3.6.4 – Express Collector Systems: Best Practices

- This Section is Applicable with the following additional Guidance:

A separated highway system using the express and collector lanes aims to allow for more efficient use of the highway which helps to lower overall emissions through efficient travel. Express lanes allow vehicles to remain at more constant speeds without weaving in and out of traffic. This leads to less braking and speed variability in those lanes and hence the reduction of emissions from the vehicles in express lanes. Collector lanes aim to accommodate vehicles entering or exiting the highway and serve the same purpose of allowing for more efficient travel in the express lanes. As well, separating the highway system into collector and expressway lanes allows one to continue to accommodate traffic in the event of the other having to shut down.

Section 3.7.1.1. – Technical Foundation

- This Section is Applicable with the following additional Guidance:

  With good lane balance practices, drivers are more likely to quickly recognize which lanes are suited for their travel needs and maintain free flow speeds. Good lane balance discourages unnecessary braking and reduces the amount of weaving to change lanes, in turn lowering vehicle emissions.

Section 3.8.1 – Introduction

- This Section is Applicable with the following additional Guidance:

  In addition to climbing lanes being a safety feature, they can also prevent congestion, backups, and associated emissions. For example, on hills, these lanes allow road users to pass slower-moving vehicles.

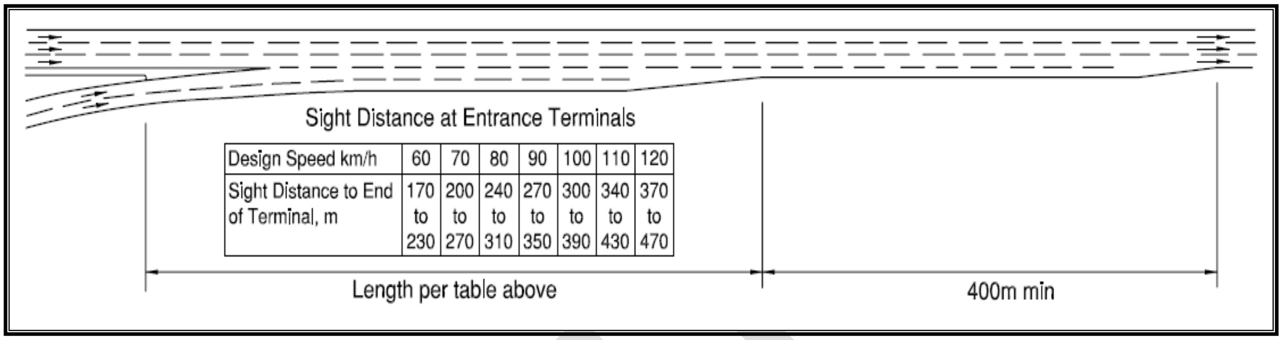
Section 3.8.2 – Grades and Operations: Technical Foundation

- This section is Applicable with the following additional Guidance:

A mass/power ratio of 120 g/W should be used as representative of the size and type of vehicle for design control within Ontario right-of-ways.

Exhibit-3U

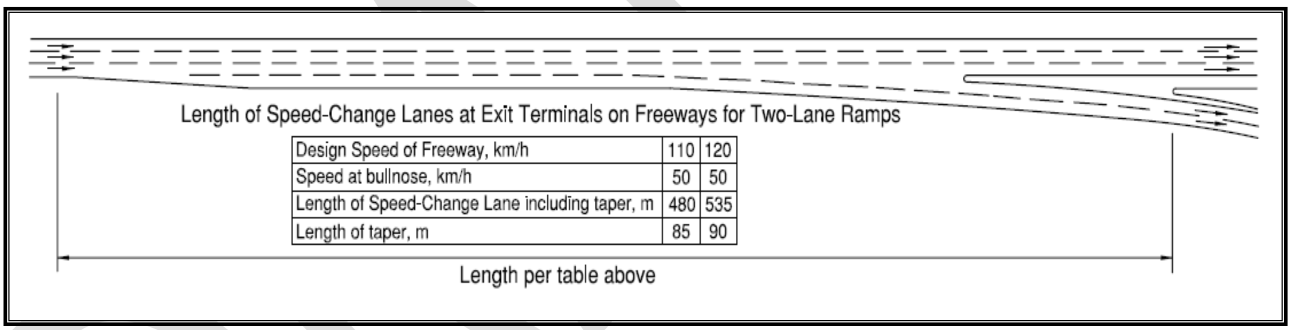
AUXILIARY LANE EXTENDED BEYOND ENTRANCE



Design Speed km/h	60	70	80	90	100	110	120
Sight Distance to End of Terminal, m	170 to 230	200 to 270	240 to 310	270 to 350	300 to 390	340 to 430	370 to 470

Exhibit-3V

AUXILIARY LANE INTRODUCED BEFORE AN EXIT



Design Speed of Freeway, km/h	110	120
Speed at bullnose, km/h	50	50
Length of Speed-Change Lane including taper, m	480	535
Length of taper, m	85	90

Section 3.8.3.3 – Warrants for Multilane Roads

- This section is Not Applicable and is replaced with the following:

Warrants on Multi-Lane (4 Lanes or more) Highways

On a multi-lane highway, a drop in the level of service or a speed reduction of 15 km/h (critical length of grade), on the upgrade, should be regarded as an indication that a climbing lane may be required. To verify this, an operational analysis of the roadway should be performed, both for the approach segment and the upgrade.

Should this analysis reveal that an additional lane is required on the upgrade, this is an indication that a climbing lane is warranted. However, the designer should then determine what the expected level of service is, on the upgrade, in the mixed vehicle lanes, after the climbing lane is constructed, to ensure that this will bring them up to the desired level of service.

To determine the capacity of the climbing lane and the number of trucks which can realistically be expected to use it, use the following equations:

$C_T = 2000/E_T$

Where

C_T is the capacity of the climbing lane in v/h

And

E_T is the passenger car equivalent of trucks; refer to **Exhibit-3W**

The climbing lane should operate at approximately the same v/c ratio (i.e. level of service) as the rest of the roadway, thus select the v/c ratio corresponding to the desired design level of service. The service flow for the climbing lane can then be calculated:

$SF_T = C_T(v/c)_i$

Where

SF_T is the service flow for the truck lane and $(v/c)_i$ is the v/c for LOS_i

This is the number of trucks that can reasonably be assumed to use the climbing lane. The remaining heavy vehicles will share the mixed traffic lanes.

Exhibit-3W

PASSENGER CAR EQUIVALENTS ON EXTENDED GENERAL MULTI-LANE HIGHWAY SEGMENTS

	Type of Terrain		
Factor	**Level**	**Rolling**	**Mountainous**
E_T (for trucks)	1.7	4.0	8.0
E_R (for RV’s)	1.5	3.0	5.0
E_B (for buses)	1.6	3.0	4.0

Section 3.9.1 – Introduction

- This Section is Applicable with the following additional Guidance:

Introducing a passing lane where appropriate will help alleviate queues and platoons along with increased frustration and risk behavior in drivers resulting in unsafe maneuvers. Alleviating queues by the inclusion of passing lanes can help in reducing congestion and associated emissions.

Section 3.9.4.6 – Signing and Lane Marking

- This Section is Applicable by using *Ontario Traffic Manual Books* instead of *MUTCDC (Manual of Uniform Control Devices for Canada).*

Section 3.9.3 – Best Practices: Warrants
Figure 3.9.2 – Typical Traffic Simulation Output of Percent Following and Correlation with LOS
Section 3.9.4 – Application Heuristics
Section 3.9.4.1 – System Consideration
Table 3.9.1 – Typical Passing lane Spacing

- These above noted Sections, Figure, and Table are Not Applicable. Refer to *Section 6.3 Passing Lane Requirements of ministry's Capacity Analysis Manual – January 2016*.

MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 4 for Chapter 4

Cross Section Elements

June 2023

MTO Design Supplement
Appendix 4 for Chapter 4
Cross Section Elements

The following design supplements are applicable to Chapter 4 – Cross Section Elements of TAC Geometric Design Guide for Canadian Roads - June 2017:

Section 4.1.6 – Cross Section: Design Domain Controls

- This Section is Applicable with the following additional Guidance:
    - Inclusion of vegetation and other landscaping architecture measures can act as carbon sinks absorbing carbon dioxide. Landscaping also has the added benefits of improving drainage, providing soil stability, reducing erosion, improving air quality, countering snow/wind drifts and reducing driver stress.
    - Vegetation can be used as a measure to reduce the impacts of the heat island effect. Road surfaces absorb—rather than reflect—the sun's heat, causing surface temperatures and overall ambient temperatures to rise. Heat islands increase overall electricity demand as a result of the need to air condition surrounding buildings. This is of particular concern in highly urbanized areas. Having vegetation in these areas can cool the surrounding environment and reduce the resultant electrical demand.
    - In areas that tend to experience stronger winds, trees and vegetation can be considered in the design to act as barriers. For example, rows of trees (windbreaks), can block some wind and reduce wind strength while also shielding roadways and structures from snow drifts. However careful consideration should be given to ensure debris from branches and down trees will not potentially impact highway operations.
    - Wildfires are becoming an increasing concern in the province. Incorporating trees in areas more at risk of wildfire may create additional concern for roadway operations. The threat of wildfire should be examined when including trees and building next to forested areas.

- As the frequency and likelihood of storm events increase due to climate change, warning signs for inclement weather (for example signs for fog or snow) should be considered for areas where more dangerous roadway conditions are expected to pose threats.
- Active transportation should be included in design where it makes sense to do so. It easier to include cycling in the initial design then trying to retrofit after the fact as geometrics may be constrained.

Figure 4.1.3 – Bicycle Facility Nomenclature

- This Figure is Not Applicable. Designer should refer to the ministry's *Bicycle Design Manual – March 2014.*

Section 4.2 – Lane Widths

- Under this Section, the following Sub-sections and Tables are Not Applicable and are replaced with the Guidance and Exhibits provided below:
  - **Sub-section 4.2.1.1 – Technical Foundation**
  - **Sub-section 4.2.1.3 – Design Domain: Quantitative Aids**
  - **Table 4.2.1 – Through Lane Widths – Rural Roadways (Design Hour Directional Volume <= 450)**
  - **Table 4.2.2 – Through Lane Widths – Rural Roadways (Design Hour Directional Volume > 450)**
  - **Table 4.2.3 – Through Lane Widths – Urban Roadways**
  - **Sub-section 4.2.1.4 – Design Domain: Application Heuristics**

<u>**Guidance on Lane Widths**</u>

Introduction

Lane width and condition of the road surface have a significant influence on the safety and comfort of the travelling public.

Studies on 2-lane two-way highways have shown that inadequate vehicle lanes less than 3.5 m wide when carrying even moderate volumes of mixed traffic. To provide desirable clearance between commercial motor vehicles, lane widths of 3.75 m may be required. It is generally desirable to maintain this width in higher speed 2-lane roads. Traffic volumes and composition are considerations.

The capacity of a road is markedly affected by lane width. For example, on 2-lane rural roads the capacities of 3.0 m and 3.25 m lanes are reduced to 77% and 83% respectively of the capacity provided by a lane width of 3.75 m. For 4-lane undivided highways these ratios are 88% and 94% respectively. In terms of capacity the effective width if further reduced by lateral obstructions less than 2.0 m from the edge of pavement or narrow shoulders.

Through Lanes

Standard lane widths on Provincial highways are multiples of 0.25 m and generally range from 2.75 m to 3.75 m depending on a number of factors. Prior to adopting metric system, lane widths were provided in the imperial system and ranging from 9 ft to 12 ft with an increment of 1 foot. Lane widths on existing highways from the previous measurement system may be found 3.33 m (11 ft) or 3.66 m (12 ft); these widths may be maintained as long as operational and safety concerns are not present since studies have shown that small sliver widening is rarely cost effective.

Values for lane widths for various classifications of roads are set out in the following paragraphs. These are general guidelines to be followed when considering the selection of lane widths. Deviations from desirable design standards may be appropriate as outlined below, particularly for secondary highways. In general, higher design speeds warrant wider lanes. In addition, wider lanes are normally appropriate:

- for major highways which typically carry high volumes over long distances between important regional centres.
- where warranted by type, size, and volume of commercial traffic.

Narrow lanes are appropriate for minor highways, which are typically local, low volume, short distance roads and provide access to recreational or resource areas.

On new construction and reconstruction projects, lane widths from the Tables **(Exhibit-4A to Exhibit-4B)** should be applied. Lane widths which are not in these two Exhibits are provided in texts.

In rugged terrain narrower lanes may be appropriate by reason of cost and this consideration is reflected in the selection of design speed.

When a highway is to be resurfaced, consideration should be given to retaining the existing cross section dimensions where the dimensions in the Tables cannot be accommodated within the existing roadway. Alternatively, standard lane widths may be applied together with reduced shoulder width of 1.0 m gravel or 0.5 m paved is maintained for pavement support. Where the existing pavement is either fully or partially reclaimed or recycled, lane widths are determined as follows:

- reclaimed to full depth and recycled:
  - the new pavement width should be the design standard.
- reclaimed to partial depth and recycled:
  - If the design standard is less than the new existing width, the new pavement width should be identical to the existing width.
  - Where partially or fully paved shoulders are required, consider providing the paved portion of the shoulder.
  - If the design standard is greater than the existing width, the design standard should be used. This practice should be applied regardless of shoulder surface treatment.

Where adjacent sections off secondary highways are to be resurfaced and reconstructed, different lane and shoulder widths are acceptable.

2-Lane Rural Roads

Lane widths for 2-lane King's Highways are shown in **Exhibit-4A** and **Exhibit-4B** for a range of volumes stated in terms of Annual Average Daily Traffic (AADT) and Design Hour Volume (DHV). If both are known, DHV should be used for design. Width adjustments for commercial motor vehicle percentages are indicated.

The selection of lane width for 2-lane rural roads is dependent primarily in design speed, traffic volume and traffic compassion. Service function and topography influence the selection of design speed and therefore have a bearing on lane width.

Lane and shoulder widths may be designated on important long-distance highways to ensure continuity, regardless of traffic volumes.

Exhibit-4A

LANE WIDTH FOR 2-LANE RURAL HIGHWAYS

Design Speed km/h	**Traffic Volume for Design Year**					
	AADT					
	>4000	3000-4000	2000-3000	1000-2000	400-1000	<400
	DHV					
	>600	450-600	300-450	150-300	60-150	<60
120	3.75	-	-	-	-	-
110	3.75	3.75	3.75	3.5C	-	-
100	3.75	3.5A	3.5B	3.5	3.5	-
90	3.5A	3.5A	3.5	3.25	3.25	-
80	3.5	3.5	3.25	3.25	3.25	3.25D
70	-	3.25	3.25	3.0	3.0	3.0
60	-	-	-	3.0	3.0	3.0
50	-	-	-	-	-	2.75

Notes:

- Minimum lane width for all paved 2-lane Highways is 3.5m
- For design, use DHV if available
- Lane width may be increased by 0.25 m to a maximum of 3.5 m if warranted by type, size and volume of commercial motor vehicles.

A. If commercial motor vehicle percentage exceeds 10% increase by one increment

B. If commercial motor vehicle percentage exceeds 15% increase by one increment

C. If commercial motor vehicle percentage exceeds 25% increase by one increment

D. 3.0 m may be acceptable where the type, size, and volume of trucks are not significant

2-Lane and 4-Lane Undivided Urban Roads

Lane widths for 2-lane and 4-lane undivided urban roads are shown in **Exhibit-4B** for a range of design speeds from 40 km/h to 80 km/h and for ranges of traffic volumes stated in terms of AADT and DHV. No adjustment for commercial motor vehicle percentages is required for the use of this Table.

Exhibit-4B

LANE WIDTH FOR UNDIVIDED URBAN ROADS

Design Speed km/h	**Traffic Volume for Design Year**				
	AADT				
	>6000	3000-6000	2000-3000	1000-2000	<1000
	DHV				
	>600	300-600	200-300	100-200	<100
80	3.5 - 3.75*	3.5 - 3.75*	3.5	-	-
60-70	3.5	3.5**	3.25	3.25	-
50	-	-	3.0	3.0	-
40-50	-	-	-	-	2.75 - 3.0*
No. of lanes	4	2 - 4**	2	2	2

Notes:

- Minimum lane width for all paved 2-lane King's Highways is 3.5 m
- For design use DHV if available

  *****Upper value is desirable, lower value is acceptable

  ******Four lanes are appropriate in the upper part of this traffic range where there is a measurable capacity deficiency with only two lanes

4- Lane Undivided and Divided Rural Roads

Lane widths for 4-lane undivided and divided rural roads depend primarily on design speed and to a small degree on traffic volume or commercial motor vehicle percentages. Widths for 4-lane rural roads for design speed ≥ 100 km/h should be 3.75 m while 3.5 m width should be used for design speed less than 100 km/h.

4- Lane Divided Urban Roads

Lane widths for 4-lane divided urban roads depend only on design speed and not on traffic volume or commercial motor vehicle percentages. Lane widths for 4-lane divided roads for design speed ≥ 80 km/h should be 3.75 m while 3.5 m width should be used for design speed less than 80 km/h.

Freeways, Multilane Divided Urban Roads

For freeway and multi-lane divided roads, the width of the median lane should be 3.50 m while all other lanes should be 3.75 m, to minimize the overall pavement width. The pavement may be striped in equal lane widths.

Section 4.2.2.2 – Centerline Rumble Strips: Best Practices

- This Section is Applicable with the following additional guidance:

Introduction

Centreline Rumble Strips (CRS) are a grooved formation installed on the centreline of the highway. The intention of CRS is to provide the motorist with both an audible and tactile warning that their vehicle has partially encroached over the centreline onto the opposing traffic side of the highway. The audible warning to the motorist is produced by noise generated by the vehicle tires passing over the CRS. The tactile warning to the motorist is provided by vibration induced in the vehicle by the CRS. An encounter with CRS is expected to alert an inattentive motorist to steer back onto their side of the highway.

The approach to CRS installation should be proactive rather than reactive and may be in coordination with the Ontario Provincial Police (OPP) when needed. CRS shall be installed on sections of rural undivided highways as a safety measure to deter head-on collisions or opposite direction sideswipe collisions attributable to inattentive or drowsy drivers.

CRS shall be considered on sections of rural undivided highways where there is a history of head-on collisions or opposite-direction side swipe collisions attributable to inattentive or drowsy drivers.

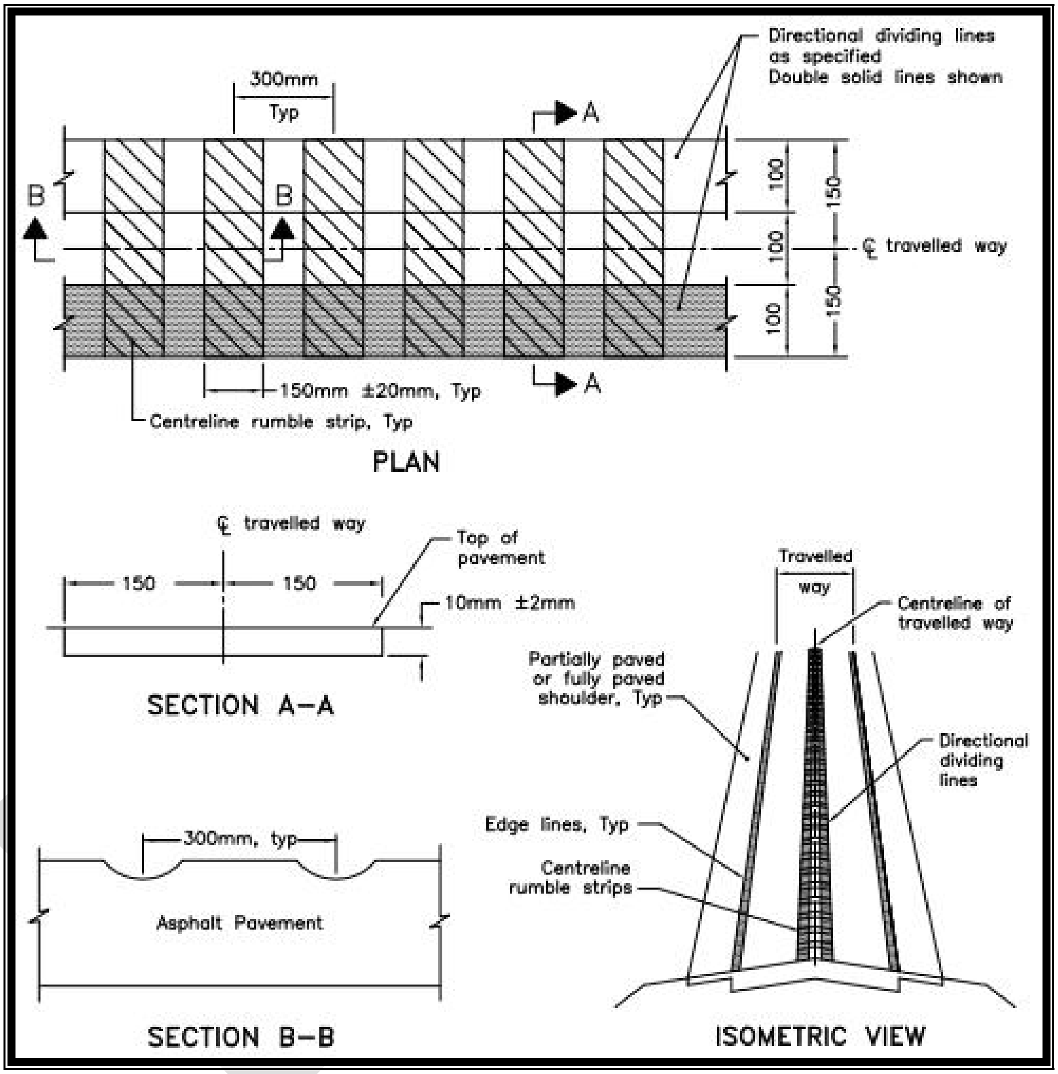
Design Guidance and Installation Considerations

- CRS shall be considered for installation on sections of rural high speed (posted speed 70 km/h) undivided highways.
- General arrangement of CRS in plan, section and isometric view is provided in **Exhibit-4C.**
- CRS shall be installed all along undivided highways in passing zones and in no-passing zones, and on curved and tangent sections.
- CRS may be considered for installation on sections of rural low speed (posted speed < 70 km/h) undivided highways identified through Traffic Engineering Software (collisions attributable to inattentive or drowsy drivers causing head-on or opposite direction side-swipe collisions).
- Regions shall make the decision for selection of section of highways considering technical and environmental aspects. Regions may involve the Ontario Provincial

Police in the process.

Exhibit-4C

GENERAL ARRANGEMENTS OF CENTRELINE RUMBLE STRIPS



- CRS may be installed either in conjunction with a construction project or as a retrofit by means of a separate contract. It is the responsibility of each Region to set priorities for the locations being considered for CRS.
- All ministry contracts that include CRS shall use the Centreline Rumble Strips item.
- CRS should not be installed on highways with lane widths less than 3.5 m adjacent to the centreline of highway unless identified through Traffic

Engineering Software (collisions attributable to inattentive or drowsy drivers causing head-on or opposite direction side-swipe collisions).

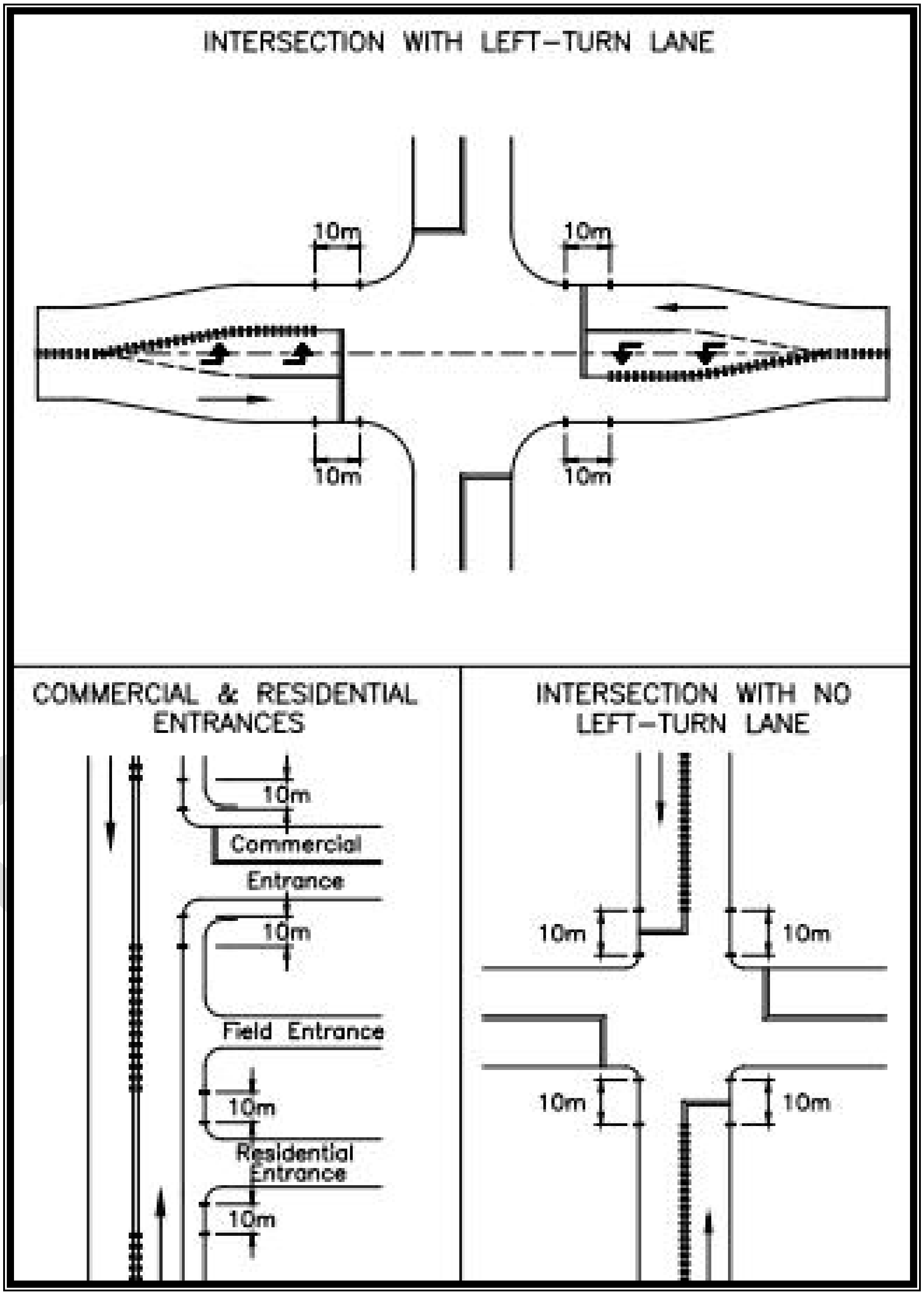
- On curved sections of highway where CRS are to be installed, pavement widening on curves should be in accordance with *TAC Geometric Design Guide (GDG) -2017* and ministry's *Design Supplement for TAC GDG*.
- CRS may be installed in the centre of rural divided high speed (posted speed ≥ 70 km/h) highways with flush medians.
- CRS should only be installed in asphalt pavement that is in good condition. CRS should not be installed in asphalt pavement having moderate to very severe surface defects, distortions or cracking distresses that are extensive to throughout as defined in the Manual for Condition Rating of Flexible Pavements (SP-024) and as verified during site review.
- Where CRS are being considered as a retrofit project on highways that were recently paved, the existing pavement warranty shall be reviewed.
- CRS should not be installed in exposed concrete pavements.
- CRS should not be installed on bridges.
- Where there are noise sensitive areas (e.g., residential build-up areas/urban) located closer than 100 m from the centreline of the highway, CRS should be discontinued 200 m on either side of the area.
- CRS should be discontinued 10 m in advance of the start of the corner radii of intersecting road or residential and commercial entrances as illustrated in **Exhibit-4D**.
- When planning/installing/designing CRS: 500 series standard drawings (MTODs), specification (OPSS), and Contract Design and Estimation Document (CDED) for CRS should be considered.
- Directional dividing pavement markings will need to be reinstated after installation of CRS.
- For inventory purposes, locations of all CRS being installed shall be documented describing their location by highway number, Linear Highway Referencing System's (LHRS) offsets, length, and installation date.

Figure 4.2.2 – Centreline Rumble Strips

- This Figure is Not Applicable

Exhibit-4D

CENTRELINE RUMBLE STRIPS AT INTERSECTIONS AND ENTRANCES



Section 4.3.2.1 – Passing and Climbing Lanes

- This Section is Not Applicable and is replaced with the following Guidance:

Truck Climbing Lanes

These are introduced on steep upgrades to provide a lane for commercial motor vehicles and other slow-moving vehicles whose speed drops more than 15 km/h because of the grade. The through uphill lanes are kept free for faster traffic. Truck-climbing lanes increase capacity, improve travel times, and reduce accident rates.

The width of the truck-climbing lane may be 0.25 m less than the adjacent through lane, but it should not be less than 3.25 m.

Passing Lanes

Passing lanes are similar to truck-climbing lanes but are not necessarily located on upgrades. Passing lanes are applied to 2-lane roads carrying large volumes of slow-moving vehicles (for example, recreational routes). A slow-moving vehicle will cause a queue to form because of lack of passing opportunity, sight distance restrictions or large volumes of opposing traffic. Passing lanes are introduced at intervals to allow following vehicles to overtake. Passing and climbing lanes also help to ensure that free flow traffic conditions can be achieved which results in less associated emissions from slower moving vehicles causing congestion.

The width of the passing lane may be 0.25 m less than the adjacent through lane, but it should not be less than 3.25 m.

Section 4.3.2.2 – Right-Turn Lanes

- This Section is Not Applicable and is replaced with the following Guidance:

Right-turn lanes are auxiliary lanes added to the right of through lanes ahead of intersections to allow right-turning traffic to slow down before making the turn, without interfering with following through traffic, and to provide additional capacity at intersections. The lane may or may not lead directly into an exclusive right-turning roadway.

The width of the right-turn lane may be 0.25 m less than the adjacent through lane, but it should not be less than 3.25 m.

Section 4.3.2.3 – Left-Turn Lanes

- This Section is Not Applicable and is replaced with the following Guidance:

Left-Turn Lanes are auxiliary lanes added to the left of through traffic lanes to provide a refuge for left-turning traffic waiting to make the turn and to avoid interference with following through traffic. Left-turning traffic typically will move into the left-turning lane, slow down and wait for a suitable gap in oncoming traffic to make the turn. Left- tum lanes are used with and without medians.

The width of the left-turn lane not adjacent to a median should be 0.25 m less than the adjacent through lane, but it should not be less than 3.25 m. Left-turn lanes adjacent to a raised median without a gutter should have the curb offset by 500 mm. Left-turn lanes adjacent to a raised or painted median should be not less than 3.0 m wide.

Section 4.3.2.4 – Parking Lanes

- This Section is Not Applicable and is replaced with the following Guidance:

Cross section design may include provision for parking. This is normally limited to urban roads. Parking facilities should offer safe and convenient access and egress for parking users and at the same time maintain safe and convenient operation for other traffic.

Parking dimensions depend on the vehicle dimensions and steering geometry of vehicles to be parked, and on the form of parking provided. Although there is a marked trend toward smaller cars in recent years which would suggest smaller parking dimensions, parking facilities should be able to accommodate most cars and dimensions should be adequate for all but the larger passenger vehicles.

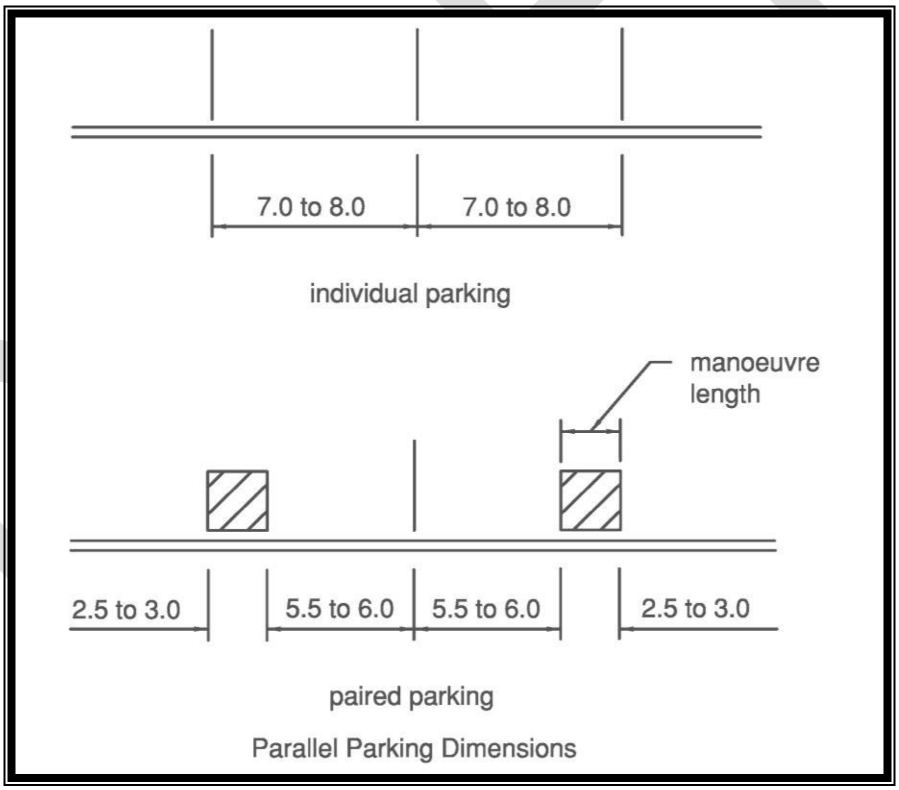
On-street parking is normally parallel or angled to the alignment of the roadway. Parking at right angles to the alignment offers the most efficient use in terms of parking area but is seldom considered for on-street parking since it calls for a very wide cross section and is very interruptive to the flow of through traffic.

For parallel parking the parking lane width for design speeds up to 70 km/h should be 2.5 m and for higher design speeds the width should be 3.0 m.

In selecting a suitable stall length for parallel parking, consideration should be given to either individual stalls or to pair parking stalls, as shown in **Exhibit-4E**. The individual stall provides for maneuvering within its own length, whereas in the paired stall a maneuvering area is delineated by paint and can be used by either of the two vehicles entering or leaving the two adjacent areas.

Exhibit-4E

PARALLEL PARKING



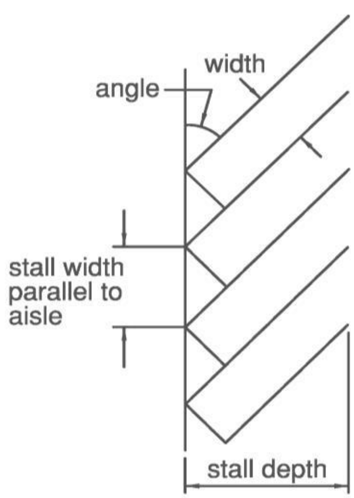
For individual parking stalls the length should be 7.0 m to 8.0 m to allow for a 6.0 m vehicle. The smaller dimension may be used but shorter stalls cause drivers to take more time maneuvering and cause additional delay and turbulence to through traffic.

For paired parking stalls, the stall should be from 5.5 m to 6.0 m and the maneuver length from 2.5 m to 3.0 m. Since the maneuver area is used for two stalls, the average length of roadway per stall is 6.75 m to 7.5 m, a saving over the individual stall of 3.5% to 6%. Angle parking allows more vehicles to be parked in a given length of roadway than parallel parking; the higher the angle the more vehicles parked. Typical dimensions for angle parking are shown in **Exhibit-4F.**

The choice of angle is usually governed by available width. However, although a higher angle permits more vehicles to be parked in a given length of roadway and reduces wasted area, the higher angle increases maneuver time and, consequently, generates more turbulence and delay in the through traffic flow. For in-street angle parking, angles in the 45° to 60° range are normally used.

Exhibit-4F

ANGLE PARKING



Angle	Width m	Stall width parallel to aisle m	Stall depth m
45°	2.5	3.5	3.9
45°	2.75	3.9	3.9
45°	3.0	4.2	3.9
60°	2.5	2.9	4.8
60°	2.75	3.2	4.8
60°	3.0	3.5	4.8
75°	2.5	2.6	5.3
75°	2.75	2.8	5.3
75°	3.0	3.1	5.3
90°	2.5	2.5	5.5
90°	2.75	2.7	5.5
90°	3.0	3.0	5.5

Angle Parking Dimensions

Carpool Parking Facilities – Accessible Parking Spaces for Persons with Disabilities

All projects involving new or expanded carpool parking facilities shall comply with the barrier-free parking space requirements contained in the Ontario Realty Corporation (ORC) Standards for Barrier-Free Design of Ontario Government Facilities. These Standards are intended to inform designers, contractors and government personnel, providing services to the Government of Ontario of the minimum requirements for barrier-free design in Government of Ontario owned and occupied facilities. According to Section 4 of the Ontarians with Disability Act which does not apply retroactively, these Standards shall be applied and implemented on a "go-forward" basis on new carpool and expanded carpool facilities. These Standards represent the minimum requirements regarding government facility accessibility. The ORC standards are:

- Provided a minimum number of barrier-free car parking spaces in each parking area per **Exhibit-4G** below:

Exhibit-4G

MINIMUM BARRIER-FREE CAR PARKING SPACES

Total Parking Spaces Provided	Minimum Barrier-free Spaces Required
1 – 10	1
11 – 20	2
21 – 50	3
51 – 75	4
76 – 100	5
101 – 200	6
Over 200	1 additional for each additional 100 spaces or part thereof

- In addition to the barrier-free car parking spaces, a minimum number of van parking spaces should be provided in each parking area per **Exhibit-4H**.

Exhibit-4H

MINIMUM VAN PARKING SPACES

Total Parking Spaces Provided	Minimum Van Spaces Required
1 – 50	1
51 – 300	2
301 – 700	3
Over 700	4

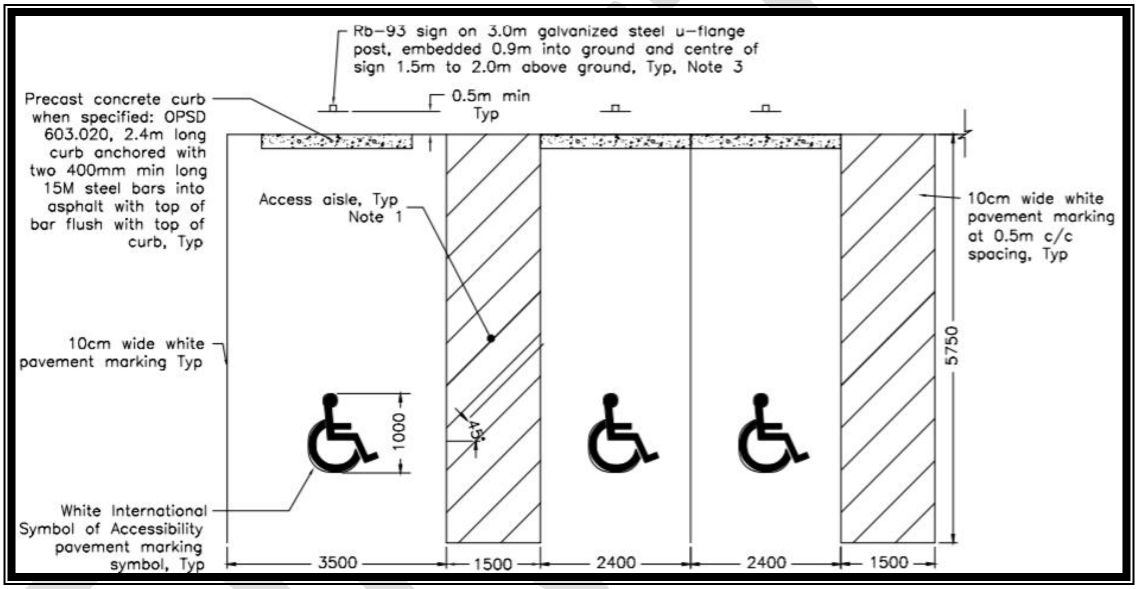
- The surface of all barrier-free parking spaces must be level (maximum slope in any direction 2%), firm (no gravel) and slip-resistant. Pavement markings must use non-slip paint. Do not paint the entire surface of the parking space.
- Provided signage and pavement markings illustrated in **Exhibit-4I** (For details see 500 series MTOD) to designate the barrier-free spaces as reserved for permit-

holders.

- A vertical post-mounted sign in front of the space, with the centre of the sign between 1500mm and 2000mm above the ground. Sign shall be in accordance with *Ontario Highway Traffic Act, Ontario Reg. 581*; and
- A painted pavement marking in the centre of the space, in contrasting colour to the pavement, 1000mm in length, with the International Symbol of Access.

Exhibit-4I

BARRIER-FREE PARKING SPACES – SIGNAGE AND PAVEMENT MARKINGS



Section 4.3.3.1 – Left-Turn Slip-Around Lane

- This Section is Not Applicable. Replace with the following:

Left-turn slip-around lanes may be used on 2-lane highways at ‘T’ intersections, where the left-turning traffic volumes do not warrant the standard left-turning treatment but may pose a threat to the safety of through traffic, and where by-passing vehicles throw gravel from the shoulder onto the highway.

The width of left-turn slip-around lanes should not be 0.25 m less than the width of the through lanes but not less than 3.25 m. For more guidance on the design of left-turn slip-around lanes refer to *Chapter 9 – Intersections.*

Section 4.3.3.2 – Continuous Right-Turn or Left-Turn Lane For Access

- This Section is Not Applicable and is replaced with the following Guidance:

  Continuous left-turn lanes are introduced between through lanes in both directions to provide storage for left-turning vehicles from either direction and are usually designated for left turns only throughout their length. This form of operation is well suited to 4-lane and multilane urban arterial roads where operating speeds are relatively low, in the range of 40 km/h to 70 km/h.

  Continuous left-turn lanes provide access to closely spaced, low-volume commercial driveways along arterial or collector roads. Continuous left-turn lanes may be inappropriate at many locations and conversion of existing continuous left-turn lanes to non-traversable medians may be considered. From an access management perspective, they increase rather than control access opportunities.

  Continuous left-turn lanes should be 4.8 m wide. The additional width over the adjacent through lane recognizes that vehicles are making turning maneuvers from both directions simultaneously, and the additional width adds a measure of safety. Lesser width to a minimum of 3.0 m may be applied where turning traffic is very low and operating speeds are less than 40 km/h.

Section 4.3.3.3 – Acceleration and Deceleration Lanes

- This Section is Not Applicable and is replaced with the following Guidance:

  Acceleration and deceleration lanes are auxiliary lanes adjacent to through lanes on freeways and arterial roads at interchanges for vehicles changing speed at entrances and exits. They also commonly known as Speed Change Lanes (SCL)

  - The width of acceleration and deceleration lanes should not be less than 0.25 m the width of the through lane, but not less than 3.25 m in any case.
  - Further information on SCL is contained in *Chapter 9 – Intersections* and *Chapter 10 – Interchanges.*

Section 4.3.3.4 – Weaving Lanes

- This Section is Not Applicable and is replaced with the following Guidance:

  Weaving lanes are auxiliary lanes introduced between an entrance followed by an exit in close succession, usually less than 1000 m, to minimize turbulence in the traffic stream and to maintain adequate capacity.

  The width of weaving lanes desirably should not be 0.25 m less than that of the through lane, but not less than 3.25 m in any case.

Section 4.3.3.5 – Transit Lanes

- This Section is Applicable except third bullet point. The second bullet point should be replaced with the following Guidance:

  Where a contraflow or counter-flow lane is provided, the width should be 4.0 m for design speed greater than 60 km/h, and 3.75 m to 4.0 m for design speed equal to or less than 60 km/h.

Section 4.3.3.6 – Service or Frontage Road Lanes

- This Section is Applicable except all three bullet points in the Section. For more guidance refer to Chapter 4 of the latest edition of ministry's *"Highway Corridor Management Manual".*

The following additional Guidance is Applicable for Section 4.3. – SPECIAL PURPOSE LANES

Bus Bays

Bus bays have the advantage of separating buses from other traffic during loading and unloading of passengers, however, they sometimes require additional right-of-way.

To be fully effective a bay should include: a deceleration lane or taper to permit convenient entrance to the loading area, a standing space sufficiently long to accommodate the maximum number of buses expected at one time, and a merging lane to provide convenient re-entry into the through traffic lanes. The dimensions of these elements should encourage the bus driver to position the bus completely clear of the through lane of traffic. Ideally the deceleration and acceleration lanes should be sufficiently long so that all acceleration and deceleration is contained within them, however this is normally not feasible.

Taper lengths for deceleration and acceleration should be 25 m each. The loading area should be about 15 m per bus and the width should be 3.0 m to the edge of curb. For details refer to *OPSD 501.010.*

Ramps and Transfer Lanes

An interchange is an intersection of two (or more) roadways separated vertically, with at least one roadway for travel between them. These interconnecting roadways are called ramps. A ramp is also applied to separate right turn lanes at channelized at-grade intersections. Transfer lanes are roadways to provide for travel between express lanes and a collector road or a service road. For more details see *Chapter 9, and 10 of TAC GDG 2017* along with *Appendices 9 and 10* of the ministry's *Design Supplement*.

The pavement width for single-lane ramps and transfer lanes is 4.75 m. The pavement width for ramps and transfer lanes of two or more lanes should be 3.75 m each and adjusted for curvature.

The pavement width of 4.75 m is based on the premise that interchanges carry sufficient single unit and semitrailer vehicles to govern design requirements. It also provides for widening on curves of radius greater than 50 m. For 50 m and smaller radii the width should be increased. For more guidance on the design refer to *Chapter 9 – Intersections* and *Appendix 9.*

Section 4.4.2 – Shoulder Width

- Within this Section, the following Sub-sections and Tables are Not Applicable and are replaced with the Guidance and Exhibits provided below:
    - **Sub-section 4.4.2.1 – Design Domain: Quantitative Aids**
    - **Table 4.4.1 – Shoulder Widths for Undivided Rural Roads**
    - **Sub-section 4.4.2.2 - Design Domain: Application Heuristics**

Guidance

Shoulder Width

For high-speed and/or high-volume highways the normal shoulder width is 3.0 m.

For highways of lower speed and/or lower volume, this width of shoulder is normally not justified, and a narrower shoulder may be applied.

The minimum shoulder width acceptable for pavement support is 0.5 m if the shoulder is paved, and 1.0 m if the shoulder is gravel surfaced.

It is desirable that a vehicle stopped on a shoulder for emergency reasons be clear of the pavement by at least 0.25 m and preferably 0.5 m. The minimum usable shoulder width required to accommodate a disabled vehicle is 2.0 m.

Where curb and gutter is placed at the outside edge of a shoulder, the gutter width is regarded as part of the usable shoulder width. Where a mountable curb and gutter is placed between the traffic lane and the shoulder, the entire unit is treated as part of the usable shoulder.

Where guide rails, walls or other obstructive elements are introduced adjacent to a shoulder, it is desirable that the shoulder be wide enough to allow for opening of a vehicle door. However, it is not always practical or economical to do so.

Shoulders desirably should be continuous so that at any location along the roadway a driver can leave the traffic lanes to use the shoulder. If the shoulder is intermittent some drivers may find it necessary to stop in the traffic lane, causing a hazardous condition. However, it may not always be economical to maintain shoulder width in all cases as for example, in deep rock cuts.

Shoulder widths are normally multiples of 0.5 m. Shoulder widths for undivided rural highways are given in **Exhibit-4J**.

For 4-lane divided highways the width of the shoulders are as follows:

- right shoulder is the same as for undivided highways, see **Exhibit-4J**.
- left or median shoulder is 1.0 m.

- If highway has narrow median with barrier, left or median shoulder is 2.5 m. Shoulder width may be varied depending on type of barrier used.

For multi-lane divided highways, the width of the shoulders are as follows:

- right shoulder is 3.0 m.
- left or median shoulder is 2.5 m, where a median barrier system is placed, the median shoulder width varies according to the type of barrier used.

For all interchange ramps the right shoulder width is 2.5 m.

The right shoulder on a single-lane ramp may be partially paved or paved depending on rural or urban locations and maintenance considerations. The right shoulder of a ramp with two or more lanes is normally paved.

For interchange ramps the left shoulder width is as follows:

- single-lane ramp 1.0 m
- 2-lane ramp 1.0 m
- ramps of more than two lanes 2.5 m

The left shoulder is normally paved.

The shoulder width for collector-distributor roads on urban freeways should be the same as those for express lanes.

The shoulder widths adjacent to acceleration, deceleration and weaving lanes on freeways are the same as those of the adjacent ramps.

For speed-change lanes at entrances and intersections on roads other than freeways, the shoulder width is 1.0 m. The transition in shoulder width should take place over the length of taper of the speed-change lane.

For truck-climbing and passing lanes the shoulder width should be the same as the shoulder width on the typical cross section for the roadway but may be reduced to not less than 1.0 m where the cost of maintaining the shoulder width is considered prohibitive, in which case the shoulder should be fully paved.

Fully Paved Shoulder

Full shoulder paving is warranted:

- On all freeways having three or more lanes in one direction.
- On 4-lane divided highways for the median shoulder.
- On all Major Capital Freeway Contracts involving new pavement construction, reconstruction or pavement rehabilitation.
    - The pavement structure under the right shoulder is to be designed to accommodate future traffic detours.
- In Urban areas:
    - where the sidewalk is located 3 m or less from the through lanes, and where reverse shoulders are utilized to suit existing condition.
    - where three or more adjacent commercial establishments are present, or
    - where the total density of entrances (all types) exceeds 10 per 300 m per side.
- On 2-lane highway, shoulder paving should be applied on both sides of the highway.
- On highways with more than two lanes, shoulder paving should apply only to the side on which the entrances are located.
- As protection against shoulder erosion on gradients. The conditions under which protective measures are warranted are:
    - gradients less than 3%; no treatment is required,
    - gradient of 3% to 5%; treatment should be based on local considerations,
    - gradient greater than 5%; treatment advisable.

To prevent excessive shoulder erosion caused by stormwater, steep grades and superelevation, shoulder paving is an acceptable alternative to the application of curb and gutter. The entire width of shoulder should be paved.

Exhibit-4J

SHOULDER WIDTH FOR UNDIVIDED KING'S HIGHWAYS AND SECONDARY HIGHWAYS

Design Speed km/h	Traffic Volume for Design Year					
	AADT					
	>4000	3000-4000	2000-3000	1000-2000	400-1000	<400
	DHV					
	>600	450-600	300-450	150-300	60-150	<60
130	3.0	-	-	-	-	-
120	3.0	-	-	-	-	-
110	2.5[1]	2.5[1]	2.5	2.5	-	-
100	2.5[1]	2.5	2.5	2.0[3]	1.0	-
90	2.5	2.5	2.0[2]	2.0	1.0	-
80	2.5	2.5	2.0	2.0	1.0	1.0[4]
70	-	2.0	2.0	1.0	1.0	1.0[4]
60	-	-	-	1.0	1.0	1.0[4]
50	-	-	-	-	-	1.0[4]

Notes:

1. If commercial motor vehicle percentage exceeds 10% increase by 0.5 m
2. If commercial motor vehicle percentage exceeds 15% increase by 0.5 m
3. If commercial motor vehicle percentage exceeds 25% increase by 0.5 m
4. Shoulder width of 0.5 m is acceptable on two-lane roads where there is no foreseeable possibility of the road being paved within a 20-year period. Where steel beam guide rail is installed, shoulder width must be 1.0 m

- For design, use DHV if available
- For Secondary Highways, if commercial motor vehicle percentages exceed 25% of AADT, or if AADT is >2000, shoulder width to increase by 0.5m.
- Minimum width for pavement support: 0.5 m paved, 1.0 m gravel surfaced
- Minimum usable width for disabled vehicle: 2.0 m

Partially Paved Shoulders

Partially paved shoulders should be included on all two-lane highways unless otherwise recommended by the responsible Manager.

Partially paved shoulders are not normally used on secondary highways, however, at the discretion of the responsible Manager, and based on engineering evaluation, they may be provided. Appropriate documentation of the shoulder treatment and rationale should be included in the Design Criteria. Where a shoulder is partially paved, a width of 0.5 m closest to the adjacent travel lane is hard surfaced, usually with asphalt, and the remaining shoulder surface is gravel.

On existing highways having a median shoulder width and/or outside shoulder width ≤ 1.0 m. the full shoulder width should be paved to avoid the existence of a narrow gravel strip which is extremely difficult to maintain.

Partially paved shoulders should preferably be constructed in conjunction with resurfacing, reconstruction or new construction. In order to avoid a joint at the interface, partially paved shoulders are not normally placed adjacent to the existing pavement without resurfacing. A stand-alone partially paved shoulder retrofit may be justified based on continuity, median safety or maintenance considerations.

Partially paved shoulders should be carried through on passing lanes and truck-climbing lanes.

The beginning and termination points of 0.5 m wide partially paved shoulder sections should be tapered to the through pavement edge over a distance of 10 m. Exceptions to this are at speed-change lanes where the partially paved shoulder should be feathered into the auxiliary lane taper, or where the presence of curves would create discontinuity of the edge of paved surface.

As a general rule, continuous partially paved shoulders should terminate either at an intersection where there is a significant change in traffic volume or at locations where changes in the characteristics of roadside developments occur, such as the beginning of an urban cross section.

Section 4.4.3.2 – Shoulder Material

- This Section is Not Applicable. Designers if interested should contact to the ministry's Material Office.

Section 4.4.3.4 – Shoulder Rumble Strips

- This Section is Not Applicable and is replaced with the following Guidance:

Introduction

Shoulder Rumble Strips (SRS) are a cost-effective warning device intended to reduce Run-off-Road (R-o-R) type collisions. SRS is a grooved formation installed within the paved shoulder or partially paved shoulder on a highway. The intention of SRS is to provide the motorist with both an audible and tactile warning that the vehicle has partially or completely departed the travelled way of a highway. An audible warning to the motorist is produced by noise generated by the vehicle tires passing over the SRS. A tactile warning to the motorist is provided by the vibration induced in the vehicle by the SRS. An encounter with SRS is expected to alert an inattentive motorist to steer the vehicle back onto the travelled way of the highway.

Implementations

- Decisions to install SRS shall consider the timing of planned rehabilitation and reconstruction work as budgets allow.
- The Regions should set priorities for the locations being considered for SRS. SRS may be installed either in conjunction with a construction project or as a retrofit by means of a separate contract.

Locations

SRS should be installed on all rural freeways with fully paved shoulders or partially paved shoulders, both on the median side (left side) and outside (right side).

SRS should also be considered at the following locations where such SRS are considered to have a practical potential to reduce R-o-R type collisions:

- On urban freeways and rural highways with fully paved shoulders or partially paved shoulders.
- At certain critical locations such as on shoulders of approaches to narrow bridges or parapet walls, in gore or bull-nose areas, in advance of impact attenuators, in areas with narrow clear zones and at other critical locations.

SRS may be placed at locations where geometric deficiencies exist but shall not be considered as a method to correct geometric deficiencies.

General Description and Details of SRS

- Typical Design Details for SRS are included in **Exhibit-4K, Exhibit-4L** and **Exhibit-4M**.
- Pavement condition and thickness on the shoulders may dictate whether it is feasible to install SRS. Such conditions should be verified by the appropriate ministry expertise areas.
- SRS can be constructed on either asphalt or concrete shoulders and should be milled in.
- All depressions of the Shoulder Rumble Strips should have a circular concave cross-section and the cutting tips on the milling head should produce a relatively smooth cut.

Design Considerations

- SRS should only be installed on paved shoulders that are in good condition, having a minimum asphalt thickness of 80 mm (2 lifts). In all cases, the depth of the SRS must be less than the depth of a single lift of asphalt. SRS should not be milled into existing shoulders having moderate to very severe surface defects, distortions or cracking distresses that are extensive to throughout as defined in the Manual for Condition Rating of Flexible Pavements (SP- 024) and as verified during a site review by the appropriate ministry expertise areas.
- General details and isometric view of SRS in plan and cross section is provided in **Exhibit 4-K.**
- Where SRS may be considered beneficial on a highway with an OFC asphalt surface, the appropriate ministry expertise areas shall be consulted for recommendation prior to installation.
- An inspection of the proposed site of the SRS will be required to confirm the distance from the travelled way to any obstructions as the current machinery used to mill-in rumble strips require a minimum lateral clearance of 0.85 m between the outside edge of the depression and any obstruction such as guide rail, concrete barrier, concrete curb, etc.
- The installation of SRS should be deferred if planned construction activities will require diversion of traffic onto the shoulders for a substantial period.
- When SRS are being considered as a retrofit project on highways which were recently paved, the appropriate ministry expertise areas shall be consulted to confirm that installation of the SRS will not invalidate any existing pavement warranty.

- SRS should be installed at right angle (90 degrees) to the direction of travel.
- At freeway entrance terminals and freeway exit terminals, SRS should start or end at the bullnose per **Exhibit-4L**.
- SRS should not be installed within 1.0 m of sawn and sealed transverse joints.
- SRS should not be installed within 1.0 m of sealed traffic counting loop detector lead wires.
- SRS should not be installed on bridge decks and overpass structures and within 1.0 m of expansion joint dams.
- SRS should not be installed across residential or commercial driveway entrances and intersecting roadways. Gaps in SRS installation should be provided in advance of and beyond commercial and residential entrances where motorists are likely to make turns on a continual basis.
- At residential or commercial driveway entrances, SRS should stop 60 m in advance of the entrance and start 30 m beyond the entrance per **Exhibit-4M**.
- At intersecting roadways, SRS should stop 60 m in advance of the intersection and start 30 m beyond the intersection per **Exhibit-4M**.
- At right turn lanes or tapers, SRS should stop 30 m before the right turn lane or taper per **Exhibit-4M**.
- SRS should not be installed on highways with partially paved shoulders (0.5 m pavement width) that are designated as bicycle routes or have substantial volumes of bicycle traffic.
- Details of SRS are provided in 500 series MTODs.
- On bicycle routes, SRS should be installed per the guidance provided in 500 series MTODs.

Maintenance Requirement

- When grading the gravel shoulders adjacent to partially paved shoulders, care must be taken to eliminate getting debris in the SRS.

Exhibit-4K

GENERAL DETAILS OF SHOULDER RUMBLE STRIPS

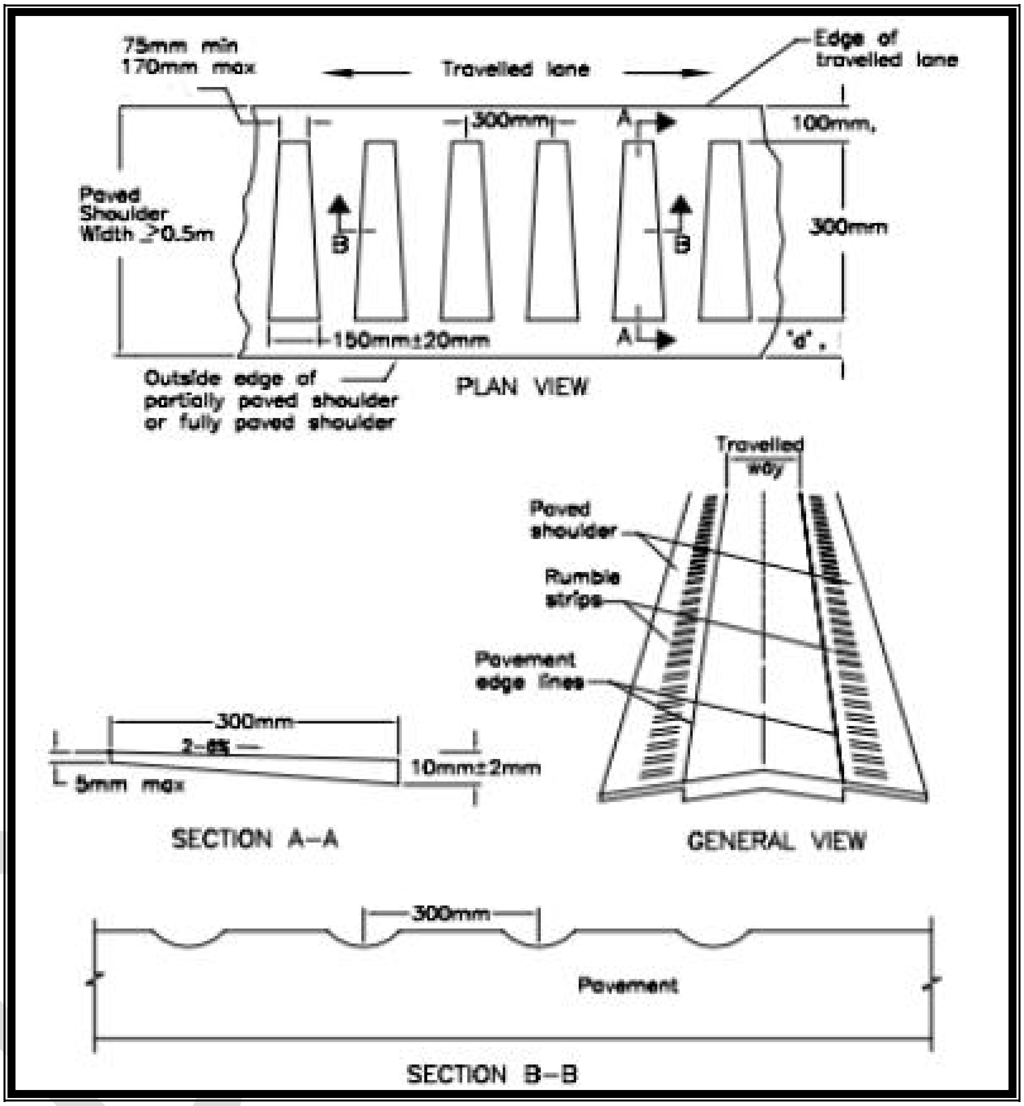


Exhibit-4L

SHOULDER RUMBLE STRIPS AT FREEWAY ENTRANCE AND EXIT

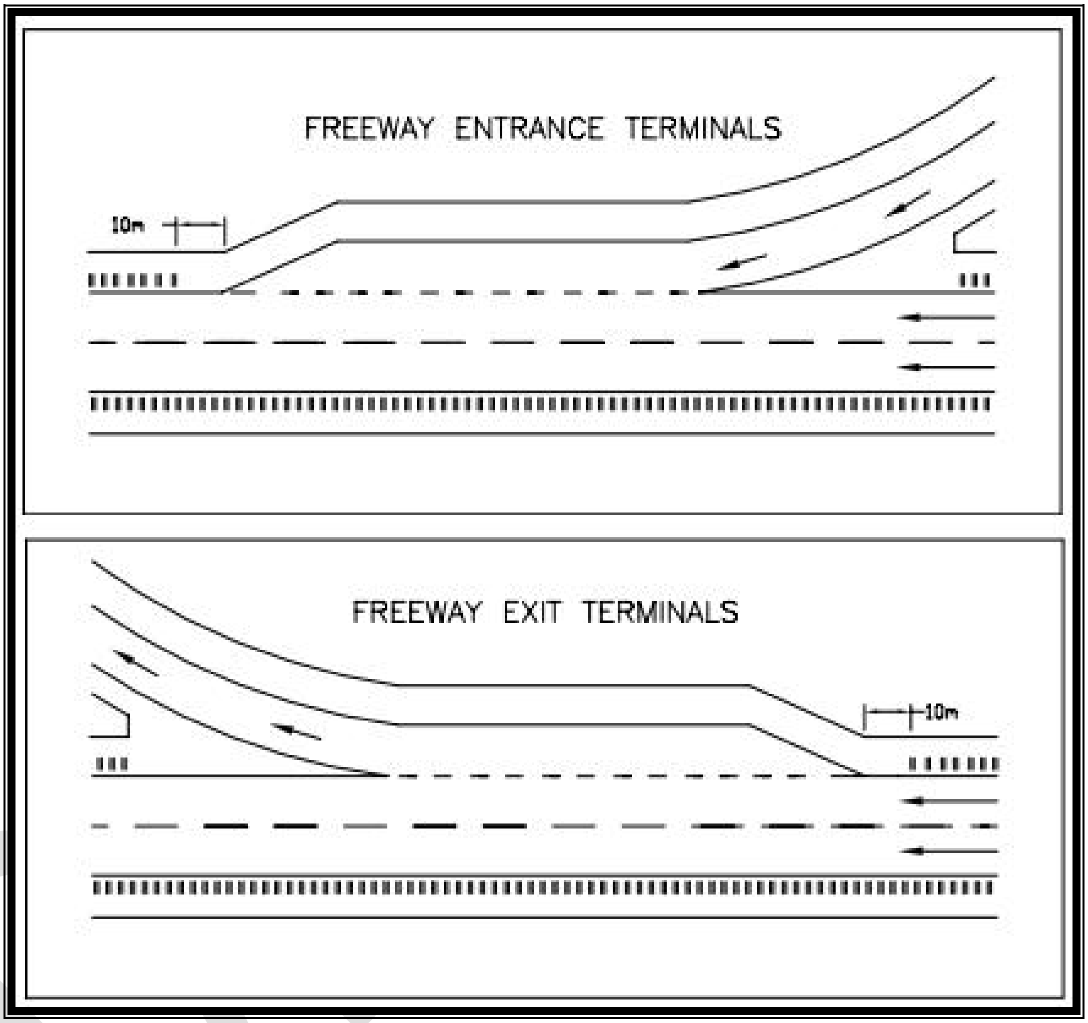


Exhibit-4M

SHOULDER RUMBLE STRIPS AT INTERSECTIONS AND ENTRANCES

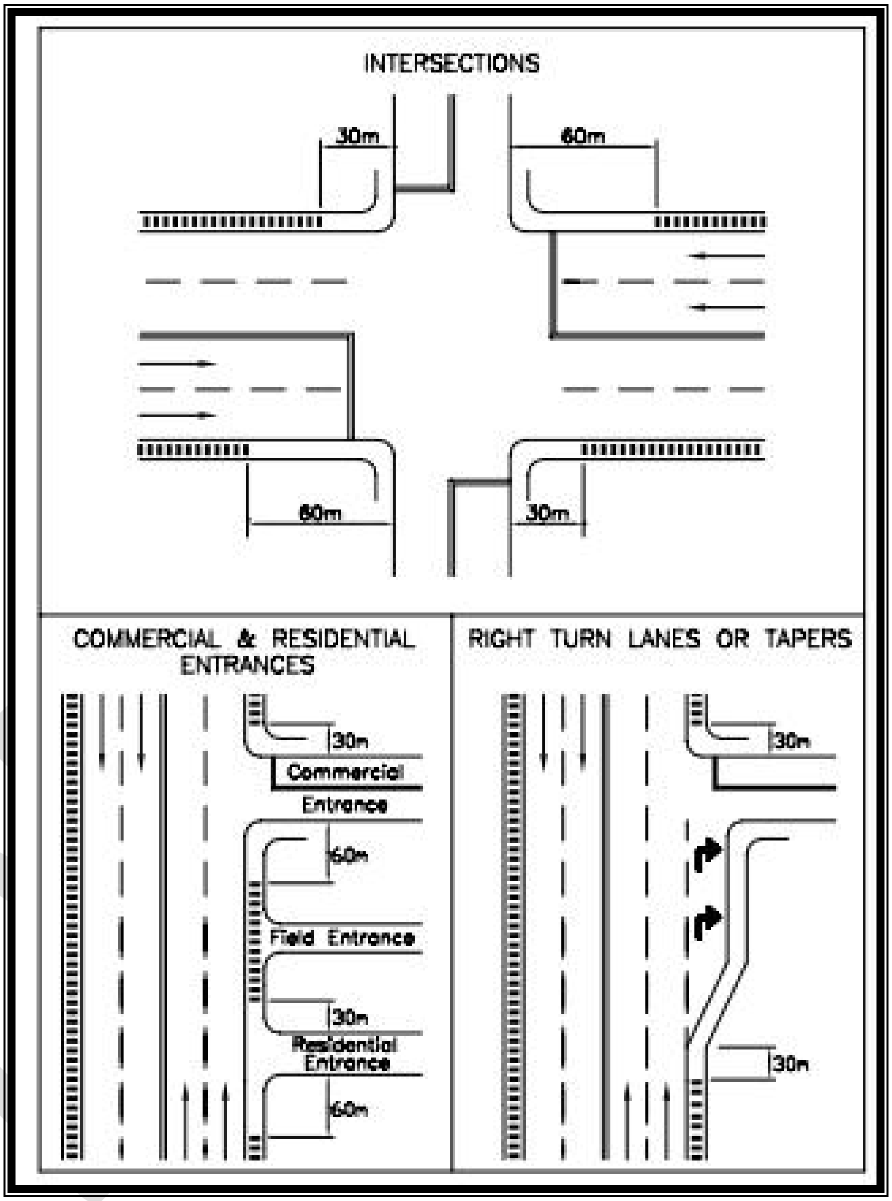


Figure 4.4.3. – Shoulder Rumble Strips

Figure 4.4.4. – Bicycle Friendly Shoulder Rumble Strips

- These Figures are Not Applicable.

Section 4.4.4 – Shoulder Cross Slopes: Best Practices

- This Section is Not Application and is replaced with the following Guidance:

  Cross-Fall and Superelevation
  Standard values for cross-fall and superelevation of shoulders on undivided and divided highways are listed and illustrated in **Exhibit-4N, Exhibit-4O, Exhibit-4P,** and **Exhibit-4Q**.

  - On tangent, unpaved, partially paved, or paved — -0.06 m/m
  - On the high side of superelevated sections, unpaved, partially paved, or paved — see **Exhibit-4Q**
  - On paved part of partially paved shoulder on high side or superelevated section — same as adjacent superelevation
  - On the low side of superelevated sections, unpaved, partially paved, or paved — -0.06 m/m

Exhibit-4N
UNPAVED SHOULDER CROSS-FALL

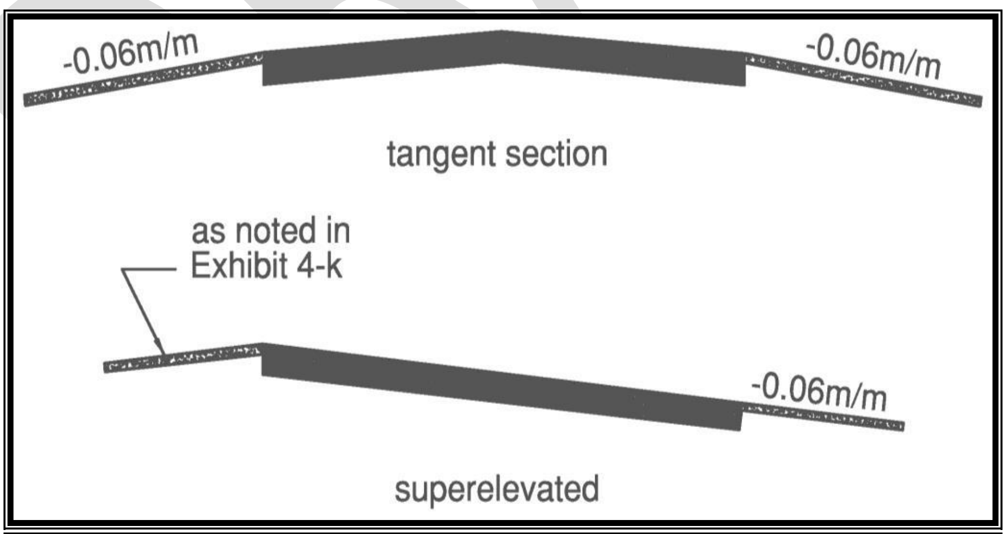


Exhibit-4O

PARTIALLY PAVED SHOULDER CROSS-FALL

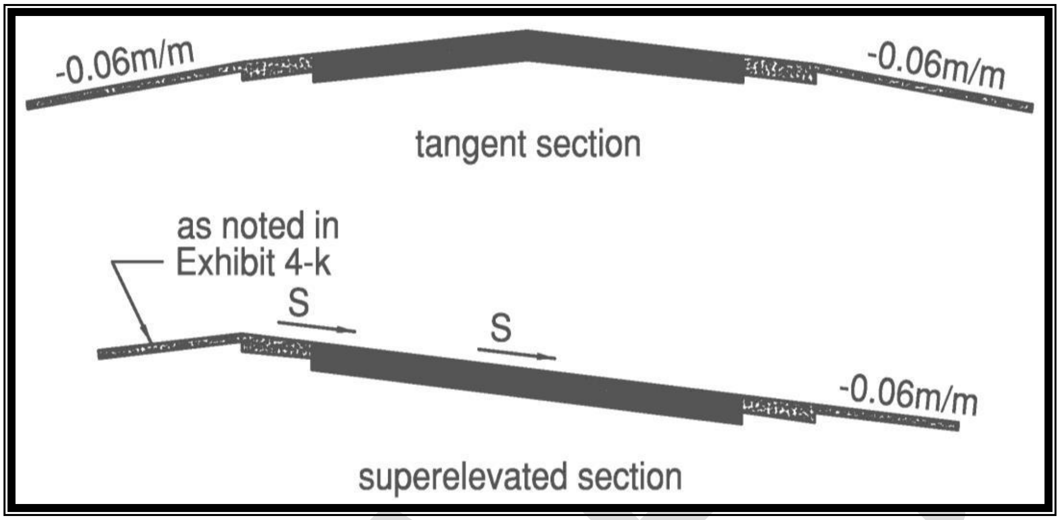


Figure 4.4.5 – Shoulder Cross Slope and Superelevation

- This Figure is Not Applicable and replace with **Exhibit-4N, Exhibit-4O, Exhibit-4P.**

Exhibit 4-P

PAVED SHOULDER CROSS-FALL

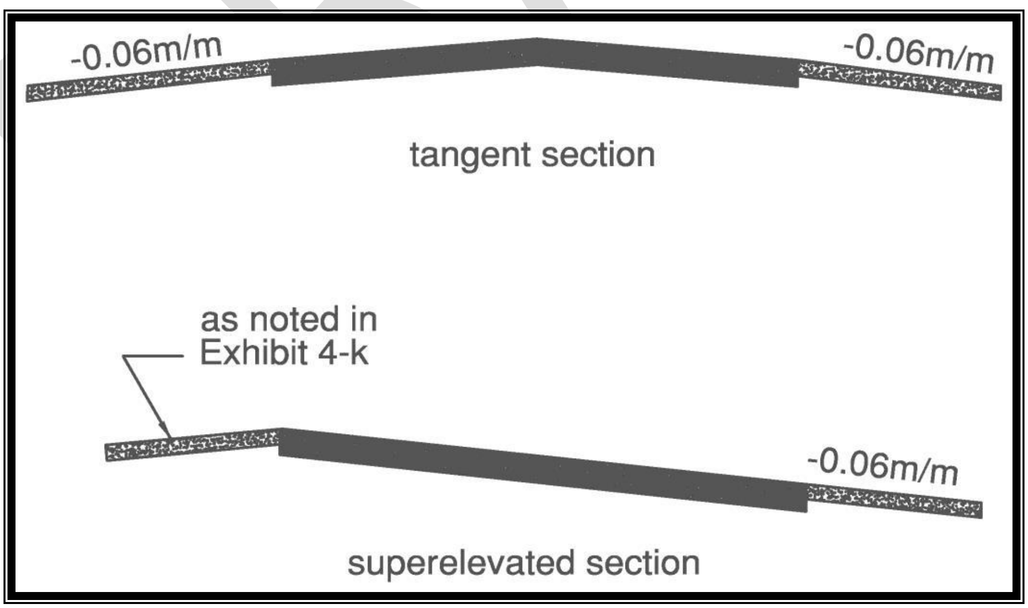


Exhibit-4Q

SUPERELEVATION FOR SHOULDERS ON HIGH SIDE OF SUPERELEVATED SECTIONS

Adjacent Traffic Lane	+0.06	+0.05	+0.04	+0.03	+0.02	+0.01	0.00	-0.01	-0.02
Shoulder	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04	-0.05	-0.06

Section 4.4.5 – Shoulder Rounding: Best Practices

- This Section is Not Applicable. Designer should refer to the latest edition of ministry's *Roadside Design Manual*.

Section 4.5.3 - Arterials Road Medians: Application Heuristics

- This Section is Applicable except point # 9.

Figure 4.5.2 – Arterials Medians

This Figure is Not Applicable. The figure consists of four illustrations. For the Illustration in the north-west quadrant, designer may refer to 500 series MTODs. The remaining three illustrations are addressed in the ministry's *Roadside Design Manual.*

Section 4.7.2 – Curbs: Best Practices

- This Section is Applicable with the following additional Guidance:

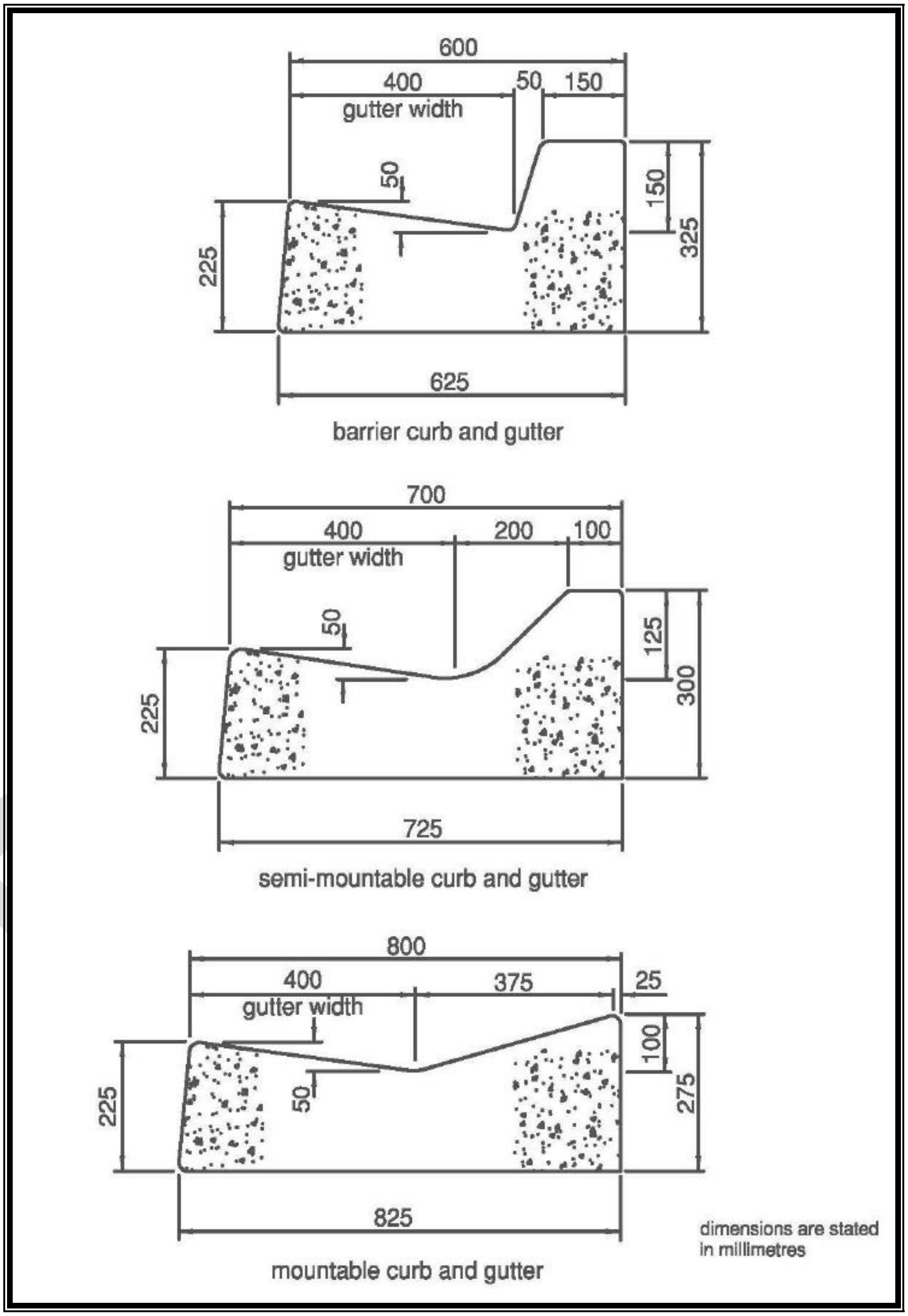
  Barrier curbs should not be used adjacent to bridge parapets. A concrete parapet having a profile similar to that of a concrete median barrier is preferred. However, on urban roads where the cross section includes sidewalks on the approaches and the bridge, a barrier curb is carried across the bridge.

Figure 4.7.1 – Curb and Gutter Types

- This Figure is Not Applicable and is replaced with **Exhibit-4R.** Designer may also refer to 600 series MTODs and OPSDs.

Exhibit-4R

CONCRETE CURB AND GUTTER DIMENSIONS



Section 4.8.2 – Rural Drainage Channels (Ditchline): Best Practices

- This Section is Not Applicable and replace with the following Guidance:

  Slopes
  Earth cut and fill slopes should be flattened and generally rounded to be consistent with the topography and the type of highway. Effective erosion control maintenance costs and adequate drainage of thesubgrade are largely dependent upon proper shaping of the side slopes. Overall economy depends not only on the element of first cost, but also on costs of maintenance of which slope stability is a factor. Inaddition to these reasons for gentle and rounded slopes on any highway, the proximity of any urban highway to the development and residents of the community call for additional attention to slope treatment and the overall appearance.

  On freeways and arterial roads with reasonably wide roadsides, side slopes on embankments and in cuts should be designed to provide a reasonable opportunity for recovery of an out-of-control vehicle. Where the roadside, at the point of departure, is reasonably flat, smooth and clear of fixed objects, many potential accidents can be avoided. Flat and well-rounded side slopes simplify the establishment of turf and its subsequent maintenance. For details about side slope beyond shoulder, designer should refer to ministry's *Roadside Design Manual*.

  Contour Design
  Contour design is usually applied to residual areas of land in interchange areas between ramps, for noise berms and disposal areas. These areas can be graded with varying slopes to give an undulating and natural looking appearance. Contour design is carried out in conjunction with drainage design with consideration for safety and, where appropriate in conjunction with landscaping. Residual pockets of land in interchange areas, particularly loop ramps, can be used to dispose of some surplus material and to minimize spoil. Conversely, they may be used to generate additional excavation and to minimize borrow.

Drainage Channels

Drainage channel cross sections must have adequate hydraulic capacity and should be designed to keep water velocities below the scour limits wherever possible. Generally additional capacity should be derived by widening channels. The depth must be a minimum of 0.5 m below the bottom of the subgrade to provide drainage of the pavement structure. The drainage channel therefore should be kept at an adequate depth below the pavement. Channels should have a streamlined cross section for safety, ease of maintenance, and to minimize snow drifting. In areas of rock cut where fallen boulders can be expected, it may be desirable to provide a wider drainage channel to collect the boulders. This will reduce the possibility of the boulders resting on the shoulder or roadway, and will facilitate maintenance clean up. For further details, refer to *ministry's Drainage Management Manual*.

Section 4.8.3 – Urban Strom Drainage: Best Practices

- This Section is Applicable with the following additional Guidance:

Climate change shall be considered when undertaking the design of the Ministry of Transportation drainage infrastructure. Please refer to the Implementation of the Ministry's Climate Change Consideration in the Design of Highway Drainage Infrastructure policy for more details.

With increased frequency and duration of storm events, culverts, sewers, and catch basins can become more susceptible to blockages. It is therefore desirable to perform increased routine maintenance and to ensure proper drainage can be maintained at all times.

Section 4.8.4 – Cross-fall (Slope): Best Practices

- This Section is Applicable except point # 5. The following additional Guidance is also applicable:

Cross-Fall Requirements

Cross slope and cross-fall terminologies may be interchangeably used in this section. On 2-lane highways the pavement is normally crowned at the centreline and the pavement slopes down to either edge at cross-fall rate of 2%.

On 4-lane undivided highways and 4-lane divided highways with a flush median, the crown is normally placed in the centre of the pavement of median, and cross-fall to either pavement edge is 2%.

On a 4-lane divided highway with a depressed median, the crown is normally placed at the centre of each roadway with a cross-fall of 2% to each edge. For roadways on structures, the cross-fall should be a minimum of 2%.

There are two reasons for this: the first is to permit storm water to drain to either side of the roadway; the second is to facilitate the treatment of the roadway with de-icing chemicals which are spread in a narrow strip about the crown line, allowing the action of traffic and cross-fall to further spread the chemicals across the entire pavement. If the road eventually requires expansion to six lanes by adding two lanes in the median, the additional lanes will slope toward the median.

If a 4-lane divided highway is to be expanded to six lanes within a short period of time of initial construction, it should be designed for six lanes and built without the median lanes initially, in this case both lanes of each roadway will slope towards the outer edge.

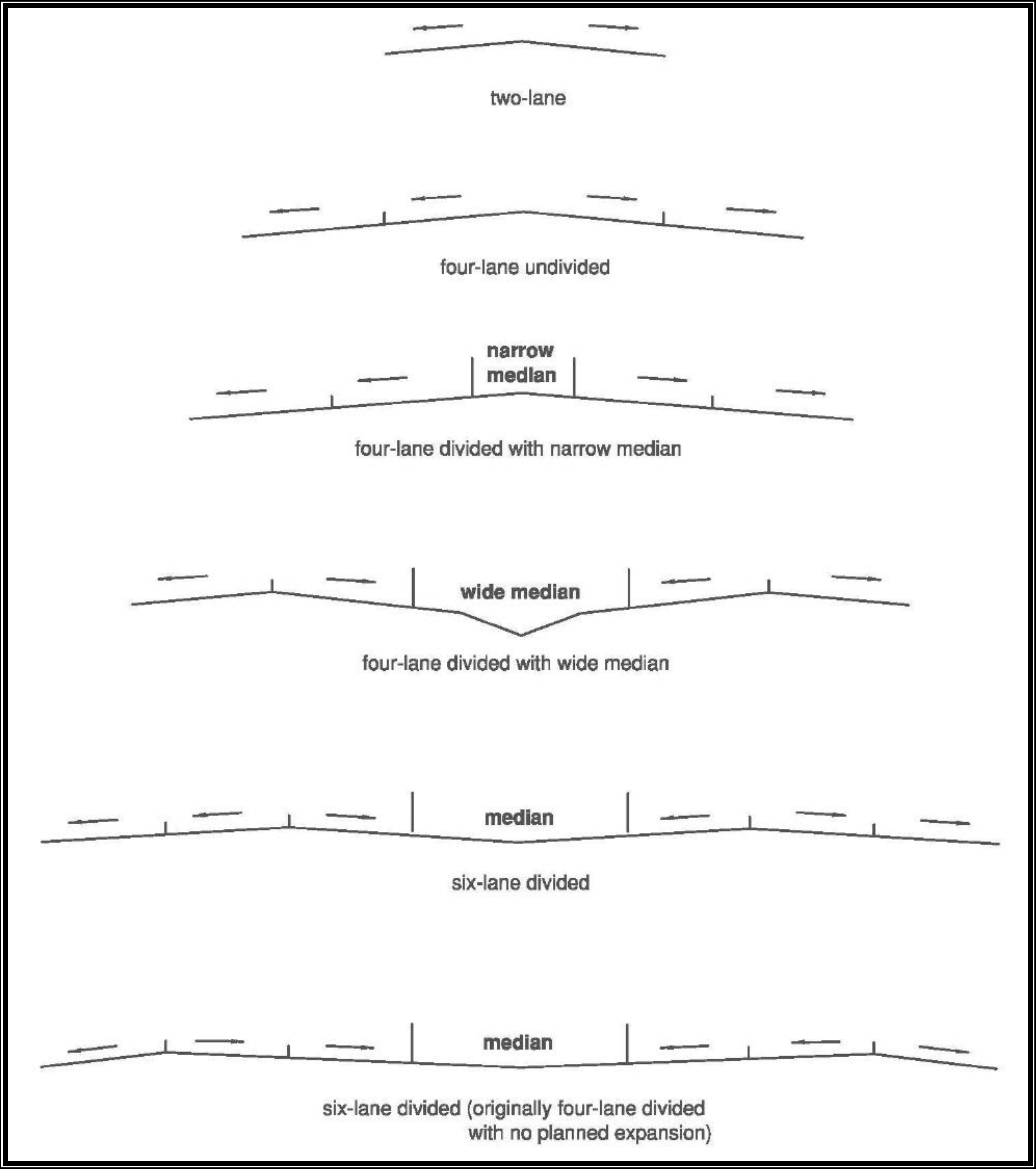
For 6-lane divided highways, the crown for each roadway is applied to the common edge of the centre and median lanes, the two outside lanes having a cross-fall of 2% towards the outside edge, and the median lane having a cross-fall of 2% draining towards the median. If this cross section is expanded to an 8-lane cross section with the additional lanes in the median, the additional lanes have 2% cross-fall applied draining towards the median. The above cross-fall requirements are illustrated in **Exhibit-4S.**

Cross-fall on auxiliary lanes is the same as that of the adjacent through lane.

At intersections where two roads on tangent intersect, normal cross-fall is maintained on the major road, and cross-fall on the minor road is run out on the approaches to the intersection to match the profile of the major road. This treatment is typical of intersections controlled by a stop sign on the minor road. In the case of an intersection where the two roads are of equal importance, or where the intersection is signalized, the normal cross-fall is run out on all four approaches so that the cross-fall on each road matches the profile of the crossing road. Simply put, the pavements are warped to maintain smooth profiles for traffic on both roads.

Exhibit 4-S

APPLICATION OF 2% (NORMAL) CROSS-FALL ON TANGENT SECTION



Section 4.10.1.1 – Roads under Bridges: Design Domain and Application Heuristics

- This Section is Applicable except point # 4 and with the following additional Guidance:

  With increased severity and frequency of storms it is recommended to have the primary road go over the secondary road in areas prone to flooding when it makes sense to do so.

Figure 4.10.1 – Horizontal Clearance at Bridges on Urban Arterial Roads (Underpass)
Figure 4.10.2 – Horizontal Clearance at Bridges on Urban Freeways (Underpass)

- These Figures are Not Applicable. Designer should refer to ministry's *Roadside Design Manual.*

Section 4.10.1.2 – Roads on Bridges: Design Domain and Applications Heuristics

- This Section is Not Applicable and is replaced with the following Guidance:

  General

  The material contained in this section is intended to assist the designer when designing cross sections where bridges, retaining walls or other structures are required. This section gives direction in setting structure dimensions that influence geometric design of horizontal alignment, vertical alignment and cross sections. In general:

  - Bridges should be designed to match the geometric requirements of the roadway.
  - Where practicable, the horizontal centerline alignment on bridges should be on tangent or of constant curvature.
  - The cross section elements of roads on and under bridges should match those of the approach roadway.
  - Sag curves on bridges should be avoided as much as possible.

  Deck Width and Traffic Lanes

  The number and width of through lanes and auxiliary lanes should be the same on the bridge deck as onthe approach roadway. Traffic lane widths should be in accordance with **Section 4.2** and **Section 4.3**.

In general, the minimum acceptable bridge deck roadway width for two-way traffic is 8.5 m to allow for passing of snowplows on the bridge. To facilitate bridge rehabilitation, the bridge deck roadway width should accommodate the future staging requirements and be a minimum width, as shown in **Exhibit-4T**, unless bridge closure would be acceptable during the required rehabilitation.

Exhibit 4-T*

MINIMUM BRIDGE WIDTHS TO ACCOMMODATE FUTURE REHABILITATION

Roadway	Temp Clearance (m)	Barrier Overlap** (m)	Minimum Width (m)
Freeway	4.50	2.8	11.8
Trans-Canada	4.50	2.4	11.4
King’s Highway	4.00	2.2	10.2
Secondary Highway / Arterial	3.75	1.7	9.2
Collector / Local Road	3.40	1.7	8.5

** Exhibit 4-T is intended for new construction of mainline freeway bridges. It is not for rehabs or ramp structures. The guidance is provided to achieve correct minimum width for future rehabs. The new design should meet all safety rules to account for barrier deflection width and Ministry of Labour requirements.*

***Barrier Overlap includes two positions of a Temporary Construction Barrier, plus the buffer distance behind for barrier deflection and overlap of the waterproofing and asphalt.*

Single lane bridges shall be between 4.0m and 4.9m roadway width, except for single lane ramp bridges that shall be a minimum of 4.75 m roadway width.

Provision of single lane bridges and narrower two-lane bridges may be permitted as shown in on low volume roadways in accordance with the Ministry's Guidelines for the Design of Bridges on Low Volume Roads.

Side Clearances on Bridges

Side clearances on bridge decks defines as the distance between the edge of the travelled way and the adjacent curb or barrier. It should be in accordance with **Exhibit-4U,** and **Exhibit-4V** for urban and rural structures.

Median Widths

The width of a median on a bridge should match that of the approach roadway.

Table 4.10.1 – Horizontal Clearance at Bridges on Local and Collector Urban Roads
Table 4.10.2 – Horizontal Clearance at Bridges on Rural Roads

- These two Tables are Not Applicable and is replaced with **Exhibit-4U.**

Exhibit-4U

MINIMUM SIDE CLEARENCE AT BRIDGES

Highway Classes	Design Speed (km/h)	Urban Roads			Rural Roads		
		Left	Right		Left	Right	
			No Sidewalk	Sidewalk		No Sidewalk	Sidewalk
FREEWAY 4-LANE DIVIDED	100 to 130	2.5 a	3.0 a		2.5 a	3.0 a	
FREEWAY MULTI-LANE DIVIDED	100 to 130	2.5 a	3.0 a		2.5 a	3.0 a	
ARTERIAL DIVIDED	90 to 110	2.0 a	2.5 a	1.5	2.0	3.0 a	
	80	2.0 a	2.0 a	1.5	1.5	2.5 a	
ARTERIAL UNDIVIDED	90 to 110	-	2.0	1.5	-	3.0 a	2.5 a
	80	-	2.0	1.5	-	2.5 a	2.0 b
COLLECTOR UNDIVIDED	90 to 100	-	1.25 c	1.0	-	2.5 a	1.5 c
	70 to 80	-	1.25 c	1.0	-	1.5 d	1.25
	60	-	1.0	1.0	-	1.5 d	1.25
LOCAL UNDIVIDED	60 to 80	-	1.0	0.5	-	1.25	0.5 d

Notes:

1. If a barrier is to be placed between the sidewalk and roadway, then clearance should be the same as when there are no sidewalks
2. All clearance should meet requirements for sight distance
3. The width of a median on a bridge should match that of the approach roadway
4. L = length of bridge between centerline of abutment bearings
   a. For bridges with L>50 m, consideration can be given to decreasing the clearances to 1.5 m

b. For bridges with L>50 m, consideration can be given to decreasing the clearance by up to 0.5 m
c. For bridges with L>50 m, consideration can be given to decreasing the clearance by 0.25 m
d. For bridges with L>50 m, consideration can be given to increasing the clearance by up to 0.75 m
e. The values of the clearances given above are the minimum values. Consideration may be given providing more than the minimum if justification is documented.

Exhibit-4V

SIDE CLEARANCE ON BRIDGES

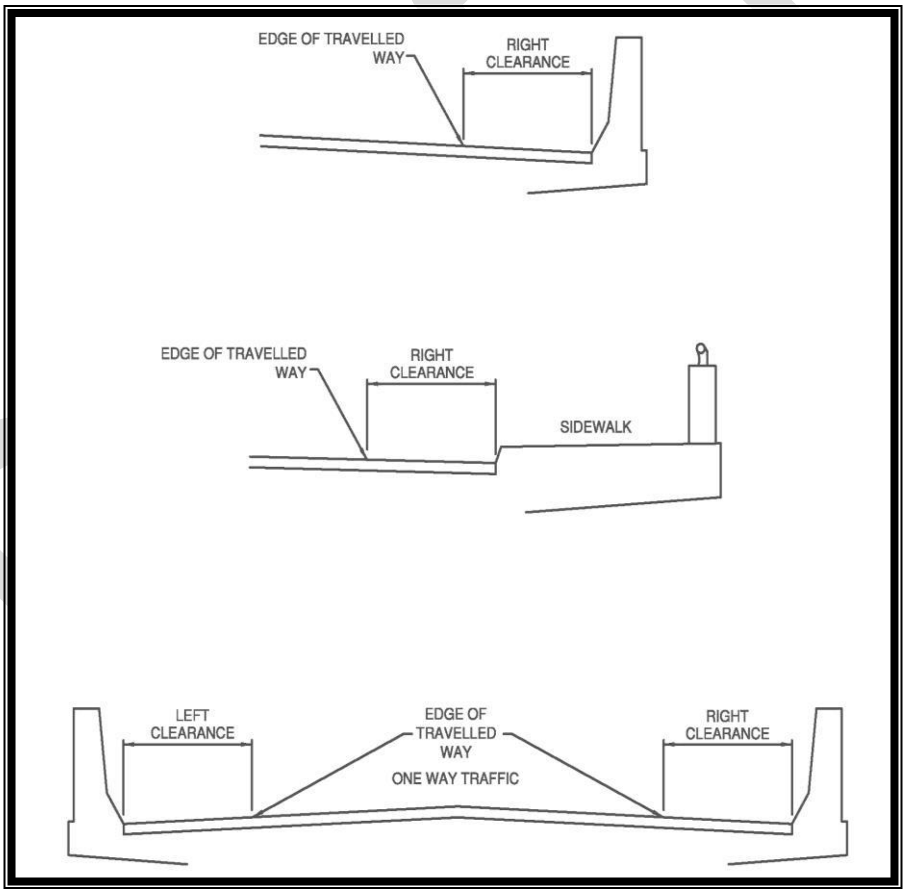


Figure 4.10.3 – Horizontal Clearance on Bridges on Urban Arterial Roads

Figure 4.10.4 – Horizontal Clearance on Bridges on Urban Freeways (Overpass)

- These Figures are Not Applicable.

Section 4.10.1.3 – Multi-Modal Configurations

- This section is Not Applicable and is replaced with the following Guidance.

Sidewalk, Bikeways and Curbs

According to the Ontario Regulation 413/12 which came into force on January 1, 2013, under the *"Accessibility for Ontarians with Disability Act (AODA) 2005",* the design of new bridges with sidewalks or bridge rehabilitations where the sidewalks are rehabilitated, unless otherwise permitted in *Section 80.31* of the *AODA Regulation,* the minimum clear sidewalk width shall be 1500 mm. In addition, the minimum clear sidewalk width shall:

- be maintained over the entire length of the bridge and transition smoothly to the approaches.
- not be reduced below 1500 mm by appurtenances such as guiderail connections to the bridge. and
- apply to the clear surface of the sidewalk excluding surfaces of other elements such as curbs or tops of walls that are separated from the sidewalk by longitudinal joints.

The above requirements are also illustrated in **Exhibit-4W**

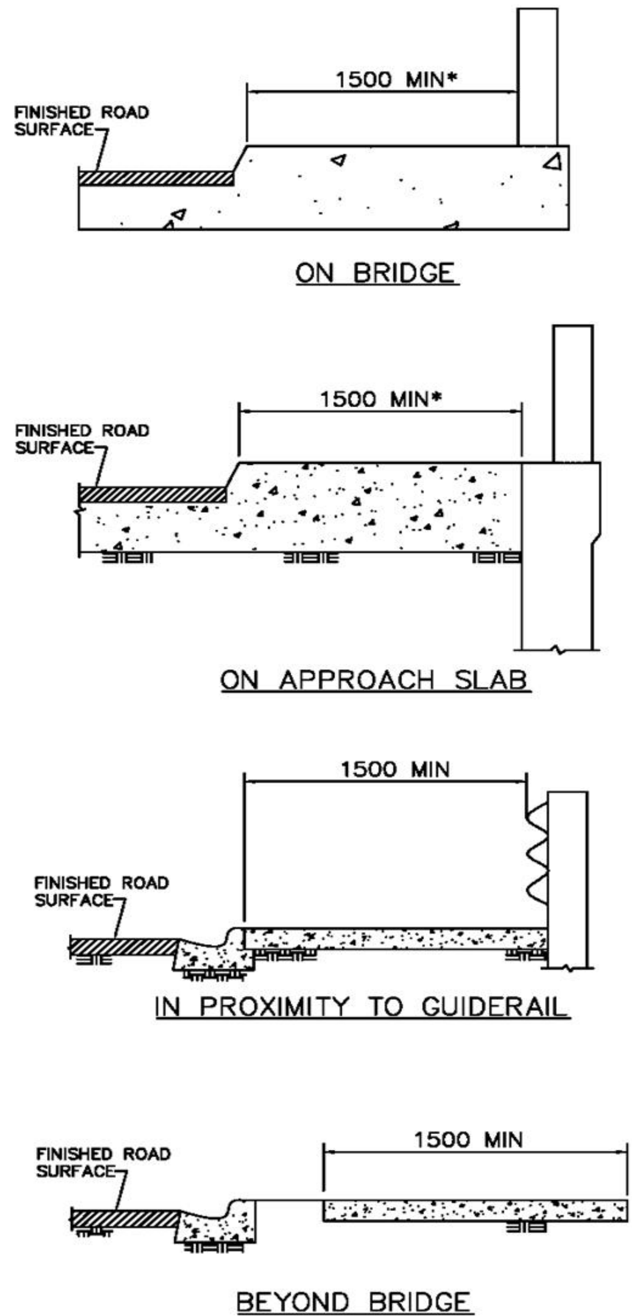
Where required, the widths of sidewalks and bikeways on bridge decks should meet the following requirements:

The edge of a sidewalk adjacent to the roadway on a bridge should match that of the approach sidewalk.

- Where the approach roadway is not provided with a curb, the clear sidewalk width should be at least 1.5 m.
- Paved bike lane and bikeway widths should be in accordance with the *Ministry's Bikeway Design Manual – March 2014*.
- The height of curbs should not be less than 150 mm above the adjacent roadway except to match the height of curbs on the approach roadway.
- Curbs should not be used in conjunction with barrier walls except where the curb and the barrier wall are separated by a sidewalk.

Exhibit-4W

GUIDELINE FOR SIDEWALK WIDHTS ON BRIDGES



NOTE:
* SIDEWALK WIDTH MAY INCREASE IN SOME LOCATIONS IN ORDER TO ALLOW SMOOTH TRANSITION BETWEEN CROSS–SECTIONS

Section 4.12.1 – Introduction

- This Section is Applicable with the following additional Guidance:

  When designing highway infrastructure, it is important to consider how future rehabilitation and maintenance will be performed. Congestion from construction staging accounts for a significant amount of greenhouse gases as space is constrained and often leads to reducing the number of lanes which can contribute to significant traffic backups.

  Ensuring adequate traffic flow during future construction staging can result in fewer emissions from vehicle idling and start/stop maneuvers. It is significantly easier to plan ahead rather than retrofit after the fact, especially in constrained situations. Additionally, when designing bridge spans, it is important to consider future widening and how construction staging can be accommodated.

Section 4.13 – Typical Cross Sections

- This Section including all associated Figures (Figure 4.13.1 to Figure 4.13.13) are Not Applicable.

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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 5 for Chapter 5

Bicycle Integrated Design

June 2023

MTO Design Supplement
Appendix 5 for Chapter 5
Bicycle Integrated Design

The following design supplements are applicable to Chapter 5 – Bicycle Integrated Design of TAC Geometric Design Guide for Canadian Roads - June 2017:

Chapter 5 – Bicycle Integrated Design

- This Chapter in its entirety is Not Applicable for the planning and design of bikeway facilities on provincial highways network.
- Designer should use ministry's *Bikeway Design Manual - March 2014* for the planning and design of bikeways on provincial highways.
- The ministry *Bikeway Design Manual – March 2014* can be accessed at the ministry's Technical Publications website:
- https://www.library.mto.gov.on.ca/SydneyPLUS/TechPubs/Portal/tp/tdViews.aspx?lang=en-US

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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 6 for Chapter 6

Pedestrian Integrated Design

June 2023

MTO Design Supplement
Appendix 6 for Chapter 6
Pedestrian Integrated Design

The following design supplements are applicable to *Chapter 6 – Pedestrian Integrated Design of the TAC Geometric Design Guide for Canadian Roads - June 2017:*

Section 6.1 – Pedestrian Design Focus

- This Section is Applicable including the following:

  All pedestrian facility designs must be in compliance with the *Highway Traffic Act* and the *Accessibility for Ontarians with Disabilities Act*, and all associated regulations under these Acts.

Section 6.3.1.3 – Furnishing Zone

- This Section is Applicable including the following:

  Standard widths for furnishing zones are 3.0m for arterial roads and 2.0m for collector and local roads. The desirable minimum width for furnishing zones is 1.5m.

  Where property is limited or where sidewalks must be wider than the minimum requirement to accommodate pedestrian traffic, furnishing zones may be narrower than the desirable dimensions and in some cases may be omitted entirely. Examples are in downtown areas or in areas fully developed with retail stores and offices.

  Furnishing zones are usually sloped towards the roadway to facilitate drainage. They are normally surfaced with turf, in which case the cross fall is 0.04 m/m. The area of the boulevard immediately adjacent to the roadway may be finished with a hard surface treatment to avoid deterioration of turf due to winter road clearing operations. The hard surface setback width is normally 0.75m and is usually applied to urban conditions where this problem is anticipated.

Material commonly used for hard surface treatments are:

- Granular
- Asphalt
- Concrete
- Paving Stone

In urban areas where the sidewalk is located 3.0m or less from the traffic lanes and where a reverse shoulder is utilized as a furnishing zone to suit existing conditions, the shoulder should be fully paved.

Section 6.4.1 - Crosswalks

- Title of this Section is replaced with “Crosswalks and Crossovers”
- This Section is replaced with the following:

Crosswalks and crossovers are designated areas for pedestrians to cross a roadway, at intersections and mid-blocks respectively.

Section 6.4.1.1 - Intersection Crosswalks

- This Section is Not Applicable and is replaced with the following:

In Ontario, all signal and stop-controlled legs of an intersection are considered to contain crosswalks by default, whether or not they are marked. If a crosswalk at an intersection is unmarked, it is typically defined by the space within the extension of lines directly connecting the sidewalks on opposite sides of the roadway. Should a sidewalk or sidewalks not exist, the crosswalk would connect the space located between the curb line or edge of roadway and the adjacent property line.

At signalized intersections, all crosswalks with pedestrian signals shall be marked. At unsignalized intersections, crosswalk markings may be used in accordance with the *Ontario Traffic Manual Books*.

Additionally, consideration should be given to crosswalk markings under the following conditions:

- At an offset or complex intersection, to show pedestrians the shortest route across with the least exposure to vehicular traffic and conflicts
- At an intersection with visibility constraints, to position pedestrians where they can best be seen by oncoming traffic
- At an intersection within a school zone

The components of different types of crosswalks are provided in Tables 3A through 3F of the *TAC Pedestrian Crossing Control Guide* and Chapter 6 of *Ontario Traffic Manual (OTM) Book 15*.

Prohibiting pedestrian crossing at an intersection leg is sometimes implemented for safety or operational reasons. This practice should only be justified based on the needs of all intersection users, and the designer should consider the negative impacts on pedestrian walking distance and delay. Non-compliance can be a problem. See Section 6.5.5 for guidance to regarding physical barriers to assist with compliance, if the prohibition is fully justified.

Crossing distance on wide roadways can be reduced through the use of curb extensions (Section 6.4.3) or median refuge islands. Median refuge islands break the crossing into shorter individual segments, and are described in *TAC Synthesis of Practices for Median Design*. The minimum width of a median intended to function as a pedestrian refuge island is 2.4m.

Section 6.4.1.2 – Mid-block Crosswalks

- In this section, “Crosswalks” is replaced with “Crossovers”. *Ontario Traffic Manual* (*OTM) Book 15* is also Applicable.
- This section is applicable with the addition of the following:
  Sidewalks crossing free-flow ramps accessing or egressing controlled-access highways withy posted speed limits of 70 km/h or greater should be constructed as unmarked crossings.

Section 6.4.1.3 – Offset Mid-block Crosswalks

- In this section, “Crosswalks” is replaced with “Crossovers”.

Figure 6.4.1 – Median Refuge Islands and Offset Crosswalks at Unsignalized Mid-block Crossings

- In this section, “Crosswalks” is replaced with “Crossovers”.

Section 6.4.5 – Crosswalk Location

- This Section is Applicable including the following:

  At locations where pedestrian and traffic volumes are prohibitive, a grade-separated crossing facility should be considered. Section 8 of *Ontario Traffic Manual Book 15* provides further guidance.

Section 6.4.6.1 – Parts of the Curb Ramps

- This Section is Applicable except first and fifth bullet points which are provided below respectively:

  - Ramp – the transitional slope between two surfaces (typically a sidewalk and a roadway crosswalk). The ramp shall have a maximum slope of 1:10 (10%) where the elevation difference is greater than 75mm and less than 200 mm or 1:8 (12.5%) when the elevation difference is less than 75mm. The recommended width of the ramp, exclusive of flared sides, is 1.2m to provide continuity with the practical lower limit of the pedestrian through zone. A curb ramp shall be hard surfaced and comply with Section 80.26 of Ontario Regulation 191/11 under the Accessibility for Ontarians with Disabilities Act.

  - Tactile Walking Surface Indicator (TWSI) – a warning treatment that alerts the pedestrian to the presence of a street crossing through a tactile surface and/or contrasting colour. Examples of TWSI materials include tactile dome pads or directional tiles. TWSIs shall comply with the requirements of Section 80.26 of Ontario Regulation 191/11 under the Accessibility for Ontarians with Disabilities

Act. A curb ramp shall be hard surfaced and comply with requirements described in Accessible Design for the Built Environment (CSA, 2012).

Additional guidance on the placement of TWSI's is provided below: Implementation of TWSI's should be done on a "go-forward" basis. Retrofitting of existing paths of travel is not required unless the intersection is being redeveloped.
TWSI's shall be provided for curb ramps leading to crosswalks at signalized and stop controlled intersections, as well as on curb ramps leading to crossovers.

Section 6.4.6.2 – Types of Curb Ramps

- This Section is Applicable except the following:
  - Third paragraph is Not Applicable.
  - Fourth paragraph is Not Applicable and replace with the following:

    To form a section of full curb height of 150 mm between perpendicular curb ramps, a minimum of 3 m of separation between the curb ramps is required for the flares along the arc. On corner radii greater than 5 m or when sidewalks are separated from the curb by a furnishing zone, perpendicular curb ramps should be used, and crosswalk locations chosen accordingly as discussed in Section 6.4.5. The sidewalk should be adjusted to lead to the perpendicular curb ramp. However, in highly constrained situations, such as a 5 m radius corner with narrow sidewalks and no furnishing zones, the curb height between perpendicular ramps may be reduced to a minimum of 75mm to achieve closer ramp spacing.

Figure 6.4.8 – Recommended Curb Ramp Configurations and Dimensions

- Fig. A for Parallel Curb Ramp is Not Applicable because TWSI location and orientation as depicted in the figure is not in compliance with *Accessibility for Ontarians with Disabilities Act.*
- Fig. B for Depressed Corner Ramp is Not Applicable.

Section 6.4.7 - Pedestrian Signals

- The first paragraph is Not Applicable and is replaced with the following:

  Pedestrian signal indicators display whether pedestrians have adequate time to begin crossing a roadway at a signalized crosswalk. Installation of pedestrian signals at new and redeveloped signalized intersections shall be in accordance with *HSBM Traffic Office #2017-01*, *February 2017*. Where feasible, and particularly in areas with high pedestrian volumes (e.g., central business districts, routes to schools), consideration should be given to displaying the walk signal automatically as part of the signal phasing. Where pedestrian volumes are high, a separate pedestrian-only signal phase may be beneficial.
- References to *MUTCDC, Canadian Capacity Guide*, and *TAC Pedestrian Crossing Control Guide* are replaced with *Ontario Traffic Manual Books (OTM), OTM Book 12*, and *OTM Book 15* respectively.

Section 6.4.8 – Driveways and Alleys Crossing the Sidewalk

- This Section is Applicable including the following:

  At driveway entrances, barrier or semi-mountable curbs should be replaced by a mountable curb to provide convenient access and egress for vehicles. The length of mountable curb for residential driveways should be equal to the width of the driveway plus 1.5m on either side. For residential parking lots, apartments, and institutional developments the length should be the driveway width plus 3.0m on either side. The slope of the driveway between the sidewalk and the road should not exceed 10%. Refer to *300-series Ontario Provincial Standard Drawings (OPSDs)*.

Figure 6.4.9 - Driveway Crossing Styles

- Figure D, TWSI location and orientation depicted is not in compliance with *Accessibility for Ontarians with Disabilities Act* requirements.

Section 6.5.1 - Surface Type, Grade and Cross-Slope

- This Section is Not Applicable and is replaced with the following:

Walking surfaces shall be firm, even, and allow for good traction in all weather conditions. The maximum recommended grade for sidewalks is 1:20 (5%), although steeper grades for sidewalks, not exceeding the slope of the adjacent roadway are permitted. Intermittent landings, and/or parallel accessible ramps are recommended at intervals of no more than 9.0 m where the slope exceeds 1:20.

Cross-slopes should provide adequate drainage while allowing comfort and traction for pedestrians, especially wheelchair users. A cross-slope of 2.0% is recommended, although cross slopes of up to 3.0% on mainline sidewalks and up to 5% across short driveways are acceptable.

Section 6.5.2 - Accessible Ramps and Stairways

- This Section is Applicable including the following additional Guidance:

  Ramps and stairways shall be designed to conform to the *Accessibility for Ontarians with Disabilities Act* and associated regulations under the Act.

Section 6.5.4.1 - Pedestrian Through Zones
Section 6.5.4.2 - Intersections

- The above noted Sections are both Applicable with the note that *TAC Guide for Design of Roadway Lighting* is Not Applicable and is replaced with the ministry directive *PLNG-B-05, Ministry Policy for Highway Illumination.*

Section 6.5.4.2 - Intersections

- This Section is Not Applicable and is replaced with the following:

  The ministry directive *PLNG-B-05, Ministry Policy for Highway Illumination* shall be used to determine the warrants for lighting for intersection. For roundabouts, the “Roundabout Lighting Policy” of the ministry shall be used.

Section 6.5.4.3 - Mid-Block Crossovers

- In this section, “Crosswalks” is replaced with “Crossovers”.

Section 6.5.6.2 - Walkable Shoulders

- The third sentence is deleted and replaced with the following:
  If shoulders are also to be accessible to cyclists, refer to the ministry's *Bikeways Design Manual.*

Section 6.5.6.5 – Winter Access and Maintenance Considerations

- This Section is Applicable with the following additional Guidance:

  With increasing storm events, more consideration towards extra snow removal, maintenance, and storage should be given. It is a good practice to clear drainage grates and culverts more frequently as debris accumulation can overwhelm drainage infrastructure and impede pedestrian travel.

Section 6.5.7 – Stormwater Features/Landscaping/Trees

- This Section is Applicable with the following additional Guidance:

  Inclusion of vegetation and other landscaping architecture can act as carbon sinks absorbing carbon dioxide. Landscaping also has the added benefits of improving drainage, providing soil stability, reducing erosion, improving air quality, countering snow/wind drifts and reducing driver stress.

  Vegetation can be used as a measure to reduce the impacts of the heat island effect. Road surfaces absorb—rather than reflect—the sun's heat, causing surface temperatures and overall ambient temperatures to rise. Heat islands increase overall electricity demand because of the need to air condition surrounding buildings. This is of particular concern in highly urbanized areas. Having vegetation in these areas can cool the surrounding environment and reduce the resultant electrical demand.

Section 6.6.2 - Pedestrian Integration at Roundabouts

- This Section is Applicable with the following additional Guidance:

  In addition to ensuring pedestrian safety throughout roundabouts, the inclusion of bicycles and transits may need to be considered in the planning process.

The last paragraph is replaced with the following:
For detailed design guidance regarding roundabouts, including accessible design features, refer to *DCSO PEM 2017–05 – Implementation of Canadian Roundabout Design Guide and MTO Design Exceptions dated September 19, 2017.*

Section 6.6.6.2 – Maintenance Considerations

- This Section is Applicable with the following additional guidance:

  When determining maintenance strategies, consideration should be made for increases in frequency and severity of extreme weather events due to climate change. Increasing storm events can result in debris accumulation that can overwhelm drainage infrastructure and impede pedestrian travel. As a result, it is a good practice to clear drainage grates and culverts more frequently.

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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 7 for Chapter 7

Roadside Design

June 2023

MTO Design Supplement
Appendix 7 for Chapter 7
Roadside Design

The following design supplements are applicable to Chapter 7 – Roadside Design of TAC Geometric Design Guide for Canadian Roads June 2017:

Chapter 7 – Roadside Design

- This Chapter in its entirety is Not Applicable for the planning and design of facilities on provincial highways network.
- The ministry's *Roadside Design Manual (latest edition)* should be used for the planning and design of provincial highways.
- The ministry *Roadside Design Manual* can be accessed at the ministry's Technical Publication website: https://www.library.mto.gov.on.ca/SydneyPLUS/TechPubs/Portal/tp/tdViews.aspx?lang=en-US

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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 8 for Chapter 8

Access

June 2023

MTO Design Supplement
Appendix 8 for Chapter 8
Access

The following Design Supplements are applicable to Chapter 8 – Access of the TAC Geometric Design Guide for Canadian Roads - June 2017:

General

The ministry has statutory authority to control access to all provincial highways and within the MTO Permit Control Area, as defined by the *Public Transportation and Highway Improvement Act (PTHIA).* In accordance with the *PTHIA*, the ministry has well established processes for access management, including policies, procedures, and guidelines to assist in understanding requirements for permit applications within the MTO's jurisdiction and control.

For guidance related to access management within the MTO Permit Control Area, Chapter 8 – Access of the *TAC Geometric Design Guide* should be used in conjunction with this Design Supplement Appendix and the latest ministry *Highway Corridor Management Manual (HCMM).*

In any instance where Chapter 8 of the *TAC Geometric Design Guide* is not consistent with the *HCMM*, the latter shall take precedence.

Section 8.1.3 – Building Set-Back Guidelines

- This Section is Applicable with the following additional Guidance:

  The guidance for minimum building setbacks from a provincial highway right of way is provided in the latest MTO Highway Corridor Management policies and directives, in accordance with the *PTHIA*. Where construction/building is proposed within the MTO Permit Control Area, Chapter 2 of ministry's *HCMM* should be consulted for the application of setbacks. For setbacks related to signs, also refer to Chapter 5 of the *HCMM*.

Section 8.1.4 – Pedestrian and Cyclist Considerations

- This Section is Applicable with the following additional Guidance:

  The ministry has issued the *Bikeways Design Manual (BDM)* in March 2014. The guidelines presented in the *BDM* should be applied in the design of on and off-road bicycle facilities located within the provincial rights-of-way.

Section 8.1.5 – Capacity Considerations

- This Section is Applicable with the following additional Guidance:

  For detailed discussion on capacity analysis on various types of highways and intersections, the designer should refer to the ministry's *Capacity Analysis Manual (CAM) - January 2016.*

  The designer should also refer to the *HCMM*, MTODs and OPSDs for guidance regarding entrance design. In accordance with the PTHIA, where required for the MTO Permit application(s), capacity analysis should be done as part of Traffic Impact Study (TIS). The Traffic Impact Study should be carried out according to the latest ministry's TIS Guideline. The appropriateness of an increased intersection capacity must be carefully considered, including corresponding design elements, alternatives and impacts (e.g. left turns, entrances, signalization, roundabouts, grade separation, etc.), in keeping with *HCMM* principles and intersection spacing requirements.

  Consideration should be given to reduce traffic congestion and provide free flow conditions where operationally feasible. By reducing stop-and-go conditions, fuel efficiency can be achieved. A reduction in idling, excessive braking, accelerations, and decelerations of vehicles can reduce greenhouse gas emissions released. Left turn lanes, channelization, and roundabouts are some options that can be used to alleviate traffic congestion.

Section 8.2.2 – Access Types

- This Section including all Sub-sections from 8.2.2.1 to 8.2.2.10 and Figure 8.2.1 are Not Applicable. Designer should refer to *Section 4.4 – Types of Access Connections* of the *HCMM.*

Section 8.2.3 – Access Classification System

- This Section including Table 8.2.1 – Access Levels Keyed to Road Type are Not Applicable. Designer should refer to *Section 4.5.2 – Classification Systems* of the *HCMM.*

Section 8.3 – Access Management by Design Classification

- This Section including all Sub-sections from 8.3.1 to 8.3.5 are Not Applicable. Designer should refer to *Section 4.5.3 – Access Management Classification System – Definitions* of the *HCMM.* Also, refer to Section 4.6 of the *HCMM* for guidance on access management to highways within the jurisdiction and control of the ministry.

Section 8.4.3 – Distance from Interchanges and Intersections

- This Section is Not Applicable. Designers should refer to Section 4.6 of the *HCMM* which provides guidance on spacing requirements valid for permit applications within the jurisdiction and control of the ministry.

Section 8.4.10 – Auxiliary Lanes

- This Section is Applicable with the additional guidance provided in *Section 8.1.5 – Capacity Considerations* above and in Chapter 9 of the TAC GDG June 2017.

Section 8.5 – Continuous Right-Turn Auxiliary Lanes on Divided Arterials

- This Section including all Sub-sections from 8.5.1 to 8.5.2-8.5.2.4, Figures 8.5.1 to 8.5.7, and Table 8.5.1 are Not Applicable.

Section 8.7 – Service (Frontage) Roads

- This Section is applicable except for Sub-sections 8.7.2 and 8.7.3, Figures 8.7.1 to 8.7.5, and Table 8.7.1, which are Not Applicable. Designer should refer to *Section 8.1.3 – Building Set-Back Guidelines* above.

Section 8.8 – Corner Clearance at Major Intersections

- This Section including all Sub-sections from 8.8.1 to 8.8.2, and Figures from 8.8.1 to 8.8.2 are Not Applicable. Designer should refer to *Section 4.6* of the *HCMM* for guidance on minimum/desirable distances from intersection/interchange areas along provincial highways and municipal roads.

Section 8.9.3 – Sight Distance

- This Section is Not Applicable**.** Designer should refer to *Chapter 9* of *TAC GDG,* and the *MTO Design Supplement* to *Chapter 9* for guidance on intersection sight distance standards.

Section 8.9.5 – Width

- This Section is Applicable except Table 8.9.1 – *Typical Driveway Dimensions*. Designer should refer to the *HCMM, MTODs and OPSDs* as applicable for guidance on dimensions for the design of entrances that are within the jurisdiction and control of the ministry.

Section 8.9.7 – Corner Clearances at Minor Intersections

- This Section is Not Applicable. Designer should refer to *Section 4.6* of the *HCMM* for guidance on minimum/desirable distances from intersection/interchange areas along provincial highways and municipal roads.

Section 8.9.8 – Spacing of Adjacent Driveways

- This Section including Figure 8.9.2 and Table 8.9.2 are Not Applicable. Designer should refer to *Section 4.6* of the *HCMM* for guidance on applicable entrance spacing within the jurisdiction of the ministry.

Section 8.9.10 – Clear Throat Lengths

- This Section and its associated Table 8.9.3 are Not Applicable. Designer should refer to *Section 4.6.7* of the *HCMM* which provides guidance on access connection depths at intersections on provincial highways.

MTO Design Supplement

For
TAC Geometric Design Guide for Canadian Roads

Appendix 9 for Chapter 9

Intersections

June 2023

MTO Design Supplement
Appendix 9 for Chapter 9
Intersections

The following Design Supplements are applicable to *Chapter 9 – Intersections* of the *TAC Geometric Design Guide for Canadian Roads - June 2017:*

Section 9.4.2.2 – Collectors

- This Section is Not Applicable.

Section 9.4.2.3 – Locals

- This Section is Not Applicable.

Section 9.4.2.4 – Cross Roadway Intersection Spacing Adjacent to Interchanges
Figure 9.4.2 – Cross Road Intersection Spacing Adjacent to Interchanges
Figure 9.4.3 – Intersection Spacing / Channelization Treatment at Diamond Interchanges

- This Section and the above noted Figures are Not Applicable. Refer to Chapter 8 – Access and Appendix 8 of the MTO Design Supplement for criteria to determine access connection offset spacing to interchanges.

Section 9.4.4 – Design Options for Urban Residential Areas

- This Section is Not Applicable.

Section 9.5.1

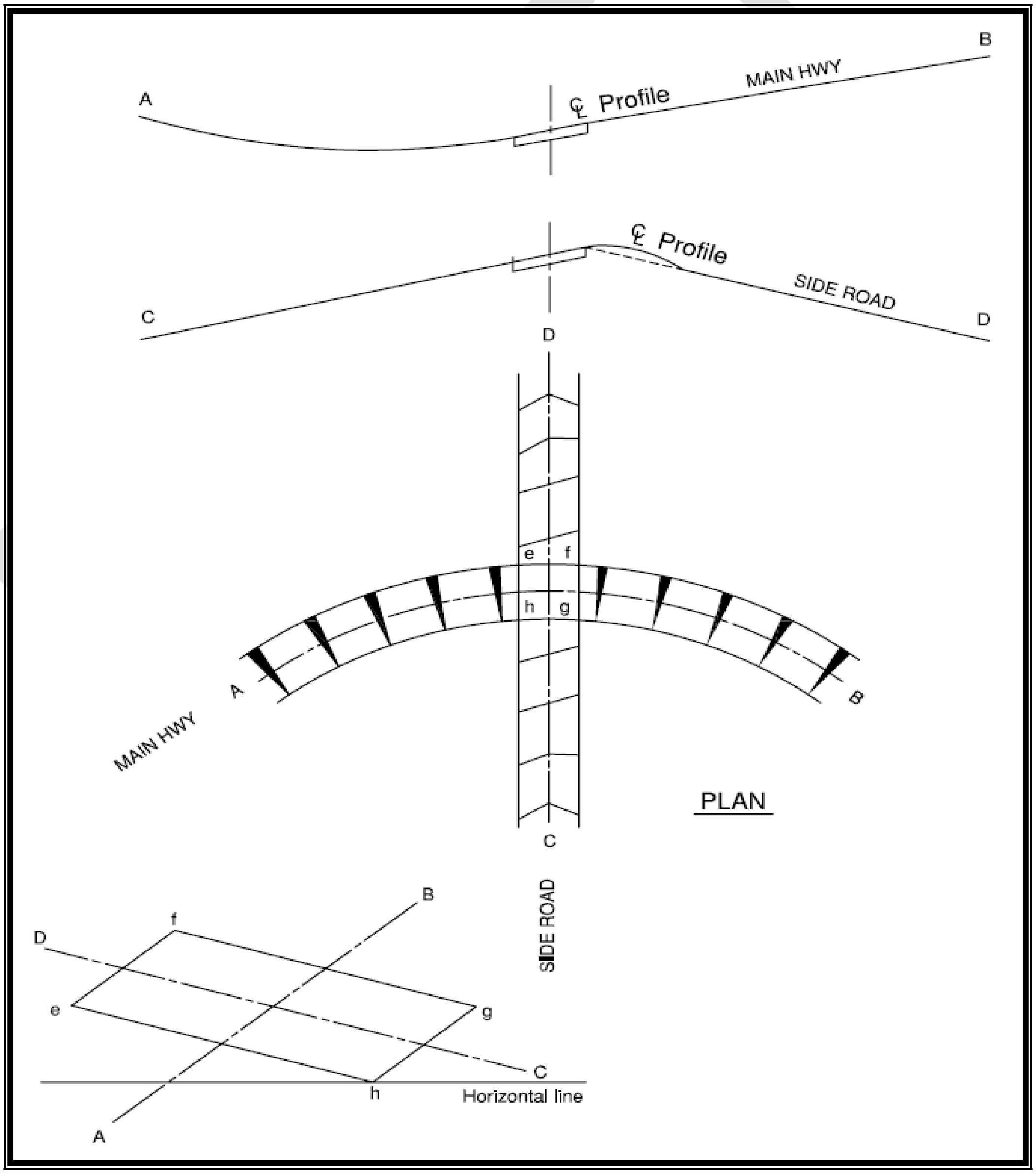
- The last sentence in this Section should be replaced with “Reference can also be made to Transport Canada’s Grade Crossings – Handbook”.

Section 9.7.4 – Combined Vertical and Horizontal Alignment

- This Section is Applicable including the following:
  "If the terrain conditions are such that a "break" in cross slope is required between the edge of pavement of the main highway and the sideroad, the effect of roll-over must be taken into consideration from an operational and visual point of view. The difference should desirably be 4% and not exceed 6%, see **Exhibit-9A**."

Exhibit-9A

PAVEMENT CROSS SECTIONS - SIDE ROAD PROFILE ADJUSTMENT



Section 9.9.2 – Sight Triangles

- This Section is Applicable including the following additional Guidance adopted from the AASHTO Green Book ***"A Policy on Geometric Design of Highways and Streets – 2018 7th Edition"***:

Identification of Sight Obstructions within Sight triangles
The profiles of the intersecting roadways should be designed to provide the recommended sight distances for drivers on the intersecting approaches. Within a sight triangle, any object at a height above the elevation of the adjacent roadways that would obstruct the driver's view should be removed or lowered, if practical. Such objects may include buildings, parked vehicles, highway structures, roadside hardware, hedges, trees, bushes, unmowed grass, tall crops, walls, fences, and the terrain itself. Particular attention should be given to the evaluation of clear sight triangles at interchange ramp/crossroad intersections where features such as bridge railings, piers, and abutments are potential sight obstructions.

The determination of whether an object constitutes a sight obstruction should consider both the horizontal and vertical alignment of both intersecting roadways, as well as the height and position of the object. In making this determination, it should be assumed that the driver's eye is 1.08 m above the roadway surface and that the object to be seen is 1.08 m above the surface of the intersecting road.

This object height is based on a vehicle height of 1.33 m, which represents the 15th percentile of vehicle heights in the current passenger car population less an allowance of 250 mm. This allowance represents a near-maximum value for the portion of a passenger car height that needs to be visible for another driver to recognize it as the object. The use of an object height equal to the driver eye height makes intersection sight distances reciprocal (i.e., if one driver can see another vehicle, then the driver of that vehicle can also see the first vehicle).

Where the sight-distance value used in design is based on a single-unit or combination truck as the design vehicle, it is also appropriate to use the eye height of a truck driver in checking sight obstructions. The recommended value of a truck driver's eye height is 2.33 m above the roadway surface.

Section 9.9.2.2 – Departure Sight Triangle

- This Section is Not Applicable and is replaced with the following *(Adopted from AASHTO's Green Book "A Policy on Geometric Design of Highways and Streets – 2018 7th Edition")*:

  A second type of clear sight triangle provides sight distance sufficient for a stopped driver on a minor-road approach to depart from the intersection and enter or cross the major road. *Figure 9.9.2 of Chapter 9 (Applicable)* shows typical departure sight triangles to the left and to the right of the location of a stopped vehicle on the minor road.

  Departure sight triangles should be provided in each quadrant of each intersection approach controlled by stop or yield signs. Departure sight triangles should also be provided for some signalized intersection approaches from which stopped vehicles may enter or cross a major road on which traffic is not required to stop *(see Case D – Intersection with Traffic Signal Control).* Distance a_2 in *Figure 9.9.2* is equal to distance a_1 plus the width of the lane(s) departing from the intersection on the major road to the right. Distance a_2 should also include the width of any median present on the major road, unless the median is wide enough to permit a vehicle to stop before entering or crossing the roadway beyond the median. The appropriate measurement of distances a_1 and a_2 for departure sight triangles depends on the placement of any marked stop line that may be present and may therefore vary with site-specific conditions.

  The recommended dimensions of the clear sight triangle for desirable traffic operations where stopped vehicles enter or cross a major road are based on assumptions derived from field observations of driver gap-acceptance behavior. The provision of clear sight triangles like those shown in *Figure 9.9.2* also allows the drivers of vehicles on the major road to see any vehicles stopped on the minor-road approach and to be prepared to slow or stop, if needed.

Section 9.9.2.3 – Intersection Control

- This Section is Applicable including the following additional Guidance:

  Case B – Intersections with Stop Control on the Minor Road
  While all vehicles must stop on the minor road at the stop-controlled intersection, approach sight triangles like those shown in *Figure 9.9.1 of Chapter 9* are desirable in

the event a driver violates the stop sign. In this situation, a clear approach sight triangle may allow a driver on the major road to detect a vehicle on an intersecting approach, perceive if the approaching vehicle is complying with the stop condition, and take action to avoid a collision if necessary.

The majority of stop sign violations are in the form of rolling stops, where the vehicle approaching the stop bar is slowing, but not stopping, and proceeds through the intersection. To account for this behaviour and to ensure adequate intervisibility at an intersection with stop control on the minor road, the designer should provide clear sight triangles based on the design speed on the major road and an assumed speed of 30 km/h on the minor road.

The length of the legs on the approach sight triangle, shown as a_1 and b in *Figure 9.9.1 of Chapter 9*, may be derived from *Table 9.9.1 of Chapter 9,* which shows the distance traveled by an approaching vehicle during perception-reaction and braking time as a function of the design speed of the roadway. For example, at an intersection with a design speed of 80 km/h for the major road and 30 km/h for the minor road with stop control, the approach sight triangle would have legs extending 75 m and 25 m along the major and minor roadways, respectively. Distance a_2, which is defined in *Section 9.9.2.1 of Chapter 9,* can also be derived from *Table 9.9.1 of Chapter 9* and adding the applicable lane and median widths. In the event the grade along the intersection approach exceeds 3%, the leg along that approach should be adjusted by multiplying the length derived from *Table 9.9.1 of Chapter 9* by the appropriate adjustment factor from *Table 9.9.2 of Chapter 9.*

Although desirable, approach sight triangles like those shown in *Figure 9.9.1 of Chapter 9* may not be required at intersections with stop control, where the need to stop is determined by the traffic control devices. It is expected the designer will exercise sound engineering judgment when considering approach sight triangles for selected road facilities. Consideration should also be given to further expand clear sight triangles at intersections with a history of collisions to provide better intervisibility.

Section 9.11 – Sight Distance at Bridge Structures

- In the third paragraph, Object Height should be replaced to 1.08 m.

Section 9.12 – Widening Through Signalized Intersection

- This Section is Applicable including the following additional Guidance:

  If a lane is to be added before and after the intersection for enhancing traffic operation, the lane should be aligned and there should not be any lateral offset between the departing end and beginning of receiving lane of the added lane through the intersection.

Section 9.13.2 – Corner Radius Considerations and Design

- This Section is Applicable including the following Guidance:

  Where vehicles will make a right turn from the edge of one traveled way to the near edge of the receiving traveled way, the corner radii should be based on minimum turning path of the selected design vehicles. The sharpest turn that can be made by each design vehicle can be find out with the help of data provided in *Chapter 2 – Design Controls, Classification and Consistency*. The maximum assumed speed of selected design vehicle may be equal to or less than 15 km/h when developing swept path and consequently offer some leeway in driver behavior for making right turn at the intersection. The turning path of the design vehicle should be checked against the proposed plan layout to verify that the turn can be accomplished. Turning templates or turning path software compatible with computer-aided design and drafting systems should be utilized to check turning radii of various vehicles for a specific design.

  Design Vehicles
  The physical dimensions and performance characteristics of various size vehicles using the highway system form positive controls in geometric design. For this reason, it is necessary to evaluate all vehicle types, select general class groupings and develop representative sized vehicles within each class for design use. In the process a design vehicle is established, and it is defined as a motor vehicle of selected dimension and operating characteristics and is a representative unit in its class or vehicle group. The design vehicle is used to establish geometric design controls for specific turning requirements for the purpose of accommodating vehicular movements of a designated type.

Selection of Design Vehicle

All intersections should be designed using the Medium Single-Unit (MSU) truck as design vehicle unless the area is part of a highway bus route or has the potential to be used as an inter-city bus route, then the Inter-City (I-BUS) bus should be used as a minimum for design purposes.

At intersections where traffic counts reveal that tractor-semitrailer traffic is predominant, a design vehicle for tractor-semitrailer combinations should be considered in design when the following applies:

- If the number of turning tractor-semitrailer combinations WB-15 type is equal to or exceeds 10 vehicles per hour (vph) in design hourly volume (dhv) and the turning traffic volume exceeds 100 vph in dhv, as per traffic count, then WB-15 vehicle should be used as a minimum for design.
- If the number of turning tractor-semitrailer combinations WB-17.5 type or larger exceeds 1 vph in dhv and the turning volume exceeds 100 vph in dhv, then the WB-17.5 design vehicle should be given consideration.
- If the number of turning tractor-semitrailer combinations WB-20.5 types exceeds 1 vph in dhv and the turning volume exceeds 100 vph in dhv, then the WB-20.5 design vehicle should be given consideration.

Intersections should be designed to accommodate tractor-semitrailer by providing the extra space demanded by such trucks negotiating turns. Operational demands, e.g., feeder routes to and from freight terminals and industrial areas etc. should be given consideration. The choice of the design vehicle should be based on local traffic counts with consideration to potential future traffic growth, particularly if the highway is in an area where industrial or resource development is planned.

Design Vehicle's Turning Paths

The principal factors and dimensions of the design vehicle affecting the intersection design are:

- the minimum turning radius,
- the wheelbase,
- the path of the inner rear wheel,
- the front overhang,
- the operational speed of the turning vehicle, and
- the driver performance or driving characteristics.

The geometric configuration of the intersection and the selected design vehicle size should satisfy the following conditions:

- The turning path of the vehicle's wheels stays within the paved area of the roadway, and
- the swept path of the vehicles' body avoids all other vehicles and fixed objects.

The turning path of each design vehicle is the minimum attainable at a selected speed and a minimum turning radius is slightly above the minimum performance capability of the vehicles in the design vehicle type e.g., turning radius 14 m; turning capability 13.5 m. The turning speed of the vehicle for the minimum radius is less than 15 km/h.

Low-Speed Off-tracking

When a large truck is driven at low speed with the left front wheel following a specified curve, called the turning radius, the rear wheels of the vehicle track inside those at the front and produce low-speed off-tracking. The demand for space while turning is based upon the phenomenon of low-speed off-tracking.

High-Speed Off-tracking

When a vehicle makes a turn at high speed, the rear of the vehicle moves outward because of the lateral acceleration of the vehicle as it negotiates a horizontal curve at higher speeds. High speed off-tracking is a function not only of truck characteristics and roadway geometrics, but also of vehicle speed and the vehicles' suspension, tire and loading characteristics. For design purposes, the pavement widening provided on turns to compensate for low-speed off-tracking is considered adequate for high-speed off-tracking.

Widening of the Side Road at Intersections

When trucks are an important factor in a left turning movement to a side road, it usually becomes necessary to widen the throat of the side road to accommodate wheels of the turning vehicle, thus avoiding tracking onto the shoulder or interfering with a vehicle standing on the side road.

An area designed to represent an island is utilized in the throat to guide the vehicle and control the turning maneuver. The need for an island and its configuration is determined using design vehicle turning characteristics and varies with:

- The type of vehicle,
- the width of highway cross-section, and

- the angle of intersection.

For illustrations see **Exhibit-9B** and **Exhibit-9C**.

Exhibit-9B

WIDENING OF SIDE ROAD AT T-INTERSECTIONS (TURNING 90 DEGREES)

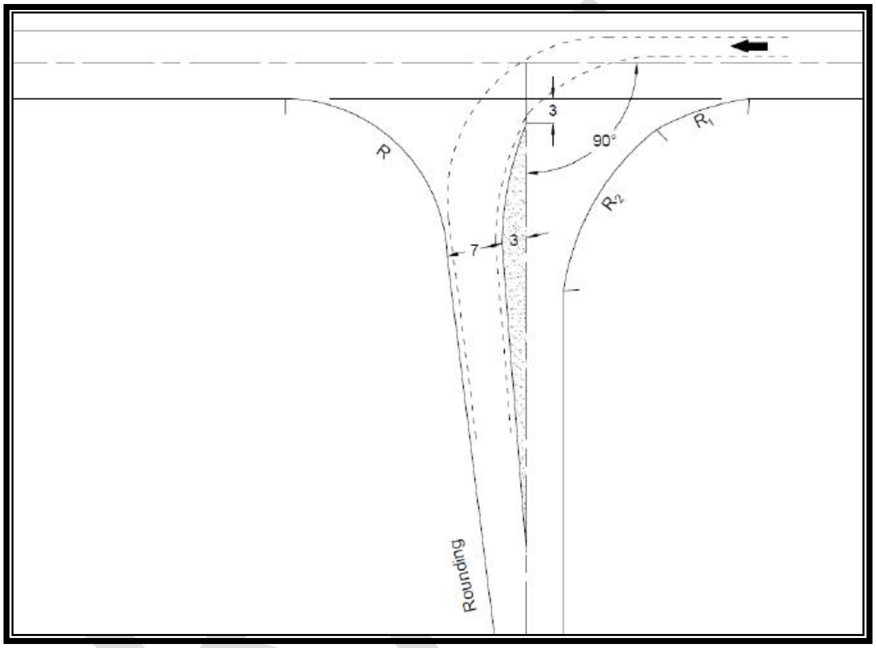
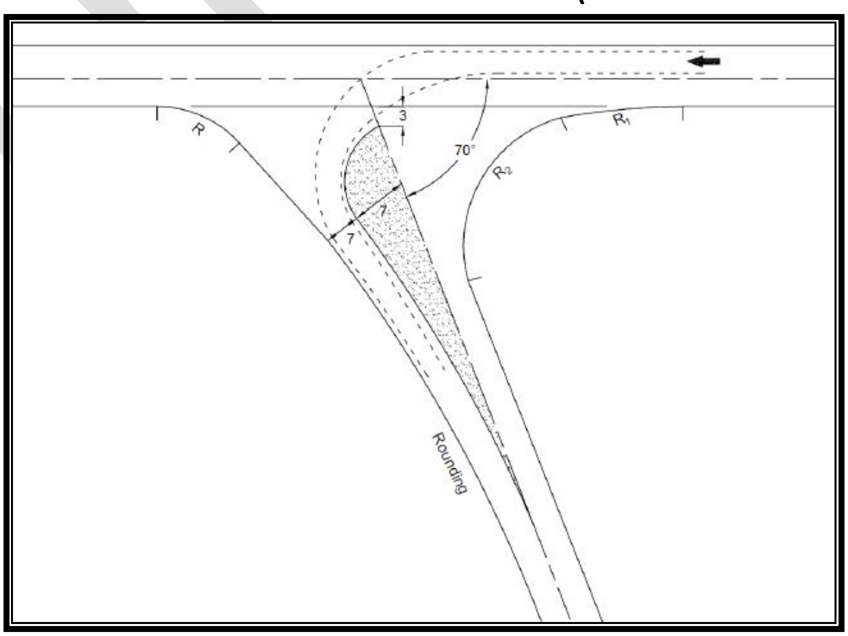


Exhibit-9C

WIDENING OF SIDE ROAD AT T-INTERSECTIONS (TURNING 110 DEGREES)

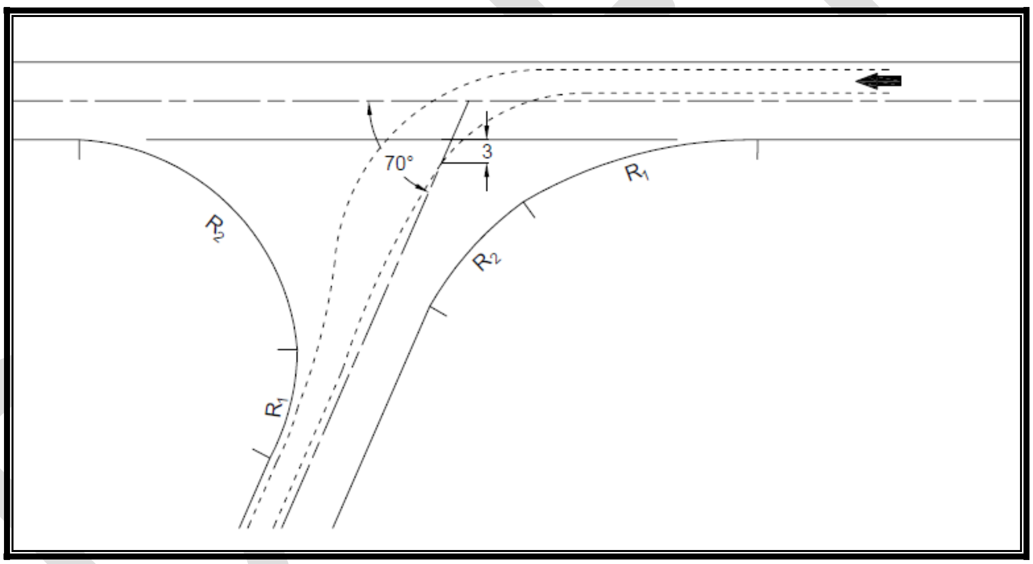


An intersection design having an adverse turning angle as shown in **Exhibit-9C** is not a desirable standard but acceptable. However, it can be improved by realignment of the side road to form approximately or close to a 90° intersection angle with the main highway.

Where the turning angle is less than 90° and favorable to the turning maneuver, and where trucks turning left from the highway do not encroach on the shoulder, it is not necessary to widen the side road cross-section as the pavement widening is provided by the edge of pavement design, consisting of two-centre compound curves for right turn movements of commercial vehicles. See **Exhibit-9D**.

Exhibit-9D

WIDENING OF SIDE ROAD AT T-INTERSECTIONS (TURNING 70 DEGREES)



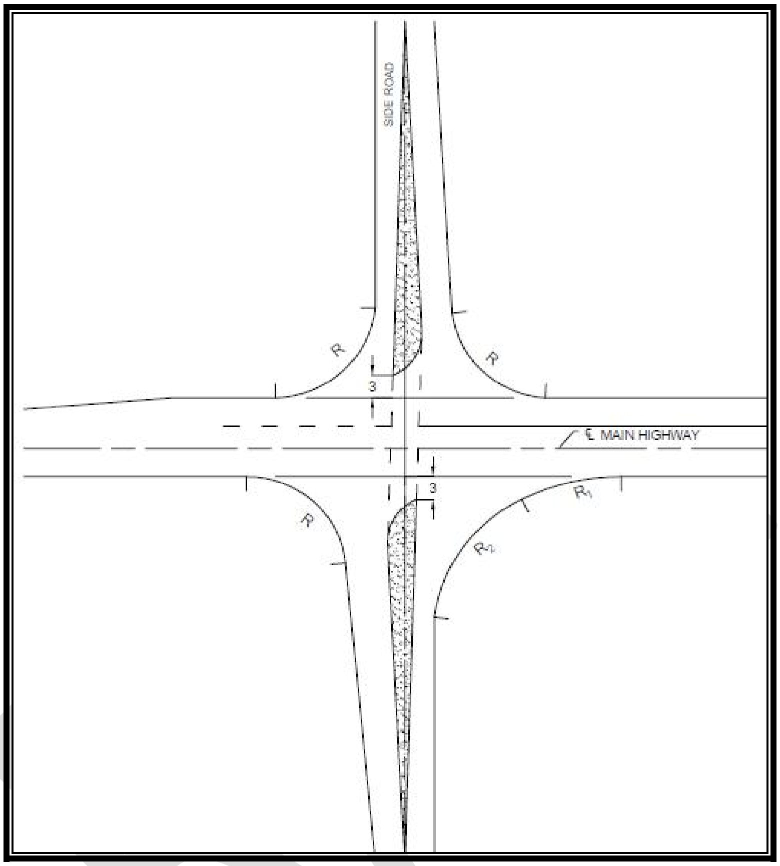
In the case of a cross intersection where widening the side road is necessary, the approach lanes for the advancing traffic are adjusted to line up with the continuation of these lanes on the opposite side of the intersection. This provides a smooth alignment for the side road traffic flow. See **Exhibit-9E**.

Special Design Considerations: Farm Vehicles and Long Combination Vehicles

In highly mechanized agricultural areas where the heavy and large size equipment is often moved along the highway system, at grade intersections should be designed to accommodate the turning maneuvers. As a general rule, the dimensions, which include

Exhibit 9-E

WIDENING OF SIDE ROAD AT CROSS INTERSECTIONS



axle spacing, front and rear overhang and width of the equipment, are obtained and the pavement width requirements determined. The computerized method is recommended to simulate the turning path of other than standard design vehicles and ascertain space and layout requirements. When farm vehicles are under considerations, it is recommended to involve Ontario Federation of Agriculture (OFA) for selection and characteristics of farm vehicles/equipment. When intersection is located on a designated highway route for long combination vehicles (LCV) or potentially the highway will be a designated route in future for LCV, the intersection should be designed to accommodate LCV. For further guidance contact Design Standards & Specification Office or refer to “LCV – Best Practices Guide” developed by Design Standards & Specification Office.

Section 9.13.2.2 – Circular Curve

- This Section is Applicable including **Exhibit-9F**:

Exhibit 9-F

MINIMUM CIRCULAR CURVES AT SIMPLE OPEN THROAT INTERSECTIONS FOR URBAN OR RURAL AREAS

	CIRCULAR CURVES FOR DESIGN VEHICLES *								
	SU: STOP CONDITION R = 15 YIELD CONDITION R = 18 **B-12: STOP CONDITION R = 18 YIELD CONDITION R = 20**								
	R = 15 m			R = 18 m			R = 20 m		
Δ°	T	E	L	T	E	L	T	E	L
70	10.50	3.31	18.33	12.60	3.97	21.99	14.00	4.42	24.43
75	11.51	3.91	19.63	13.81	4.69	23.56	15.35	5.21	26.18
80	12.59	4.58	20.94	15.10	5.50	25.13	16.78	6.11	27.93
85	13.74	5.35	22.25	16.49	6.41	26.70	18.33	7.13	29.67
90	15.00	6.21	23.56	18.00	7.46	28.27	20.00	8.28	31.42
95	16.37	7.20	24.87	19.64	8.64	29.85	21.83	9.60	33.16
100	17.88	8.34	26.18	21.45	10.00	31.42	23.84	11.11	34.91
105	19.55	9.64	27.49	23.46	11.57	32.99	26.06	12.85	36.65
110	21.42	11.15	28.80	25.71	13.38	34.56	28.56	14.87	38.40

Notes

*Edge of pavement design for P-design vehicle: R = 10 m – urban areas
R = 15 m – rural areas

For minor-local roads the radius (R) may be reduced to 5 m in urban areas and 10 m in rural areas.

Section 9.13.2.3 – Two-Centred Compound Circular Curve

- This Section is Applicable including the following additional Guidance:

Two-centred compound circular curve is useful to facilitate the right-turning manoeuvre of tractor-semitrailer combinations. Minimum curve combinations have been selected for the WB-15 and WB-17.5 design vehicles, see **Exhibit-9G**. This exhibit provides radii combinations (R_2 & R_1) for angles of turn between 70° and 110° at 5° intervals.

For intersection angles lying between those shown in the **Exhibit-9G** and for intersections on curves alignment use the **Exhibit-9G** and recalculate the appropriate curve data or by graphical means obtain best fitting combination of radii close to the standard.

The lengths of the tangents of the compound circular curve (a & b) can be calculated by using the formula:

$$T_1 = R_1 \tan \Delta_1/2 \text{ and } T_2 = R_2 \tan \Delta_2/2$$

The length of curve (L_1 and L_2) can be calculated by using the formula:

$$L_1 = \pi R_1 \Delta_1/180^\circ \text{ and } L_1 = \pi R_1 \Delta_2/180^\circ$$

The two-centred compound curve is the preferred design for all types of large trucks and fits the minimum path of the design semi-trailer combination adequately.

When pedestrians are a consideration at a signalized wide-open throat intersection the "walk" and clearance times may be affected, hence providing adequate service and protection for pedestrians may be required.

<u>Exhibit-9G</u>

MINIMUM TWO-CENTRED COMPOUND CIRCULAR CURVES AT SIMPLE OPEN THROAT INTERSECTIONS FOR URBAN AND RURAL AREAS

STOP CONDITION			**YIELD CONDITION**		
WB-15 DESIGN VEHICLE					
Δ°	**R_2**	**R_1**	**Δ°**	**R_2**	**R_1**
70-74	18	80	70-73	21	130
75-84	17	80	74-79	20	130
85-91	16	80	80-89	19	130
92-99	15	80	90-101	18	130
100-110	14	90	102-109	17	140
			110	16	150
WB-17.5 DESIGN VEHICLE					
Δ°	**R_2**	**R_1**	**Δ°**	**R_2**	**R_1**
70-71	22	110	70-71	24	130
72-74	21	110	72-76	23	130
75-77	21	110	77-85	22	130
78-83	19	110	86-94	21	130
84-90	18	110	95-96	20	130
91-94	17	110	97-105	19	140
95-99	16	110			
100-110	15	120	106-110	18	140

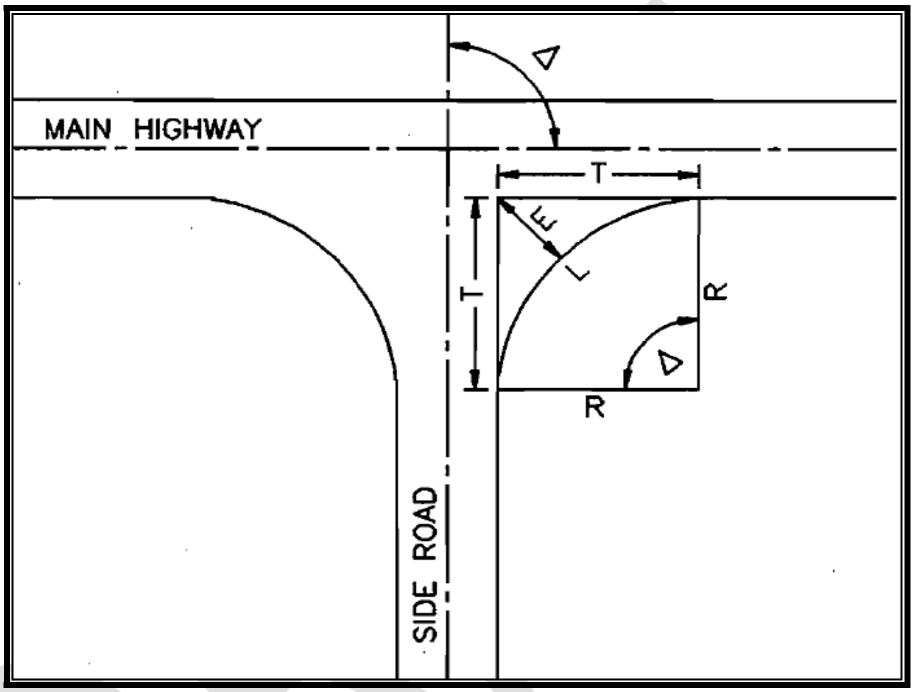
<u>Note:</u> Below the dark thick line channelization may be required

Figure 9.13.4 – Edge of Pavement Design – Circular Curve

- This Figure is Not Applicable and replaced with **Exhibit-9H**

Exhibit-9H

EDGE OF PAVEMENT DESIGN FOR PASSENGER CAR, SINGLE-UNIT TRUCK, AND BUS



Section 9.14.3 – Design Elements for Right-Turn Tapers Without Auxiliary Lanes

- This Section is Applicable except the last sentence and is replaced with “taper only design justify for a maximum design speed of 70 km/h. For speeds greater than 70 km/h, the deceleration of turning vehicles will start on the through lane. Where the turning vehicles significantly impede the through traffic flow, consideration should be given to the design technique of taper plus parallel lane.”

Table 9.14.1 – Right-Turn Tapers Without Auxiliary Lanes

- This Table is Not Applicable and is replaced with **Exhibit-9I**.

Section 9.14.4 – Design Elements for Right-Turn Tapers with Auxiliary Lanes

- This Section is Applicable including the following:
  - When the volume of right turning vehicles is such that it creates a hazard and reduces capacity at an intersection, consideration should be given to the provision of a deceleration lane in the form of a taper and parallel lane for the right turning traffic.
  - The width of the parallel lane (w) may be 0.25 m less than the width of the through lane, but should not be less than 3.25 m.
  - Similar to the right-turn taper design, a 30 m recovery taper with a 1.5 m offset should be applied beyond the intersection when using the taper and parallel lane design on two-lane highways. It is not required on a four-lane highway, at 'T' intersections or where a left-turn lane has been provided.
  - Equation 9.14.1 is only applicable for determining right-turn storage length.
  - For left-turn storage length at unsignalized intersections, refer to **Appendix 9A**.
  - For left-turn storage length at signalized intersections, refer to the latest edition of *Traffic Signal and Timing Policy # 2010-02* issued by Traffic Policy Office.

Exhibit-9I

RIGHT-TURN TAPERS WITHOUT AUXILIARY LANES

Design Speed (km/h)	Taper Length (m)	Horizontal Curve*
50	50	500
60	60	750
70	70	1000

Note:

* Flat radii as indicated can be used rather than tangent alignment for right-turn tapers.

Table 9.14.2 – Right-Turn Taper with Parallel Deceleration Lane Design

- This Table is Not Applicable and is replaced with **Exhibit-9J**.

Exhibit-9J

RIGHT-TURN TAPER WITH PARALLEL DECELERATION LANE LENGTHS*

Highway Design Speed (km/h)	Length of Taper (m)	Length of Parallel Lane (m)	Total Length of Deceleration Lane (m)
50	40	20	60
60	50	30	80
70	60	45	105
80	70	60	130
90	75	70	145
100	80	85	165
110	85	100	185
120	90	110	200

Note:

*: Flat Grade 2% or Less

Table 9.14.3 – Grade Factors for Deceleration Length

- This Table is Not Applicable and is replaced with **Exhibit-9K**.

Exhibit-9K

GRADE FACTORS FOR DECELETARION LENGTH

ALL	DOWN GRADE %	GRADE FACTOR > 1	UP GRADE %	GRADE FACTOR ≤ 1
DESIGN	8 – 7	1.5	2 – 3	1.0
	7 – 6	1.4	3 – 4	0.9
SPEEDS	6 – 5	1.4	4 – 5	0.9
	5 – 4	1.3	5 – 6	0.8
km/h	4 – 3	1.2	6 – 7	0.8
	3 – 2	1.1	7 – 8	0.7

Section 9.15.2 – Smart Channels

- This Section is Applicable with the following additional guidance:

Angle of Intersection with Cross Street

The alignment of a channelized right-turn lane and the angle between the channelized right-turn roadway and the cross street has great effect on safety and capacity. This can be set up in two different angles:

- Wide entry angle to the left, and
- Narrow entry angle to the left

Both types of design are illustrated in **Exhibit-9L**. Traditionally and typically, channelized right-turns have been designed with wide entry angle to the left. The wide entry angle design has an island that is typically shaped like an equilateral triangle. This type of design is appropriate for use in channelized right-turn lanes with either yield control or no-control for vehicles at the entry to the cross street where higher turning speeds are appropriate and active transportation (pedestrians and bicyclists) use is limited. While the narrow entry angle to the left is a newer design technique and is typically shaped like an isosceles triangle. This design can be used with stop sign control or traffic signal control for vehicles at the entry to the cross street. Yield control can also be used with this design where the angle of entry and sight distance along the cross street are appropriate. This design encourages lower turning speeds and improves driver's view of pedestrians waiting to cross.

Exhibit-9L

CHANNELIZED RIGHT-TURN DESIGN

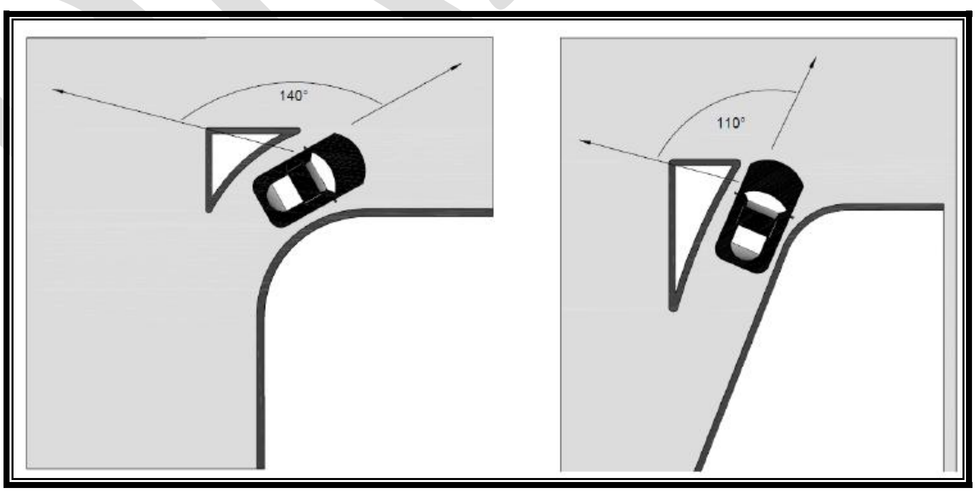


Figure 9.15.1 – Right-Turn Channelization, "Smart Channel" Example Configuration

- This Figure is Applicable including the **Exhibit-9M and Exhibit-9N**.

Exhibit-9M

RIGHT-TURN CHANNELIZATION "SMART CHANNEL" DIRECT TAPERS DESIGN

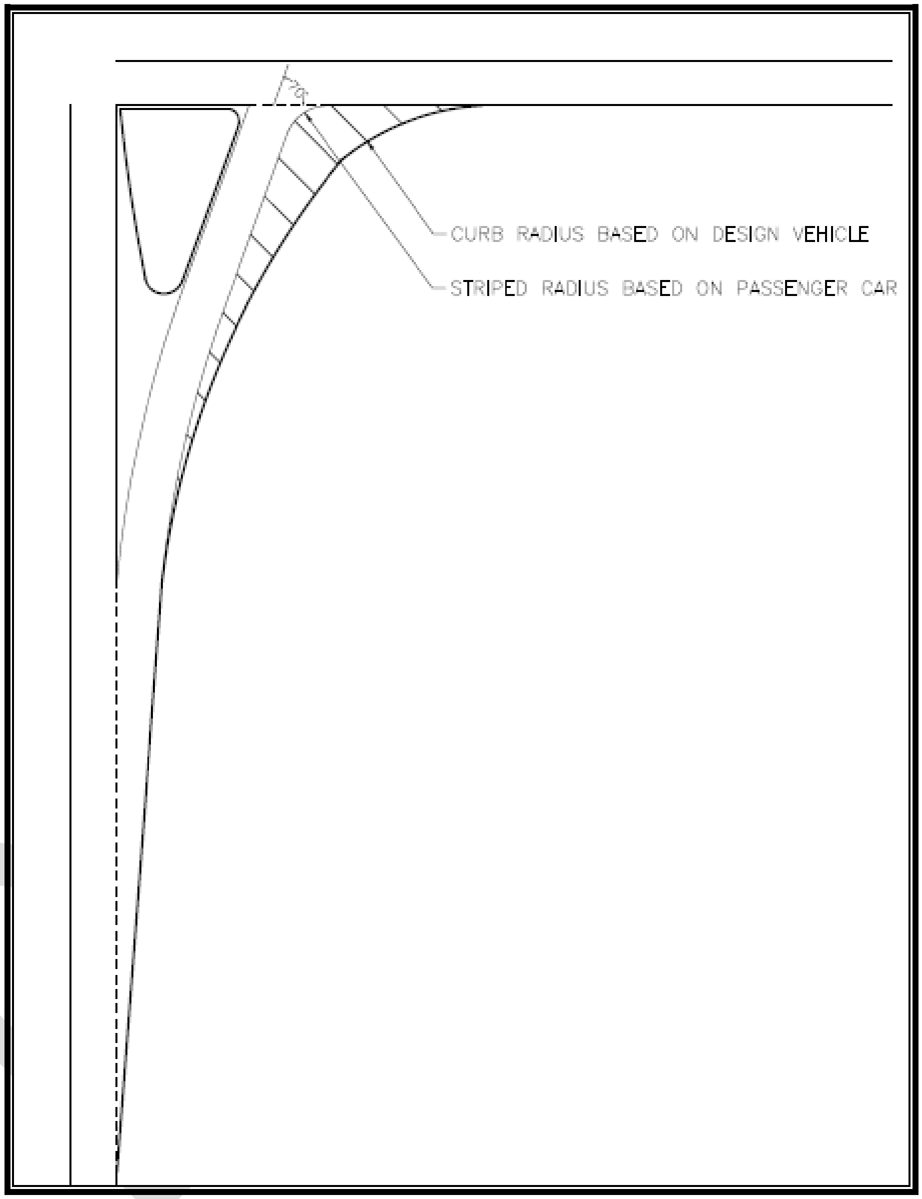
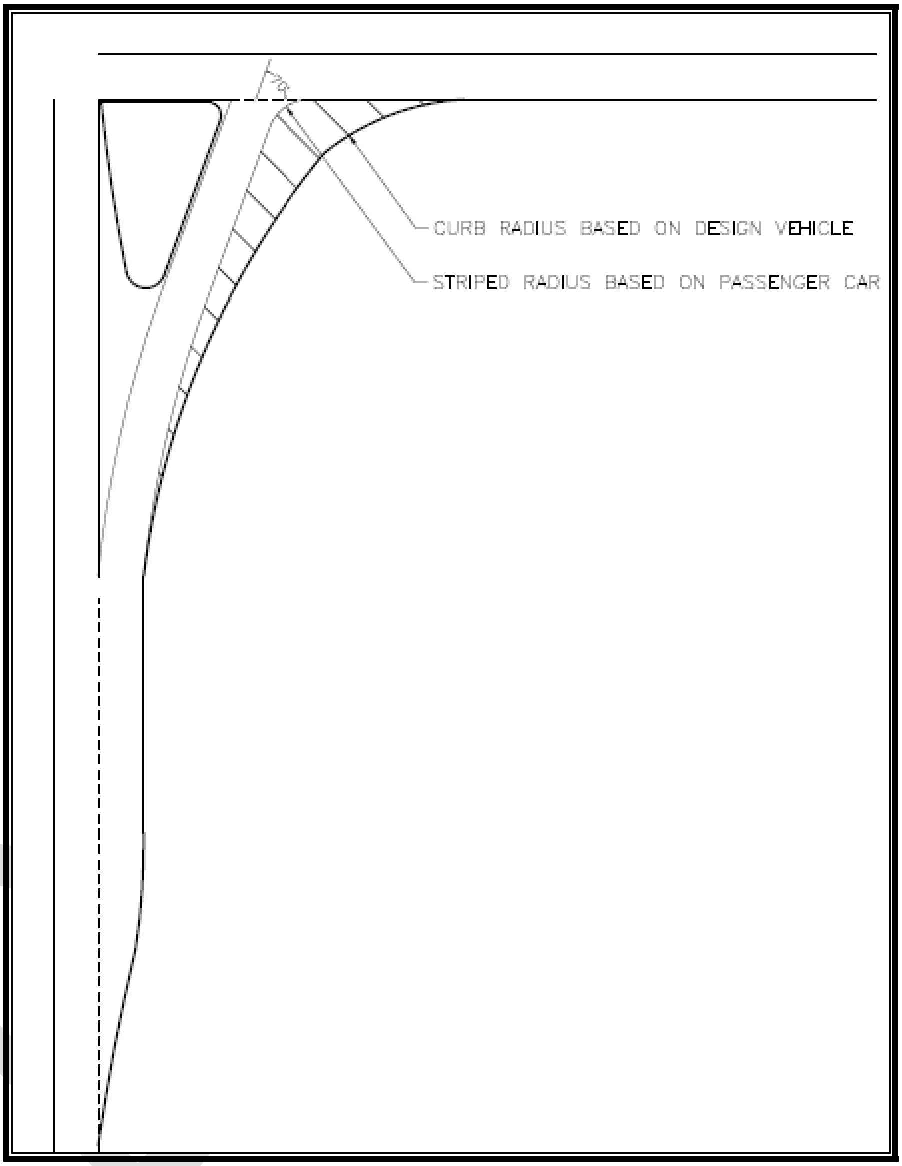


Exhibit-9N

RIGHT-TURN CHANNELIZATION "SMART CHANNEL" TAPERS AND PARALLEL DESIGN



Section 9.15.9.7 – Divisional

- This Section is Applicable including the following:
  At signalized intersections having cross-sections of five lanes or more including left-turn lanes, divisional islands shall be used. Opposing approaches should carefully designed for geometric continuity by providing the same cross section on both sides of the intersection.

Divisional islands may be considered at signalized intersections with four lane cross-sections depending on the signalization requirements.

Divisional islands should not be used at signalized intersections where the geometrics will result in only a single lane between the divisional island and the edge of the road or another island. If such a case arises because the islands are required for locating signal poles due to left-turn phasing requirements, consideration should be given to adding an auxiliary lane through the intersection.

Opposing divisional islands are designed at ‘T’-intersections where the left-turn lane is to be provided in one direction only from the major road or at ‘Cross’ intersections where the left-turn is prohibited in one direction by traffic regulations (one-way traffic). this layout provides for a permissive or an advanced green left-turn operation. This is illustrated in *Figure 9.15.5: Opposing Divisional Island – Chapter 9 of TAC GDG.*

The offset divisional island design is used where left-turn lanes are required at ‘Cross’ intersections. The islands are offset by 0.5 m from the centre line. This is illustrated in *Figure 9.15.6: Offset Divisional Islands – Chapter 9 of TAC GDG.* The offset divisional islands often are introduced at ‘T’-intersections having five lanes or more where future conversion to a ‘Cross’ intersection is expected, or, to facilitate a fully-protected left-turn phasing traffic operation. Proper evaluation of the anticipated type of traffic operation should be carried out for both present and future traffic demands.

The location or set back of the raised islands from the centre of the intersection is determined by applying appropriate design vehicle turning maneuvers. For 90° or near 90° intersections the distance of 15 m accommodates the WB-15 design vehicle turns. However, it is necessary to check the local traffic composition and future conditions for the suitable design vehicle application. The location of the pedestrian crosswalk markings should be applied as indicated in the Ontario Traffic Manuals and raised islands should not extend into the pedestrian area.

Curb islands are sometimes difficult to perceive at night and may become road hazards. This condition can be alleviated by providing the intersection with partial illumination.

Barrier curb at signalized intersection should be used according to the policy provided in the ministry’s Roadside Design Manual, Section 2.3.9.

Section 9.15.9.10 – Minimum Size

- This Section is Applicable except second paragraph. The second paragraph is replaced with the following:

  The divisional islands are a minimum of 2 m wide, including curb and gutter, and are usually 30 m long (15 m minimum). The islands, when used in conjunction with a 3 m wide left-turn storage lane from each direction, are offset, providing an overall minimum pavement width of 5 m between opposing through lanes.

Section 9.15.9.12 – Bikeway Facilities at Channelized Turn Lanes

Figure 9.15.9 – Bike Lane at Right Turn Channel

- This Section and Figure are Not Applicable. Refer to ministry's *Bikeway Design Manual – March 2014.*

Table 9.16.1 – Design Width for Turning Roadways at Intersections

- This Table is Not Applicable and is replaced with **Exhibit-9O**.

Section 9.16.3 – Turning Roadway Widths

- This Section is Applicable including the following additional guidance:

  Width of Pavement for Ramp Design
  The pavement width required on a separate right turn lane to accommodate the off-tracking of the wheels of a design vehicle increases as the radius decreases, **Exhibit-9O** provides the required width for three different scenarios. Turning template software through computer should be used to see if widening is required. Pavement widening when required, is applied to the circular curve of the ramp. The minimum pavement width to be used is 4.75 m except under special circumstances.

  On separate turn lanes with spirals, where extra width is required, the pavement width should be 4.75 m at the beginning of the first spiral and increased throughout the length of the spiral to reach its design width at the beginning of the circular curve. the design width is held throughout the curve, then diminishes to 4.75 m throughout the second spiral, refer to *Figure 9.16.1: Turning Roadway with Spirals* of *Chapter 9.*

Exhibit-9O

DESIGN WIDTHS FOR TURNING ROADWAYS AT INTERSECTIONS

Radius on Inner Edge of Pavement R (m)	PAVEMENT WIDTH IN METRES FOR:								
	CASE I 1 lane – 1 way operation – no provision for passing a stalled vehicle			CASE II 1 lane – 1 way operation – with provision for passing a stalled vehicle			CASE III 2 lane operation - either one way or two way		
	Design Traffic Conditions								
	A	B	C*	A	B	C	A	B	C
15	5.50	5.50	7.00	7.00	7.75	9.00	9.50	10.75	13.00
20	5.50	5.50	7.00	7.00	7.75	8.75	9.50	10.75	13.00
25	4.75	5.00	5.75	6.50	7.00	8.25	8.75	10.00	11.50
30	4.50	4.75	5.50	6.00	6.75	7.75	8.50	9.50	10.75
40	4.25	4.75	5.25	6.00	6.75	7.50	8.50	9.25	10.50
45	4.25	4.75	5.00	6.00	6.50	7.25	8.50	9.00	10.25
50	4.25	4.75	5.00	6.00	6.50	7.25	8.25	9.00	10.00
60	4.00	4.75	4.75	5.75	6.50	7.00	8.25	8.75	9.50
80	4.00	4.75	4.75	5.75	6.25	7.00	8.25	8.75	9.25
100	4.00	4.50	4.75	5.50	6.25	6.75	8.00	8.50	9.00
125	4.00	4.50	4.75	5.50	6.00	6.75	8.00	8.50	8.75
150	3.75	4.50	4.50	5.50	6.00	6.75	8.00	8.25	8.75
TANGENT	3.75	4.50	4.50	5.50	5.75	6.50	7.75	7.75	8.25
Semi-mountable and Mountable Curbs	none			none			none		
Barrier Curbs; One Side Two Sides	add 0.25 m add 0.50 m			none add 0.25 m			add 0.25 m add 0.50 m		
Stabilized Shoulder; One or both sides	none			deduct shoulder width; minimum pavement width as under CASE I			deduct 0.50 m where shoulder is 1 m or wider		

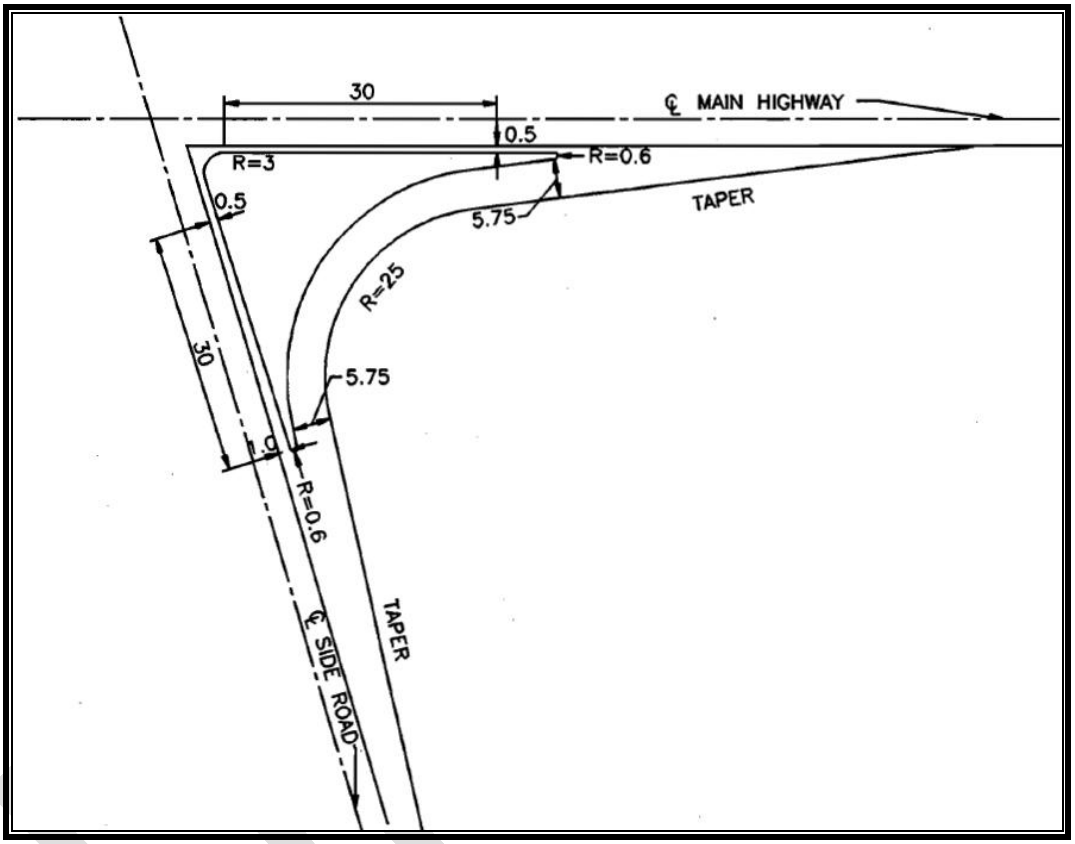
Design Traffic Condition A – Predominantly P vehicles, but some considerations for SU trucks.
Design Traffic Condition B – Sufficient SU vehicles to govern design, but some condition for semitrailer.
Design Traffic Condition C – Sufficient semitrailer, and semitrailer/trailer combinations WB-15 or WB-17.5

* CASE I, Design Traffic Condition is mostly applied to ministry designs.

Where no spirals are used, the required extra pavement width is applied uniformly throughout the circular curve which is illustrated in **Exhibit-9P**.

Exhibit-9P

RAMP DESIGNWITHOUT SPIRALS (SIDE ROAD TO MAIN HIGHWAY)



Section 9.16.6 – Method of Lane Drop for Dual Lane Right-Turning Roadway

- Second paragraph of this Section is Not Applicable.

Figure 9.16.3 – Lane Drop, Dual Lane Right Turning Roadway

- Illustration (a) – [tapered design (suitable for high-speed turning roadway with good sight distance)] of this Figure is Not Applicable.

Section 9.17.2.1 – Volume Warrants

- This Section is Applicable. More details are provided in **Appendix 9A**.

Section 9.17.2.2 – Safety Warrants

- This Section is Applicable including the following additional Guidance:

  The warrant graphs provided in Appendix 9A, based on vehicles operating at the design speed indicated, show the conditions when left turn storage lanes should be added or where traffic signals are to be considered.

  Exhibit-9Q illustrates the upstream functional area of an intersection in relation to the components of deceleration lane length, which consist of the perception-reaction distance, the lane change and deceleration distance, and the storage length.

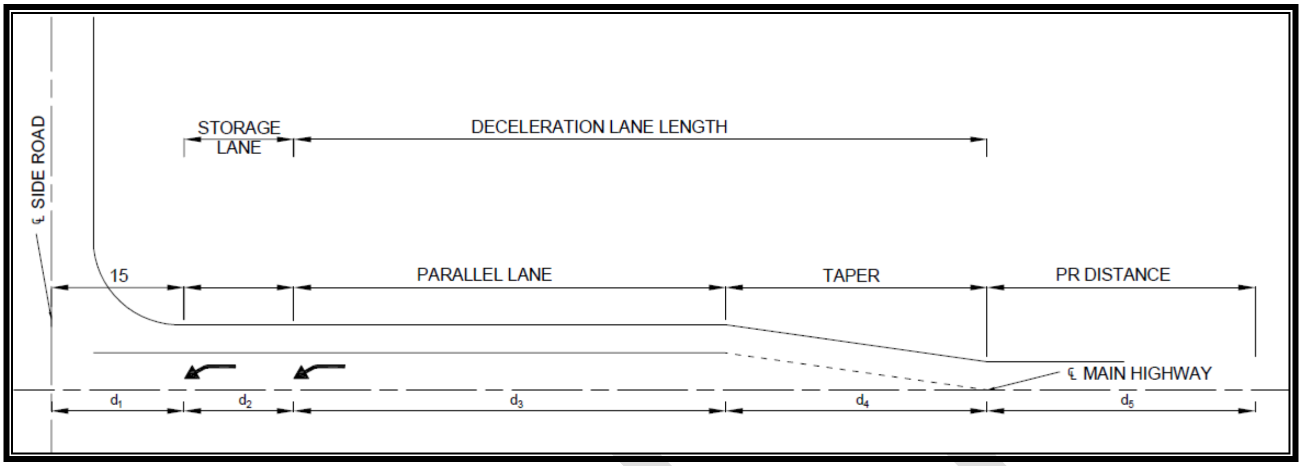
  It may not be practical to provide the full length of the turn lane for deceleration due to constraints such as restricted right-of-way, distance available between adjacent intersections and storage needs. However, research has demonstrated that providing a left- and right-turn lane on any intersection approach has a substantial crash reduction benefits[1]. Therefore, turn lanes should be installed where warranted, even where the distances of **Exhibit-9R** cannot be achieved.

Figure 9.17.1 – Left-Turn Lane, Pictorial Description of Terms

- This Figure is Not Applicable and is replaced with **Exhibit-9Q.**

Exhibit 9-Q

LEFT-TURN LANE, COMPONENETS OF DECELERATION LANE LENGTH



Notes:

- d_1 = 15 m is the assumed distance from minor roadway centerlines to auxiliary lane.
- d_2 = storage length for stopped vehicles waiting to turn.
- d_3 = distance travelled during deceleration after lane change
- d_4 = distance travelled while decelerating and changing lanes from through-lane into turn-lane.
- d_5 = percetion and reaction distance travelled while driver recognizes upcoming turn lane and prepares for the left maneuver.

Section 9.17.3 – Approach and Departure Tapers

- This Section is Applicable including the following additional guidance:

Taper Length

Long tapers approximate the path drivers follow when entering an auxiliary lane from a high-speed through lane. However, with exceptionally long tapers some through drivers may tend to drift into the deceleration lane especially when the taper is on a horizontal curve. In addition, long tapers may constrain the lateral movement of a driver desiring to enter the auxiliary lanes.

The width of left turn lanes should be one increment (0.25 m) less than the through lane with a minimum of 3.25 m and separated from through lanes by a solid painted line and indicated by painted arrow according to the *OTM Book 11 – Pavement, Hazard and Delineation Markings.*

For grades greater than 2%, the length of deceleration lane should be corrected according to the factors shown in **Exhibit-9K**. The corrected deceleration length is calculated by multiplying the deceleration length (**Exhibit-9R**) with correction factor (**Exhibit 9-K**). One-third (1/3) of the extra length may be added in parallel portion while two-third (2/3) may be added in taper length. The length of taper, parallel, horizontal curve to smooth taper, and corresponding design speeds are provided in **Exhibi-9R.**

Example

For a design speed of 100 km/h and a downgrade of 5%
Total deceleration length (taper + parallel) = 160+70 = 230 m
5% downgrade correction factor = 1.3
Corrected deceleration length = 1.3x230 = 299 m (say 300 m)
Extra length beyond original = 300-230 = 70 m
Adding 2/3rd in taper portion = 70x2/3 = 46.7 (say 45 m)
Remaining 1/3rd in parallel portion = 70-45 = 25 m
Now, corrected taper length = 160+45 = 205 m, and
Corrected parallel length = 70+25 = 95 m

Table 9.17.1 – Approach and Departure Taper Ratios and Lengths for Left Turns at Intersections

- This Table is Not Applicable and is replaced with **Exhibit-9R.**

<u>Exhibit 9-R</u>

DECELERATION LENGTH FOR LEFT-TURN LANES, 2-LANES AND 4-LANE HIGHWAYS FLAT GRADE 2% OR LESS

Design Speed (km/h)	Deceleration Length		Horizontal Curve to Smooth Taper R (m)
	Taper (m)	Parallel (m)	
50	85	20	500
60	100	30	750
70	115	40	1000
80	130	50	1200
90	145	60	1500
100	160	70	2000
110	170	80	2500

Section 9.17.4.2 – Deceleration Requirements

- This Section is Applicable including the following additional guidance:

  The designer may have to determine which distance would be appropriate for the driver to brake comfortably. The designer should choose amongst the worlds of desirable, acceptable and minimum based on-site specific conditions. For parallel lane length only, it is desirable to include perception-reaction time but in acceptable practice perception-reaction time may not be feasible and not cost effective. It is assumed that when driver enters a left-turn lane (taper) they should be expecting to brake. In most cases the driver would be expected to already transition their speed as they go through the taper using perception-reaction time. According to Section 9.17.3 decision sight distance should be considered in taper length to accommodate perception-reaction distance. Using minimums all the way around in the process should be avoided. The minimum desirable length of the taper and parallel length combined should not be less than the stopping sight distance provided in *Table 2.5.2* of *Chapter 2.*

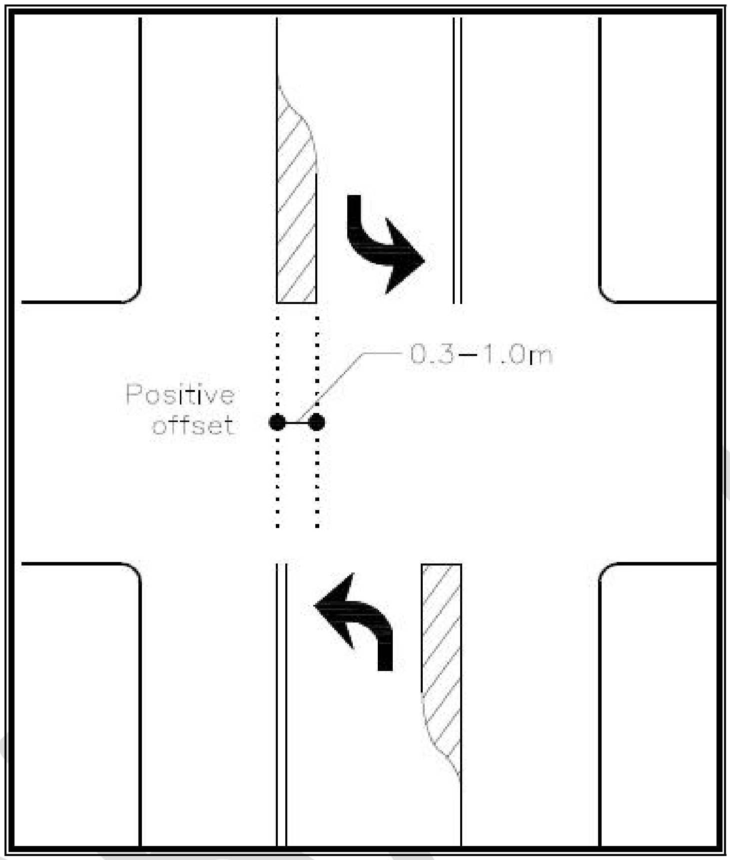
Section 9.17.4.5 – Left-Turn Lanes on Both Approaches

- This Section is Applicable including the following additional guidance:

  Positive Offset for Left-Turn Lanes
  A potential for conflict exists when vehicles in opposing left-turn lanes on the major road block the drivers' views of approaching traffic. A left-turning driver's view of opposing through traffic may be blocked by left-turning vehicles on the opposite approach. When left-turning traffic has a permissive green signal phase, this may lead to collisions between vehicles turning left from the major road and through vehicles on the opposing major-road approach[2]. To reduce the potential for crashes of this type, the left-turn lanes can be offset by moving them laterally, so that vehicles in opposing lanes no longer obstruct the opposing driver. This helps improve safety and operations of the left-turn movement by improving driver acceptance of gaps in opposing through traffic. This is especially true for older drivers who have difficulty judging gaps in front of oncoming vehicles. The effectiveness of this technique is greatest where signal operations include permissive signal phasing or permissive/protected phasing for left-turning movements. Positive offset for left-turn lanes is illustrated in **Exhibit-9S**.

Exhibit 9-S

POSITIVE OFFSET FOR LEFT-TURN LANE



The advantages of offsetting the left-turn lanes are: better visibility of opposing through traffic, decreased possibility of conflict between opposing left-turn movements within the intersection, and more left-turn vehicles served in a given period, particularly at a signalized intersection.

Positive offset for left-turn lane should be provided if median is wider than 5.4 m. The width of left-turn lane should not be less than 3.25 m. One method for laterally shifting left-turning vehicles is to narrow the turn lane width using pavement markings. This is accomplished by painting a wider stripe at the right side of the left-turn lane, which causes left-turning vehicles to position themselves closer to the median. The width of these lines ranged from 0.3 m to 1.0 m. The wider the left-turn lane line used to offset vehicles, the greatest the effect on improving sight distance.
Two types of painting: Parallel or Tapered can be installed to achieve positive offset at the intersections. This is illustrated in **Exhibit-9T** and **Exhibit-9U** respectively.

Exhibit-9T

PARALLEL POSITIVE OFFSET FOR LEFT-TURN LANE

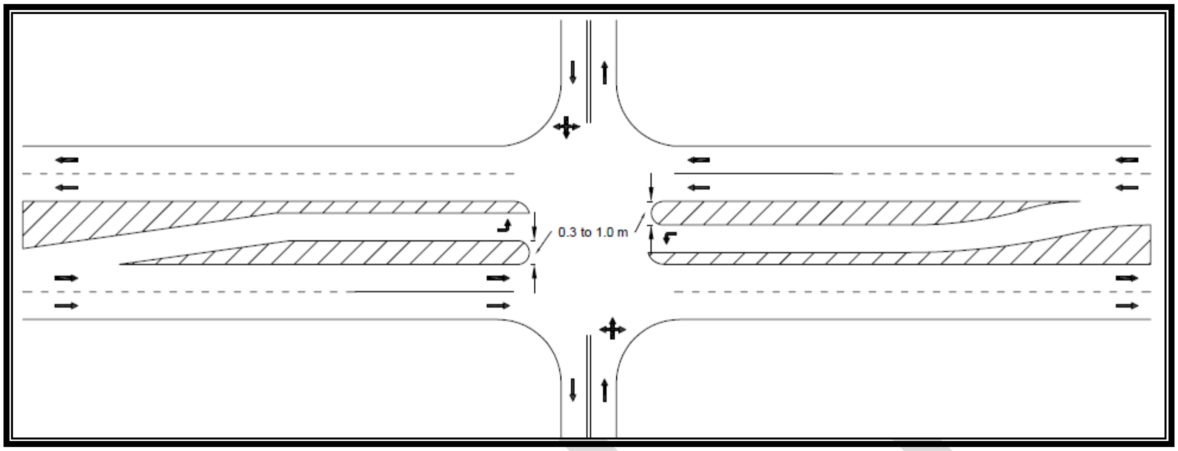
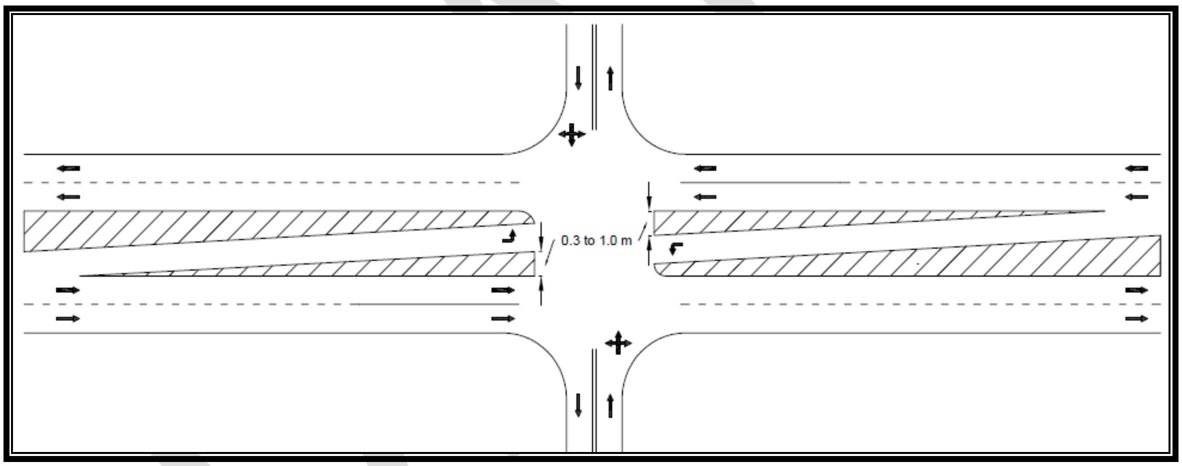


Exhibit-9U

TAPERED POSITIVE OFFSET FOR LEFT-TURN LANE



Section 9.17.5.1 – Double Left-Turn Lanes

- This Section is Applicable including the following additional Guidance.

  This additional guidance is also applicable for double right-turn lanes.
  Occasionally, the two-abreast turning maneuvers may lead to sideswipe crashes. These usually result from too sharp a turning radius or a roadway that is too narrow. The receiving leg of the intersection should have adequate width to accommodate two lanes of turning traffic. Capacity benefits can be achieved if the receiving leg width is wider. However, the capacity notwithstanding, the tradeoffs for wider crossing distances

include longer crosswalk distances for pedestrians (leading to longer clearance times in the signal cycle), a large overall intersection footprint, high turning speed, and increased cost to construct and maintain additional pavement area.

Double left and right-turn lanes are becoming more widely used at signalized intersections where traffic volume have increased beyond the design volume of the original single left and right-turn lane. The following are design considerations for double turning lanes:

- Width of receiving leg,
- Width of intersection to accommodate the two vehicles turning abreast,
- Location of downstream conflict points,
- Weaving movements downstream of turn,
- Potential of pedestrian conflict, and
- Consideration for median refuge for pedestrians given long pedestrian crossing lengths.

Design Vehicle

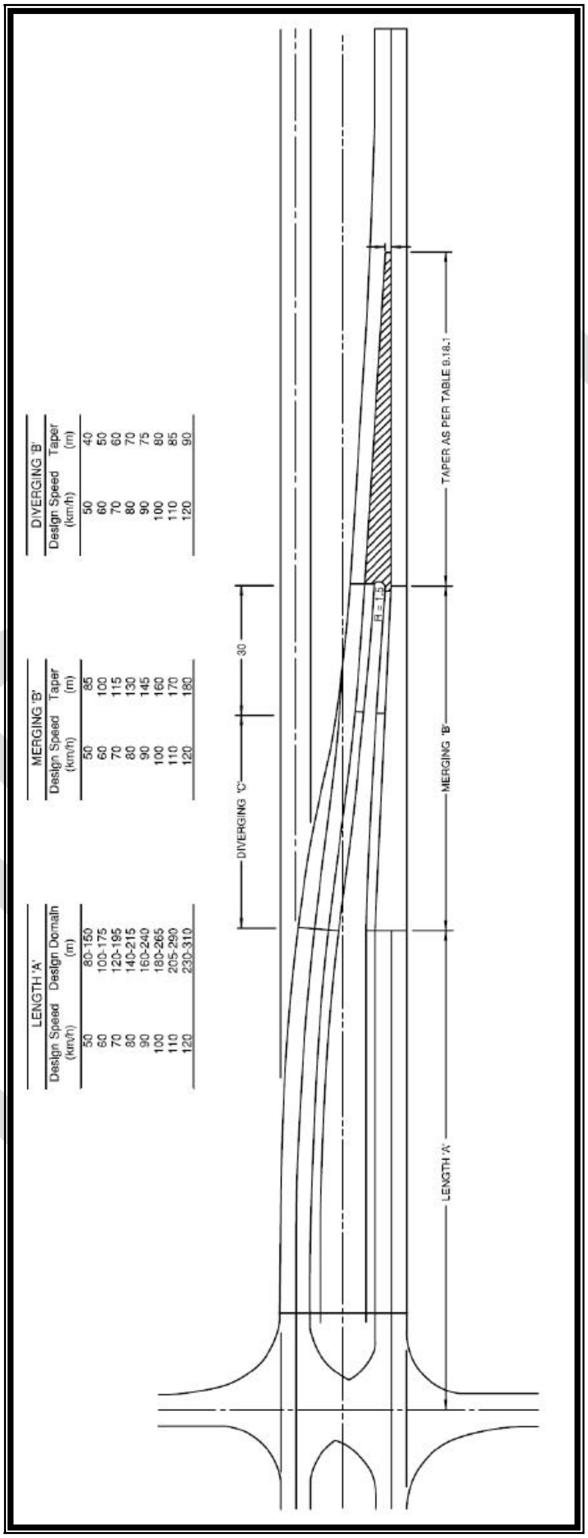
Off-tracking and swept path width are important factors in designing double left and right-turn lanes. At such locations, vehicles should be able to turn side-by-side without encroaching upon the adjacent turn lane. The designer should consider a WB-20.5 design vehicle in the outside lane and a medium single-unit (MSU) truck in the inside lane when developing the swept path. The designer may replace the MSU with other larger or smaller design vehicle based on turning vehicle classification count, traffic analysis, safety review, and engineering judgement. If the intersection is located on Long Combination Vehicle (LCV) route, consideration of LCV should be in the outside lane while MSU and other vehicle (based on the above guidance) should be considered in the inside lane.

Section 9.18.2 – Divided Roadways

- This Section is Applicable including the **Exhibit-9V**:

Exhibit 9-V

TRANSITION BETWEEN FOUR-LANE AND TWO-LANE HIGHWAY MERGE ON TANGENT ALIGNMENT



LENGTH 'A'

Design Speed (km/h)	Design Domain (m)
50	80-150
60	100-175
70	120-195
80	140-215
90	160-240
100	180-265
110	205-290
120	230-310

MERGING 'B'

Design Speed (km/h)	Taper (m)
50	85
60	100
70	115
80	130
90	145
100	160
110	170
120	180

DIVERGING 'B'

Design Speed (km/h)	Taper (m)
50	40
60	50
70	60
80	70
90	75
100	80
110	85
120	90

Section 9.19.1 – Use and Function
Section 9.19.2 – Elements of Design

- These two Sections are Not Applicable and are replaced with the following:

The outline and size of median openings at signalized or unsignalized intersections depends on the median width and is determined by the turning requirements of the design vehicle. Median end designs generally in use are:

1. Semi-circle (simple bullnose)
2. Bullet-nose
3. Flat nose

Semi-circular median opening design is used for narrow medians up to 5 m in width.

Bullet-nose shape median end design is required for medians ranging from 5 to 15 m in width. The size of opening and the shape of the bullet-nose is designed by the use of a WB-17.5 (WB 17.5 is taken as design vehicle for turning template illustration). The bullet-nose radii of the median opening guide the turning truck into the desirable path and lane. This design permits simultaneous left turn movements for trucks from each direction on the highway as well as turns from the ride road and it allows a minimum width of median opening between bullnoses. See **Exhibit-9W**.

Flat-nose median opening design is developed for wide medians of 25 m or more with the ends flattened in shape, parallel to the intersecting road centre line. This design affords a higher degree of operational advantage over the narrow bullet-nose median openings, permitting the WB-17.5 (WB 17.5 is taken as design vehicle for turning template illustration) to pause off the through pavement while waiting for an opening and to pass each other when turning. Vehicles crossing the highway relate better to the flat-nosed opening and to the through lanes of the highway and drivers stopped in the median opening have a greater sense of security to the front and rear of their vehicles. See **Exhibit-9X**.

Exhibit-9W and Exhibit-9X show the median opening requirements with a two-lane side road. Similar design principles, based on the turning requirements of the WB-17.5 design vehicle, are to be followed for the median opening design with a four-lane side road.

The design of the separate left turn lane for divided highways at median openings consists of the following:

- a storage lane 'S' with variable length beginning approximately 5 m from the bullnose. See Graph in **Exhibit-9A32 of Appendix 9A** for storage lane length,
- a parallel lane,
- a taper.

For lengths of parallel lane and taper see **Exhibit-9Y**. The length of the deceleration lane is based on comfortable braking requirement. For design purposes it is assumed that:

- drivers entering the deceleration lanes travel at average running speed,
- half of the taper is suitable for deceleration and is to be included in the required length.

Storage lane 'S' at signalized intersection can be determined from the *Traffic Signal and Timing Policy # 2010-02* issued by Traffic Policy Office.

Exhibit-9W

DESIGN OF MEDIAN OPENING – NARROW MEDIAN

BULLET-NOSE DESIGN

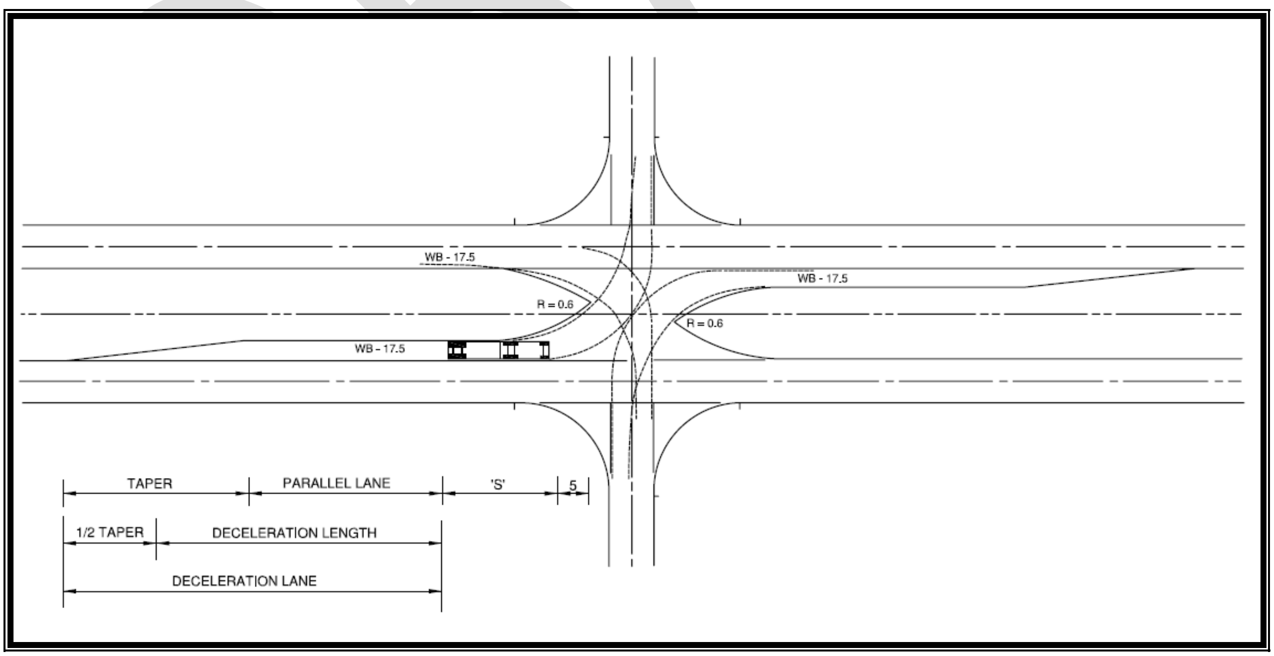


Exhibit-9X

DESIGN OF MEDIAN OPENING – NARROW MEDIAN

FLAT-NOSE DESIGN

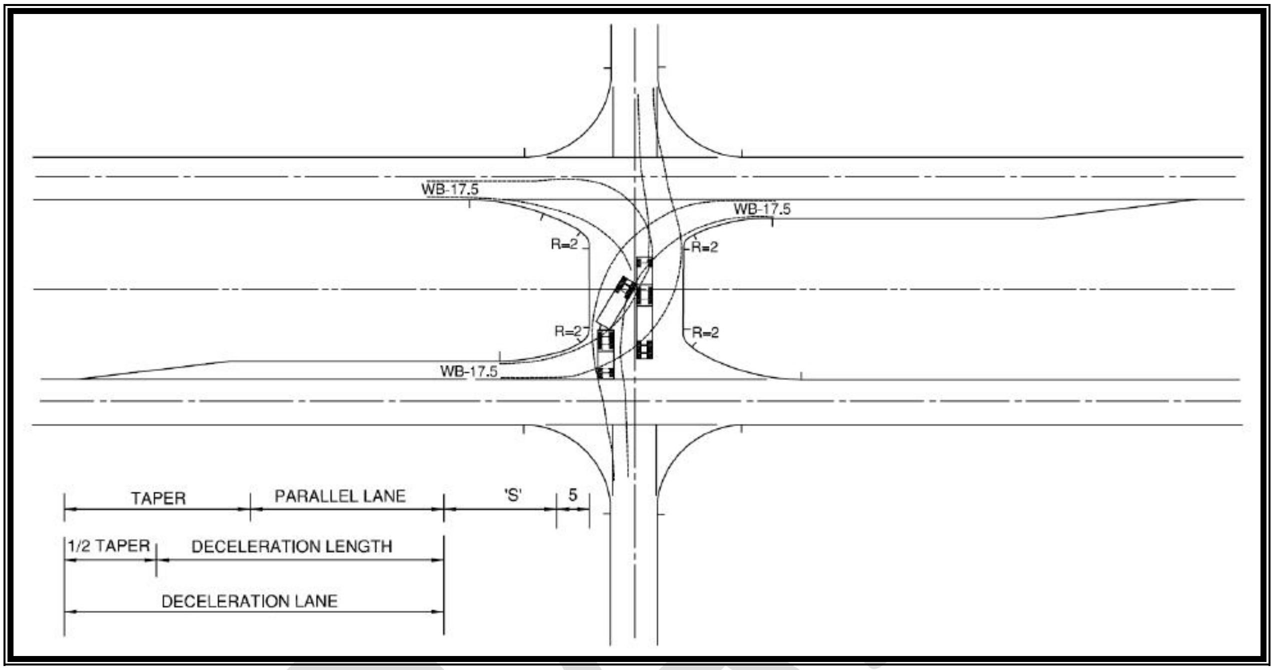


Exhibit-9Y

DECELERATION LENGTHS FOR LEFT TURN LANES

AT MEDIAN OPENING DESIGN

Design Speed km/h	50	60	70	80	90	100	110	120
Taper (m)	40	50	60	70	75	80	85	90
Parallel Lane (m)	35	45	60	70	80	95	110	120
Deceleration Lane (m)	75	95	120	140	155	175	195	210
Deceleration Length (m)	55	70	90	105	118	135	153	165
Storage Lane 'S'	VARIABLE							

Table 9.21.1 – Roundabout Categories and Characteristics

- This Table is Not Applicable and is replace with **Exhibit-9Z**.

Exhibit-9Z

ROUNDABOUT CATEGORIES AND CHARACTERISTICS

DESIGN ELEMENTS	SINGLE-LANE ROUNDABOUT	MULTILANE ROUNDABOUT
Desirable Maximum Entry Design Speed	30 to 40 km/h	40 to 50 km/h
Maximum Number of Entering Lanes per Approach	One	Two or Three
Typical Inscribed Circle Diameter (ICD)	27 to 55 m*	46 to 91 m up to three-lane
Central Island Treatment	Raised with traversable apron	Raised (may have traversable apron)
Typical Daily Service Volumes on 4-Leg Roundabout Below Which may be Expected to Operate Without Requiring a Detailed Capacity Analysis (veh/day)	Up to approximately 25,000**	Up to approximately 45,000 for two-lane roundabout

* Maximum ICD should not be greater than 46 m unless exceptional circumstances like more than four legs or design vehicle larger than WB-20.

** Operational analysis needed to verify upper limit for specific applications or for roundabouts with more than two lanes or four legs.

Section 9.21.1 – Mini-Roundabouts

- This Section is Not Applicable

Figure 9.21.1 – Features of a Typical Mini-Roundabout

- This Figure is Not Applicable

Additional Guidance for Roundabouts

The designer should refer to Highway Design Office policy memo # 2017-05 for *TAC Roundabout Design Guide – January 2017 and MTO Design Exceptions dated September 19, 2017.*

REFERENCES:

1. Harwood, D. W., K. M. Bruce, I. B. Potts, D. J. Torbic, K. R. Richard, E. R. Kohlman Rabbani, E. Hauer, L. Elefteriadou. *Safety Effectiveness of Intersection Left- and Right-Turn Lanes,* Report No. FHWA-RD-02-089. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, July 2002.
2. National Cooperative Highway Research Program Report 500, Guidance for Implementation of the AASHTO Strategic Highway Safety Plan, Volume 12: *A Guide for Reducing Collisions at Signalized Intersections.* Transportation Research Board 2004.

MTO Design Supplement

For
TAC Geometric Design Guide for Canadian Roads

Appendix 9A for Section 9.17.2.1 Volume Warrants for Left-Turn Lanes

Chapter 9 - Intersections

June 2023

MTO Design Supplement
Appendix 9A for Section 9.17.2.1 Volume Warrants for Left-Turn Lanes
Chapter 9 Intersections

The following additional guidance for left-turn lanes at intersections are Applicable to Section 9.17.2.1 Volume Warrants of *Chapter 9 – Intersections* of the *TAC Geometric Design Guide for Canadian Roads - June 2017:*

Signalized Intersections
At intersection consisting of through lanes and separate left turn lanes may require a signal control when the volume of traffic entering the intersection is such that the traffic flow allows insufficient gaps to permit all intersecting vehicles to enter, turn or cross the intersection with little delay or inconvenience. The decision to install a traffic signal must be based on a careful evaluation of the volume warrants and approved traffic guidelines (*Refer to OTM Book 12 – Traffic Signals*). The service volumes that a signalized intersection can accommodate, and the capacity are dependent on the traffic factors, intersection geometrics and signal operations. For signalized intersections the geometrical configuration of the entire intersection design should be coordinated with the appropriate signal design and traffic signal phasing consistent with the operational requirements of both present and future traffic demands. The Project Delivery office should have early liaison with the Regional Traffic office.

As a general guideline, left-turn lanes must be considered and installed on all highway approaches at all signalized intersections whether the left turn warrants are met or not, unless the left turn is prohibited by geometrics (T-intersection) or traffic regulations (one-way traffic).

Separate left turn lanes at signalized intersections have the advantages of increased safety, improved intersection capacity, flexibility for possible phasing schemes and clarity of purpose.

The left turn storage lane length is a function of the signal cycle length and left turn traffic volume. A left turn storage lane can function with or without separate left turn traffic signal phasing. The length of left turn storage lane should be determined by using the methodology provided in the latest *Traffic Signal and Timing Policy # 2010-02* issued by Traffic Policy Office.

Unsignalized Intersections

Uniform volume warrants graphs and design guidelines of left turn storage lanes at unsignalized intersections have been developed and were based on theoretical analysis and on a series of field studies of traffic behaviour at intersections.

The warrant graphs provided in this **Appendix** based on vehicle operating at the design speed indicated, show the conditions when left turn storage lanes should be added or where traffic signals are to be considered.

An additional length should be added to the graph value if the percentage of the left turning commercial vehicles is significant. **Exhibit-9A-1** lists additional storage lengths based on commercial vehicles percentages of left turning volumes, V_L, and storage length, ‘S’, obtained from warrant graphs provided in this **Appendix**.

Exhibit-9A-1

ADDITIONAL STORAGE LANE LENGTH FOR COMMERCIAL VEHICLES

“S” Storage Lengths from Warrant Graphs~~;~~ ~~Appendix 9A~~	**Percentage of Commercial Vehicles in Left Turning Volume, V_L**						
	10%	15%	20%	25%	30%	40%	50%
	Additional Storage Lane Lengths in Meters						
15	10	10	10	10	10	15	15
25	10	10	10	10	10	15	15
30	10		10	10	15	15	15
40	10	10	10	15	15	15	25
50	10	10	15	15	15	25	25
55	10	15	15	15	25	25	30
65	10	15	15	15	25	30	30
70	10	15	15	25	25	30	40
80	10	15	15	25	25	30	40
90	15	15	25	25	30	40	50
95	15	15	25	25	30	40	50
105	15	15	25	30	30	50	50
110	15	25	25	30	40	50	50
120	15	25	25	30	40	50	50
130	15	25	30	30	40	50	50

Left turn lane volume warrants and storage lane lengths for unsignalized intersections are based on turning, advancing and opposing design hour volumes, which are shown on the example of the Design Hour Volume (DHV) turning volume diagram, see **Exhibit-9A-2**, and are determined from the warrant graphs in **Exhibit-9A-3 to Exhibit-9A-30**.

The design charts have been based on passenger car dimensions and operating characteristics.

The minimum storage length that should be provided is 15 m from practical design considerations alone. This length of 15 m will provide adequate storage for two vehicles.

Use of Graphs

Select proper graph by percentage of left turns in Advance Volume, V_A, and design speed in kilometres per hour.

If the intersection of lines projected from Advancing Volume, V_A, and Opposing Volume, V_O, fall to the left of the warrant line, a left turn lane is not required.

Right of the warrant line, ‘S’, indicates the length of the storage lane in metres. If the percentage of commercial vehicles in the left turning traffic is more than 10% see **Exhibit-9A-1** and add the table value to storage lane length.

The charts also indicate conditions where the combination of advancing and opposing traffic may warrant traffic signals. A warrant for traffic signals may occur when no warrant for left turn storage lanes exist due to the requirements of the side road traffic.

On approaches where a separate turning lane is provided for right-turning traffic, the right turns are not included in the determination of V_A or V_O as the case may be. For right turning lane, refer to *Section 9.14 – Tapers and Auxiliary Lanes of Chapter 9- Intersections.*

The following example 1 relates to the turning volume diagram in **Exhibit-9A-2** and left turn storage lane chart **Exhibit-9A-4**.

<u>Example 1</u>

Design Speed = 50 km/h

Advancing Traffic Volume, V_A = 300 vph

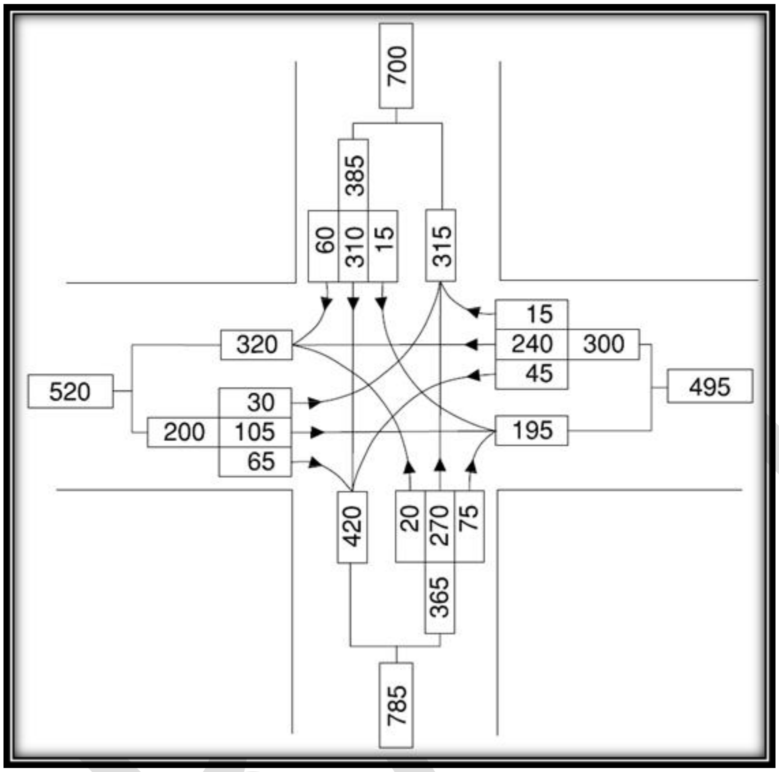
Opposing Traffic Volume, V_O = 200 vph

Left Turn Traffic Volume, V_L = 45 vph

Exhibit-9A-2

DESIGN HOUR VOLUME (DHV)

TURNING VOLUME DIAGRAM



Percentage of Left Turning Traffic = $\frac{45 \times 100}{300} = 15\ (\%)$

The projected lines intersect to the left of the warrant line and hence no left turn lane is needed. Also, the lines intersect to the left of the traffic signal warrant line indicating that traffic signals are not required.

Example 2

Design Speed = 100 km/h

Advancing Traffic Volume, V_A = 400 vph

Opposing Traffic Volume, V_O = 300 vph

Left Turn Traffic Volume, V_L = 120 vph

Percentage of Left Turning Traffic = $\frac{120 \times 100}{400} = 30\ (\%)$

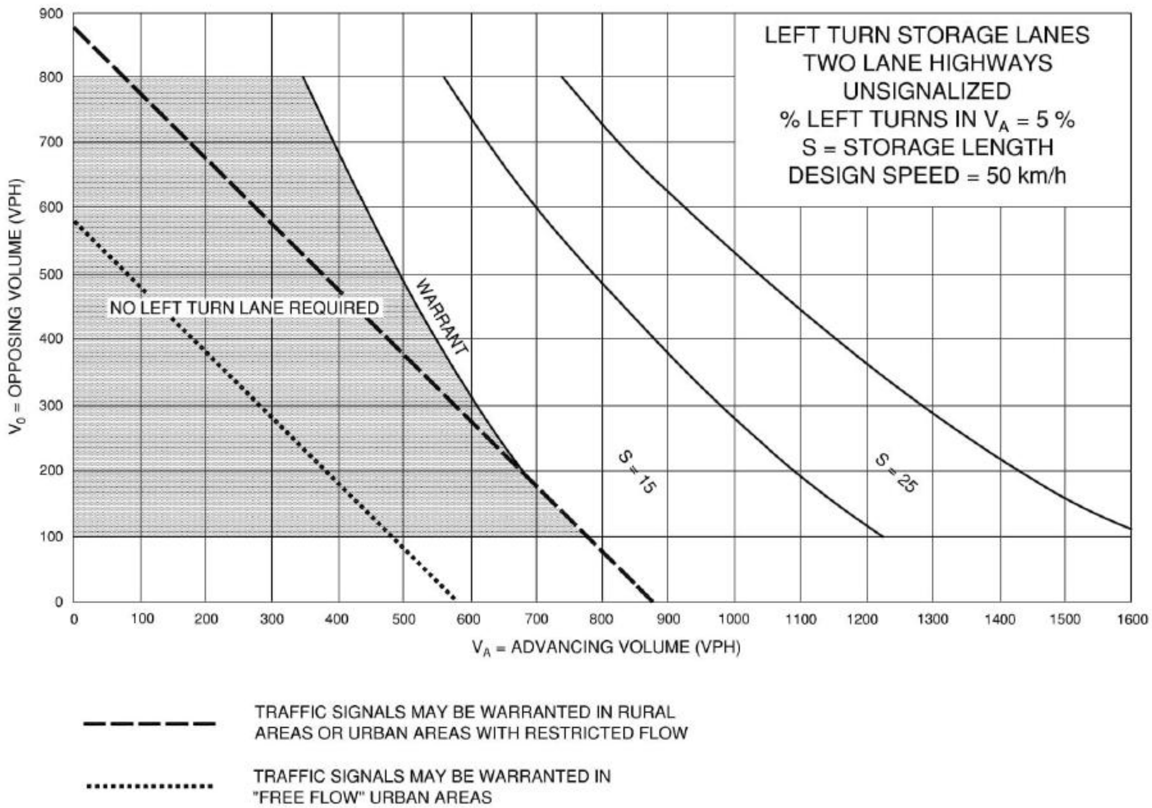
The traffic volumes and derived left turning traffic percentage of 30% are applied to **Exhibit-9A-25.**

The value in the graph indicates that the length of the left turn storage lane ‘S’ should be 25 m. If the percentage of commercial vehicles in the left turn lane is 20%, see **Exhibit-9A-1** for additional storage length and add the value to the left turn lane; 25 m + 10 m = 35 m.

Since the lines intersect to the right of the short dash line and to the left of the long dash line, therefore traffic signals may be warranted in “free-flow” urban areas only. These graphs are not the substitutes for determining signal warrants.

If the value of left turning volume is in between the two charts, e.g., 16% then the designer should be using the chart of 15% and 20% and select the conservative storage length of the two charts. Similarly, for a 28% left turning volume, charts of 25% and 30% should be looked at and the conservative storage length should be selected.

Exhibit-9A-3


LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 5 %
S = STORAGE LENGTH
DESIGN SPEED = 50 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW
TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

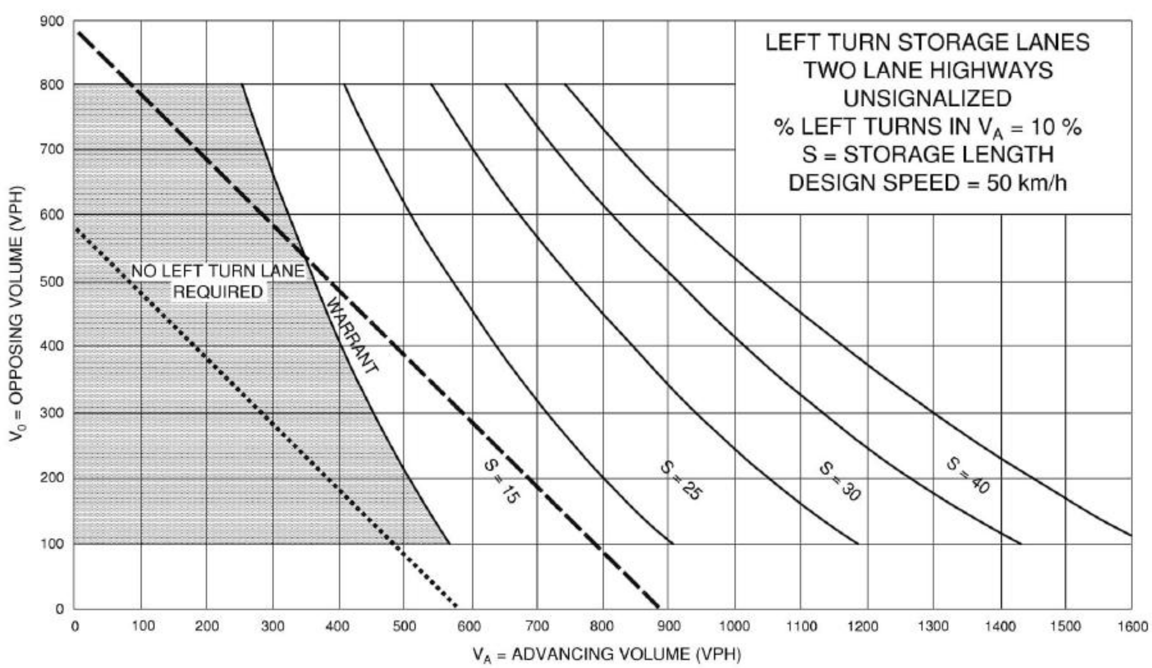
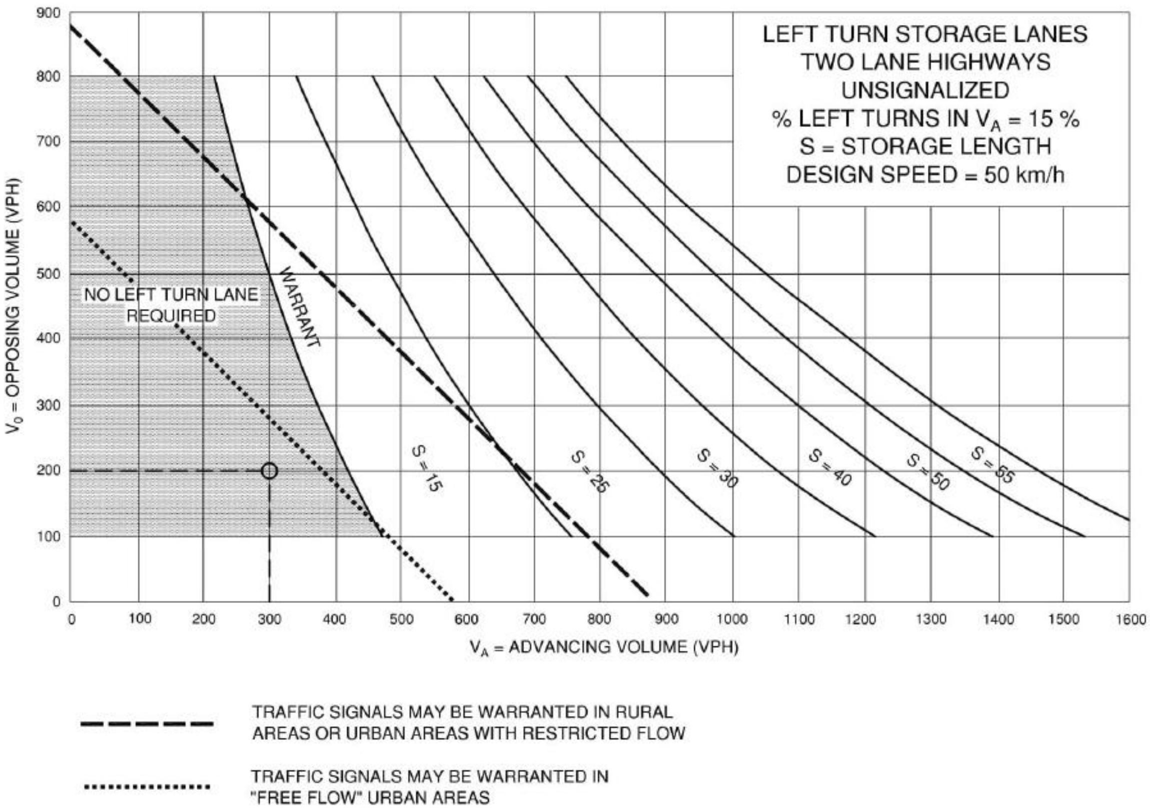

LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 10 %
S = STORAGE LENGTH
DESIGN SPEED = 50 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

Exhibit-9A-4


LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 15 %
S = STORAGE LENGTH
DESIGN SPEED = 50 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 65
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW
TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

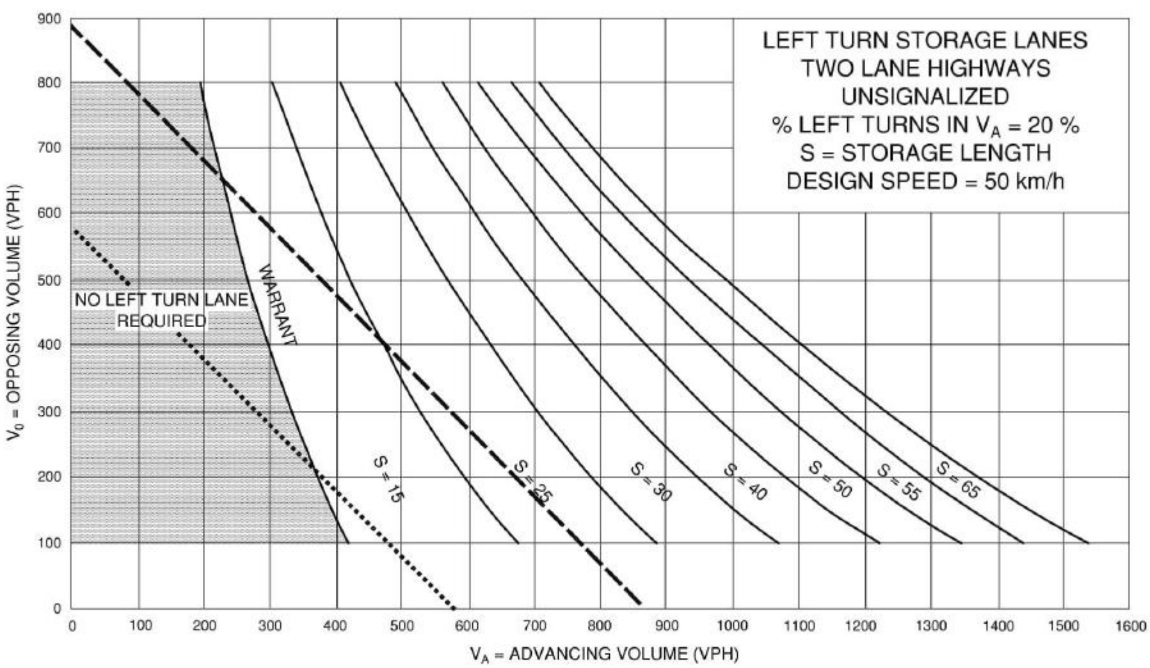
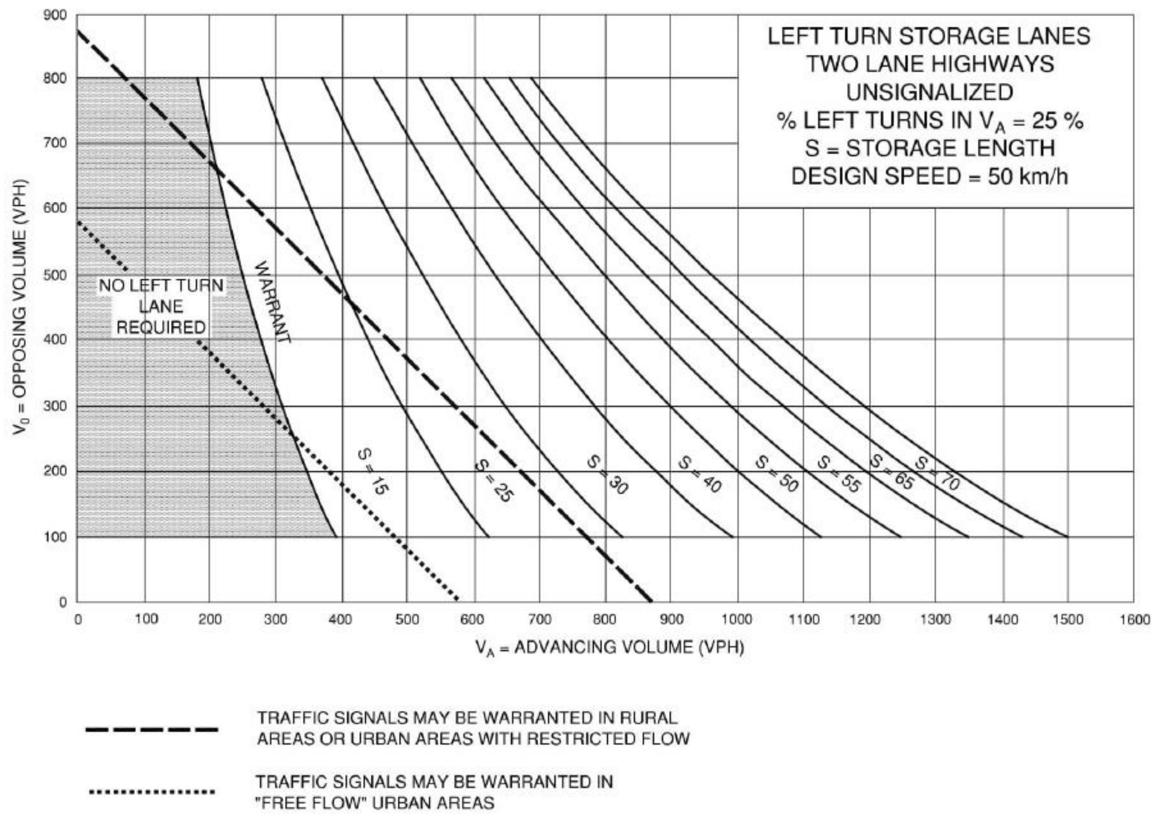

LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 20 %
S = STORAGE LENGTH
DESIGN SPEED = 50 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 55
S = 65
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)

Exhibit-9A-5


LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 25 %
S = STORAGE LENGTH
DESIGN SPEED = 50 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 55
S = 65
S = 70
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW
TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

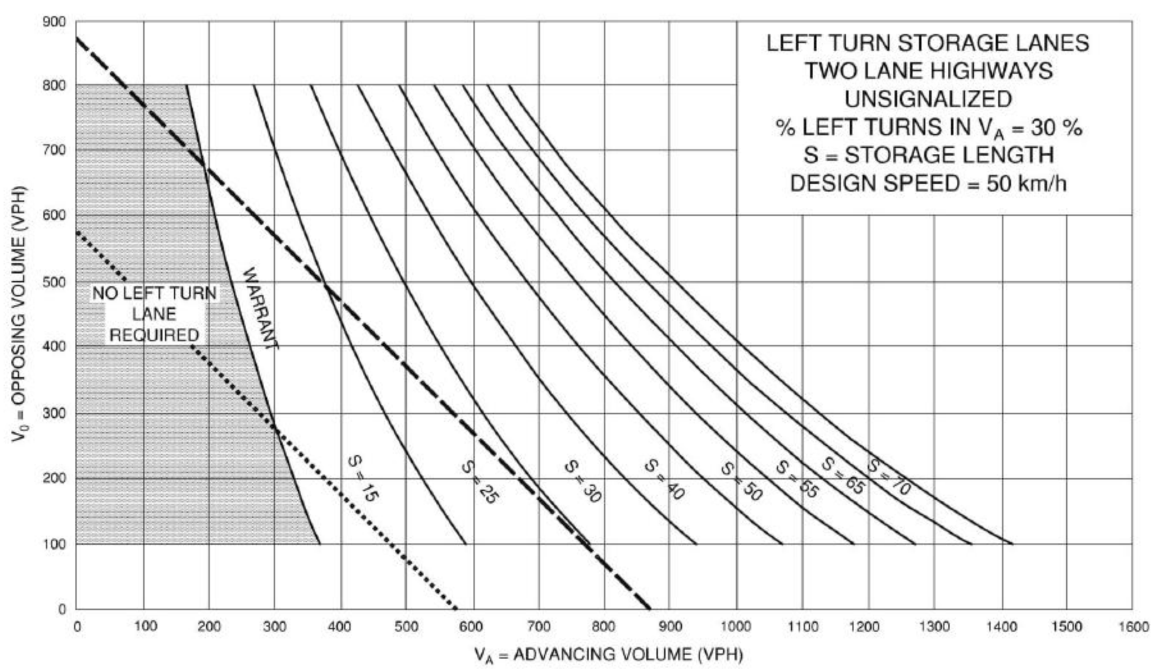
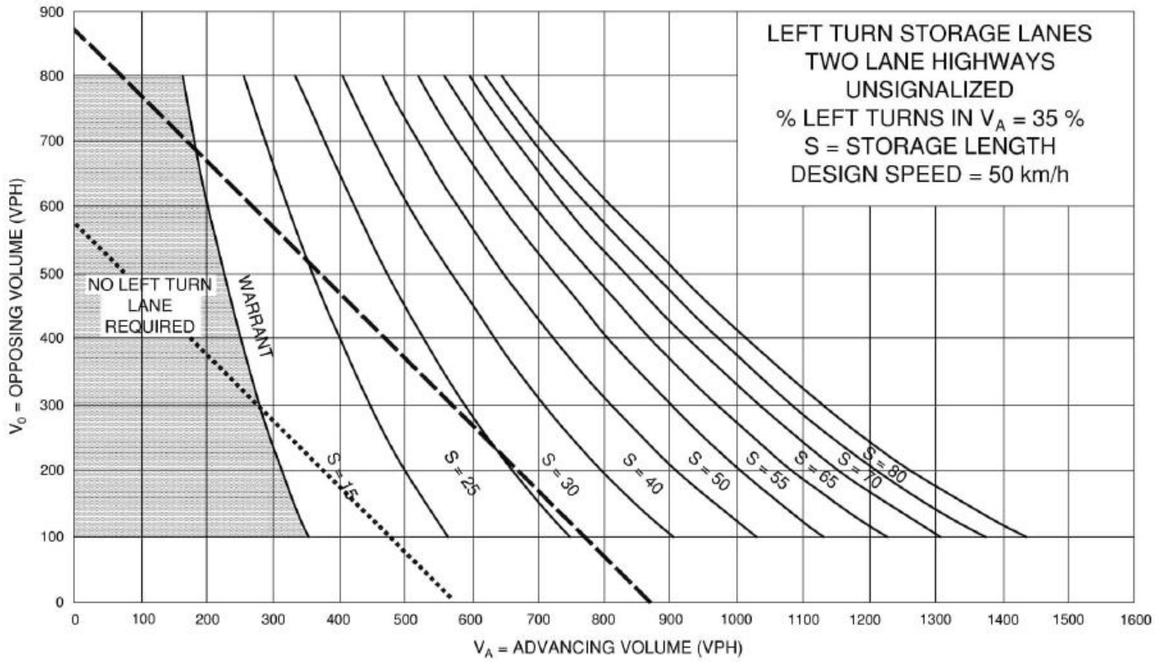

LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 30 %
S = STORAGE LENGTH
DESIGN SPEED = 50 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 55
S = 65
S = 70
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

Exhibit-9A-6



TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW

TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

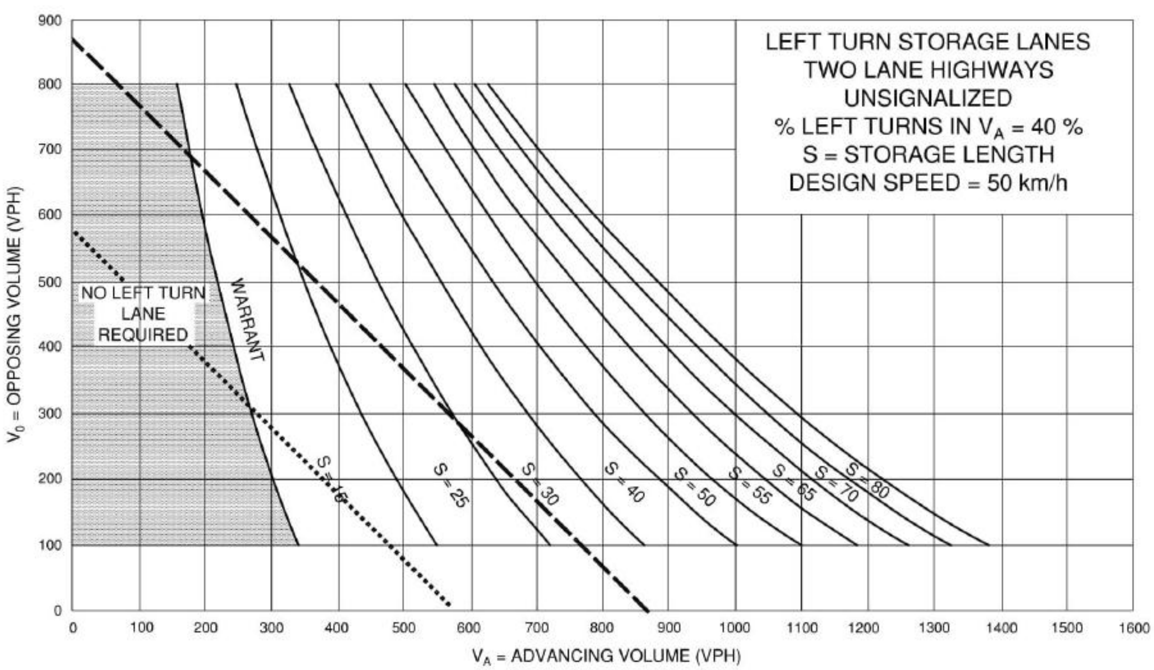
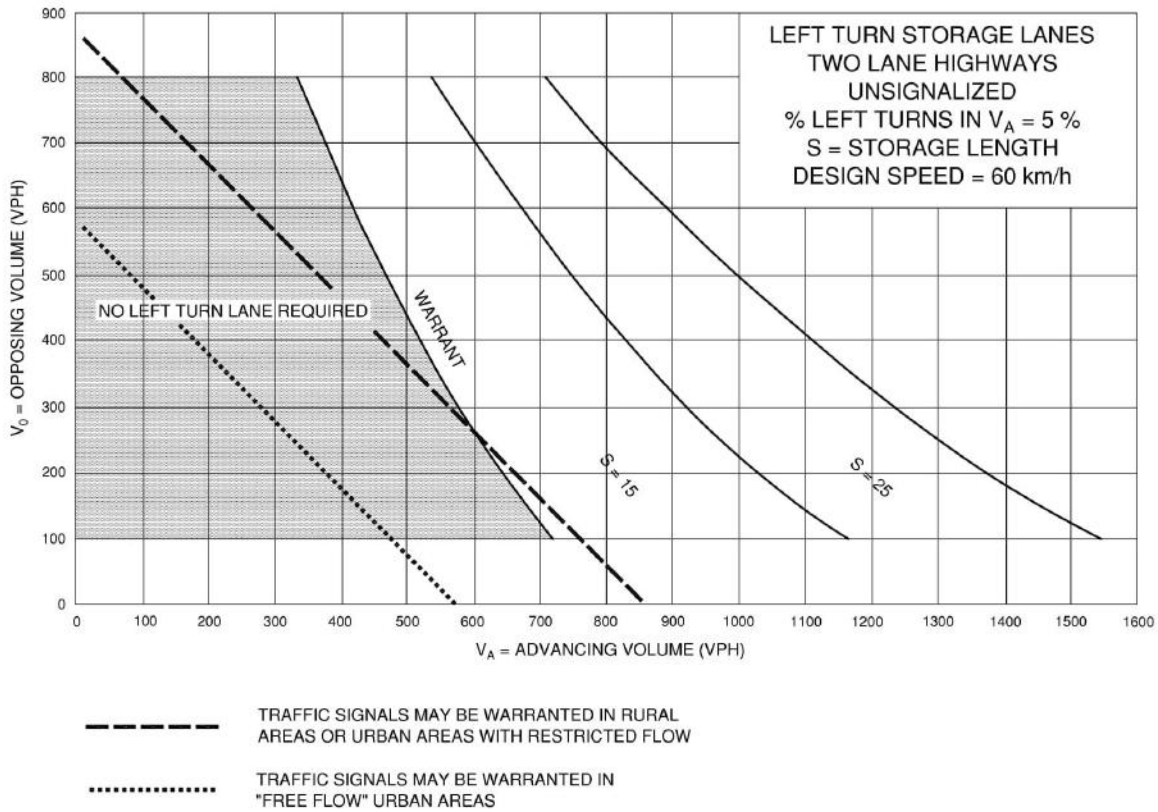


Exhibit-9A-7


LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 5 %
S = STORAGE LENGTH
DESIGN SPEED = 60 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW
TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

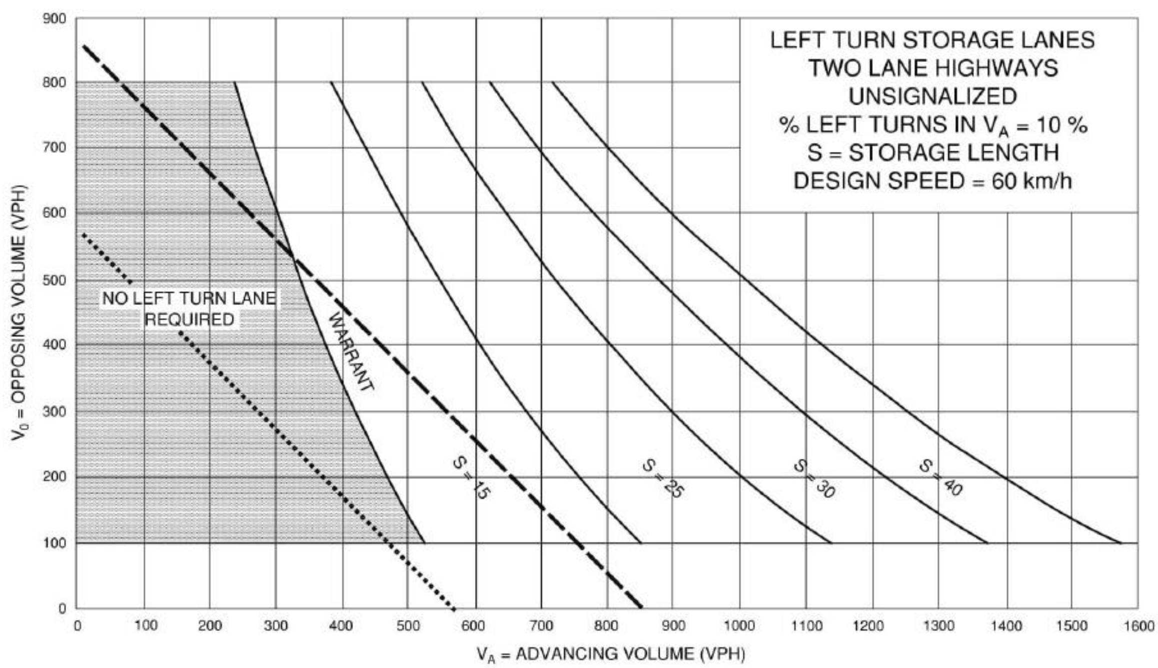
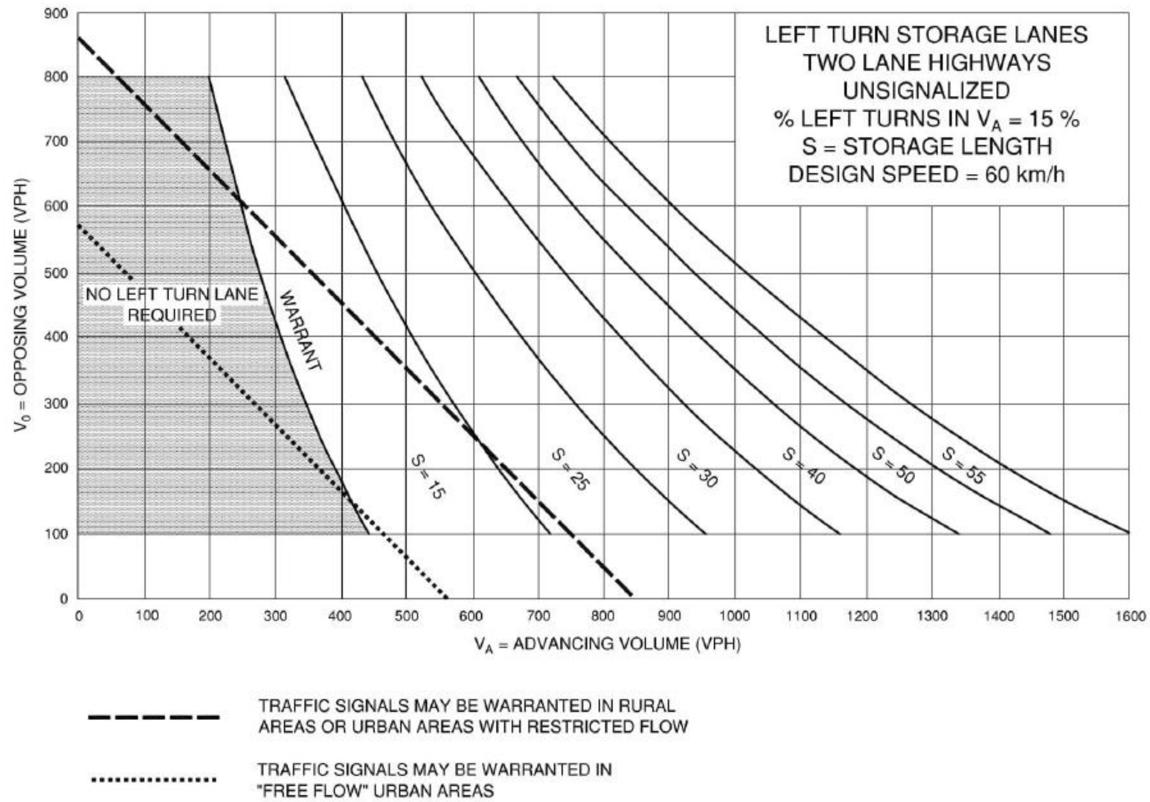

LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 10 %
S = STORAGE LENGTH
DESIGN SPEED = 60 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)

Exhibit-9A-8


LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 15 %
S = STORAGE LENGTH
DESIGN SPEED = 60 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 55
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW
TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

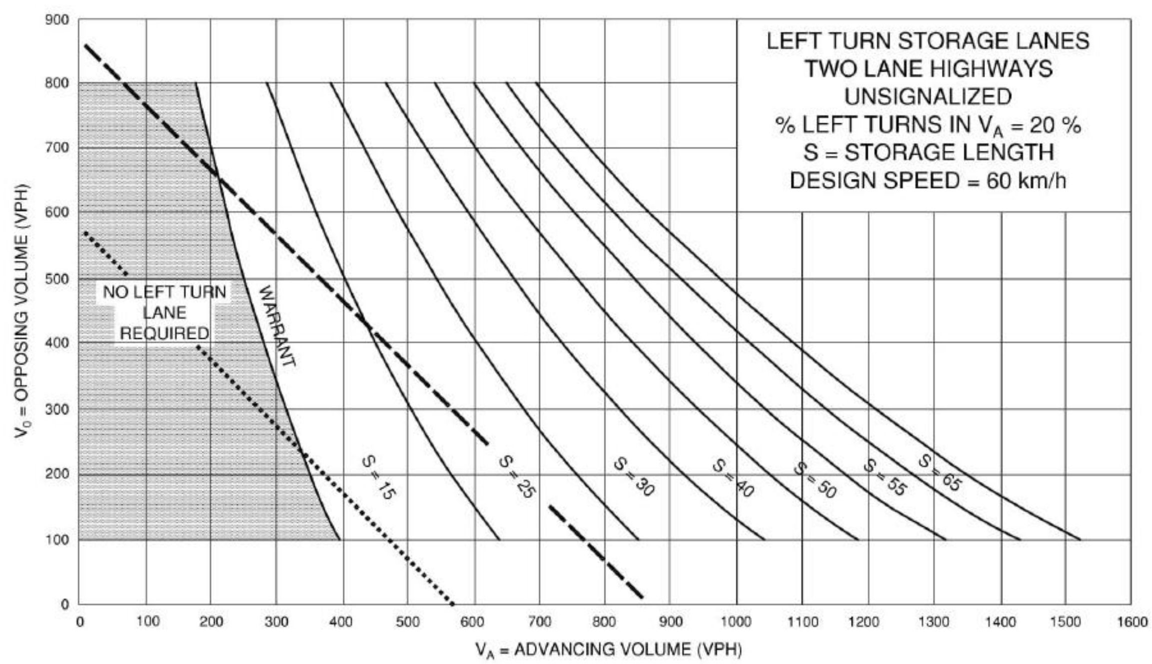
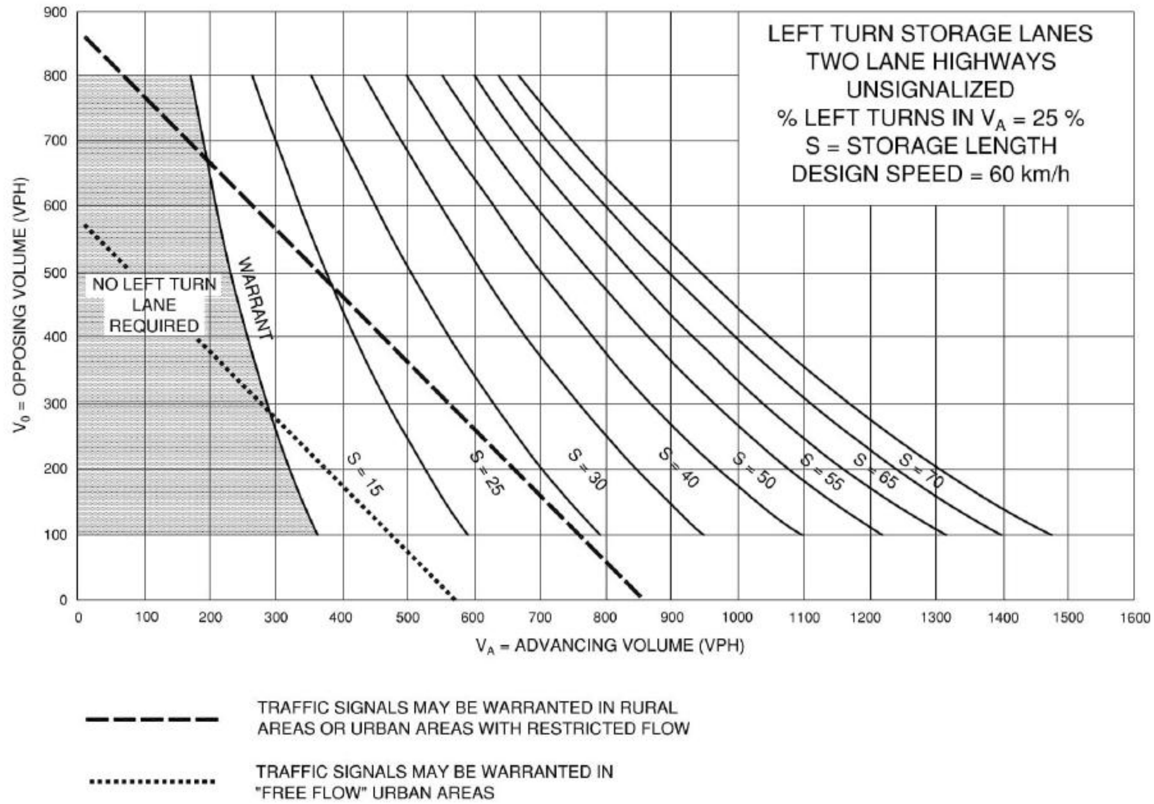

LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 20 %
S = STORAGE LENGTH
DESIGN SPEED = 60 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 55
S = 65
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)

Exhibit-9A-9


LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 25 %
S = STORAGE LENGTH
DESIGN SPEED = 60 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 55
S = 65
S = 70
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)
TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW
TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

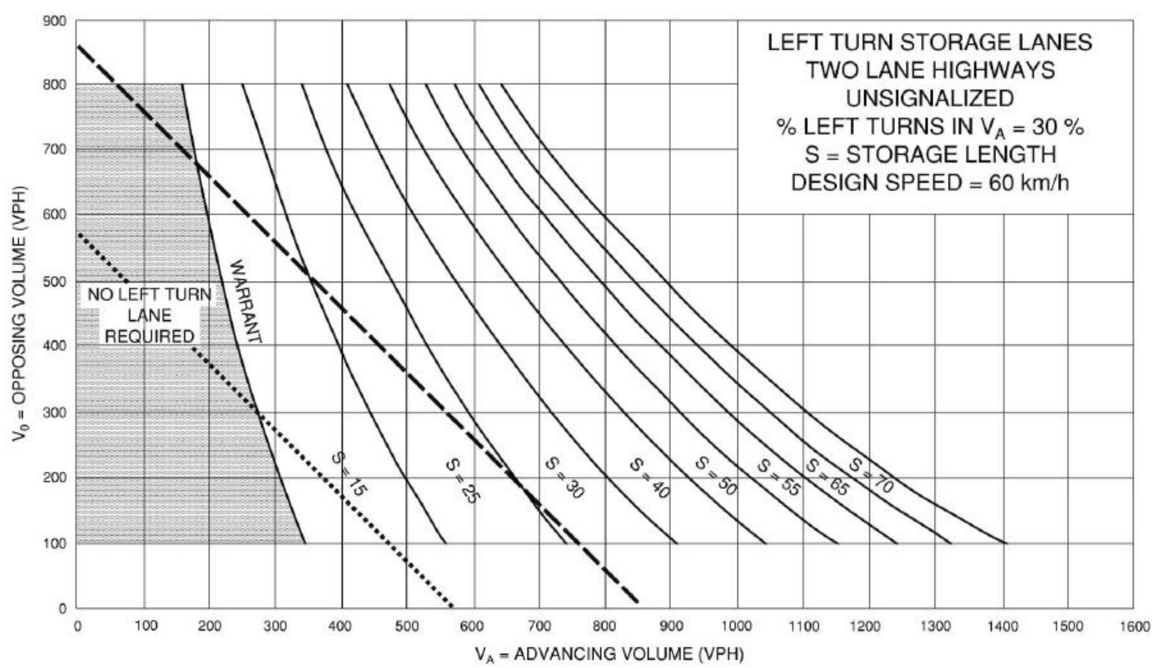
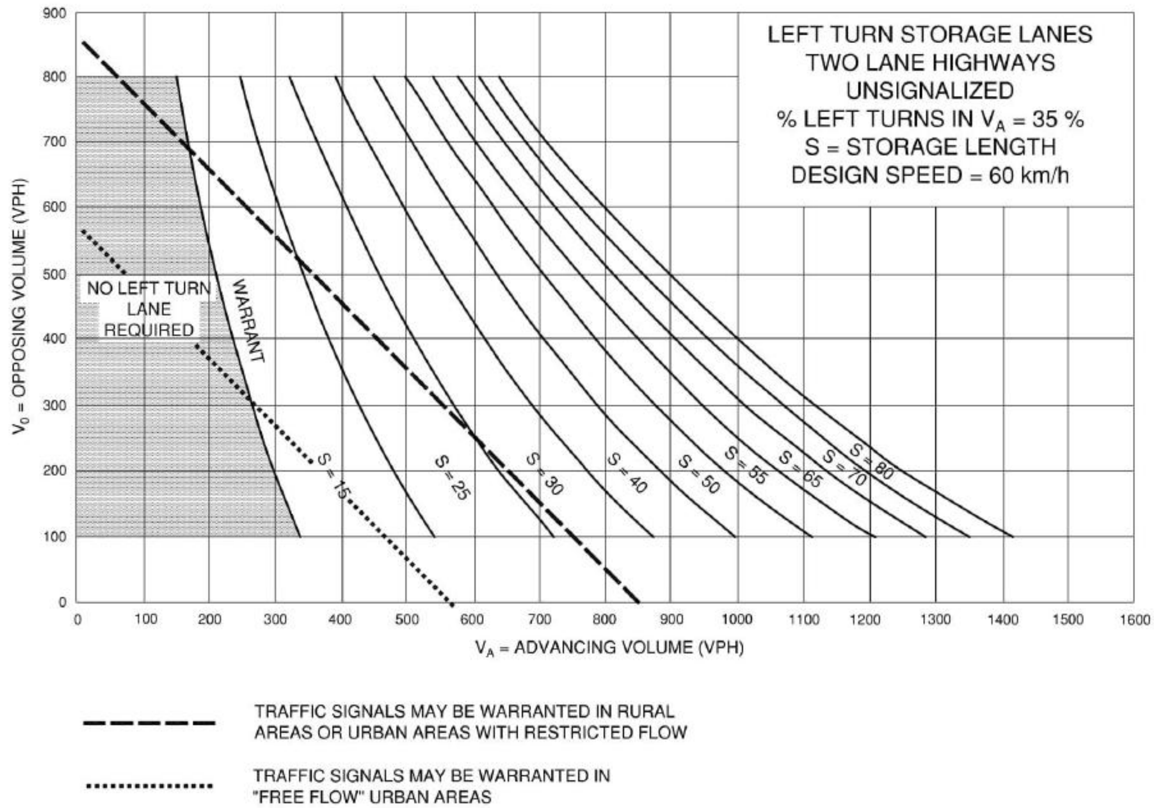

LEFT TURN STORAGE LANES
TWO LANE HIGHWAYS
UNSIGNALIZED
% LEFT TURNS IN V_A = 30 %
S = STORAGE LENGTH
DESIGN SPEED = 60 km/h
NO LEFT TURN LANE REQUIRED
WARRANT
S = 15
S = 25
S = 30
S = 40
S = 50
S = 55
S = 65
S = 70
V_0 = OPPOSING VOLUME (VPH)
V_A = ADVANCING VOLUME (VPH)

Exhibit-9A-10



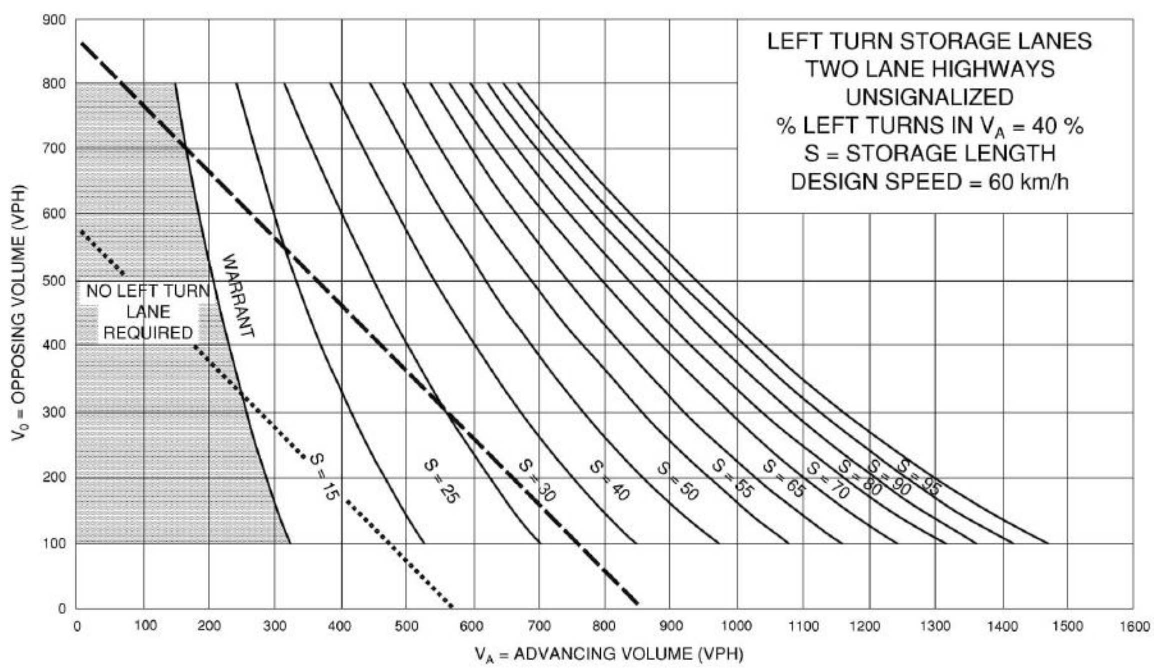
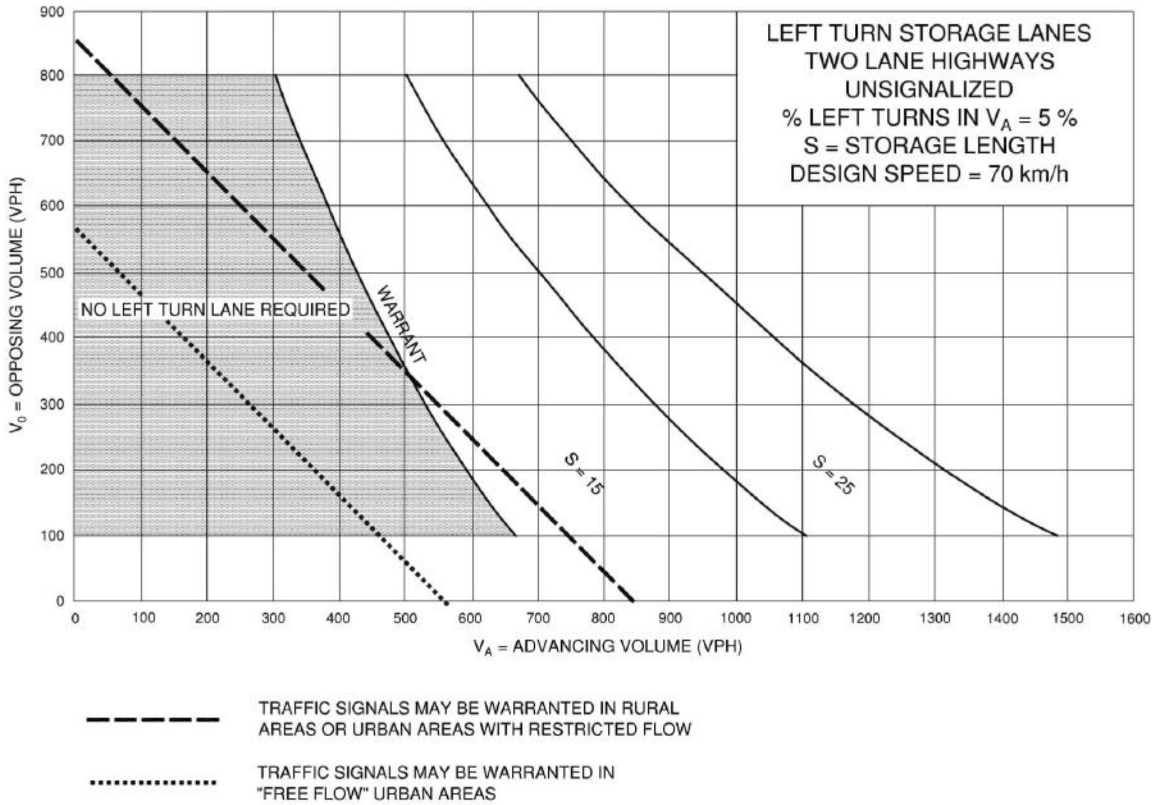


Exhibit-9A-11



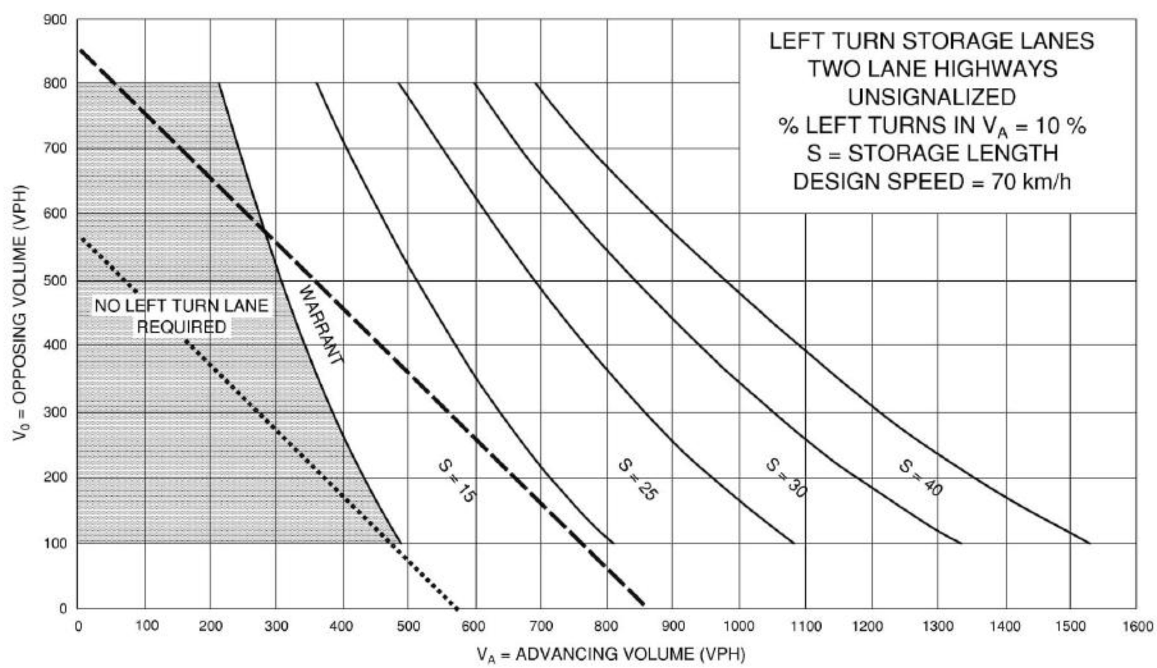
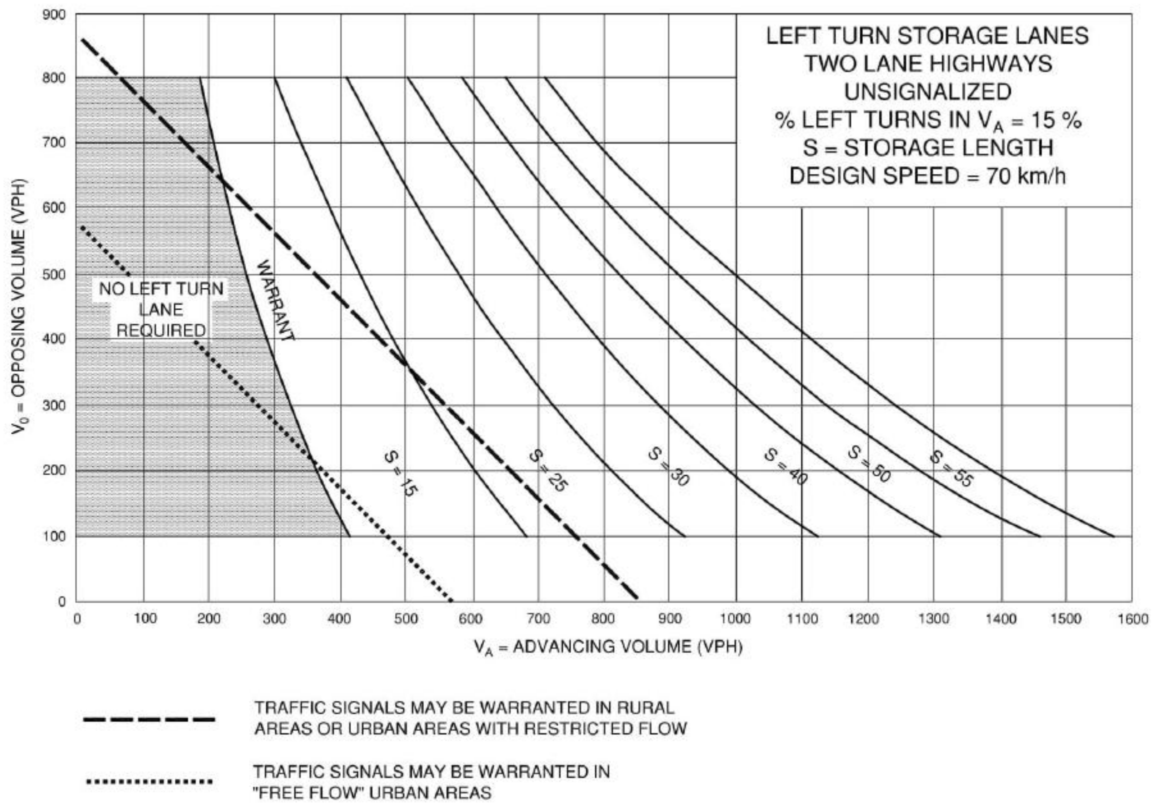


Exhibit-9A-12



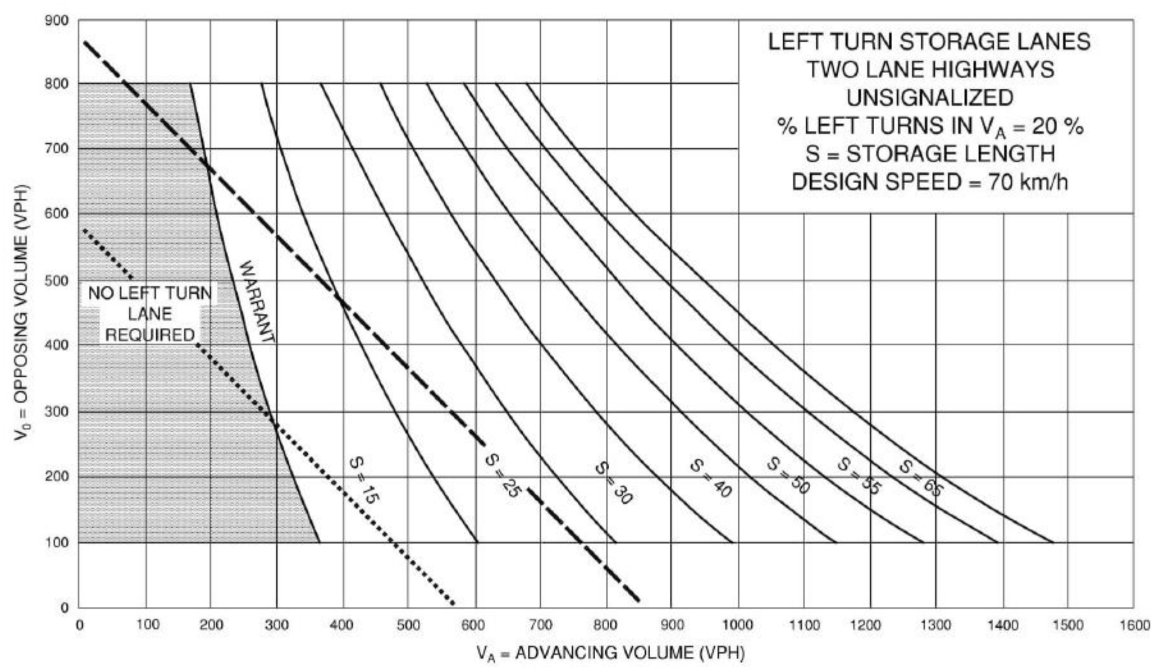
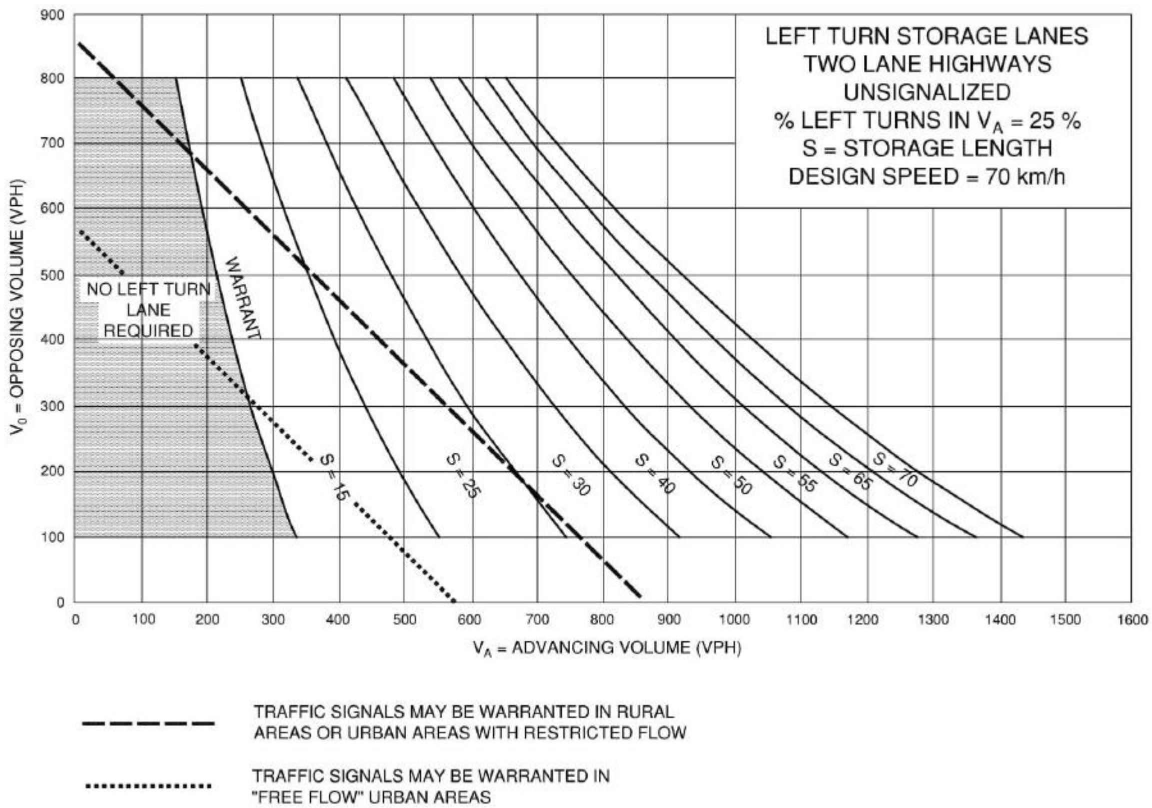


Exhibit-9A-13



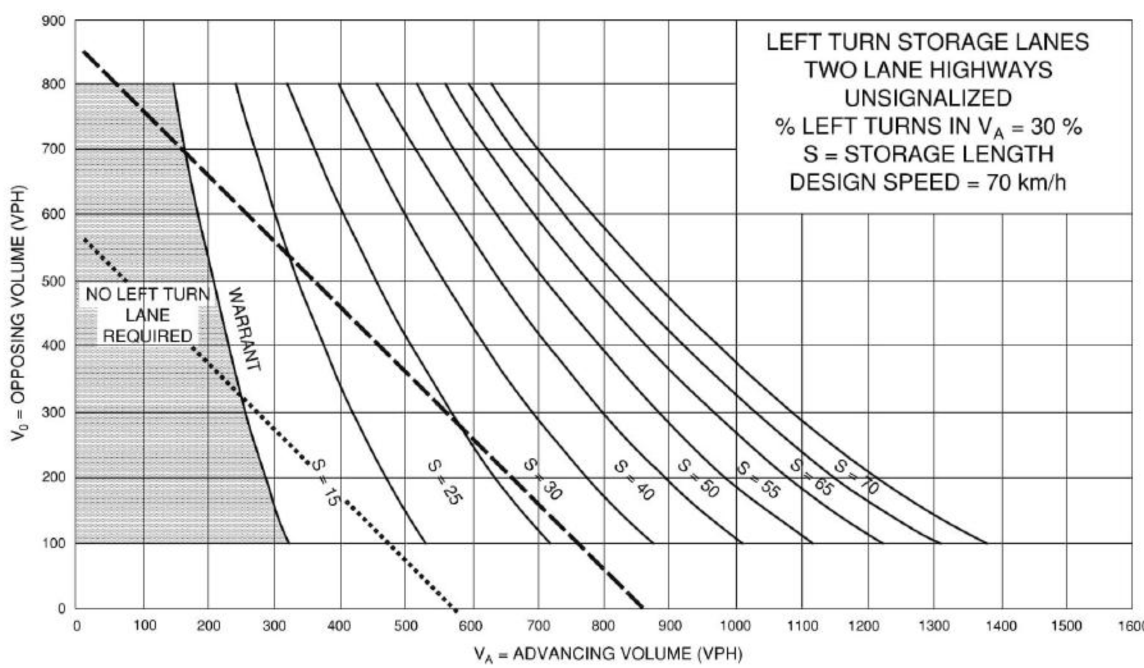
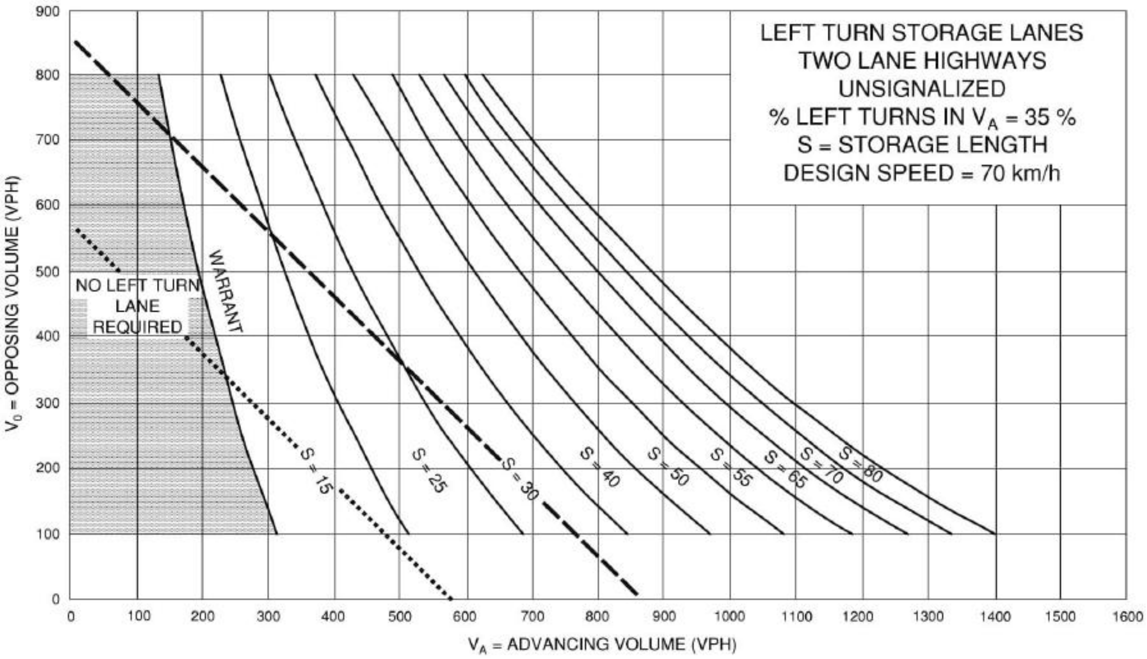


Exhibit-9A-14



TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW (dashed line)

TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS (dotted line)

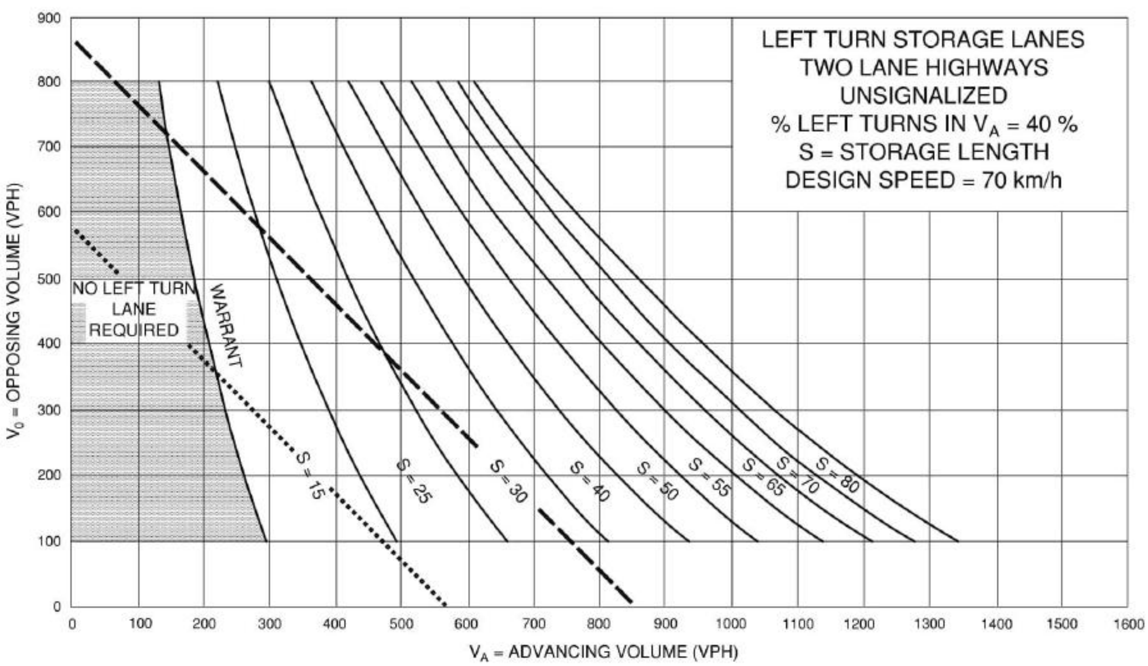
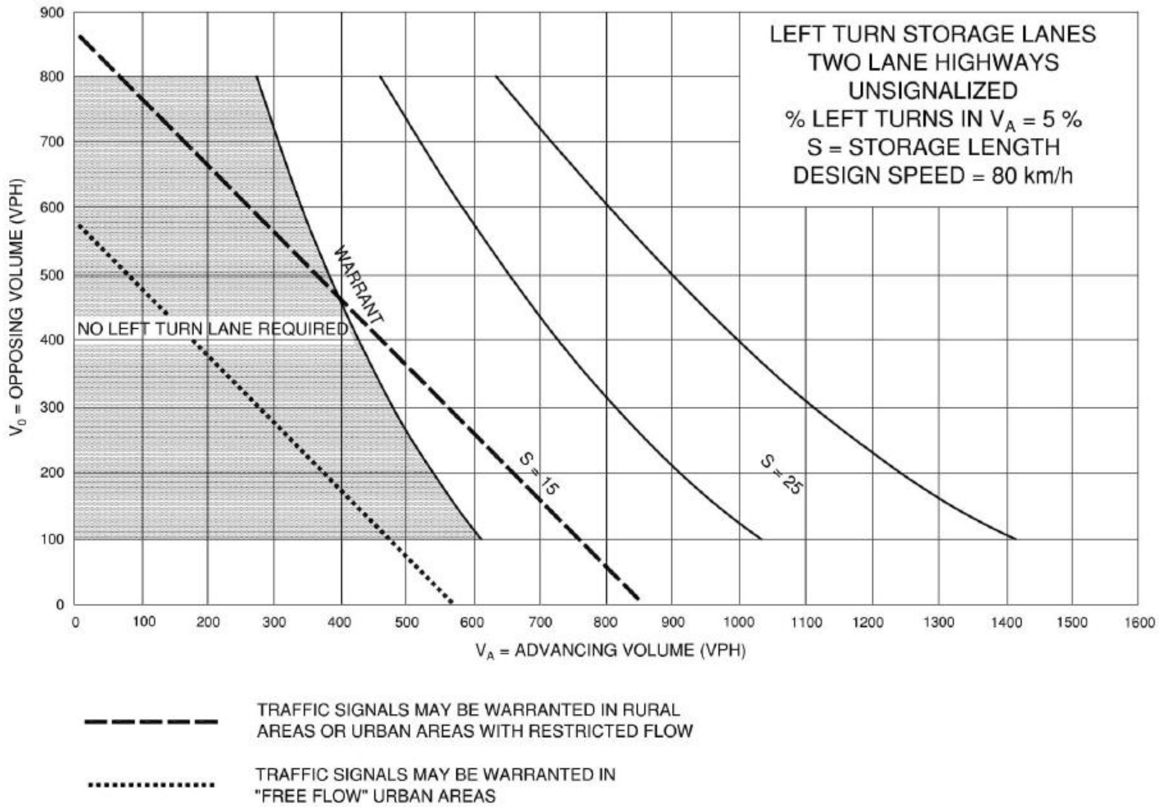


Exhibit-9A-15



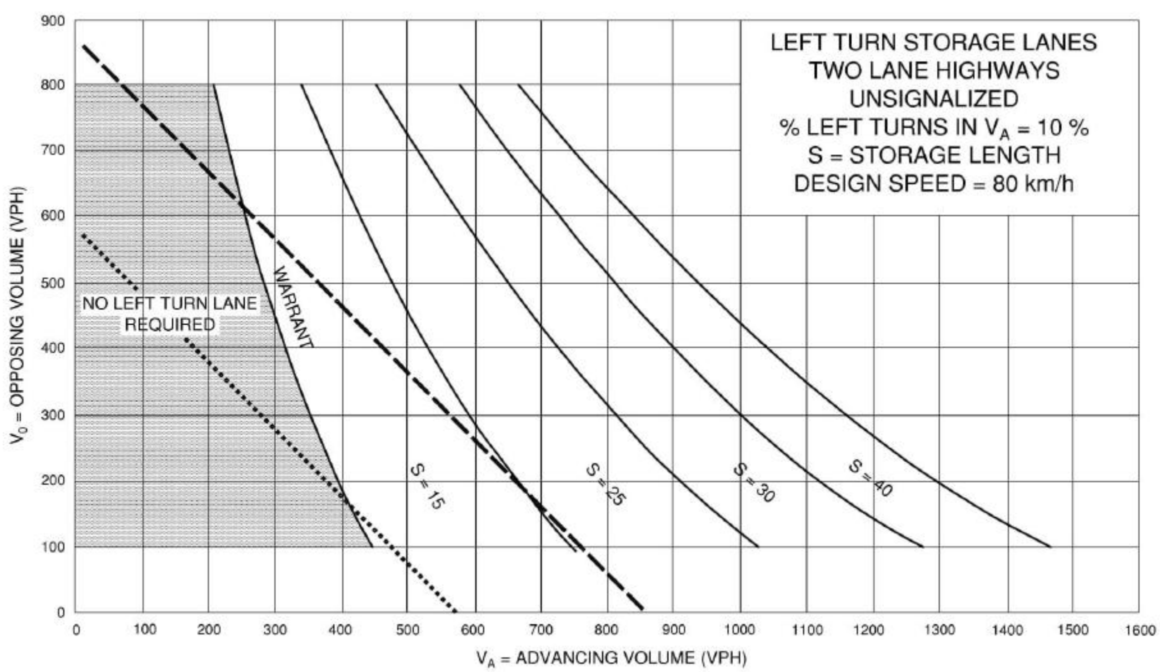
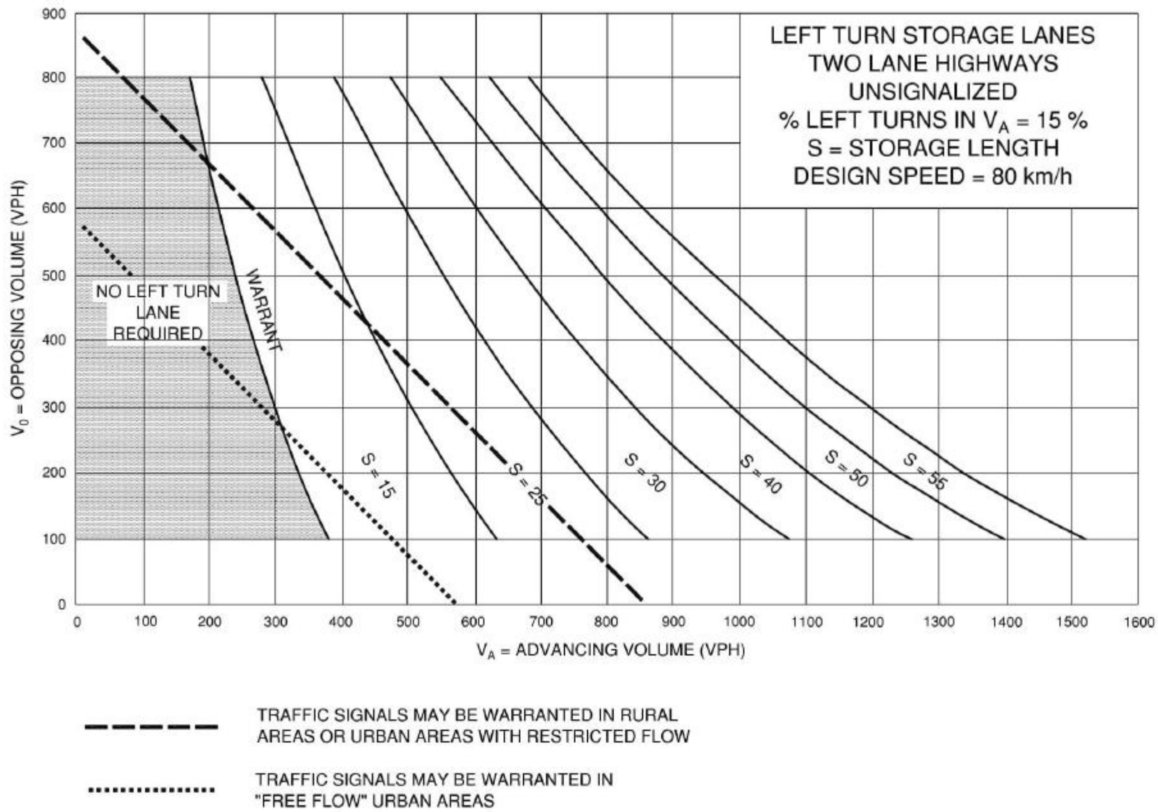


Exhibit-9A-16



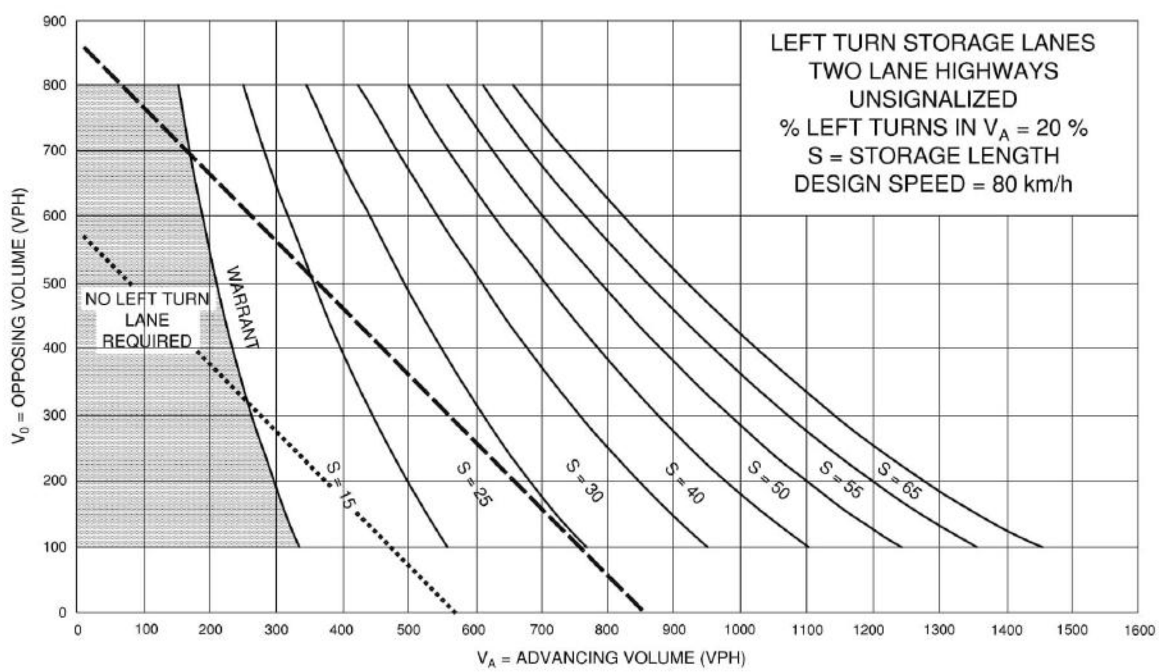
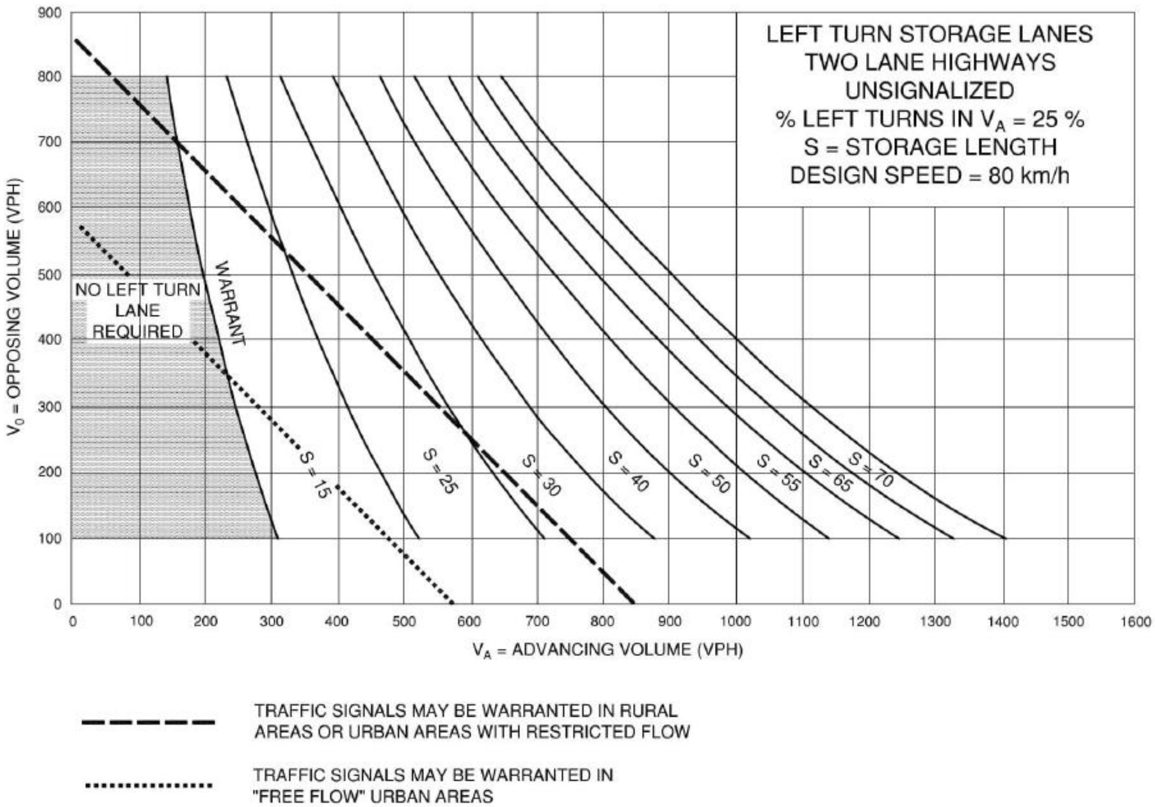


Exhibit-9A-17



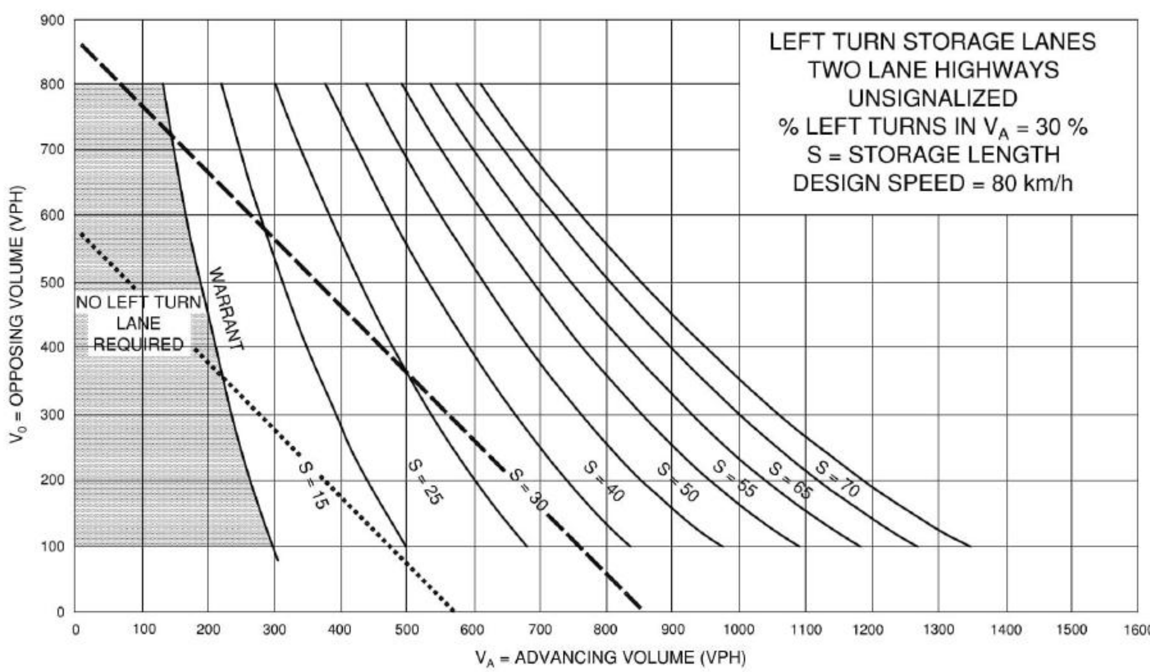
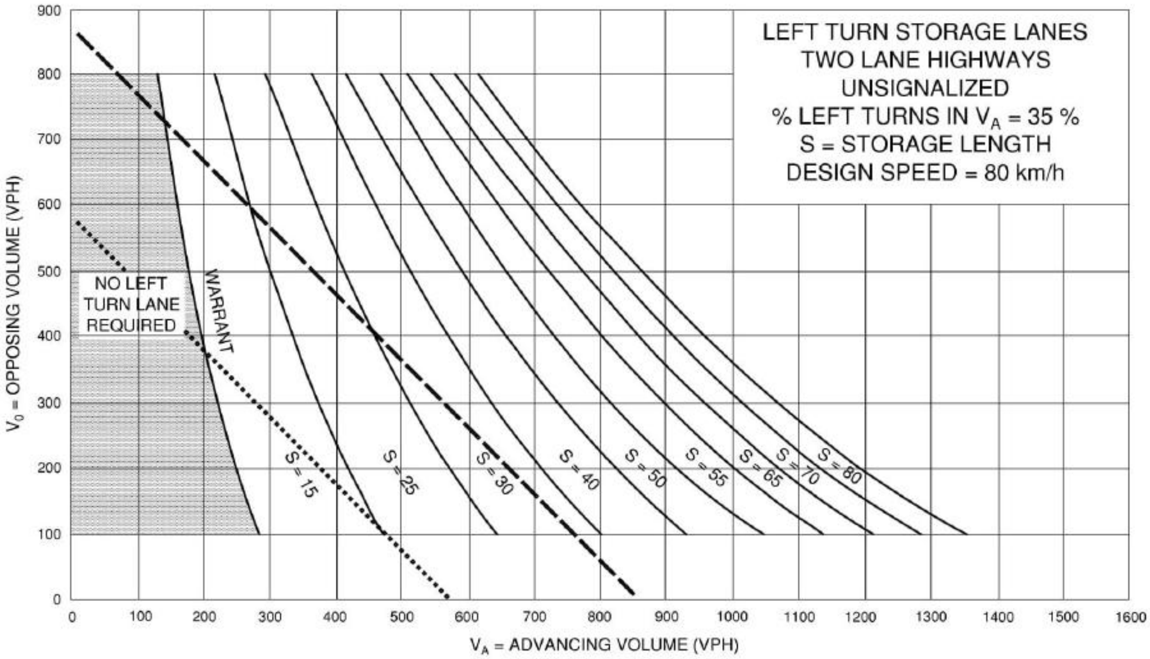


Exhibit-9A-18



TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW

TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

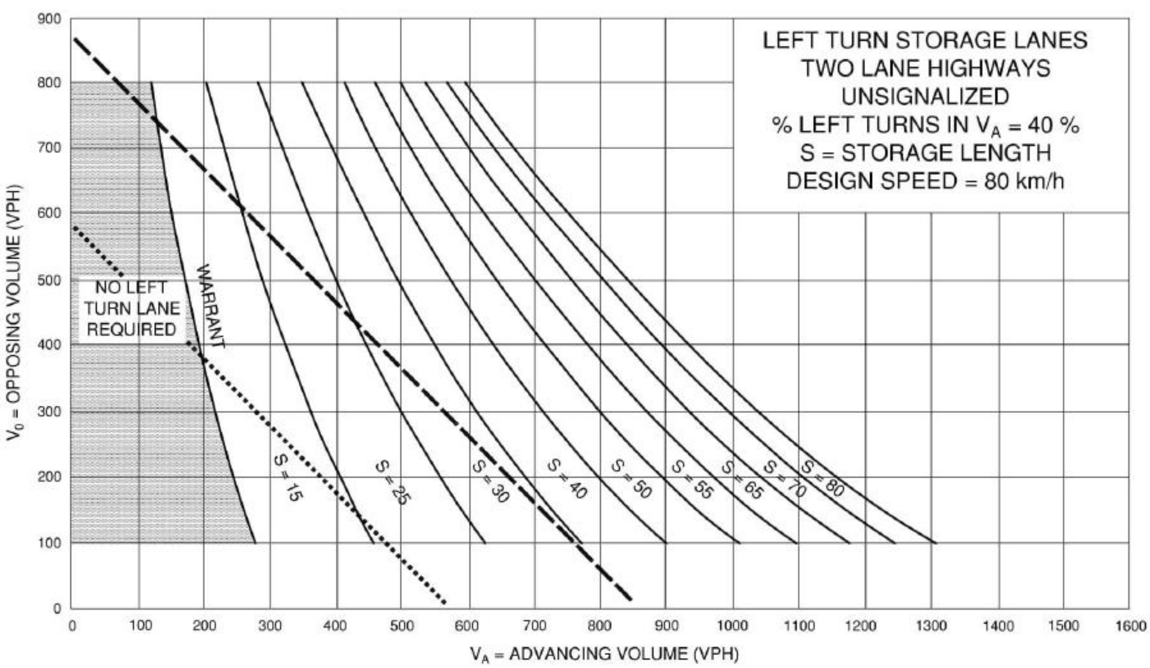
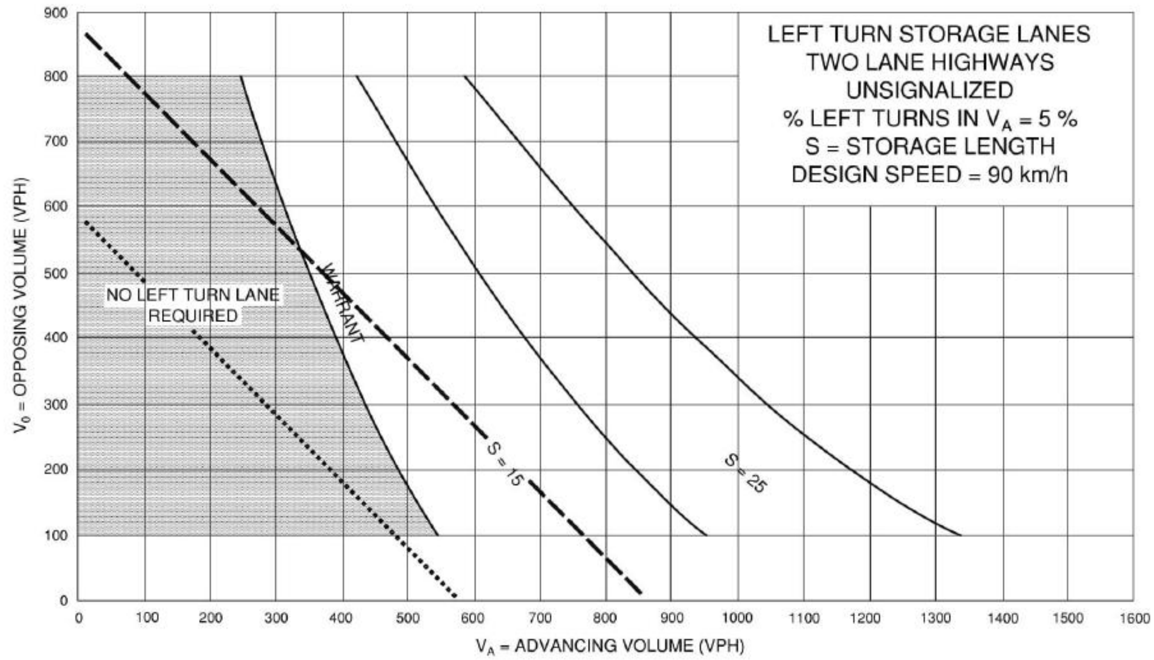


Exhibit-9A-19



TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW

TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS

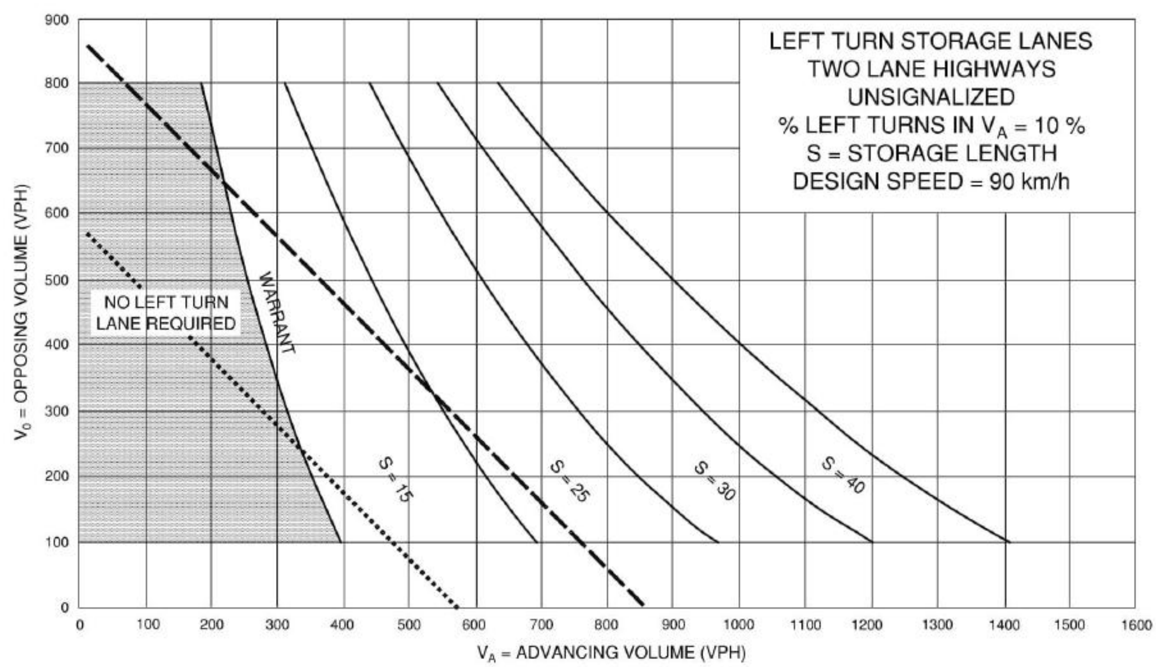
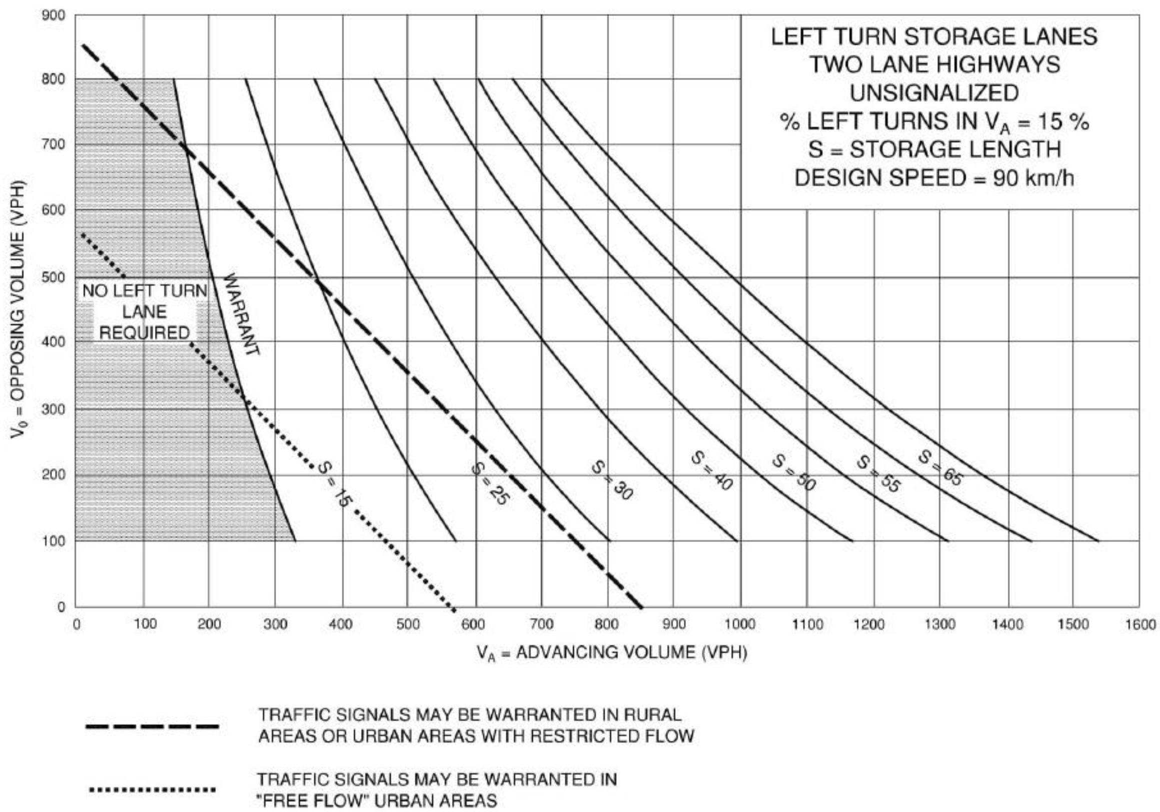


Exhibit-9A-20



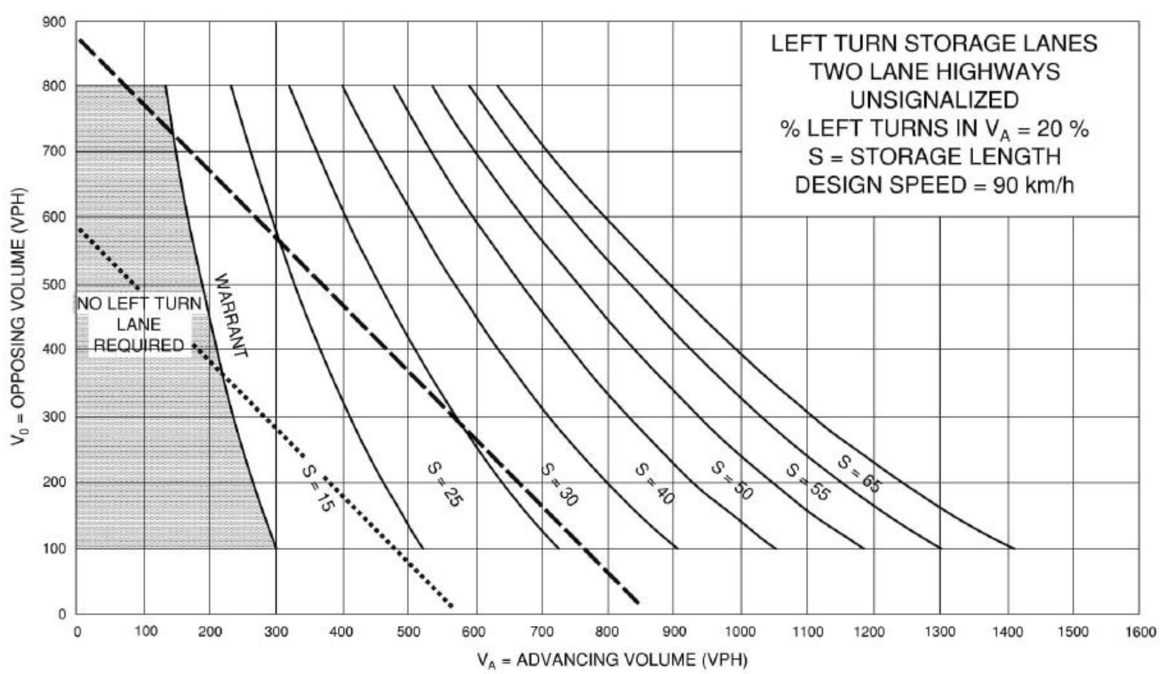
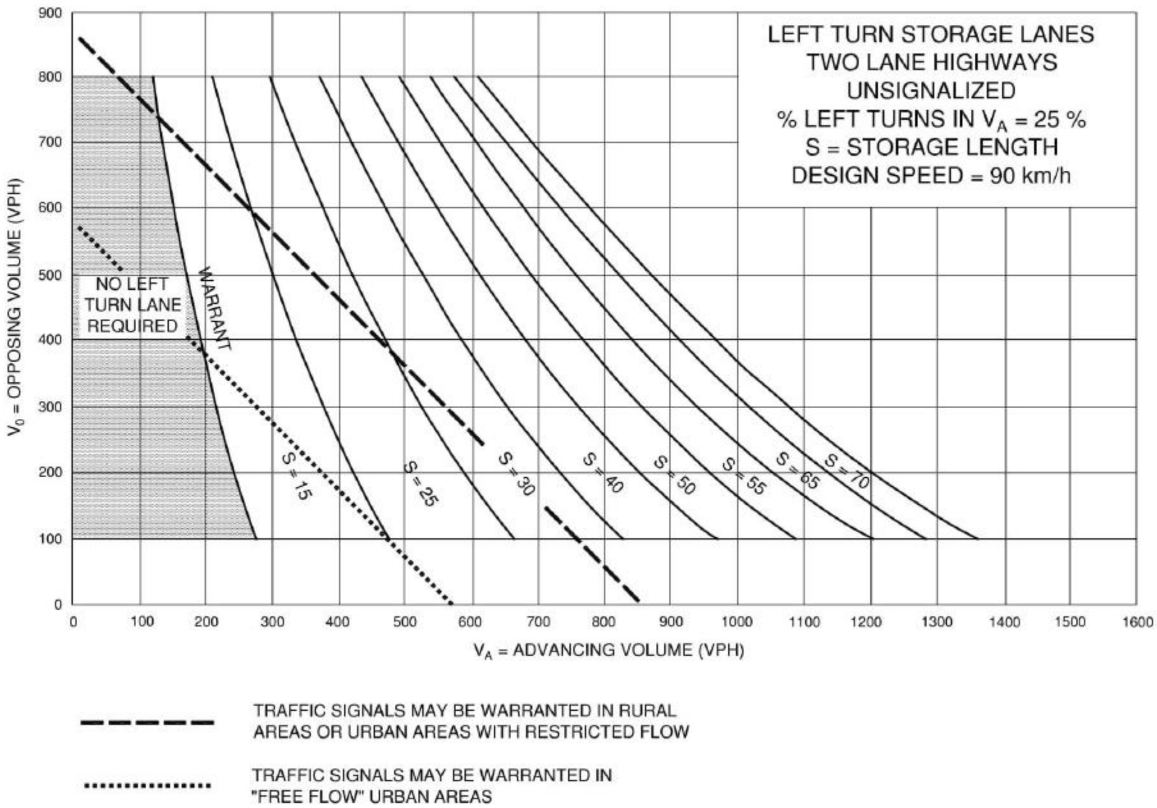
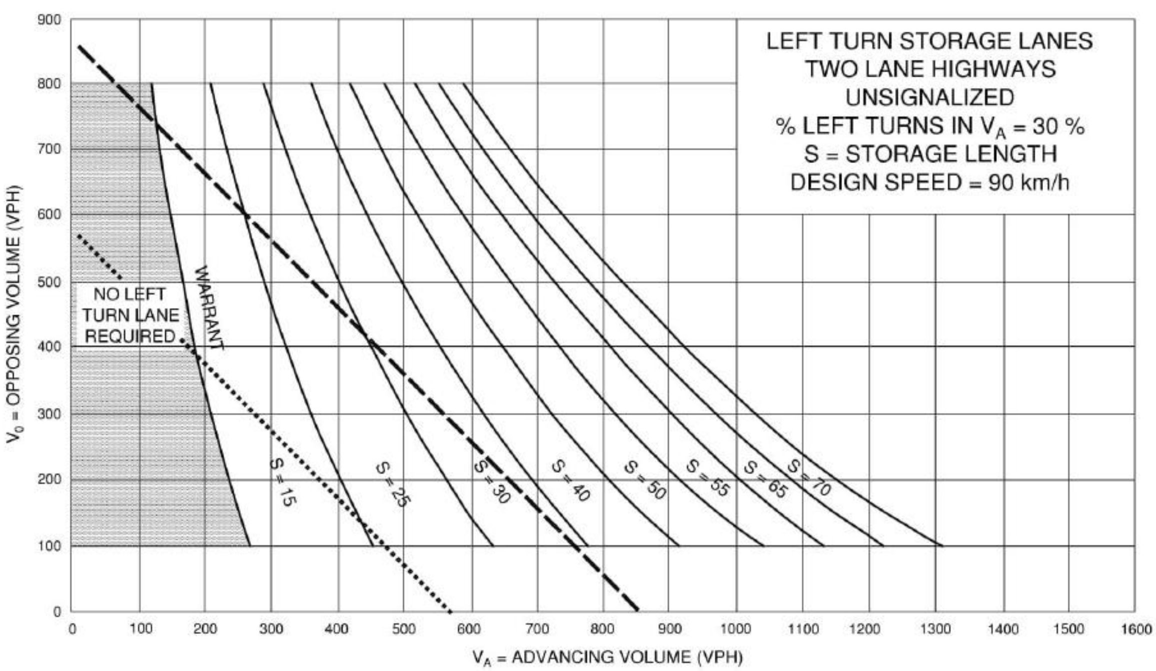


Exhibit-9A-21





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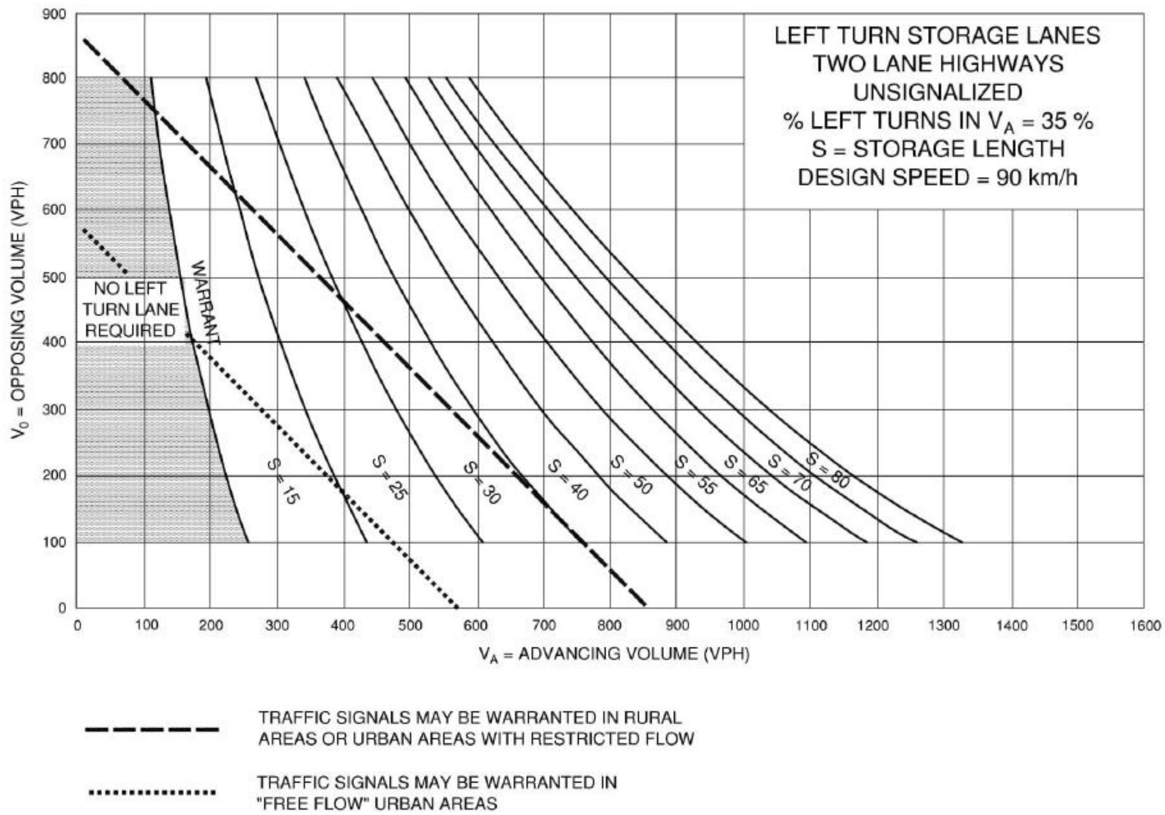

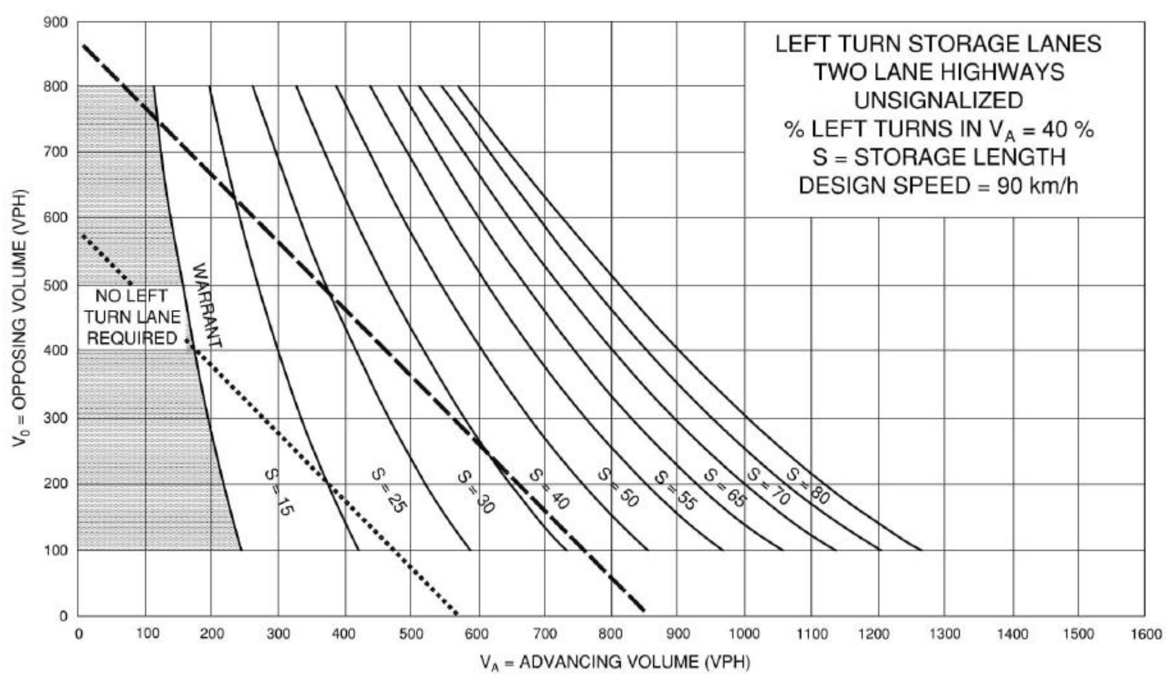

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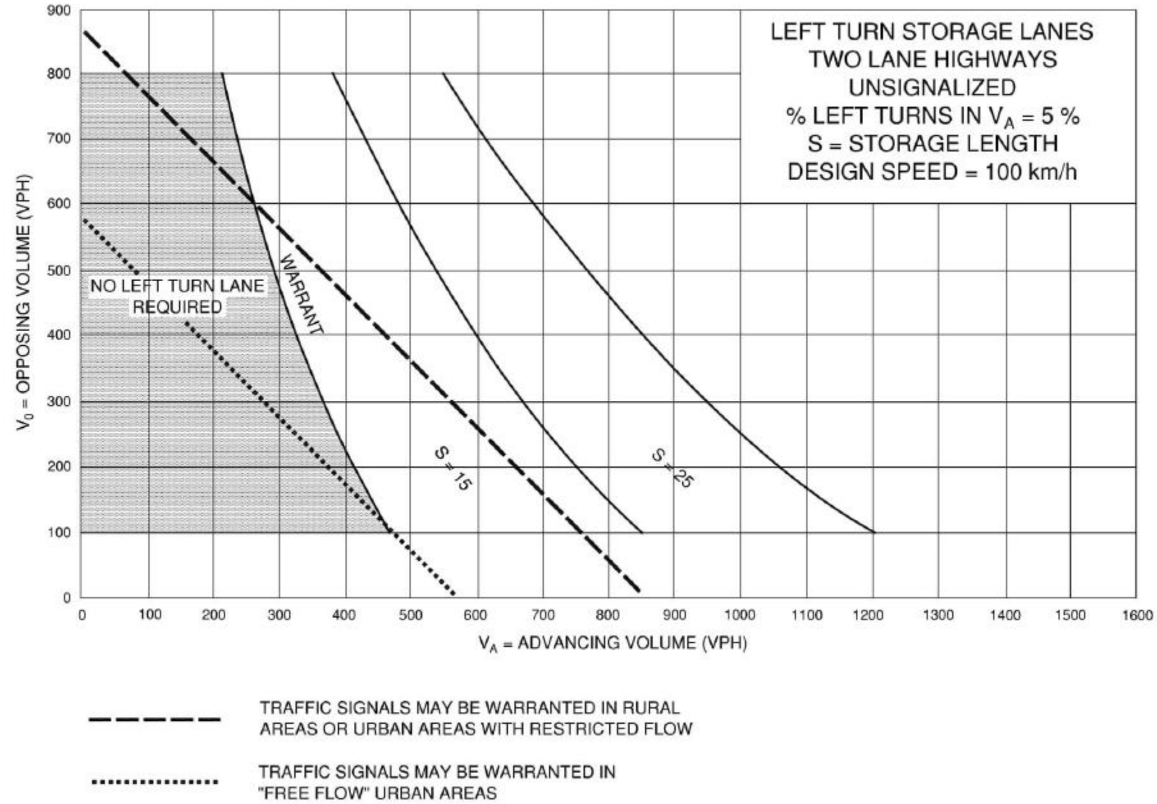

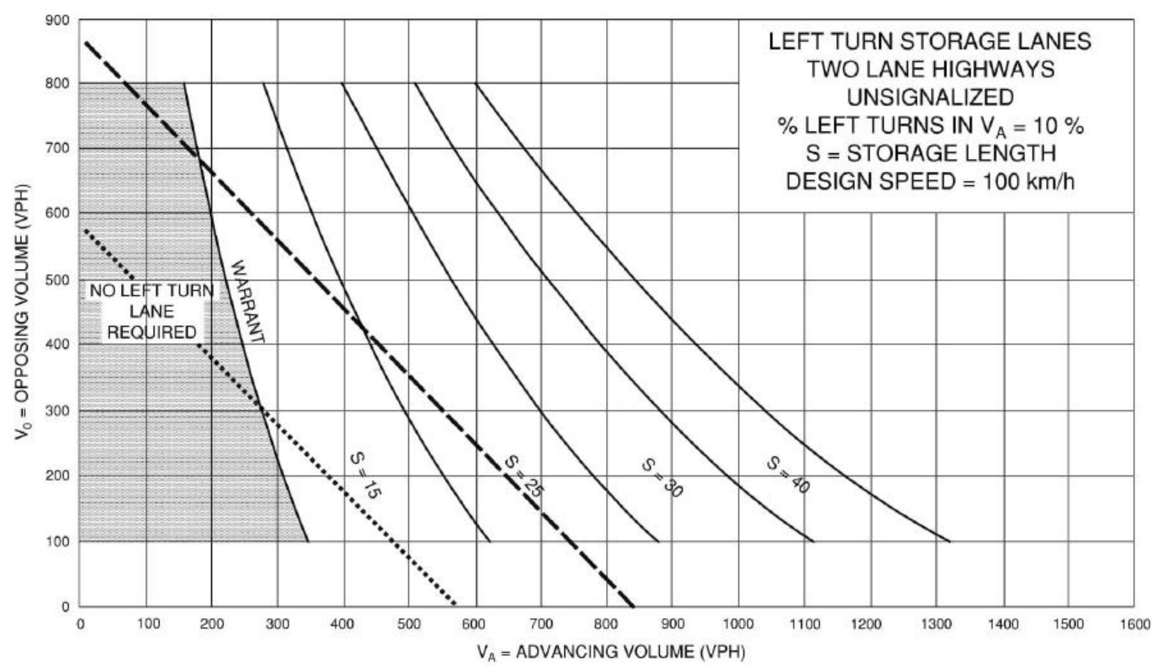

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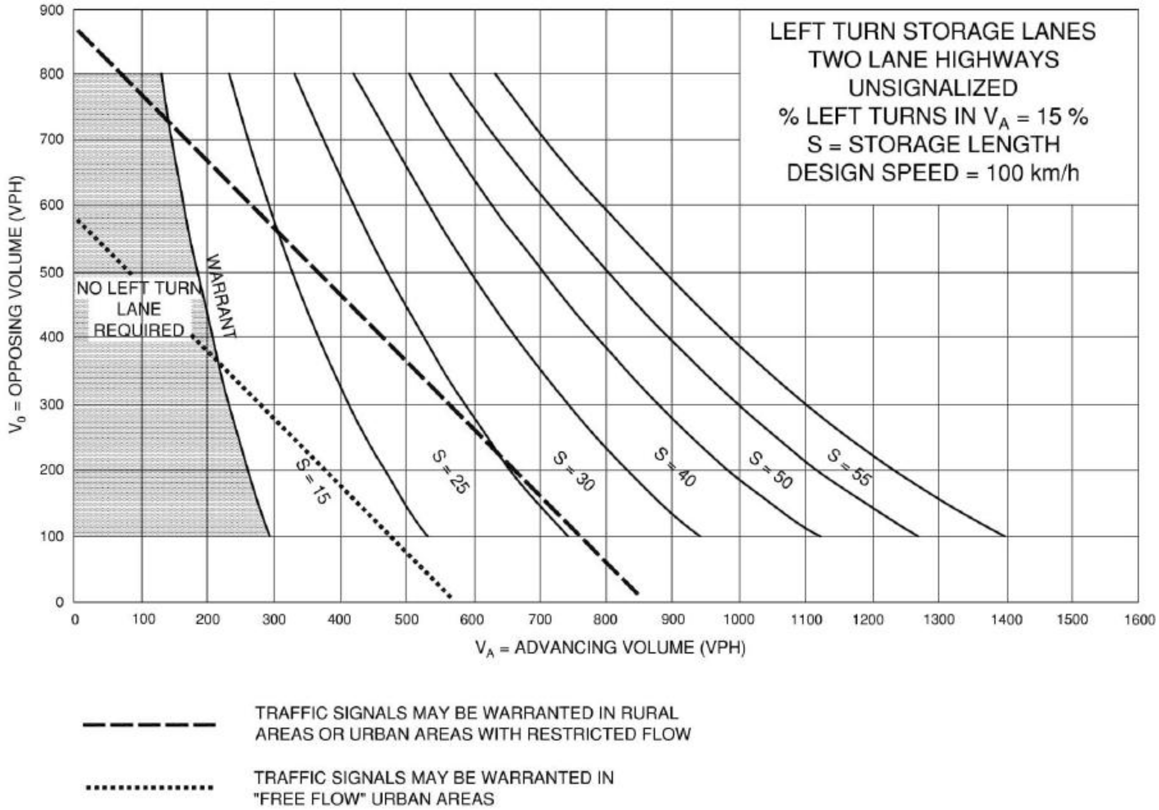

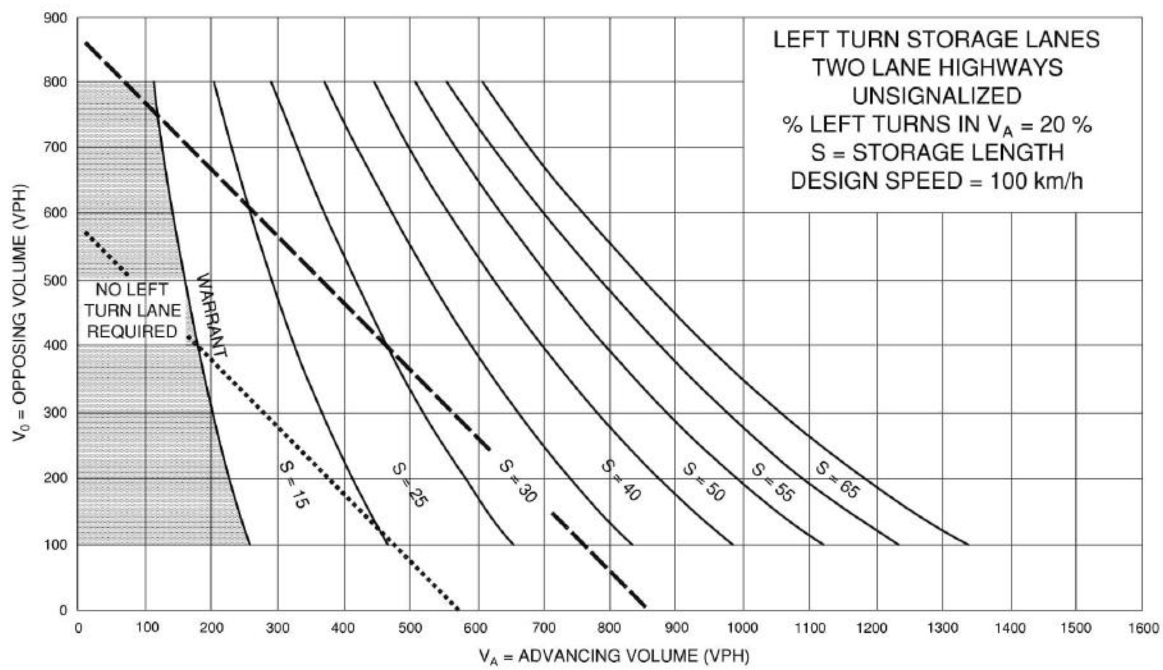

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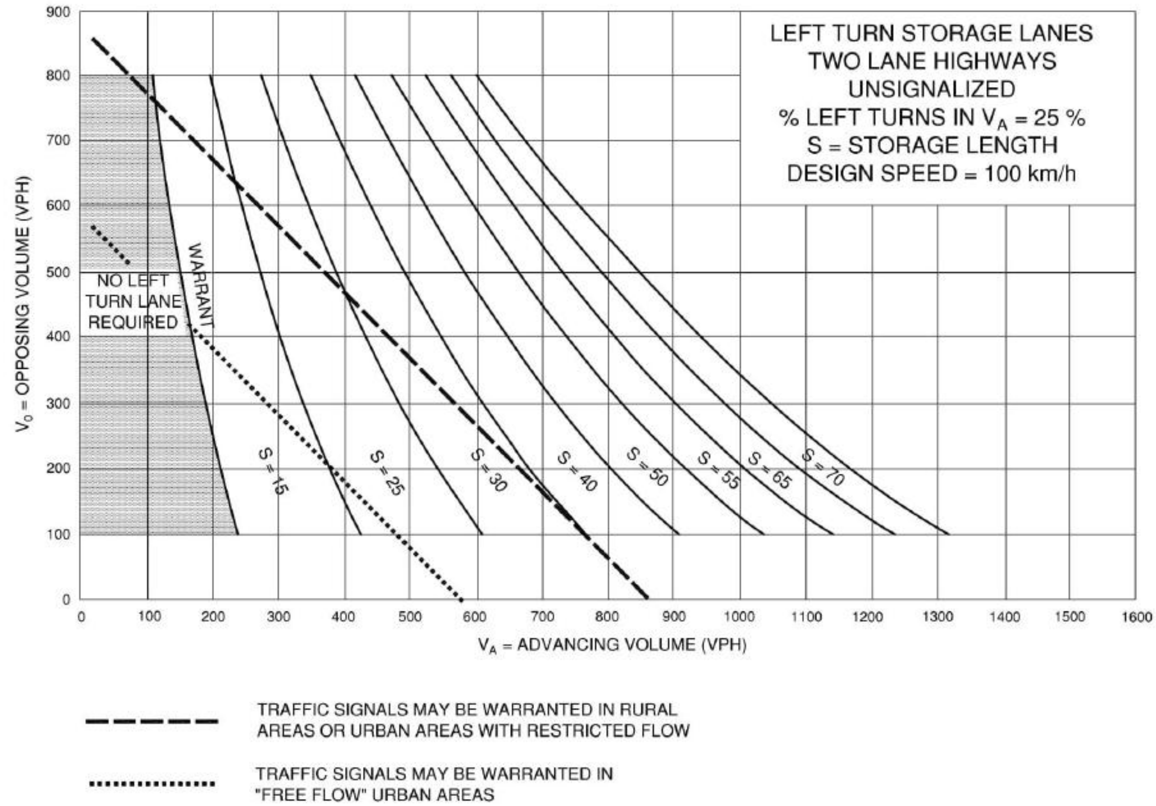


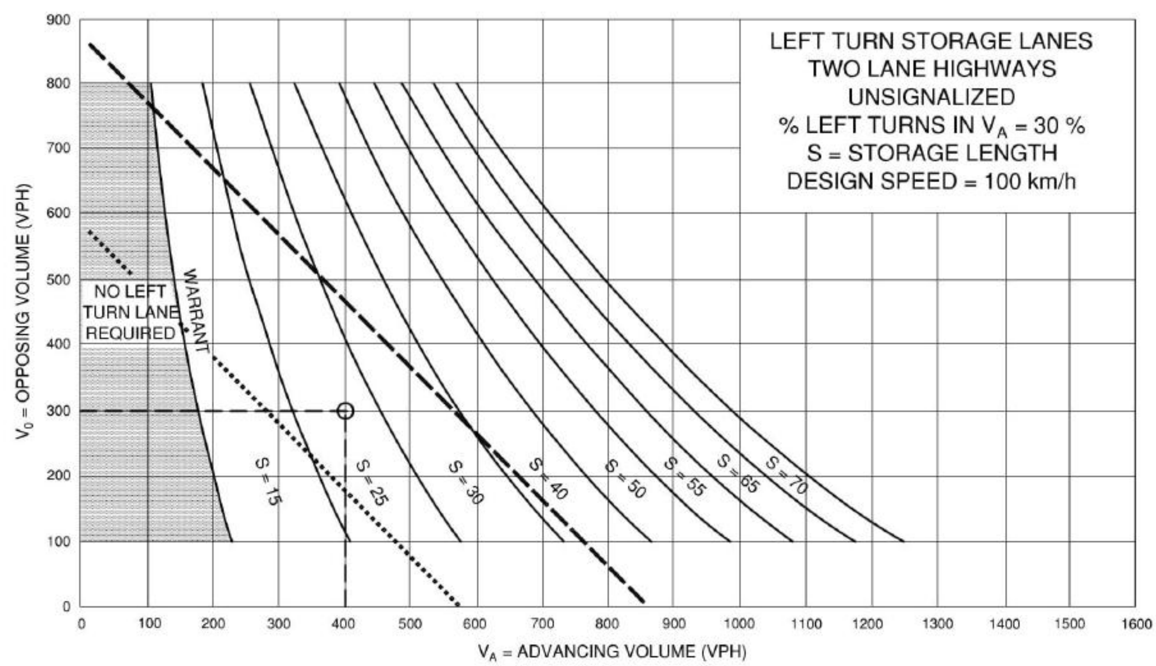
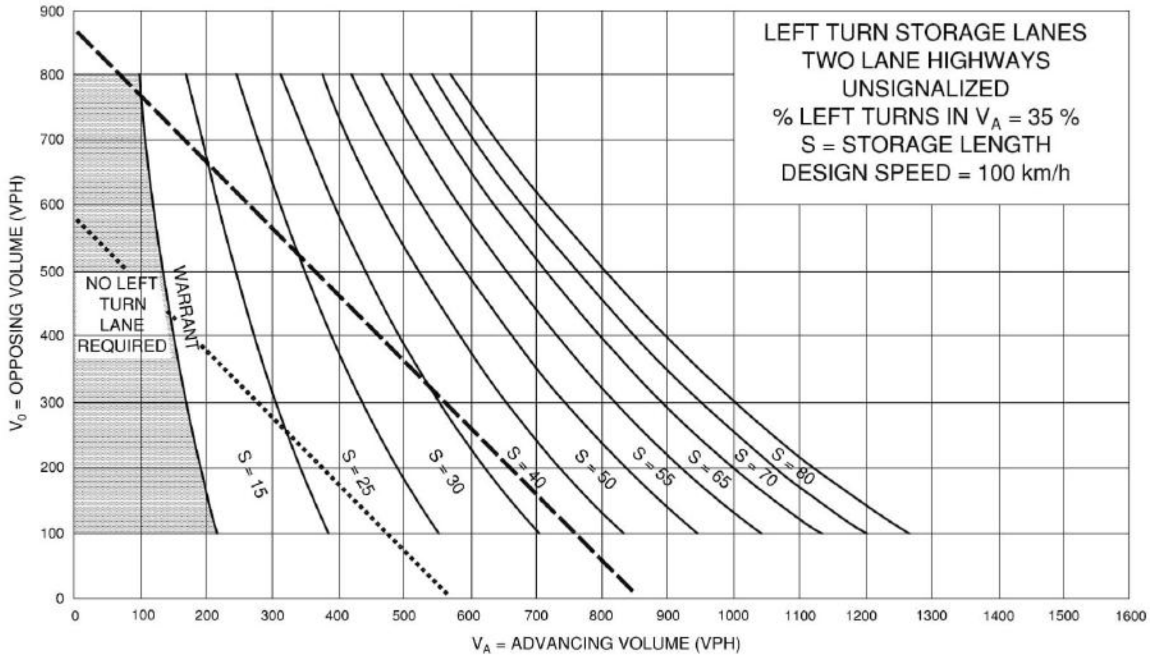
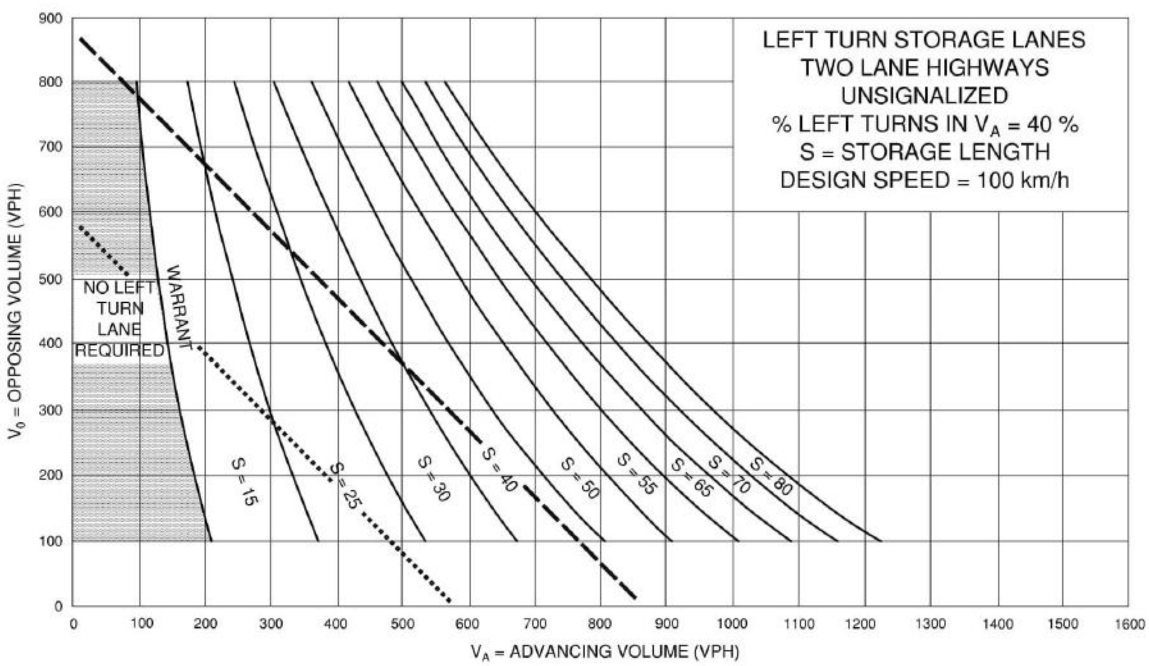


Exhibit-9A-26



TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW

TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS



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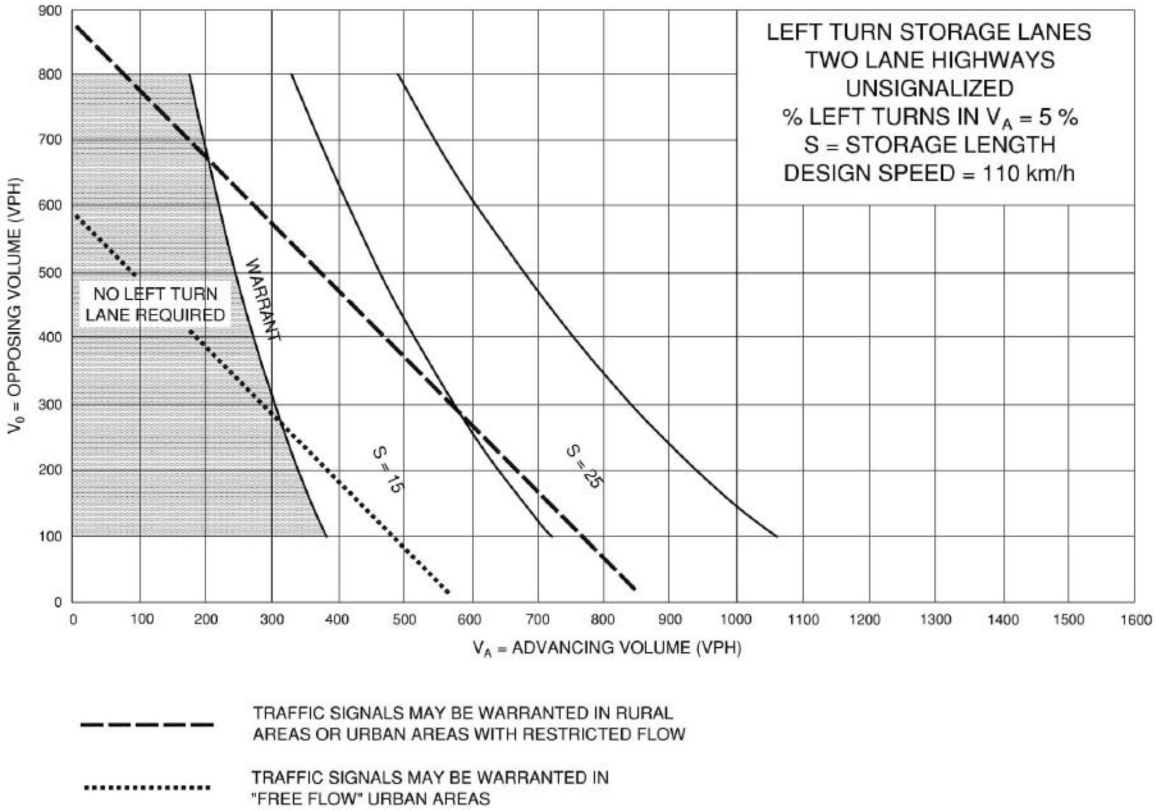

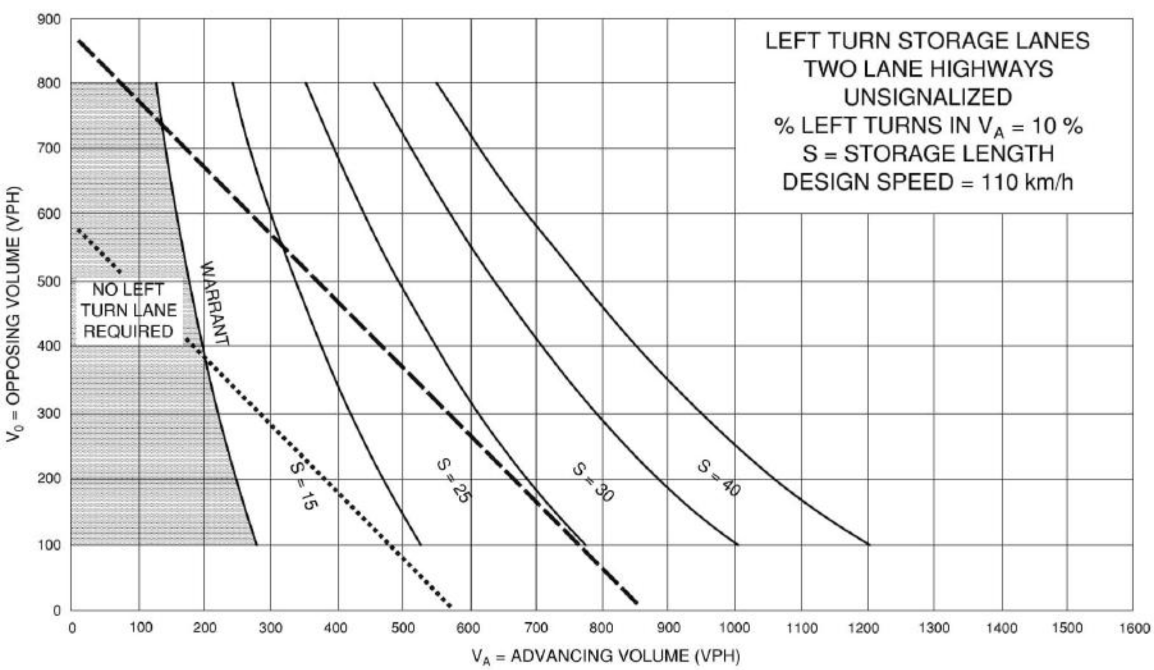

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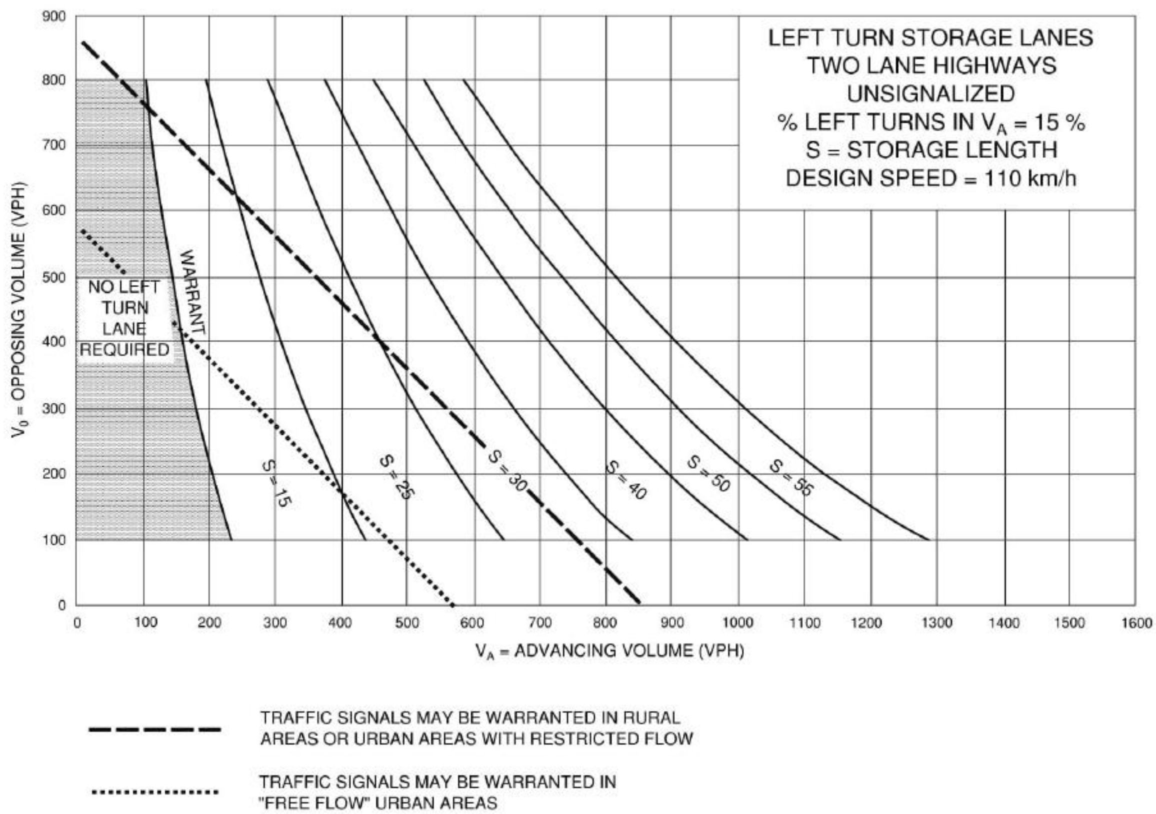


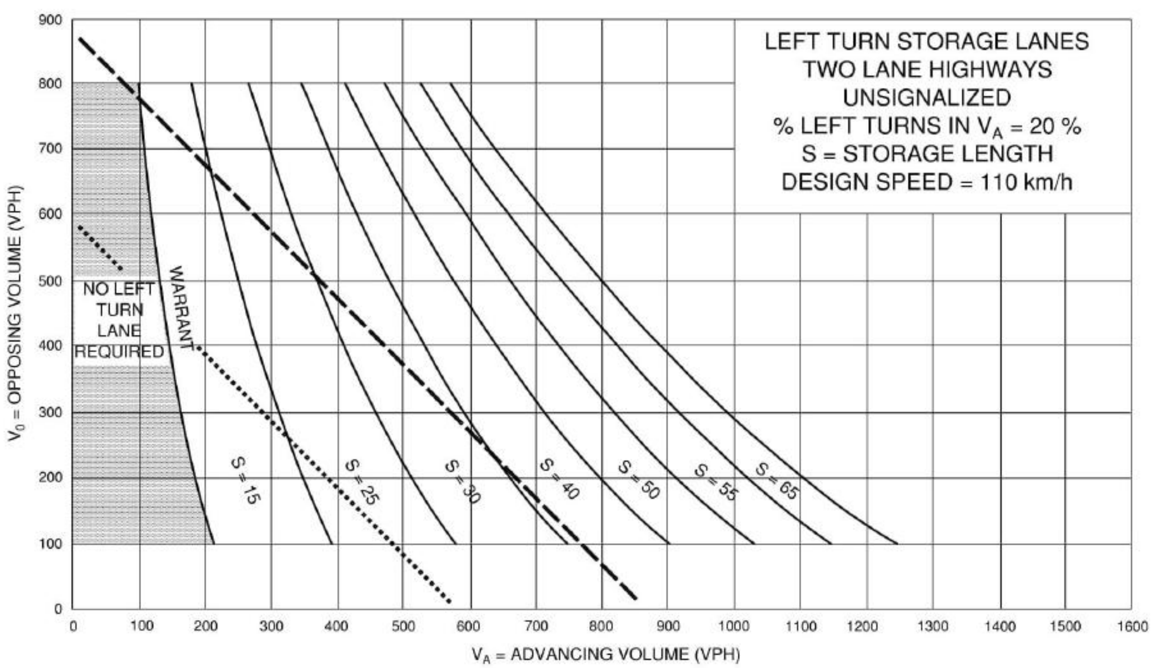
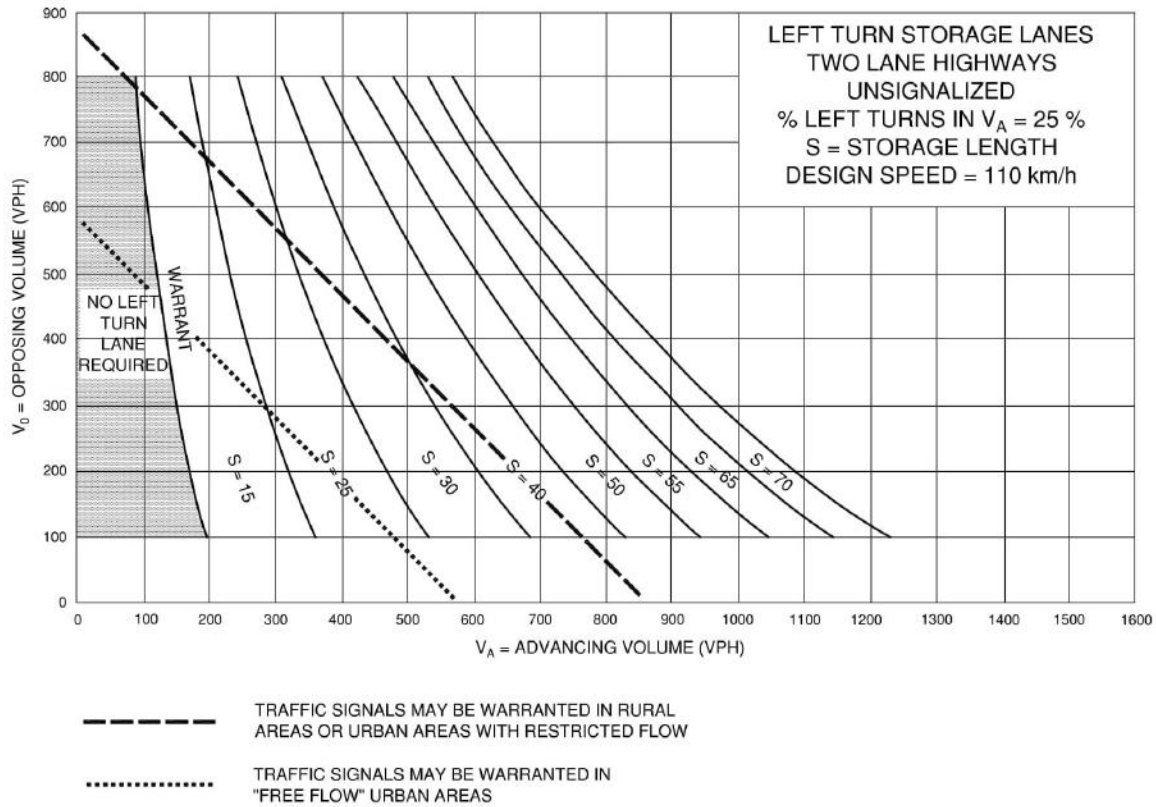


Exhibit-9A-29



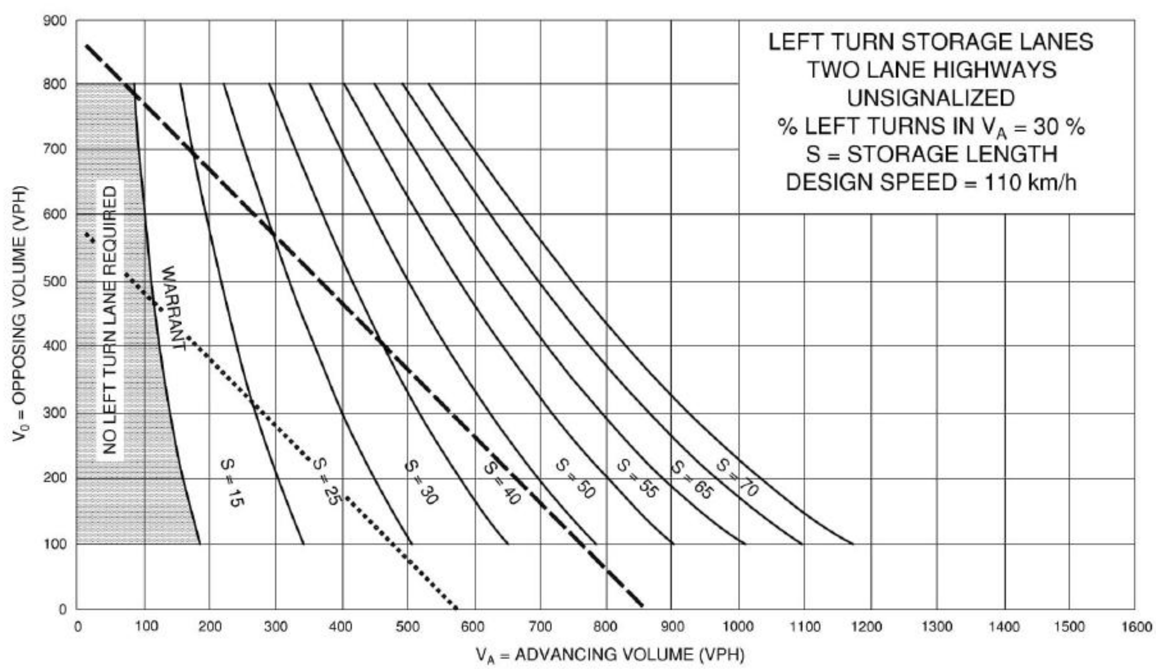
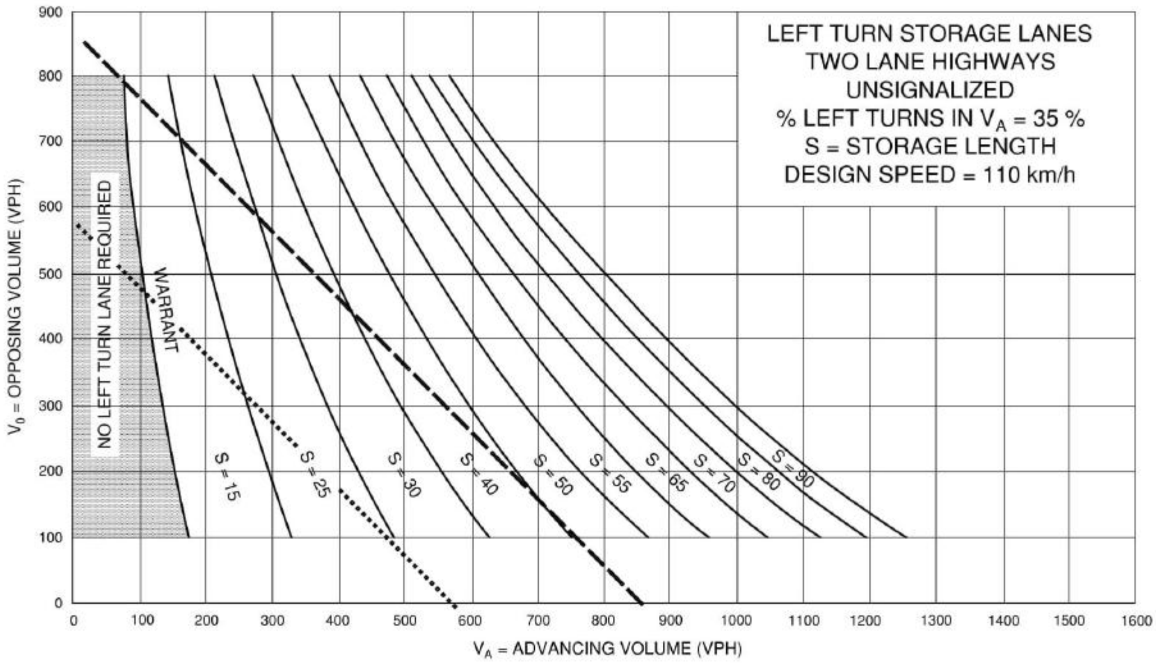
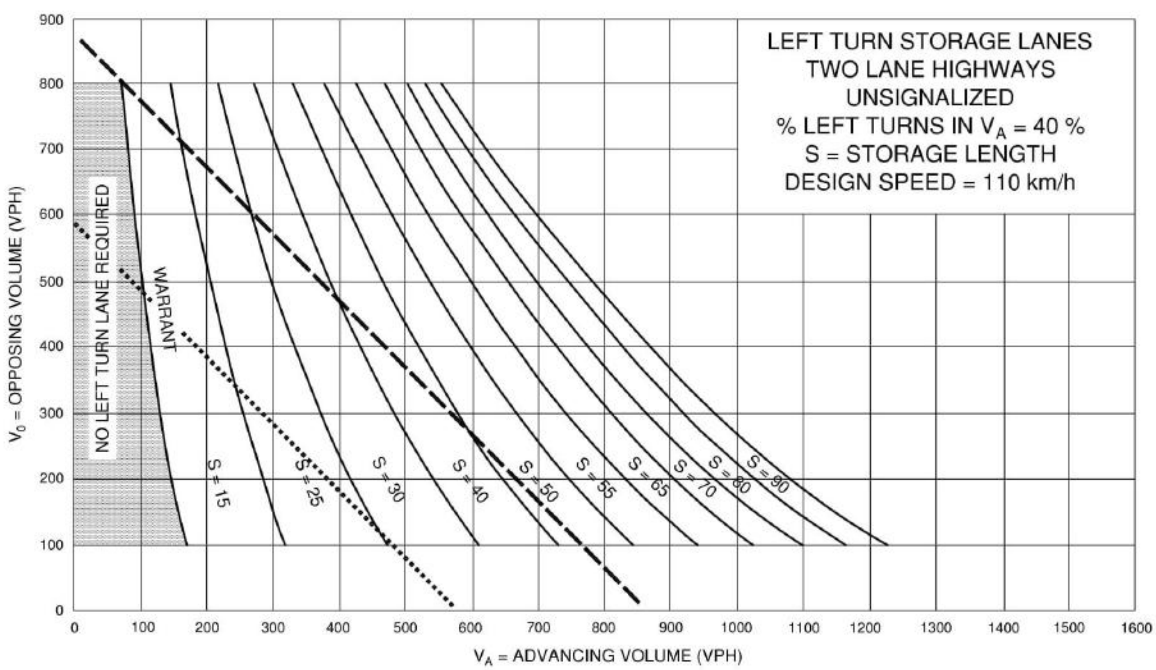


Exhibit-9A-30



TRAFFIC SIGNALS MAY BE WARRANTED IN RURAL AREAS OR URBAN AREAS WITH RESTRICTED FLOW (dashed line)

TRAFFIC SIGNALS MAY BE WARRANTED IN "FREE FLOW" URBAN AREAS (dotted line)



Left Turn Lane Warrant and Storage Lane Lengths for Four-lane Undivided Highways Unsignalized Intersections

Use of Graph

1. Select the appropriate figure for left turning volumes from the bottom of the graph and extend a line upward.

2. Select the appropriate figure for the opposing volumes from the left-hand side of the graph and extend a line across.

3. Locate the point of intersection of the extended lines. If the point falls to the left of the warrant line, a left turn lane is not warranted.

4. If the point falls to the right of the warrant line, a left turn lane is warranted, and its storage length is indicated by the value of 'S' shown on the graph.

An example of applying the graph shown in **Exhibit-9A-31** is illustrated below:

Left turning Volume V_L = 100 vph
Opposing Volume V_O = 400 vph

Projected line from these values intersect to the right of the warrant line and within the area marked 'S' – 15 m – a left turn lane is warranted, and the storage length should be 15 m.

Left Turn Lane Warrants and Storage Lane Lengths for Four-lane Divided Highways Unsignalized Intersections

For use of graph, see **Exhibit-9A-32**.

Exhibit-9A-31

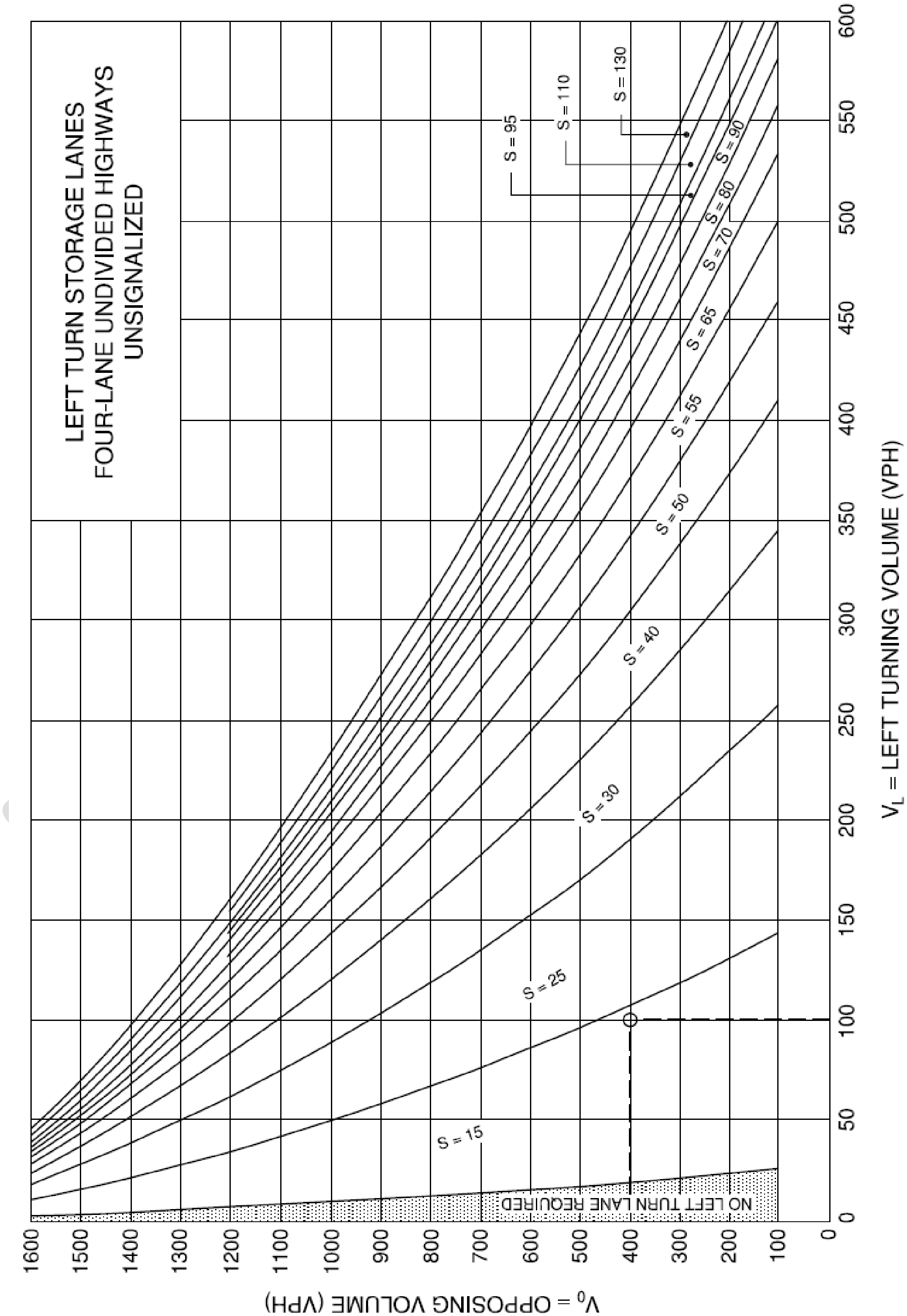
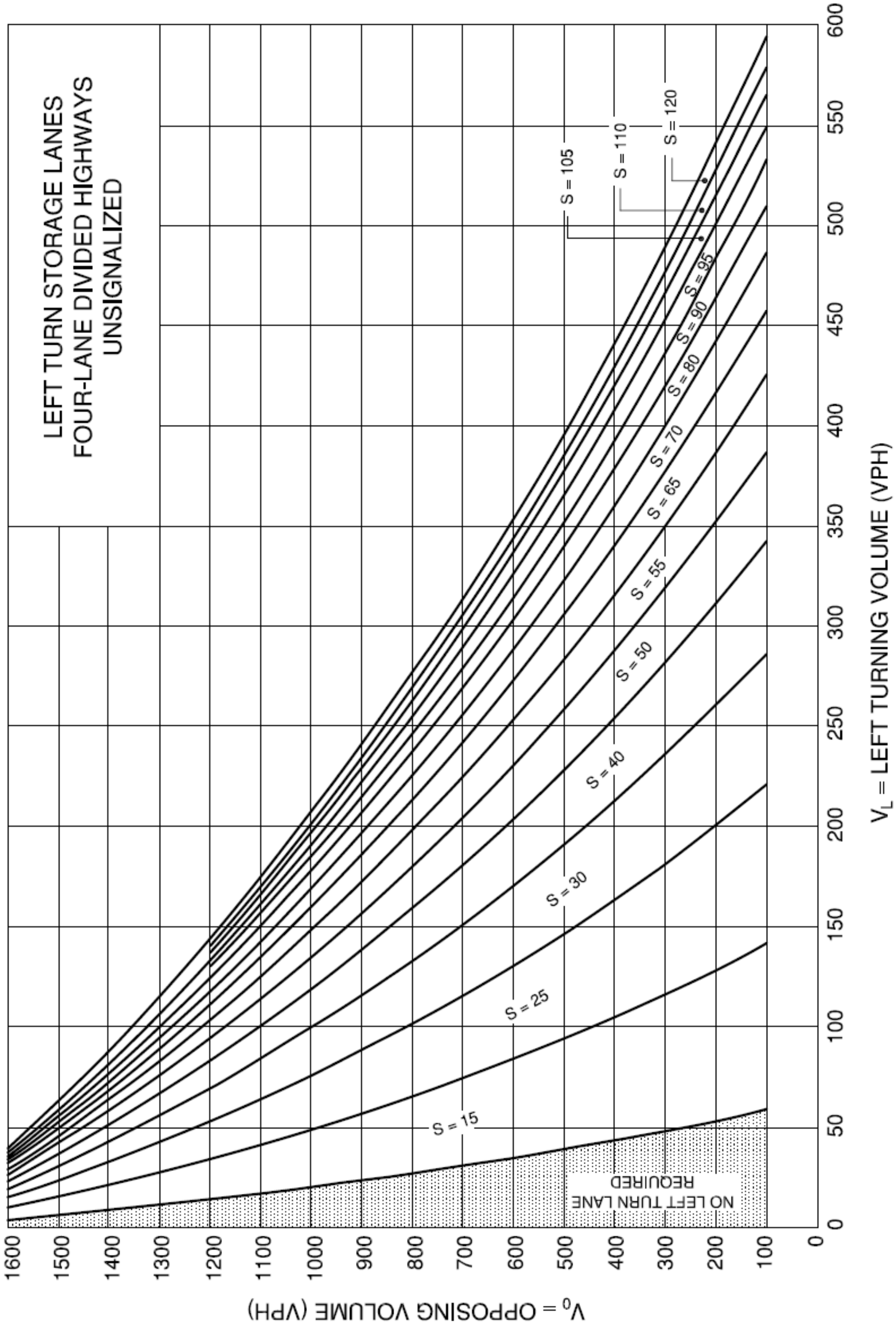


Exhibit-9A-32



MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 10 for Chapter 10

Interchanges

June 2023

MTO Design Supplement
Appendix 10 for Chapter 10
Interchanges

The following Design Supplements are Applicable to *Chapter 10 – Interchanges of the TAC Geometric Design Guide for Canadian Roads - June 2017*:

Section 10.1.1 – General

- This Section is Applicable including the following additional Guidance:

  When designing an interchange, consider the environmental footprint of the infrastructure. The land requirements associated with interchanges can be large and may result in additional habitat destruction to accommodate the space. The designer should also be cognizant of the amount of excavation required, as disrupting the earth releases greenhouse gases sequestered in the ground beneath. Additionally, construction of interchanges requires substantial amounts of building materials which have their own carbon footprint to consider.

  Other considerations for efficient interchange design include:
  - Stormwater management / bioretention cells to manage drainage
  - Commuter parking lots to encourage carpooling
  - Accelerated Bridge Construction staging areas for future construction and decommissioning of infrastructure
  - Ensuring bridge spans are wide enough to accommodate future lane widening as traffic capacity increases over time.

Section 10.1.2 - Pedestrians and Bicycles

- This Section is Applicable including the following additional Guidance:

  Interchange on and off ramps are high-risk locations for pedestrians and cyclists to cross due to the high-speed free-flowing environment. When designing an interchange, it is important to consider active transportation in the initial design, as retrofitting active transportation into existing structures can be much more difficult after the fact.

Interchanges possess unique characteristics and functions that present challenges when designing for the integration of pedestrians and cyclists. Balancing the needs of traffic volumes and cyclists is difficult, a change that could make a crossing easier for pedestrians and cyclists could cause widespread gridlock. Transitioning active transportation through interchanges is difficult and takes room that is not always available.

When balancing the needs of pedestrians and cyclists, designers must take into consideration the requirements of the *Accessibility for Ontarians with Disabilities Act* (**AODA**).

Section 10.1.3.3 – Loop Ramps

- This Section is Applicable including the following additional Guidance:

  Usually loop ramps off the freeway (B configuration) have low visibility and may not meet driver's expectations. In this situation, visibility to the bullnose should be enhanced.

Section 10.1.3.5 – Over Versus Under

- This Section is Applicable with the following additional Guidance:
  - The Manual of Uniform Traffic Control Devices for Canada (MUTCDC) should be replaced with the Ontario Traffic Manual Books.
  - The TAC Guide for the Design of Roadway Lighting should be replaced with the ministry *"Policy for Highway Illumination", Directive # PLNG-B-05* Dated May 8, 2002.
  - There are drainage challenges with advantages and disadvantages when selecting over versus under. Climate change is a factor to be considered for flooding and snow accumulation/icing when looking at over versus under
  - In areas more prone to flooding, it can be advantageous to have the primary road go over the secondary road.
  - Consider the amount of excavation required - disrupting the earth releases

greenhouse gases sequestered in the ground beneath.
  - It is generally cost advantageous when selecting an underpass where topography is such that the existing ground level is close to the major roadway.
  - Traffic volume to and from the freeway should be considered.
  - There may be a need for longer stopping distances on downgrades in icy conditions.

Section 10.1.4.8 – Task and Risks: Merging and Mental Workload

- This Section is Applicable with the following correction:

  Reference to “Section 10.1.3.7” should be read “Section 10.1.4.7”.

Section 10.2 – Interchange Warrants

- This Section is Applicable including the following additional Guidance:

  Active Modes
  Impacts to active modes should be carefully evaluated in the warrant analysis of interchanges. Interchanges may be considered at existing intersections with high pedestrian and cyclist volumes to improve the operation and safety to all road users.

  Major Transit Corridor
  More major transit corridors have been developed in the past decades due to the reliable and convenient mobility choices provided to the public. Interchange may be considered at the junction of roadways and major transit corridor to minimize impacts to operations on both corridors.

Table 10.2.1 – Selection of Interchanges, Grade Separations, and Intersection Based on Classification

- This Table is Not Applicable and is replaced with **Exhibit-10A:**

Exhibit-10A

SELECTION OF INTERCHANGES, GRADE SEPARATIONS AND INTERSECTIONS BASED ON HIGHWAY FUNCTIONAL CLASSIFICATION

	Classification	Freeway	Arterial	Collector/Local
Rural	Freeway	1	2	4
	Arterial		6	7
	Collector/Local			8
Urban	Freeway	1	3	5
	Arterial		6	6 or 7
	Collector/Local			8

Notes:

1. Interchange in all cases.
2. Normally interchange, but grade separation where traffic volume is light.
3. Normally interchange, but grade separation where interchange spacing is too close.
4. Normally grade separation or alternatively the collector/local may be closed.
5. Normally separation, but an interchange may be justified to:
   - relieve congestion
   - serve high density traffic generators
6. Normally intersection, but an interchange may be justified where:
   - capacity limitation causes serious delay
   - injury and fatality rates are high
   - cost would be lower than an intersection
7. Normally intersection, or alternatively the collector/local may be closed.
8. Normally intersection, or alternatively one road may be closed.

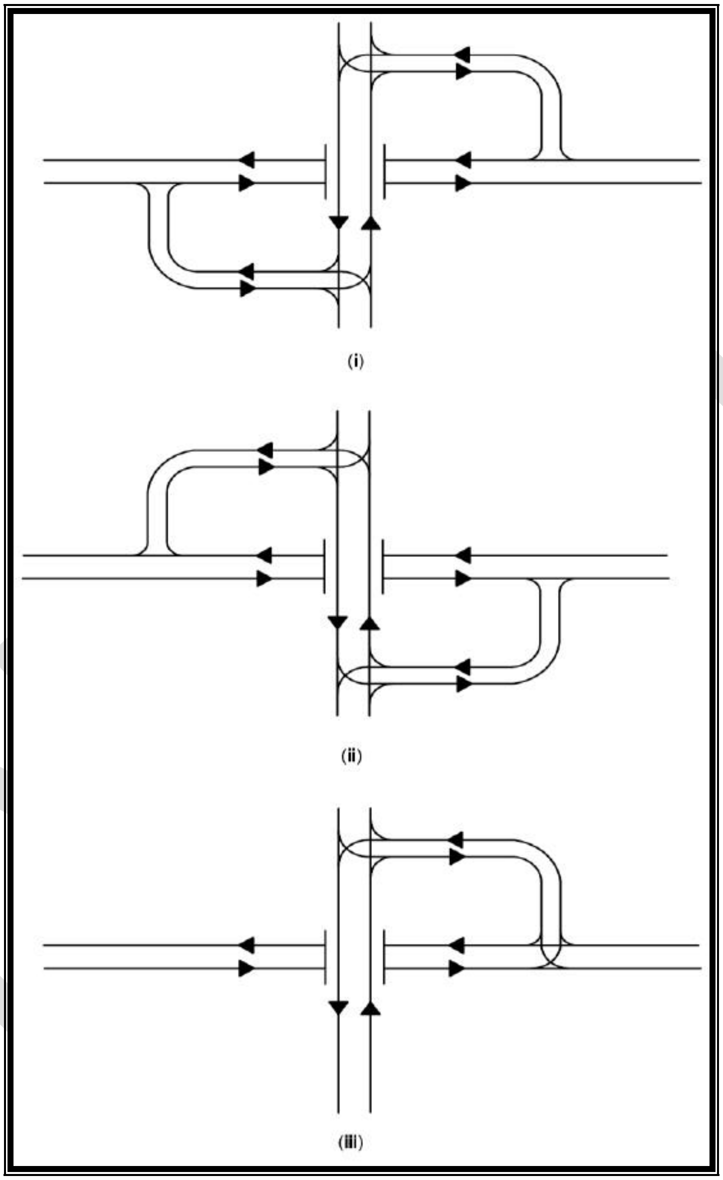
Section 10.5.4 – Interchanges between Roads other than Freeways

- This Section is Applicable including the following additional Guidance:

  Exhibit-10B shows interchanges suitable for roads other than freeways that are not applicable to freeways. Illustrations (i) and (ii) of **Exhibit-10B** are similar in configuration to Parclos A-2 and B-2 respectively but have lower quality geometric features. They have applications on rural arterial roads where it is desirable to introduce a median barrier or otherwise eliminate left-turning traffic on the arterial. Illustration (iii) of **Exhibit-10B** confines all turning movements to one quadrant and has application where turning volumes are very low yet it is desirable to separate through traffic movements.

Exhibit-10B

INTERCHANGES BETWEEN ROADS OTHER THAN FREEWAYS



Section 10.6.1 – General

- This Section is Applicable including the following additional Guidance:

  Usually ramps are fully access-controlled, and no access is permitted to other roadways or development. Three element of ramp design is illustrated in **Exhibit-10C**. The location of two bullnoses is dependent on the geometric features of the two roadways and the desired characteristics of the ramp.

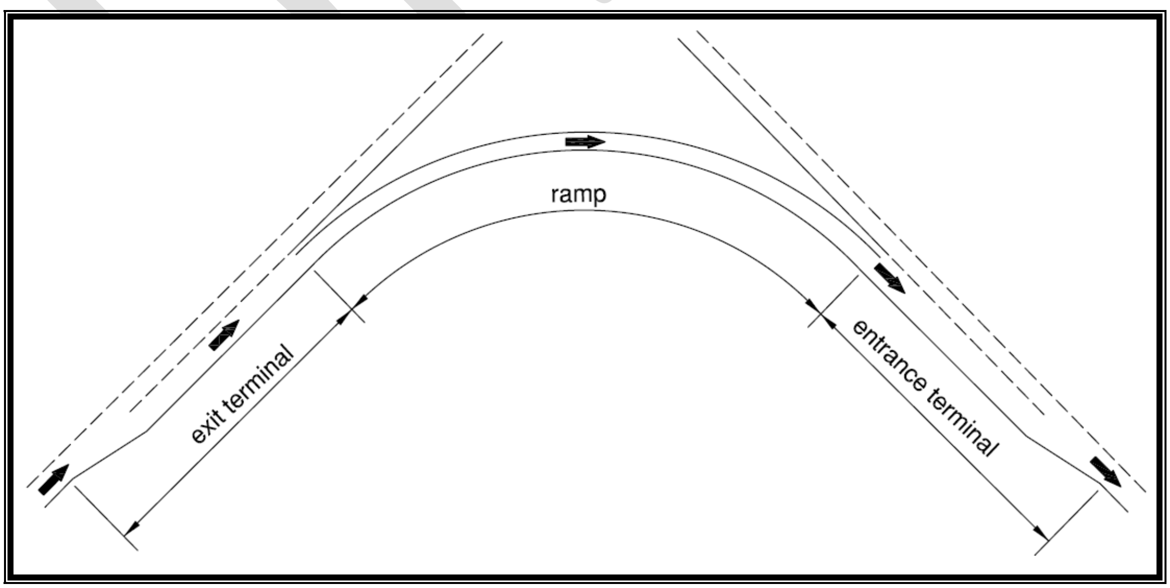
Ramps may have one, two or three lanes. Ramps on rural interchanges normally have one lane. Ramps for traffic entering freeways in urban areas normally have one lane and ramps for traffic exiting freeways in urban areas normally have two lanes and on occasions, three lanes, where there is a change in the number of basic lanes of the freeway.

In ramp capacity analysis, the three components are examined separately and the lowest of the three is regarded as the capacity or service volume. Normally this is at an exit or entrance terminal on the freeway or in the case of an intersection terminal, at the intersection. Procedures for ramp capacity analysis are provided in *Provincial Engineering Memorandum, HSBM DCSO # 2016-05 dated March 31, 2016 for Capacity Analysis Manual – January 2016*.

Based on human factors point of view, drivers are expecting to exit and enter freeways on right side. However, it may not be possible in every case. If that expectation is violated, then additional advance guidance needed for traffic safety and operation.

<u>Exhibit-10C</u>

RAMP DESIGN ELEMENTS



Section 10.6.2 – Ramp Design

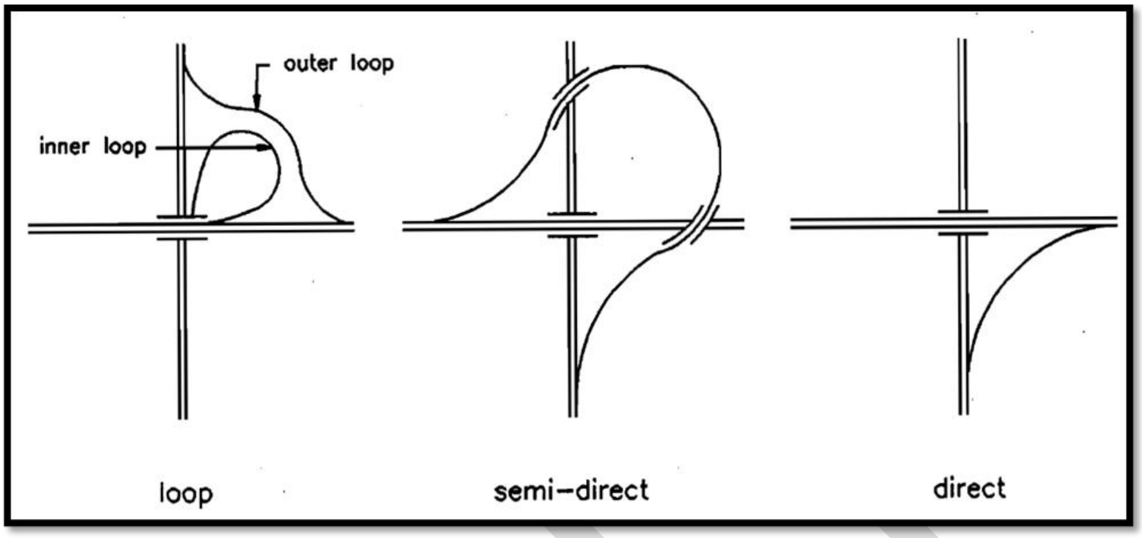
- The following general Guidance for "Ramp Design Types" added to this Section:

  Ramps fall into one of three general categories illustrated in **Exhibit-10D**, reflecting their overall configuration. Direct ramps are those having an overall deflection angle to the right of 90° more or less. Semi-direct ramps in general refer to ramps to accommodate a left turn, having overall deflection angles in the order of 90° to the left. Inner loop ramps refer to those whose configuration resembles a loop and accommodate left-turning traffic, having an overall deflection angle of 270° to the right. Outer loop ramps are direct ramps following the configuration of the inner loop.

  The design and speed selected for a ramp design is related to the design speed of the through roadway upstream of the ramp and the configuration of the inner ramp. Guide values for ramp design speed for a range of highway design speeds are given in **Exhibit-10E.**

  Horizontal and vertical alignment geometry should meet the standards and guidelines set out in **Chapter 3**, using the design speed shown in **Exhibit-10E** as a guide. Profile design should always provide at least minimum stopping sight distance and normally this constraint will be more stringent than limiting values for gradient.

<u>Exhibit-10D</u>
RAMP DESIGN TYPES – GENERAL



Section 10.6.2.1 – Design Speed

- This Section is Applicable including the following additional Guidance:

  The outer loops and direct ramps from crossing roads, the standard values of design speed given in **Exhibit-10E** should be used.

  For inner loops, standard values of design speed given in **Exhibit-10E** may not be attainable, because of large property requirements. For inner loops from a crossing road exit terminal the minimum values are:

  - Parclo A inner loop – urban condition:
    - Crossing road design speed 60 – 80 km/h
    - Ramp design speed 40 km/h
    - Minimum radius 50 m
  - Parclo A inner loop – rural condition:
    - Crossing road design speed 60 – 100 km/h
    - Ramp design speed 40 km/h
    - Minimum radius 55 m

  For inner loops from a highway exit terminal the minimum values are:

  - Parclo B inner loop – urban condition
    - Highway design speed 100 km/h
    - Ramp design speed 50 km/h
    - Minimum radius 80 m

Two-Lane Inner Loop Ramp

There is direct relationship between the growth of population, land development, economic activities, and generation of traffic on highways including freeways. The need for two-lane loop ramp has increased. The two-lane loop configuration should not be immediately preceded or followed by a loop ramp. The radius of the inner edge of the traveled way of the loop ramp normally should not be less than 55 to 60 m.

Table 10.6.1 – Ramp Design Speed

- This Table is Not Applicable and is replaced with **Exhibit-10E**.

Exhibit 10E

RAMP DESIGN SPEED, RADIUS, AND SUPERELAVATION

Highway Design Speed km/h	50	60	70	80	90	100	110	120	130
Ramp Design Speed, km/h									
Desirable	40	50	50	60	70	70	80	80	90
Minimum	30	40	40	40	50	50	60	60	70
e_{max} = 0.6 m/m minimum radius, m									
Desirable	55	90	90	130	190	190	250	250	340
Minimum	30	55	55	55	90	90	130	130	190

Section 10.6.2.2 – Speed Change Lane

- This Section is Applicable including the following additional Guidance:

For two-lane freeway exit terminals, the speed change length is based on a different concept, whereby the exit curve to the bullnose is considered to govern the manoeuvre of the vehicle exiting to the left-hand of the two lanes. This lane configuration has been based on deceleration in gear for 3 seconds at the assumed speed followed by comfortable braking to 50 km/h at the bullnose, with deceleration commencing at the point where a half lane width is available to the vehicle exiting to the left lane. For two-lane freeway exit terminals the total length is based on the vehicle exiting to the right lane of the two lanes, utilizing a 3 second lane shift taper at the assumed speed plus deceleration in gear to a speed of 50 km/h at the bull nose. The design values for length of deceleration lanes are provided in **Exhibit-10F**, and their method of measurement are shown in **Exhibit-10G**.

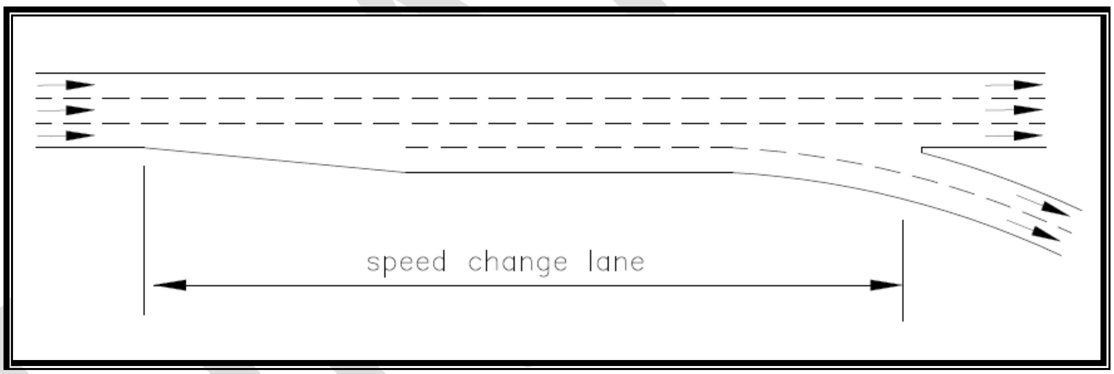
Exhibit-10F

LENGTH OF SPEED-CHANGE LANES AT EXIT TERMINAL FOR TWO-LANE RAMP

Design Speed of Freeway, km/h	**110**	**120**	**130**
Speed at Bullnose, km/h	50	50	50
Length of Speed-Change Lane including Taper, m	480	535	590
Length of Taper, m	85	90	95

Exhibit 10G

MEASUREMENT OF SPEED-CHANGE LANES AT EXIT TERMINAL FOR TWO-LANE RAMP



Section 10.6.2.4 – Sight Distance

- This Section is Applicable including the following additional Guidance:

  There should be a clear view of the entire exit terminal, including the exit nose and a section of the ramp roadway beyond the gore. The sight distance on a freeway preceding the approach nose of an exit ramp should exceed the minimum stopping sight distance for the through traffic design speed, desirably by 25 percent or more. Decision sight distance should be considered in complex situations and provided where practical. Sight distance for passing is not required.

Section 10.6.2.5 – Ramp Width

- This Section is Not Applicable and is replaced with the following Guidance:

Ramp traveled-way widths are governed by the type of operation, curvature, and volume and type of traffic. The roadway width for a turning roadway includes the traveled-way width plus the shoulder width or equivalent offset outside the edges of the traveled way. *Section 9.16.3 – Turning Roadway Widths in Chapter 9 – Intersections* should be referred. The design width of ramp traveled ways for various considerations are provided in *Exhibit 9-E – Design Widths for Turning Roadways at Intersections* in *Appendix 9 – Intersections*. Width of pavement for turning roadways are classified for the following types of operation:

- Case I: one lane, one-way operation – no provision for passing
- Case II: one lane, one-way operation – with provision for passing a stalled vehicle
- Case III: two lane operation.

Types of operation I, II, and III are described in broad terms. In general, operation I has a small volume of trucks or only an occasional large truck; operation II has a moderate volume of trucks (in the range of 5 to ten percent of total traffic); and operation III has more and large trucks.

Cross Slope

The cross slope on tangential portions of ramps should normally be sloped one way at a practical rate ranging from 1.5 to 2 percent. The design control at the crossover crown line (not to be confused with the crown line normally provided at the centerlines of a roadway) is the algebraic difference in cross slope rates of the two adjacent lanes. Where both roadways slope down and away from the crossover crown line, the algebraic difference is the sum of their cross-slope rates; where they slope in the same direction, it is the difference of their cross-slope rates. A desirable maximum algebraic difference at a crossover crown line is 4 or 5 percent, but it may be as high as 8 percent at low speeds and where there are very few trucks. The suggested maximum differences in cross slope rates at a crown line, related to the speed of turning traffic, are given in **Exhibit 10H.**

Exhibit-10H

MAXIMUM ALGEBRAIC DIFFERENCE IN CROSS SLOPE AT RAMPS

Design Speed of Exit or Entrance Curve (km/h)	Maximum Algebraic Difference in Cross Slope at Crossover Crown 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

Shoulders and Curbs
Shoulders should be provided on ramps and ramp terminals in interchange areas to provide a space that is clear of the traveled way for emergency stopping, to minimize the effect of breakdown, and to aid drivers who may be confused (human factors). Ramps at interchanges should be designed without curbs. Curbs should be considered only to facilitate in difficult drainage locations, such as in urban areas where restricted right-of-way favors enclosed drainage. In some cases, curbs are used at the ramp terminals but are omitted along the central ramp portions.

Profile and Grade
The profile of a typical ramp usually consists of a central portion on an appreciable grade, coupled with terminal vertical curves and connections to the profiles of the intersection legs. Profiles at the terminals are mostly determined by through-road profiles and are seldom tangent grades.

Ramp grades should be as flat as practical to minimize the driving effort needed in maneuvering from one road to another. For any ramp, the gradient to be used is dependent on number of factors unique to that site. The flatter the gradient on a ramp, the longer it will be, but the effect of gradient on ramp length is not substantial.
In general, adequate sight distance is more important than a specific gradient control and should be favored in design. Usually, these two controls are compatible.

Superelevation
The following should be considered for development of superelevation on ramps:

- Superelevation rates, as related to curvature and design speed on ramps, are provided in *Chapter 3* of *TAC GDG.*
- The maximum superelevation on ramps should not be greater than 6 percent.

The method of developing superelevation at ramp terminals is illustrated in the following Exhibits:

- **Exhibits-10I** – Development of Superelevation on Tangent Road with Direct Taper

- **Exhibits-10J** – Development of Superelevation on Tangent Road with Taper and Parallel
- **Exhibits-10K** – Development of Superelevation on Same Direction Curved Road
- **Exhibits-10L** – Development of Superelevation on Opposite Direction Curved Road

The guidance and arrangement illustrated in **Exhibit-10I** to **Exhibit-10L** for exit terminals are also directly applicable to entrance terminals, except that the details at the merging end are different from those of an approach nose. The merging end of an entrance terminal would be located in proximity of D.

Superelevation Runoff

The principles of superelevation runoff design discussed in *Chapter 3* of *TAC GDG* and generally apply to free flow turning roadway. In general, the rate of change in cross slope in the runoff section should be based on the maximum relative gradients. Usually, the profile of one edge of the traveled way is established first, and the profile on the other edge is developed by stepping up or down from the first edge by the amount of desired superelevation at that location. This step is done by plotting a few control points on the second edge by using the maximum relative gradients and then plotting a smooth profile for the second edge of traveled way. Drainage may be an additional control, particularly for curbed roadways.

Exhibit-10I

DEVELOPMENT OF SUPERELEVATION ON TANGENT ROAD WITH DIRECT TAPER

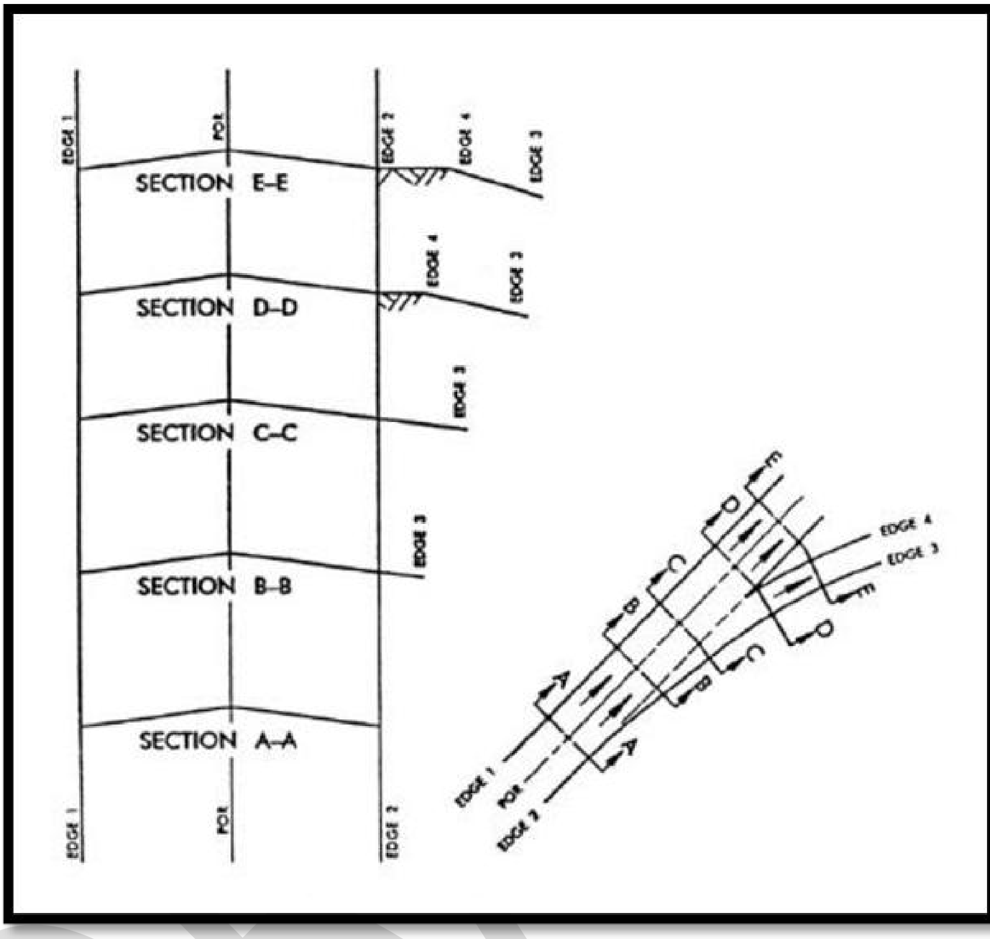


Exhibit-10J

DEVELOPMENT OF SUPERELEVATION ON TANGENT ROAD WITH TAPER AND PARALLEL

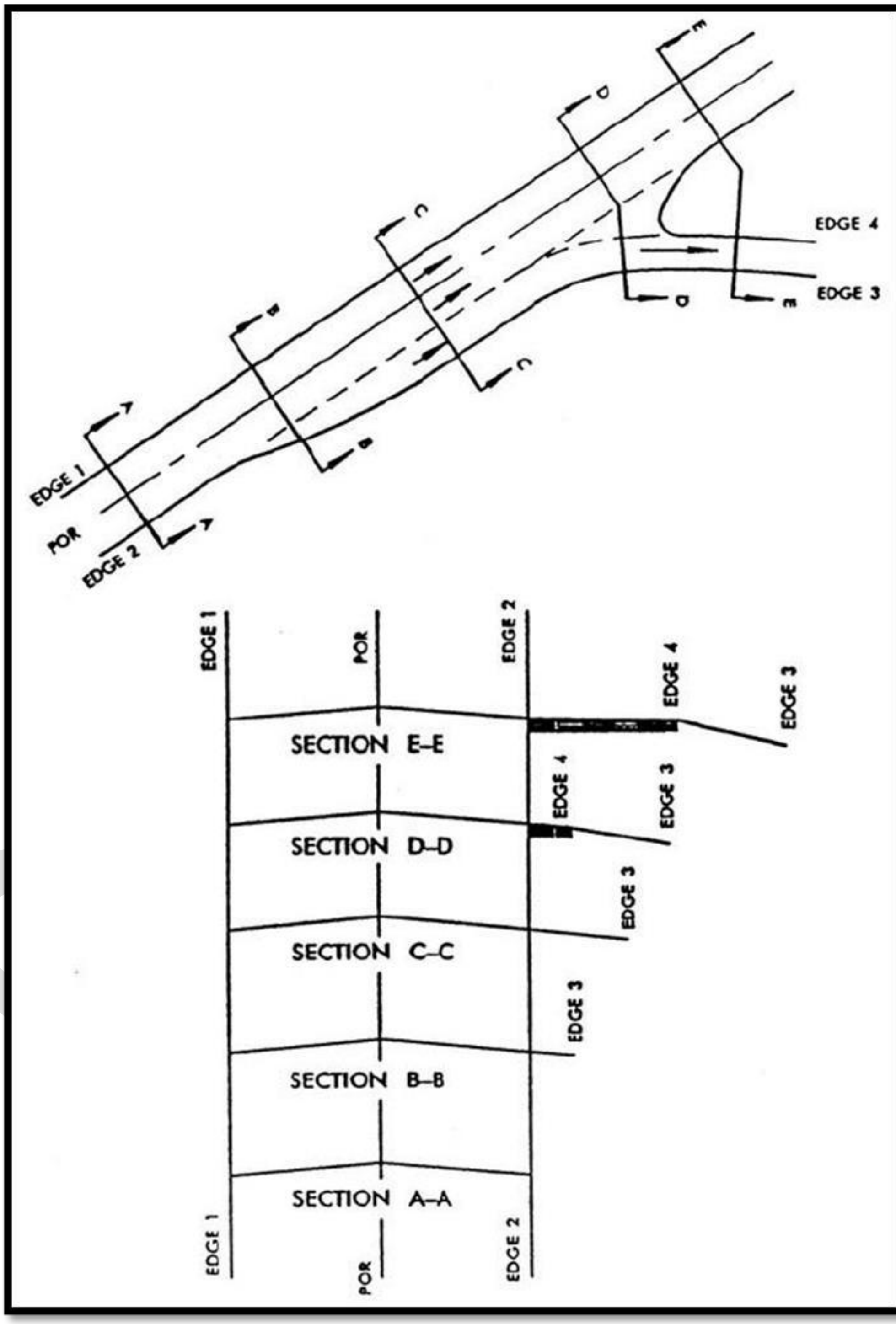


Exhibit-10K

DEVELOPMENT OF SUPERELEVATION ON SAME DIRECTION CURVED ROAD

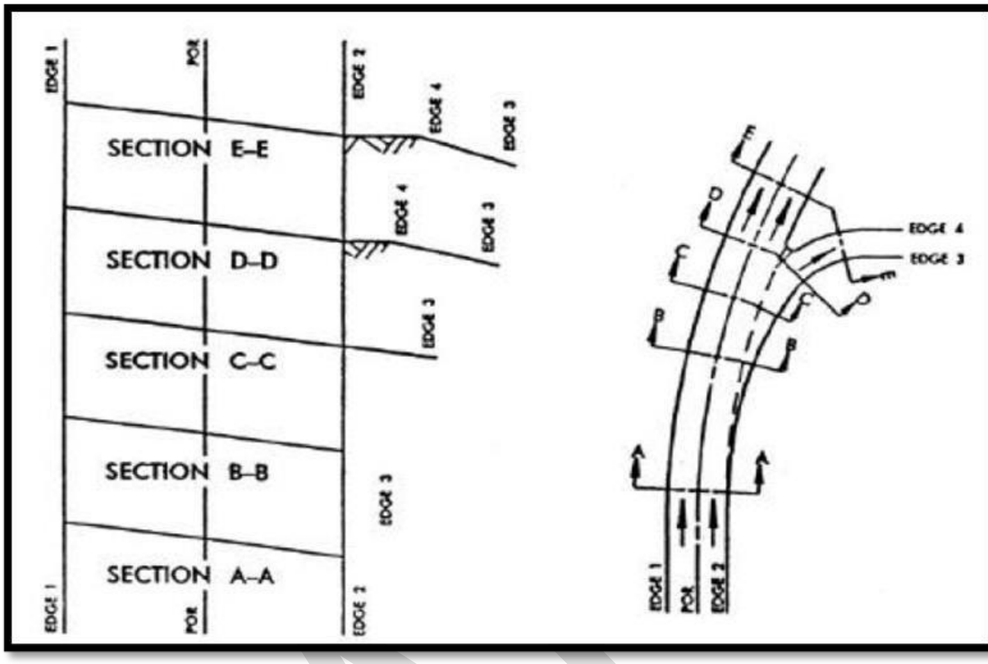
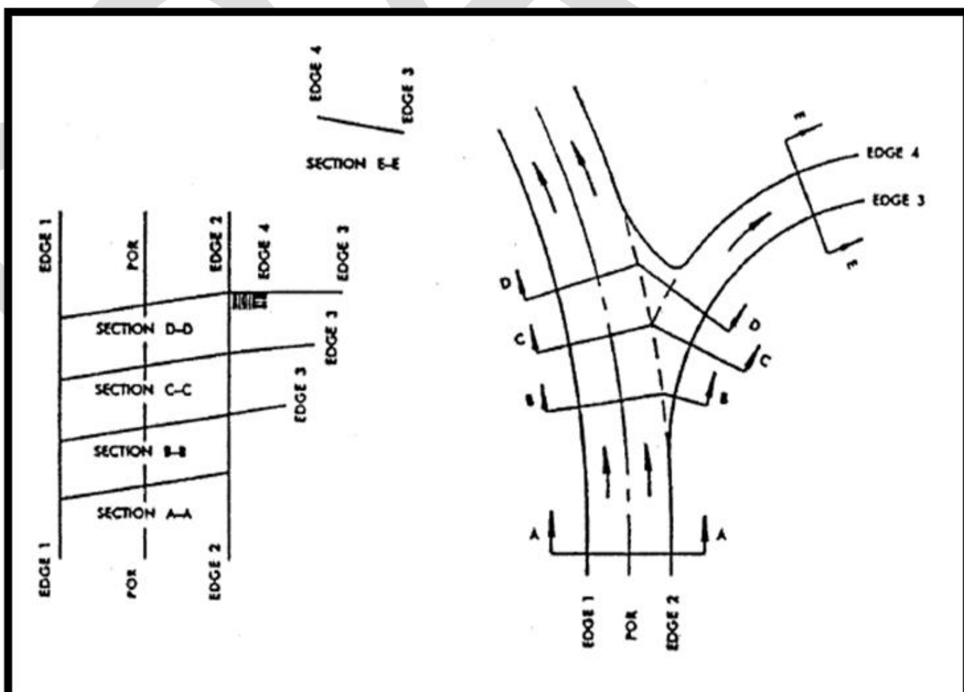


Exhibit-10L

DEVELOPMENT OF SUPERELEVATION ON OPPOSITE DIRECTION CURVED ROAD



Signing and Pavement Marking

The ability of drivers to follow the intended paths at interchanges depends largely on

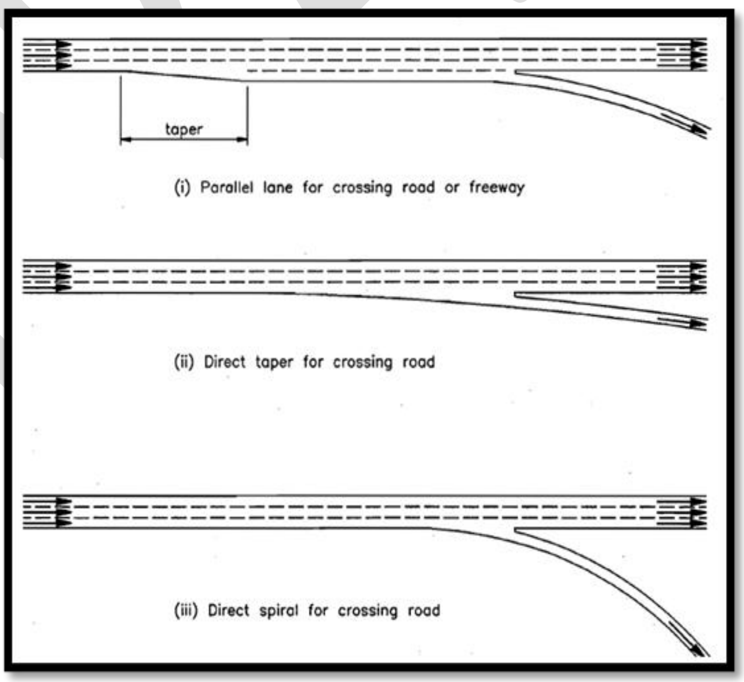
their relative spacing, geometric layout, and positive signing. The location and proper distances between the signs both depend to a large degree on whether effective and positive message can be provided to inform, warn, and control drivers.
Pavement striping, delineators, and other markings are also important elements of driver communication at ramps. Signing and pavement marking should be uniform and consistent with the *Ontario Traffic Manual Books.*

Section 10.6.3.1 – Exit Terminal Design

- This Section is Applicable including the following additional Guidance:

Single-Lane Exit Design
On crossing roads, the direct spiral form of exit terminal design is used for through road design speeds up to 60 km/h, the direct taper form is used for through road design speeds up to 100 km/h, and the parallel form is used for higher design speeds. Types of single-lane exit configuration are shown in **Exhibit-10M**.

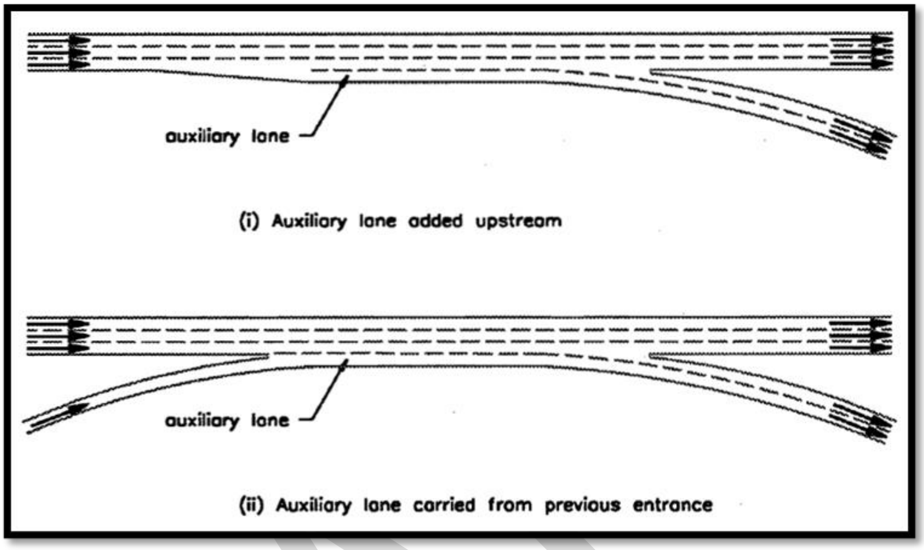
Exhibit-10M
SINGLE-LANE EXIT TERMINAL CONFIGURATION



Two-Lane Exit Design
Types of two-lane exit configuration are shown in **Exhibit-10N**.

Exhibit-10O

TWO-LANE EXIT TERMINAL CONFIGURATION

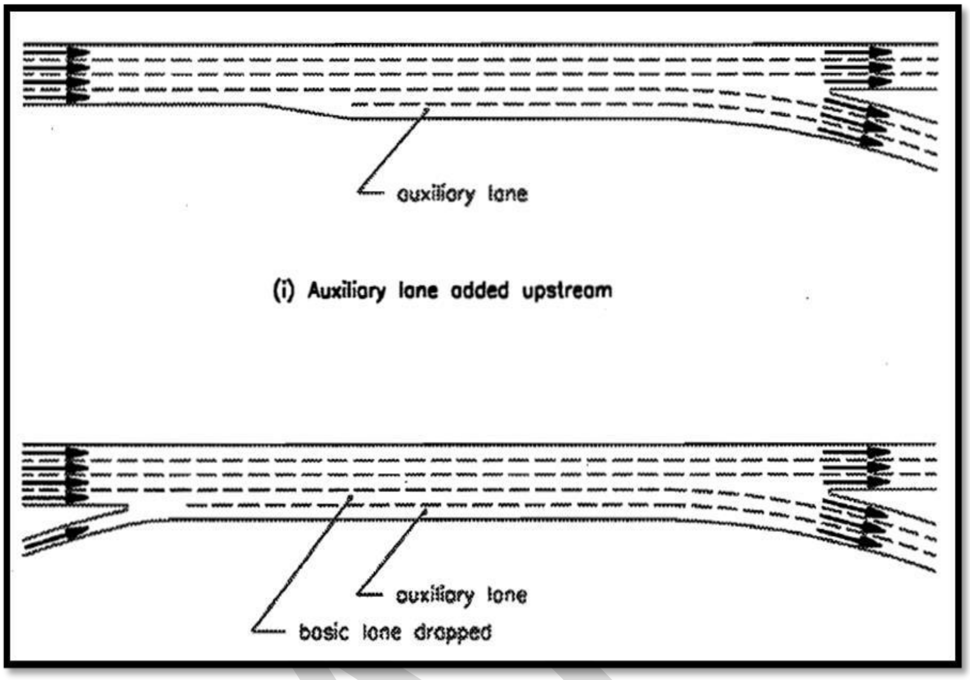


Three-Lane Exit Designs

Three-lane exits are sometimes applied at a freeway-to-freeway interchange where there is a reduction in the number of basic lanes. The design of a three-lane exit terminal is identical to that of a two-lane exit with an additional lane to the right (looking in the direction of travel). Generally, the right lane is an auxiliary lane, and the adjacent lane is a basic lane to be dropped at the interchange, illustrated in **Exhibit-10O**.

Exhibit-10O

THREE-LANE EXIT TERMINAL CONFIGURATION



Exit Terminal Bullnoses

Bullnoses for exit terminals may include or exclude curb and gutter. If curb and gutter is omitted, the bullnose is squared off and if it is included the bullnose is rounded. Illustrations and dimensions and are shown in **Exhibit-10P** and **Exhibit-10Q** respectively.

The exit bullnose is the decision point area that must be clearly seen and understood by the approaching driver. Collision rates in the vicinity of bullnoses are higher than at other locations at exit and for this reason the bullnose is usually offset from the through traffic to provide a recovery area for errant vehicles.

Bullnose areas normally consist of pavement only, without curb, unless drainage considerations indicate a benefit from use of curb.

Exhibit-10P

EXIT TERMINAL BULLNOSE AND OFFSET ILLUSTRATIONS

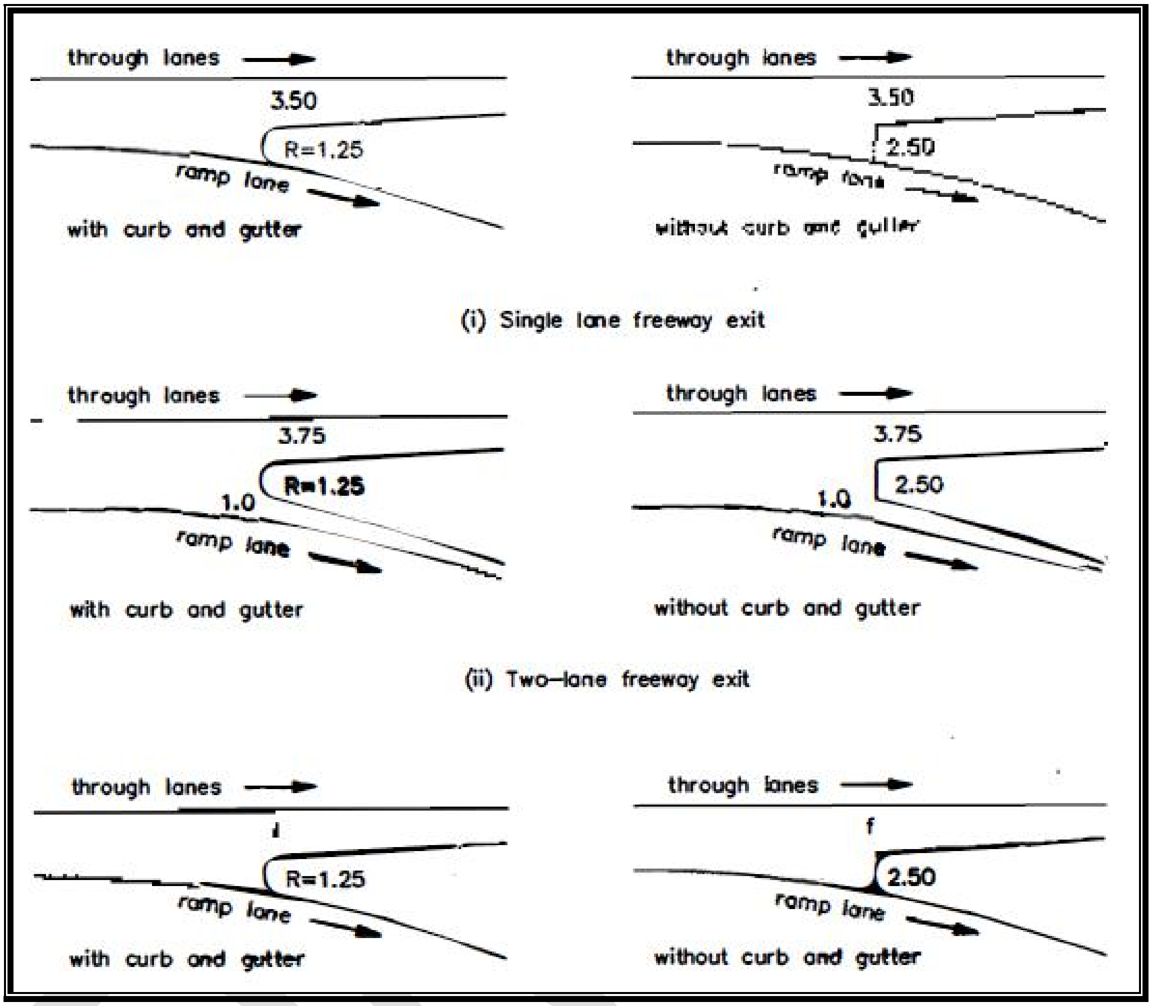


Exhibit-10Q

EXIT TERMINAL BULLNOSE AND OFFSET DIMENSIONS

Design Speed km/h	50	60	70	80	90	100	110	120	130
Bullnose Offset 'f' (m)	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6

Section 10.6.3.4 – Sight Distance to Exit Terminals

- This Section is Applicable including the following additional Guidance:
  Sight distance, greater than minimum stopping sight distance, is required for the driver to make a series of decisions and execute the manoeuvre safely. **Exhibit-10R** shows sight distance to the bullnose for exit terminal (or sight distance to end of terminal for entrance

ramp) for a range of design speeds. It is desirable for the driver to see the pavement surface at the bullnose from a distance at least equal to this sight distance, illustrated in *Figure 10.6.3 of Chapter 10 - Interchanges*. Ideally the driver should have a view of the pavement surface of part of the ramp beyond the bullnose. A range of values is shown in the table to reflect the variation in complexity of different cases. In general, rural conditions are less complex and therefore the lower values are adequate, but urban conditions present a variety of complexities and higher values should be used.

Exhibit-10R

SIGHT DISTANCE AT EXIT OR ENTRANCE TERMINALS

Design Speed km/h	60	70	80	90	100	110	120	130
Exit Sight Distance to Bullnose (m) / **Entrance Sight Distance to End of Terminal (m)**	170 to 230	200 to 270	240 to 310	270 to 350	300 to 390	340 to 430	370 to 470	390 to 510

Figure 10.6.3 – Sight Distance at Exit Terminals

- This Figure is Applicable except height of driver's eye should be 1.08 m.

Section 10.6.4.1 – Entrance Terminal Design

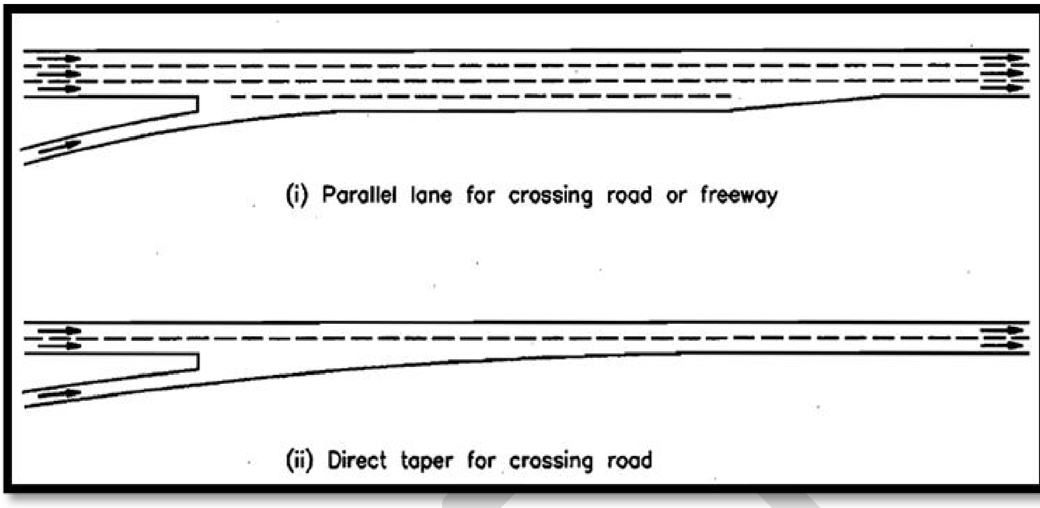
- This Section is Applicable including the following additional Guidance:

Single-Lane Entrance

On crossing roads, the direct taper form of entrance terminal is used for through road design speeds up to 80 km/h, and the parallel form is used for higher design speeds. Types of single-lane entrance configuration are shown in **Exhibit-10S**.

Exhibit-10S

SINGLE-LANE ENTRANCE TERMINAL CONFIGURATION

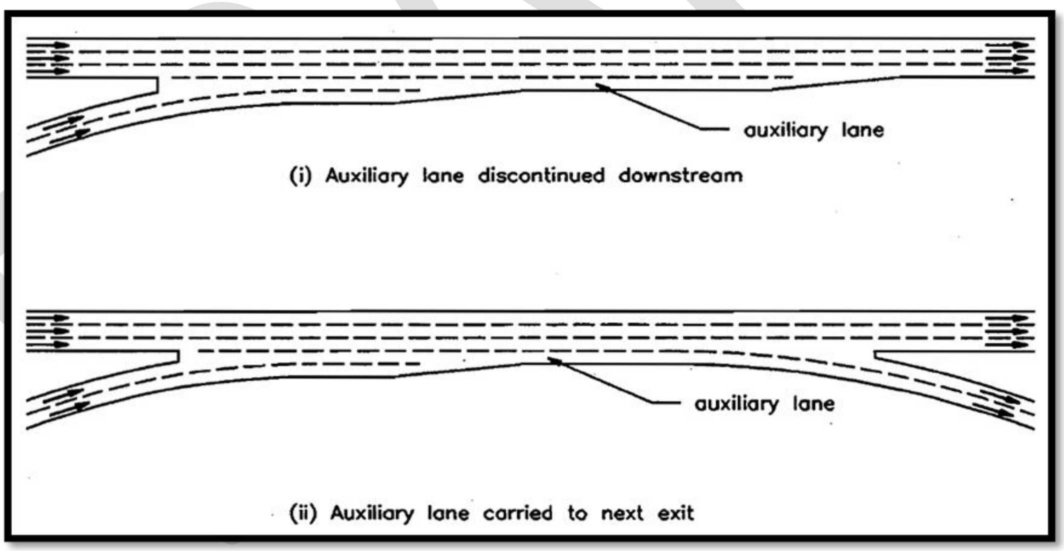


Two-Lane Entrance

Types of two-lane entrance configuration are shown in **Exhibit-10T**.

Exhibit-10T

TWO-LANE ENTRANCE TERMINAL CONFIGURATION

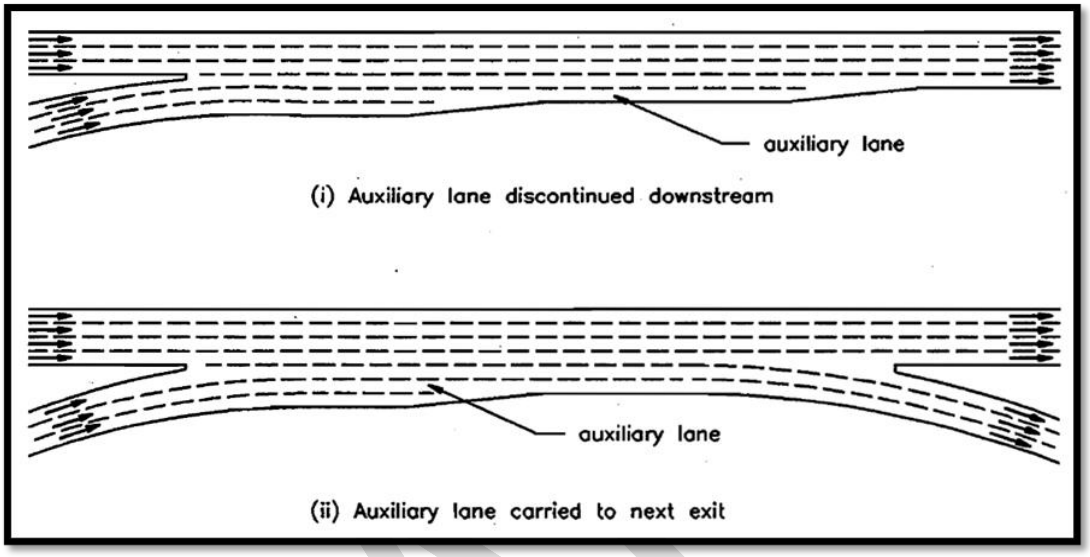


Three-Lane Entrance

Three-lane entrances are sometimes required at a freeway-to-freeway interchange where there is an increase in the number of basic lanes. The design of a three-lane freeway entrance terminal is identical to that of a two-lane entrance with an additional lane to the right. Commonly, the two right lanes are auxiliary lanes, and the adjacent lane is a basic lane added at the interchange, illustrated in **Exhibit-10U.**

Exhibit-10U

THREE-LANE ENTRANCE TERMINAL CONFIGURATION



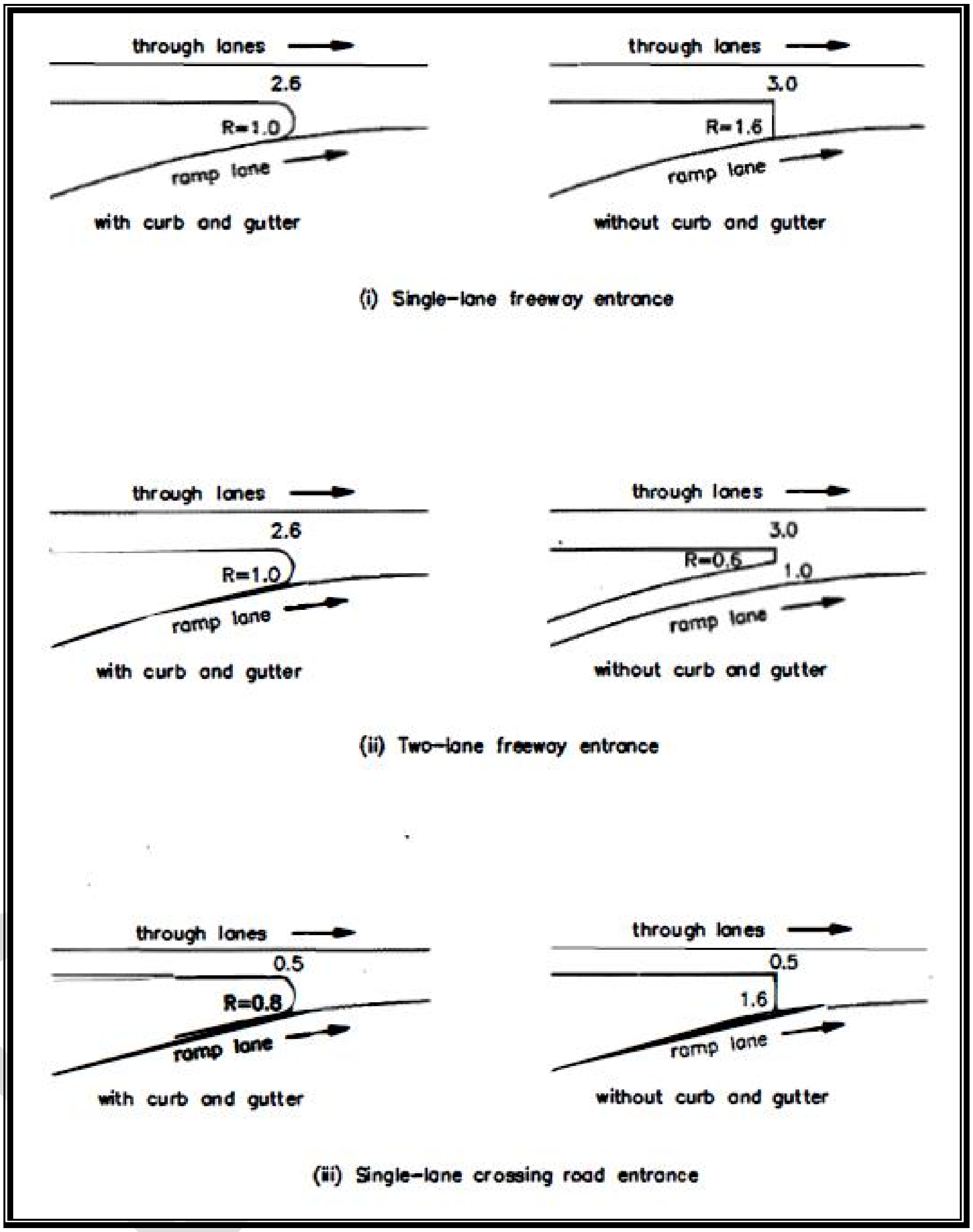
Entrance Terminal Bullnoses

Similar to exit terminal bullnoses, entrance terminals bullnoses may include or exclude curb and gutter. If curb and gutter is omitted the bullnose is squared off, and if it is included it is rounded. Dimensions are shown in **Exhibit-10V**.

Bullnose areas normally consist of pavement only, without curb, unless drainage considerations indicate a benefit from use of curb.

Exhibit-10V

ENTRANCE TERMINAL BULLNOSE AND OFFSET DIMENSIONS



Section 10.6.4.4 – Sight Distance at Entrance Terminal

- This Section is Applicable including the following:

  The required length of sight distance is provided in **Exhibit-10R**.

Figure 10.6.4 – Line of Sight and Sight Distance at Entrance Terminals

- This Figure is Applicable except height of driver's eye should be 1.08 m.

Section 10.6.5 – Ramp Terminal Spacing

- This Section is Applicable including the following additional Guidance:

  Successive Entrance Ramps
  Where two ramps enter a freeway in close succession, for example, in the case of a parclo A-4, the configuration may be treated in one of two ways as illustrated in **Exhibit 10-W.**

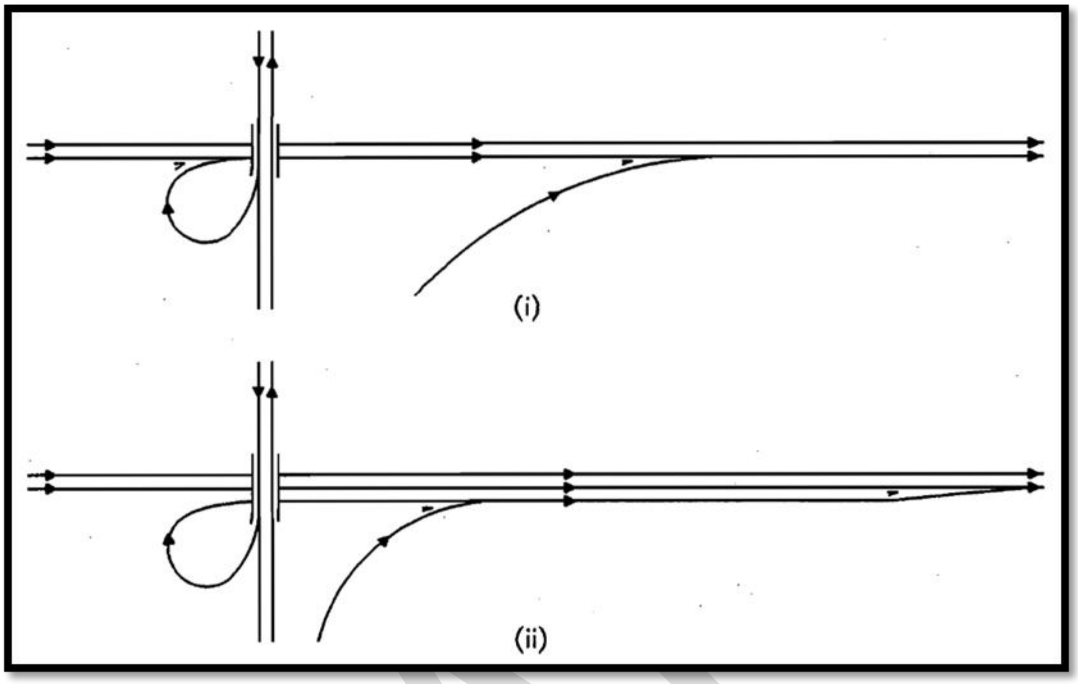
  The most usual treatment is to carry each ramp directly and independently to the freeway as shown in **Exhibit-10W (i).** This form provides ramp traffic with separate opportunities to merge with through traffic and to disperse.
  An alternative treatment is to merge the two ramp movements with a single movement and then to carry the combined ramp traffic onto the freeway through a single entrance, as shown in **Exhibit-10W (ii)**. This form has the disadvantage in that a stalled vehicle or accident downstream of the merging of the two ramp movements will also delay the upstream ramp traffic. The design shown in (ii) is useful to minimize the number of ramp entrances to a freeway for example, if this were required for ramp metering.

Section 10.7.4 – Grading and Landscaping Development

• This Section is Applicable including the following additional Guidance:

- Planting vegetation can increase the carbon absorption capacity and reduce the overall carbon footprint of the highway infrastructure, as well as be more aesthetically pleasing.
- Vegetation has a stabilizing effect that reduces erosion.
- Vegetation serves to retain water from precipitation events and can potentially assist with drainage capacity.

Exhibit-10-W
SUCCESSIVE ENTRANCE RAMPS



Section 10.8 – Typical Interchange Design Features

- Figure 10.8.1 to Figure 10.8.12 are Not Applicable and are replaced with the following:

  Examples of typical design for exit terminals and entrance terminals are shown in **Exhibit-10X** to **Exhibit-10AK**, followed by examples of at-grade intersections of some commonly used Parclo A and Parclo B ramp terminals at crossing arterial roads in **Exhibit-10-AG** to **Exhibit-10-AK**. Expressway/core-collector system are illustrated in **Exhibit-10-AM** and **Exhibit-10-AN**. These designs should be regarded as typical rather than standard and are for the guidance of the designer. Rigid adherence to these designs may produce unsatisfactory operation in some cases. Dimensions are typical, and variations are required to suit local conditions of alignment, grade profile, traffic volume, traffic mix and typical physical and environmental features. Nor are the designs necessarily complete in every detail, and additional detailing may be required. **These exhibits are typical examples and for guidance only. The designers should select the values from the domains provided in the Chapter 10 of TAC GDG and this Design Supplement.**

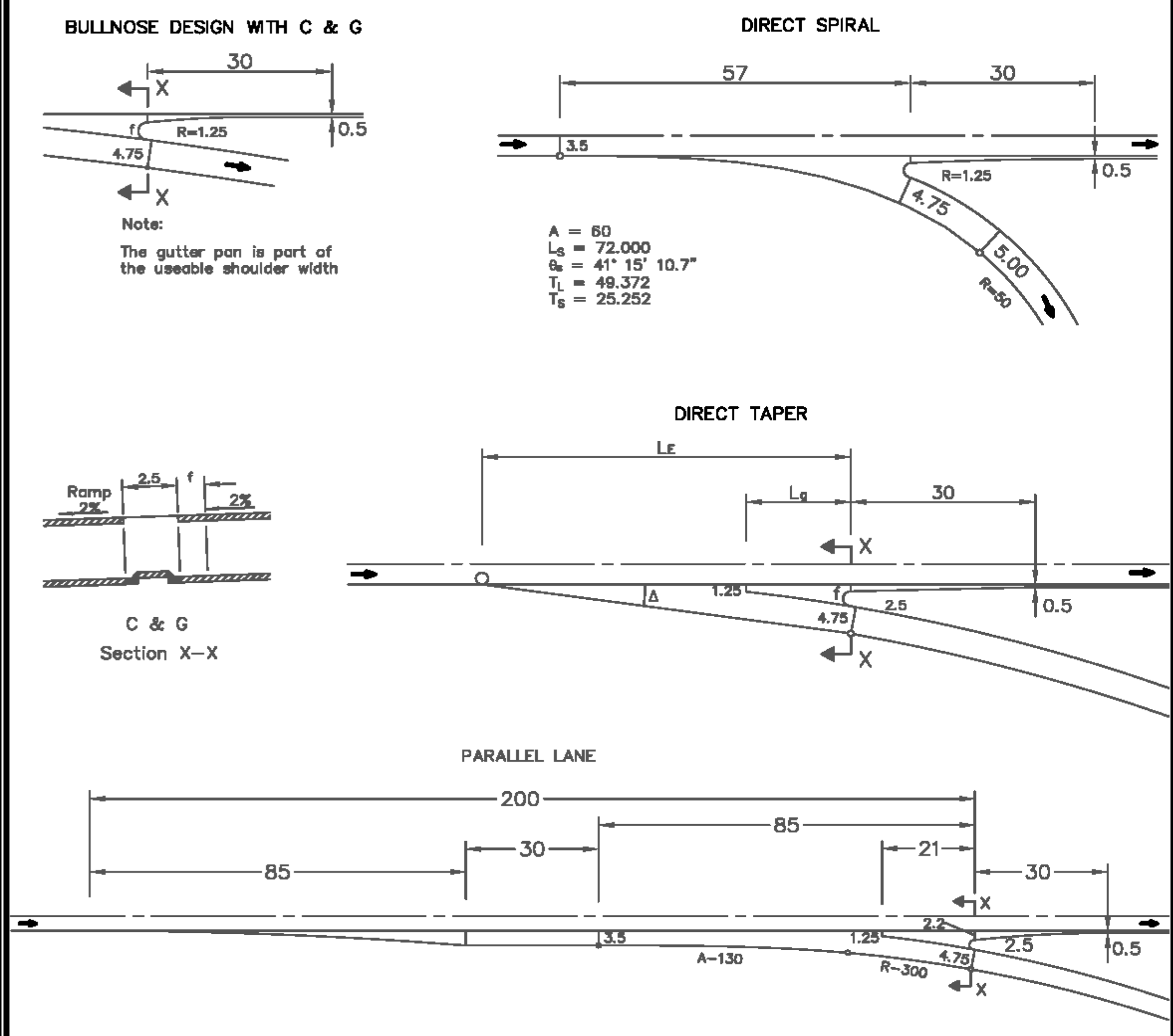
Exhibit-10X

Single-Lane Crossing Road Exit Terminals

	DESIGN SPEED OF HWY.	TOTAL LENGTH OF S.C.L. L_E	LENGTH OF GORE AREA L_g	OFFSET AT BULL-NOSE f	DEFLECTION ANGLE Δ
	km/h	m			°
	60	DIRECT SPIRAL			
DIRECT TAPER	60	60	17	1.2	8
DIRECT TAPER	70	85	26	1.4	6
DIRECT TAPER	80	110	35	1.6	5
DIRECT TAPER	90	150	51	1.8	3
DIRECT TAPER	100	180	63	2.0	3
	110	PARALLEL LANE			

NOTES:

1 — For ramp radii refer to Exhibit 10–D
2 — For ramp spiral parameters refer to Table 10.6.4 or Chapter 3
3 — Adjustment to some dimensions is required for grade, see Exhibit 9–K

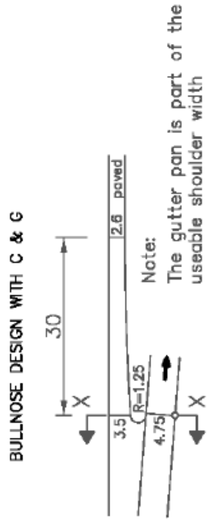


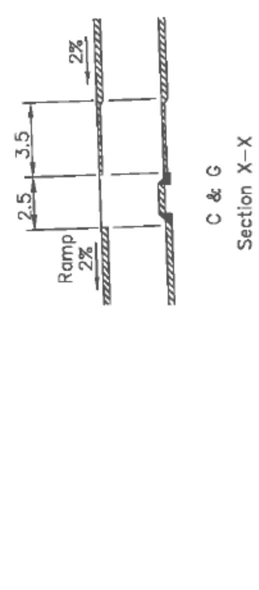
Single–Lane Crossing Road Exit Terminal

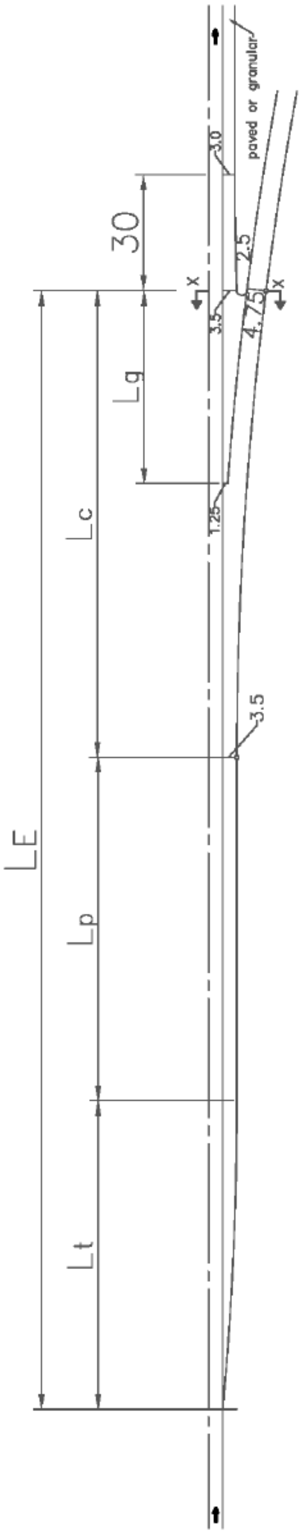
Exhibit-10Y

Single-Lane Freeway Exit Terminal

DESIGN SPEED OF HWY.	TOTAL LENGTH OF S.C.L. INCL. TAPER L_E	TO INNER LOOP: EXIT CURVE RADIUS R	TO INNER LOOP: EXIT CURVE DEFLECTION ANGLE Δ	TO INNER LOOP: LENGTH OF GORE AREA L_g	TO INNER LOOP: LENGTH OF CURVE L_c	TO INNER LOOP: LENGTH OF PARALLEL SECTION L_p	TO OUTER LOOP: EXIT CURVE RADIUS R	TO OUTER LOOP: EXIT CURVE DEFLECTION ANGLE Δ	TO OUTER LOOP: LENGTH OF GORE AREA L_g	TO OUTER LOOP: LENGTH OF CURVE L_c	TO OUTER LOOP: LENGTH OF PARALLEL SECTION L_p	TAPER LENGTH L_T
km/h	m	m	o	m			m	o	m			m
100	290	1000	7	50	121	89	1800	5	67	162	48	80
110	315	1250	6	56	135	95	2000	5	70	170	60	85
120	345	1500	5	61	148	107	3000	4	86	209	46	90







EXIT CURVE DATA						
Δ	6°55'15"	6°11'15"	5°38'45"	5°09'10"	4°53'10"	3°59'15"
R	1000	1250	1500	1800	2000	3000
T	60.481	67.561	73.964	80.994	85.330	104.435
L	120.816	134.990	147.808	161.879	170.557	208.785

NOTES:

1 – For ramp radii refer to Exhibit 10–D
2 – For ramp spiral parameters refer to Table 10.6.4 or Chapter 3
3 – Adjustment to some dimensions is required for grade, see Exhibit 9–K

Exhibit-10Z

Two-Lane Freeway Exit Terminal, 110 km/h

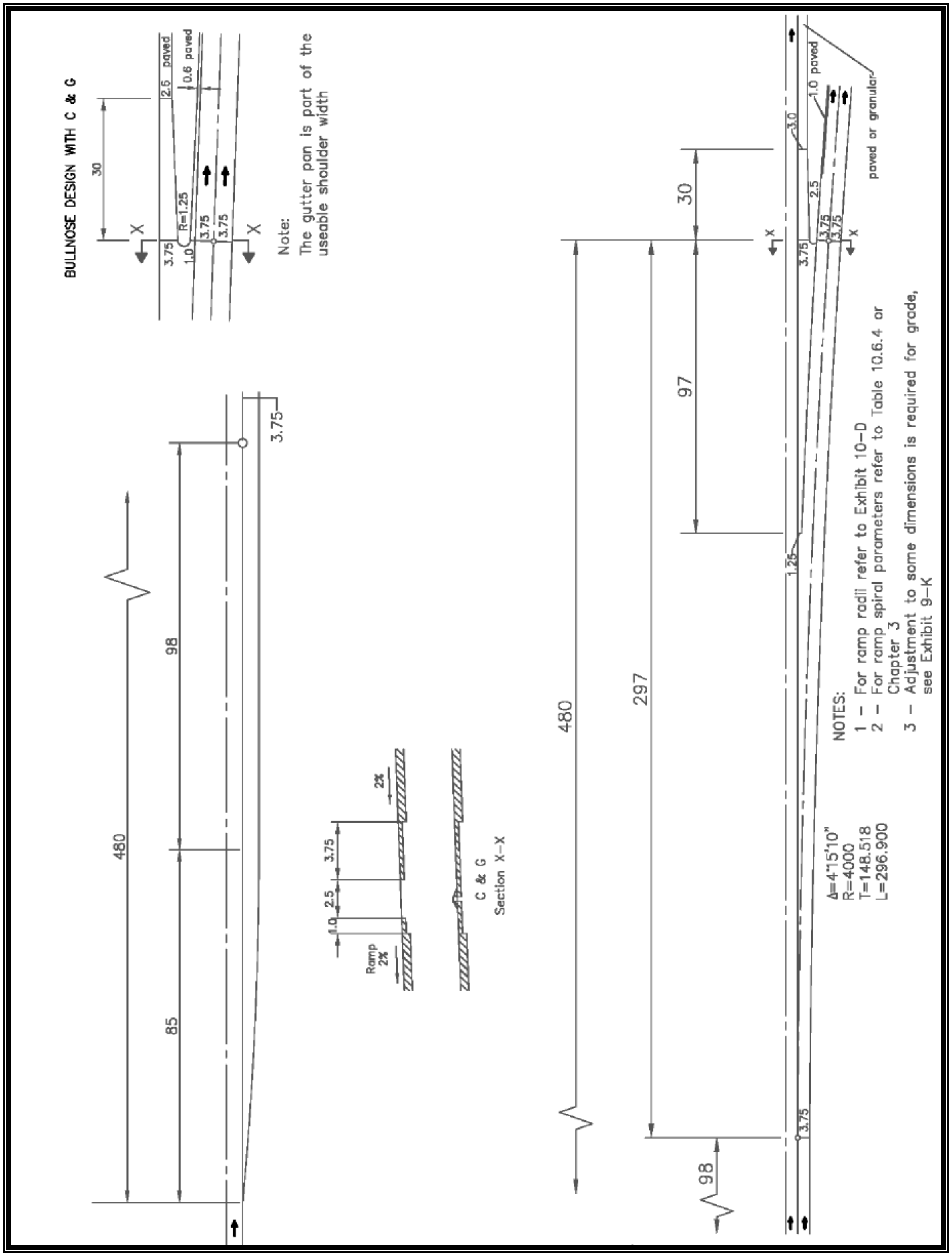


Exhibit-10AB

Two-Lane Freeway Exit Terminal, 120 km/h

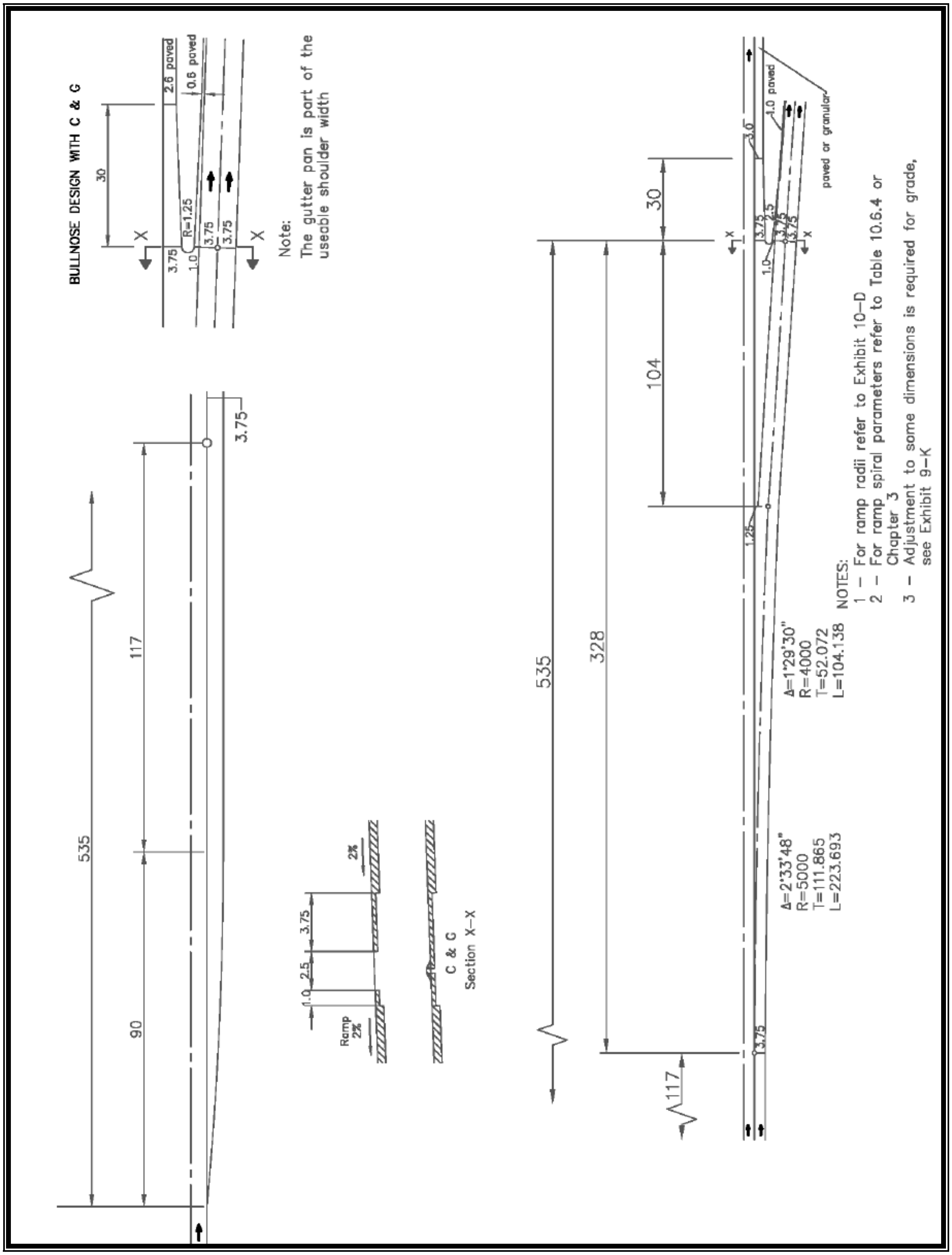
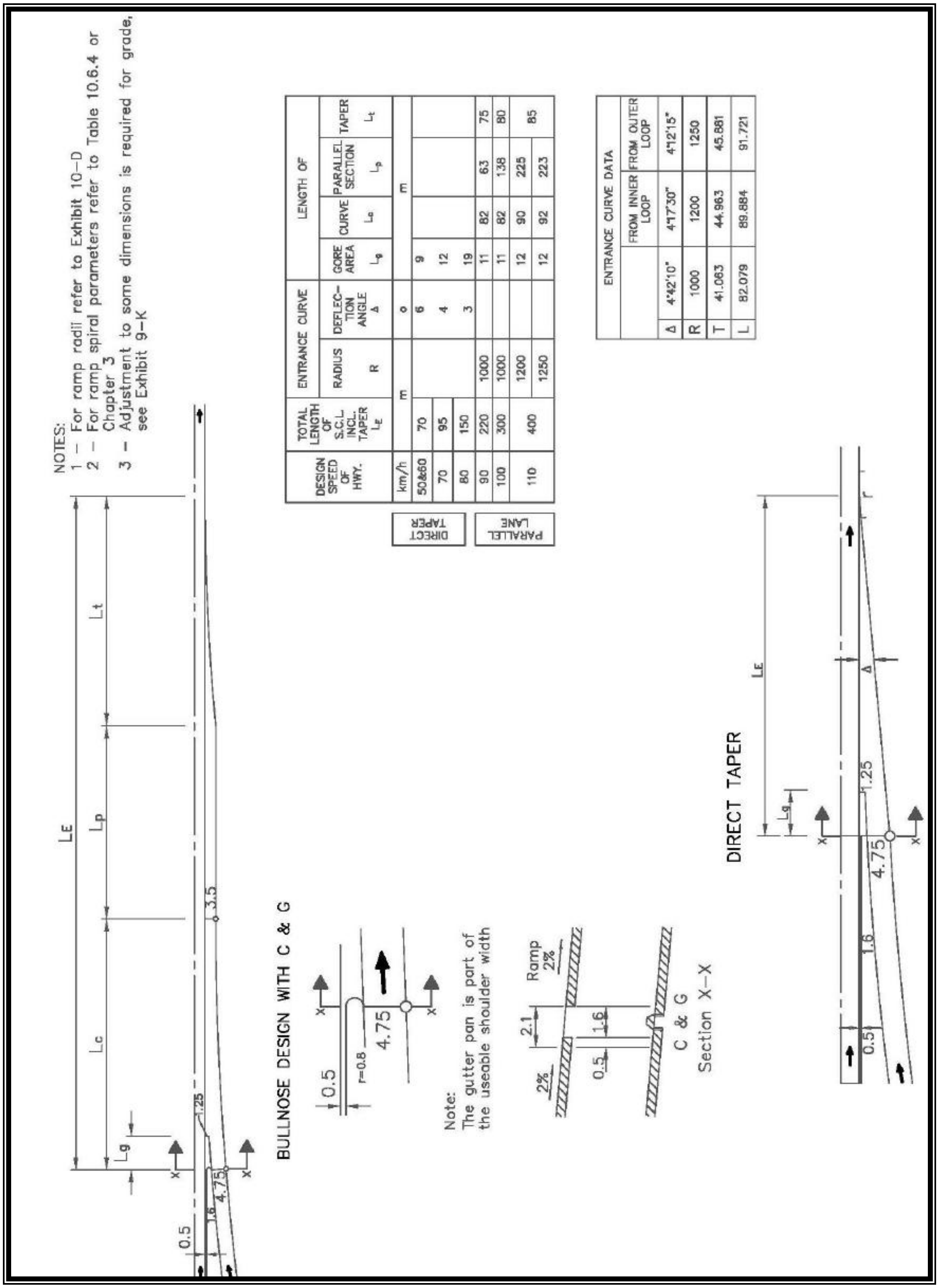


Exhibit-10AC

Single-Lane Crossing Road Entrance Terminal



NOTES:
1 – For ramp radii refer to Exhibit 10–D
2 – For ramp spiral parameters refer to Table 10.6.4 or Chapter 3
3 – Adjustment to some dimensions is required for grade, see Exhibit 9–K

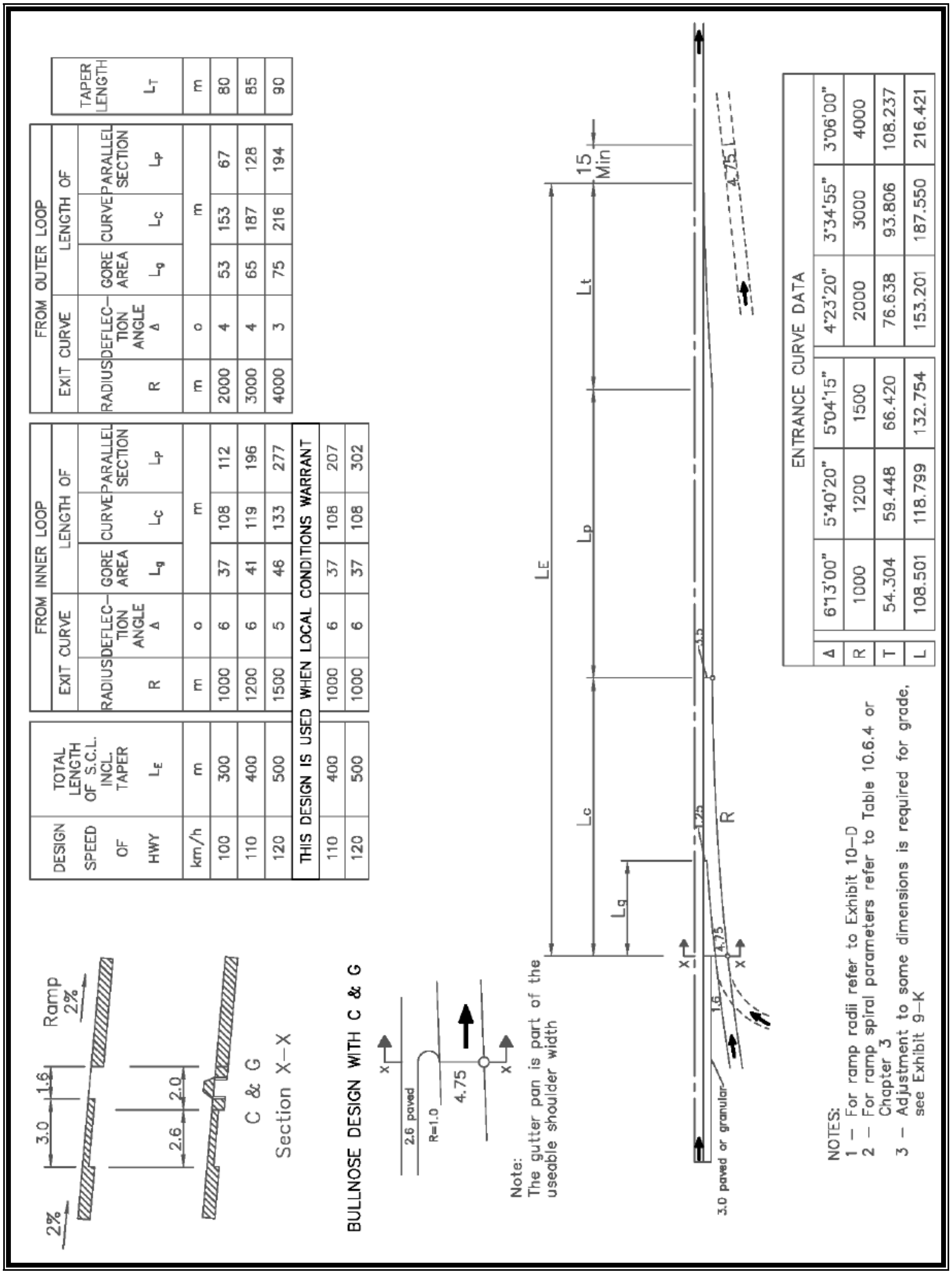
	DESIGN SPEED OF HWY.	TOTAL LENGTH OF S.C.L. INCL. TAPER L_E	ENTRANCE CURVE RADIUS R	ENTRANCE CURVE DEFLECTION ANGLE Δ	LENGTH OF GORE AREA L_g	LENGTH OF CURVE L_c	LENGTH OF PARALLEL SECTION L_p	LENGTH OF TAPER L_t
	km/h	m	m	°	m	m	m	m
DIRECT TAPER	50&60	70		6	9			
DIRECT TAPER	70	95		4	12			
DIRECT TAPER	80	150		3	19			
PARALLEL LANE	90	220	1000		11	82	63	75
PARALLEL LANE	100	300	1000		11	82	138	80
PARALLEL LANE	110	400	1200		12	90	225	85
PARALLEL LANE	110	400	1250		12	92	223	85

ENTRANCE CURVE DATA

		FROM INNER LOOP	FROM OUTER LOOP
Δ	4°42'10"	4°17'30"	4°12'15"
R	1000	1200	1250
T	41.063	44.963	45.881
L	82.079	89.884	91.721

Exhibit-10AD

Single-Lane Freeway Entrance Terminal



DESIGN SPEED OF HWY	TOTAL LENGTH OF S.C.L. INCL. TAPER L_E	FROM INNER LOOP: EXIT CURVE RADIUS R	DEFLECTION ANGLE Δ	LENGTH OF: GORE AREA L_g	CURVE L_c	PARALLEL SECTION L_p	FROM OUTER LOOP: EXIT CURVE RADIUS R	DEFLECTION ANGLE Δ	LENGTH OF: GORE AREA L_g	CURVE L_c	PARALLEL SECTION L_p	TAPER LENGTH L_T
km/h	m	m	o	m			m	o	m			m
100	300	1000	6	37	108	112	2000	4	53	153	67	80
110	400	1200	6	41	119	196	3000	4	65	187	128	85
120	500	1500	5	46	133	277	4000	3	75	216	194	90
THIS DESIGN IS USED WHEN LOCAL CONDITIONS WARRANT												
110	400	1000	6	37	108	207						
120	500	1000	6	37	108	302						

ENTRANCE CURVE DATA

Δ	6°13'00"	5°40'20"	5°04'15"	4°23'20"	3°34'55"	3°06'00"
R	1000	1200	1500	2000	3000	4000
T	54.304	59.448	66.420	76.638	93.806	108.237
L	108.501	118.799	132.754	153.201	187.550	216.421

NOTES:
1 – For ramp radii refer to Exhibit 10–D
2 – For ramp spiral parameters refer to Table 10.6.4 or Chapter 3
3 – Adjustment to some dimensions is required for grade, see Exhibit 9–K

Exhibit-10AE

Two-Lane Freeway Entrance Terminal

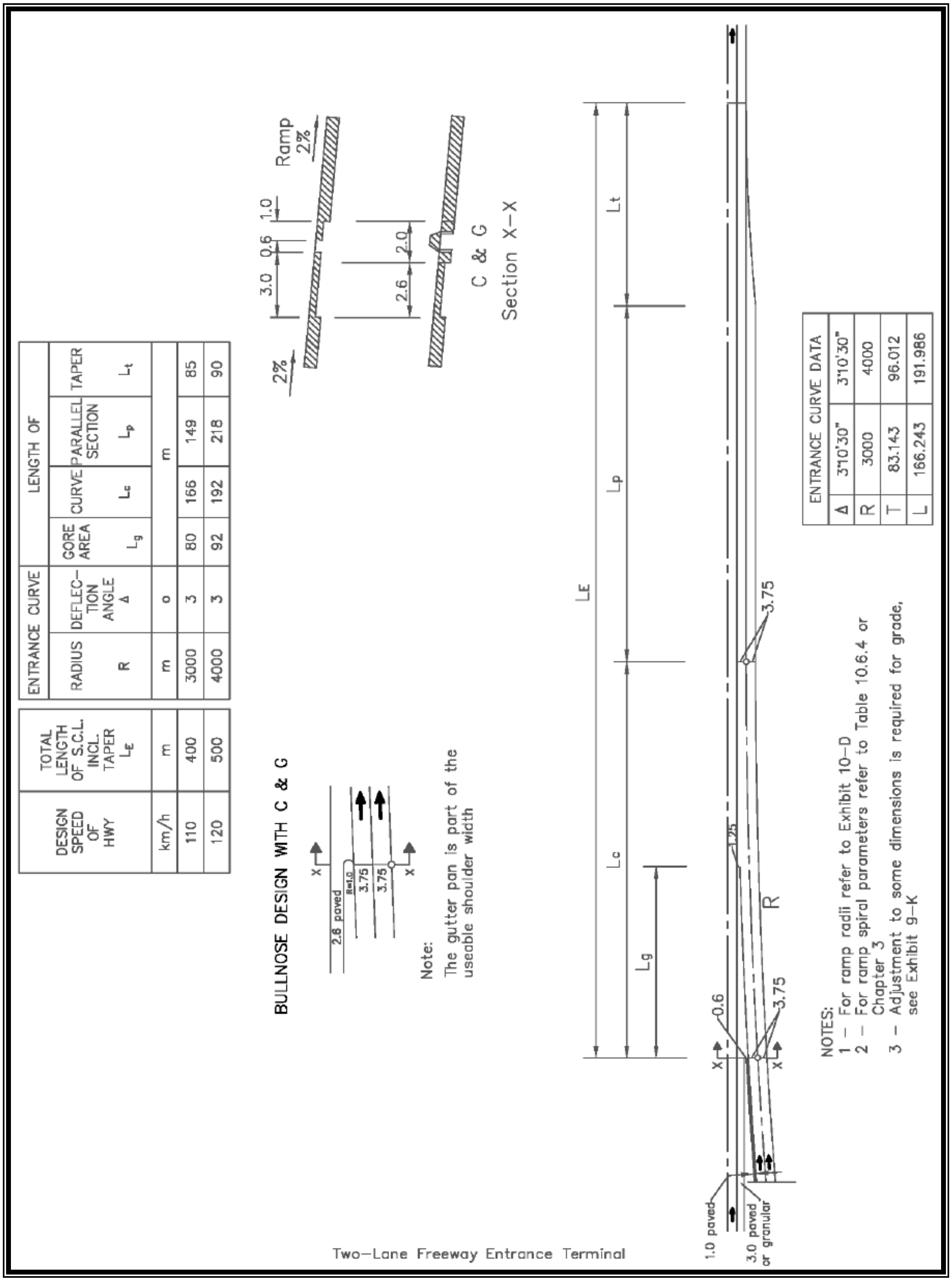


Exhibit-10AF
Major Fork

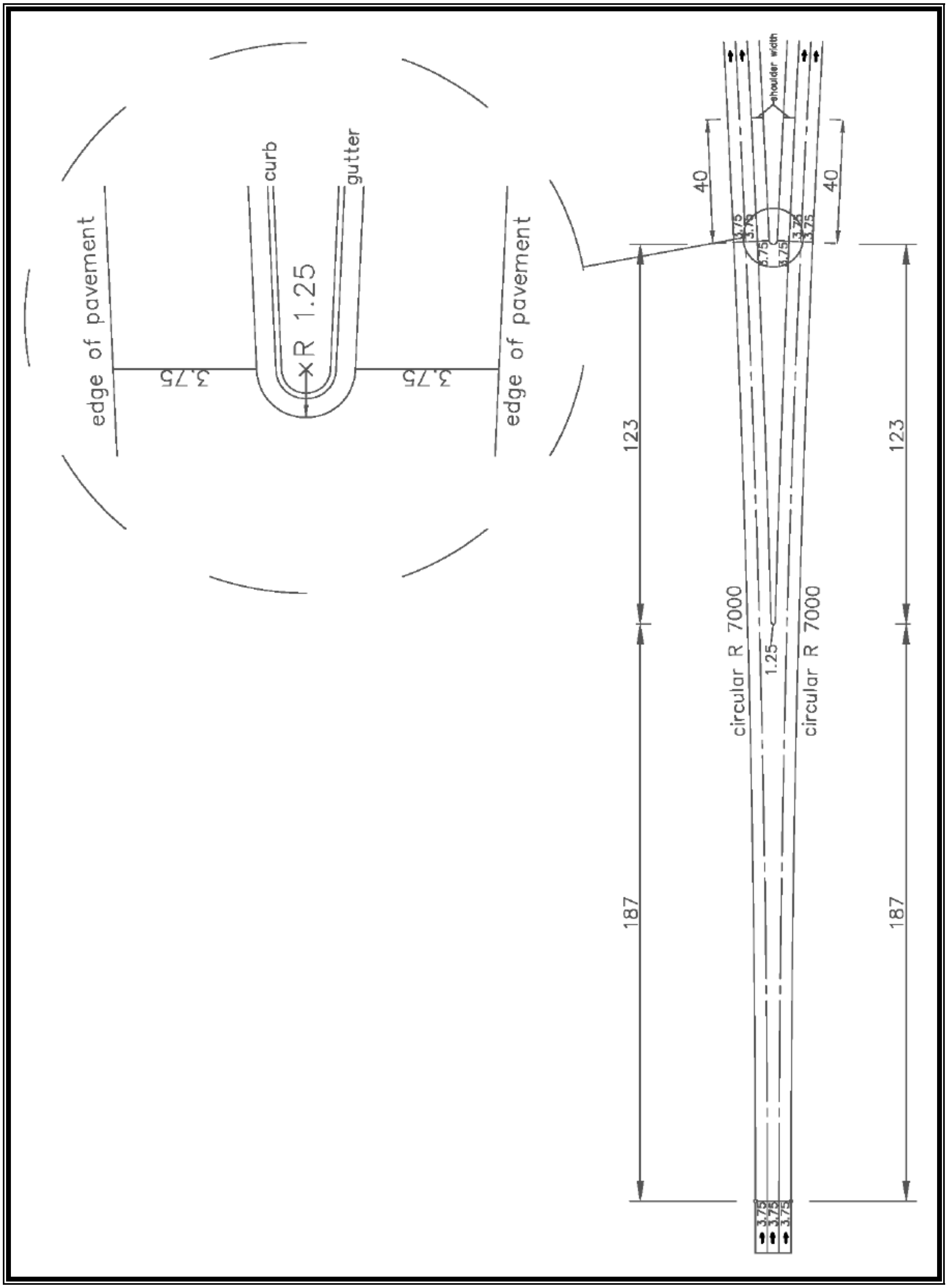


Exhibit-10AG

Parclo A-2 Crossing Road Terminal

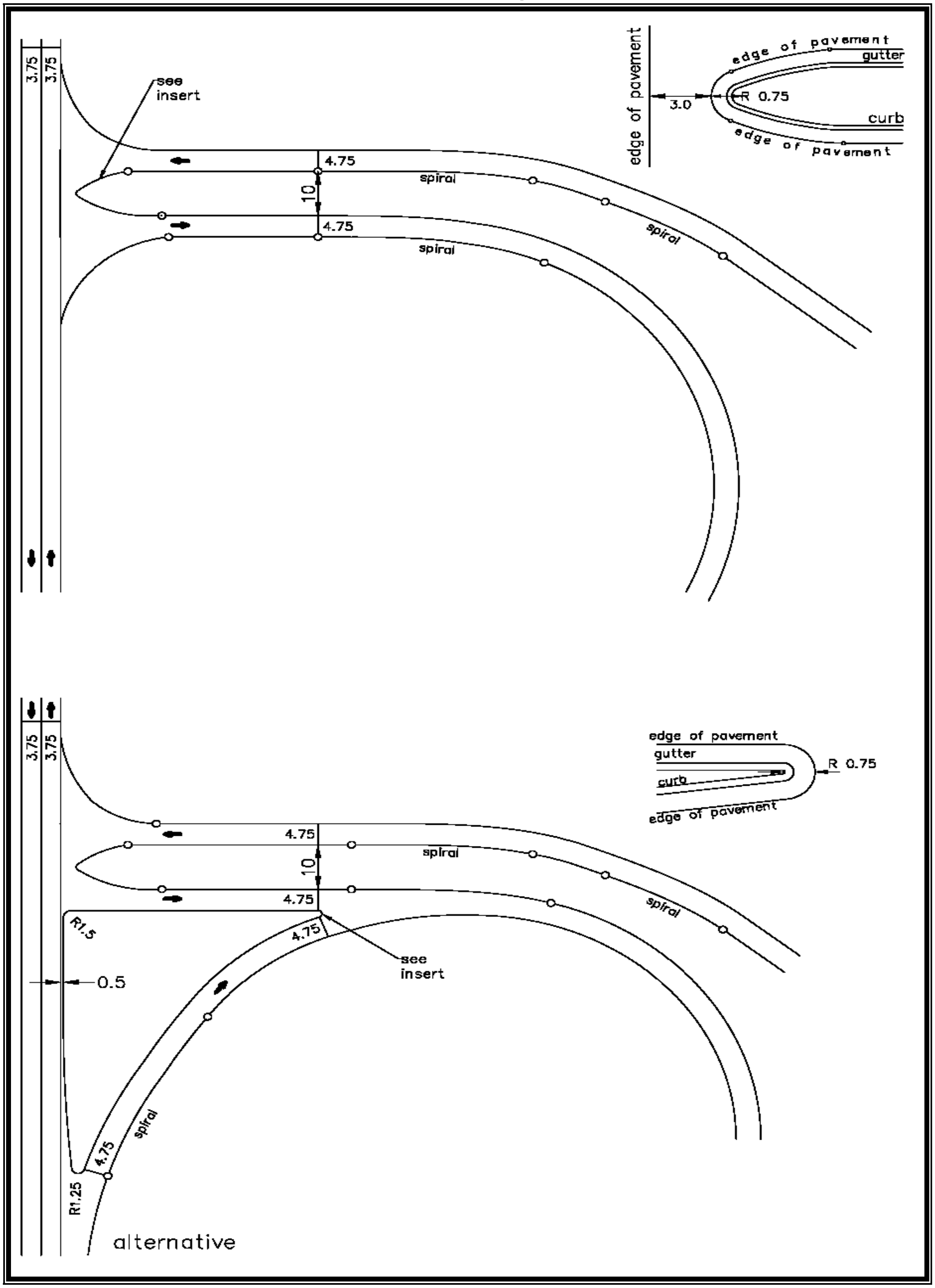


Exhibit-10AH

Parclo A-4 Crossing Road Terminal, One Left-Turning Lane

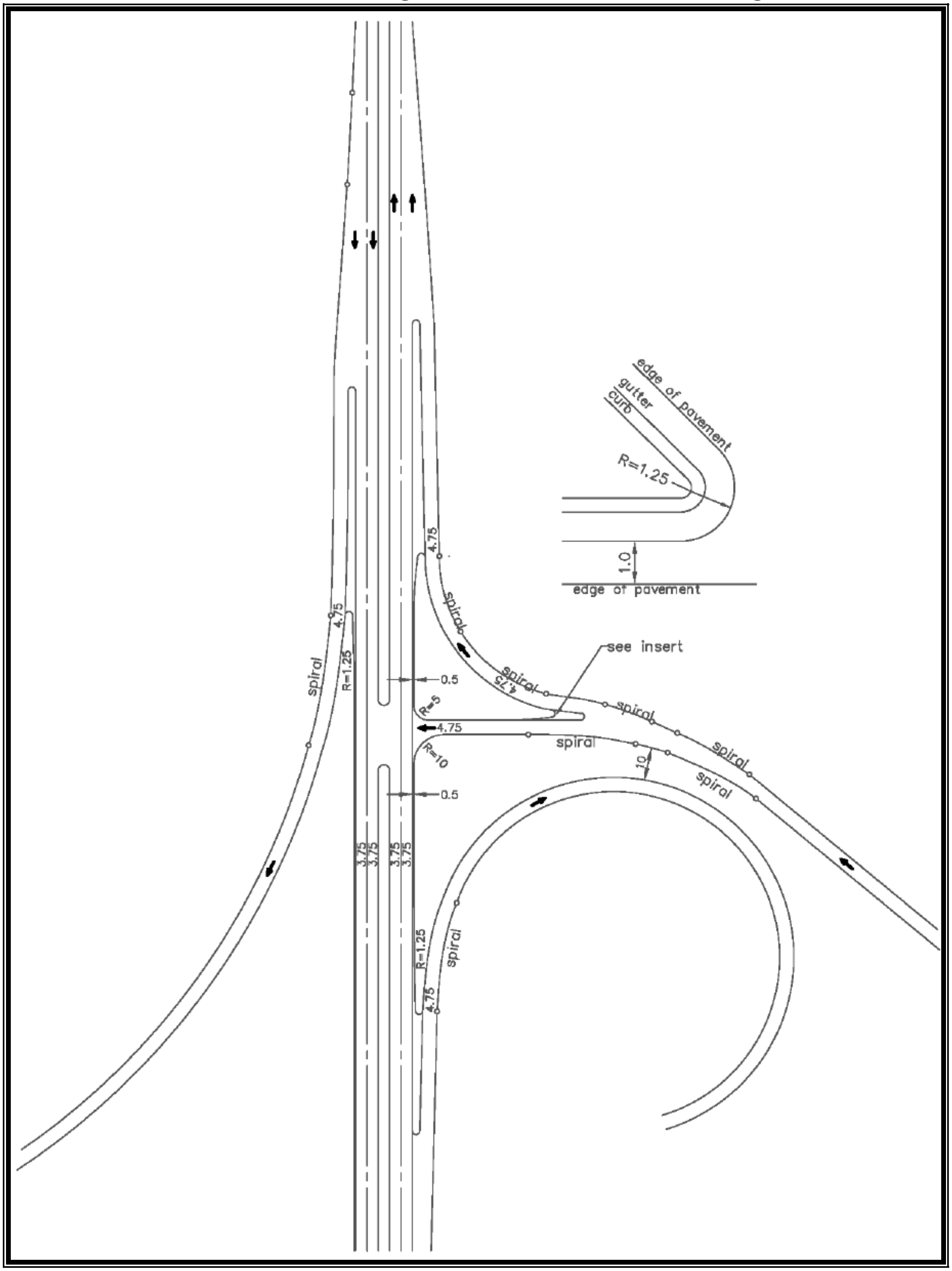


Exhibit-10AI

Parclo A-4 Crossing Road Terminal, Two Left-Turning Lanes

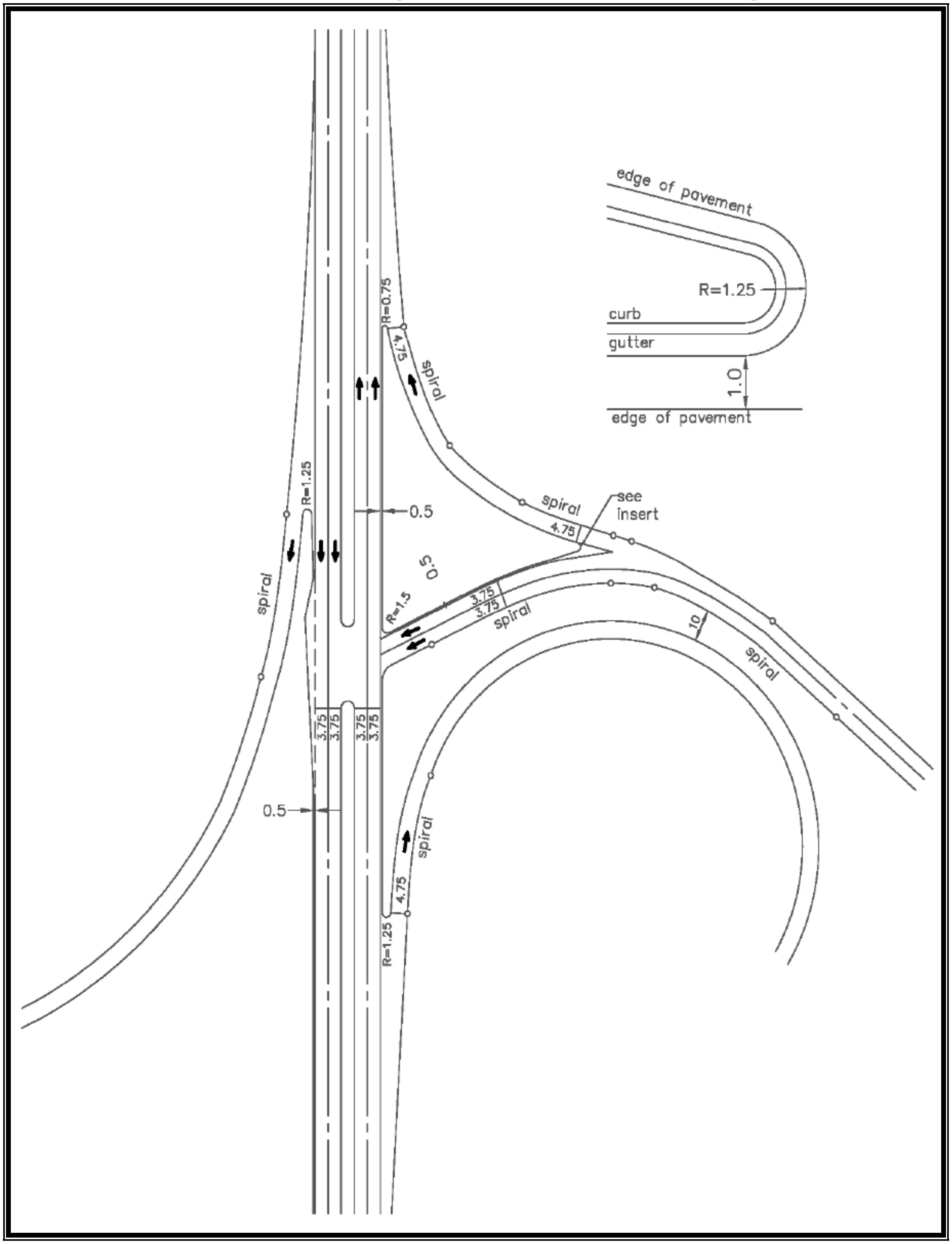


Exhibit-10AJ

Parclo B-2 Crossing Road Terminal

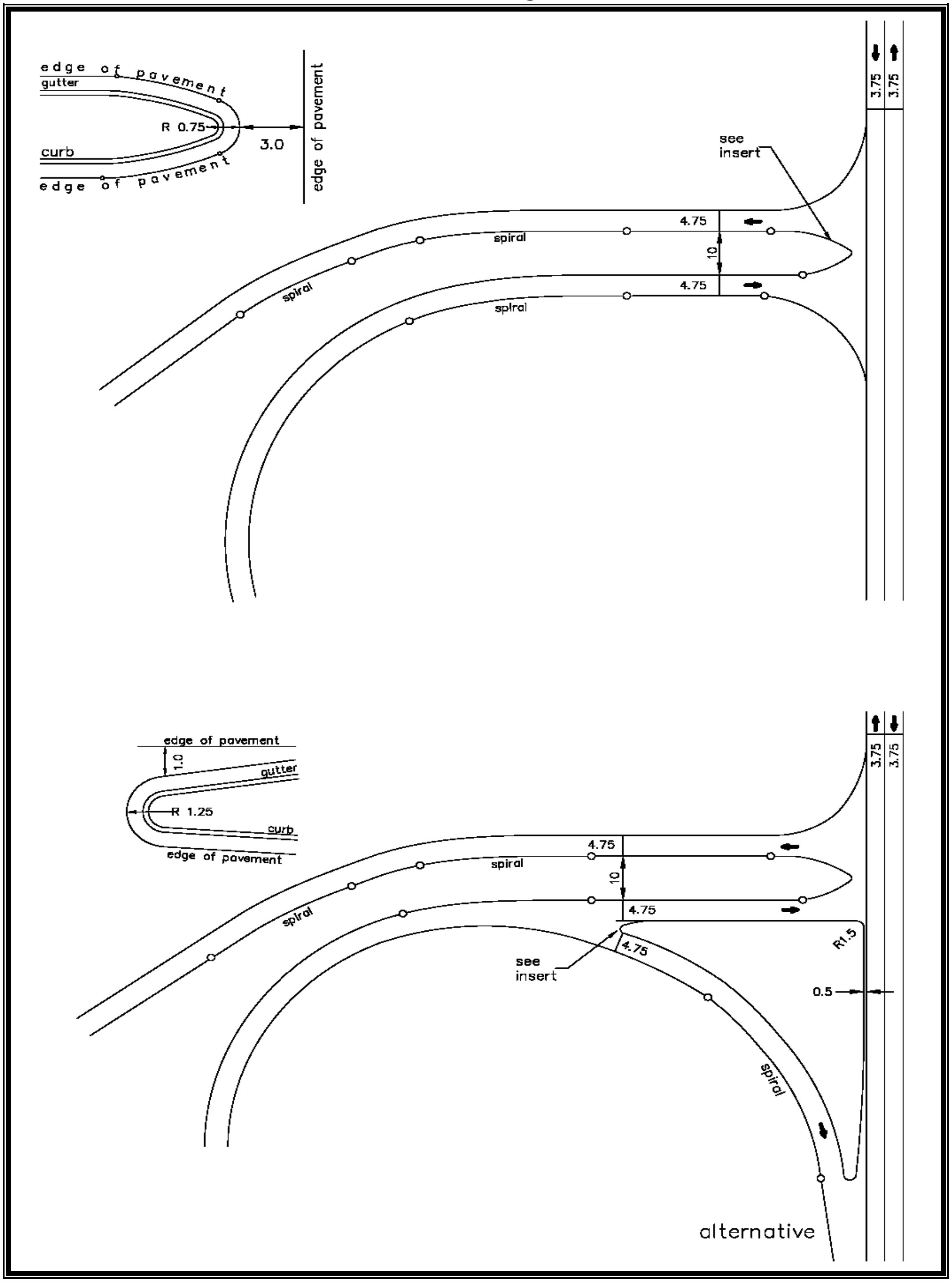
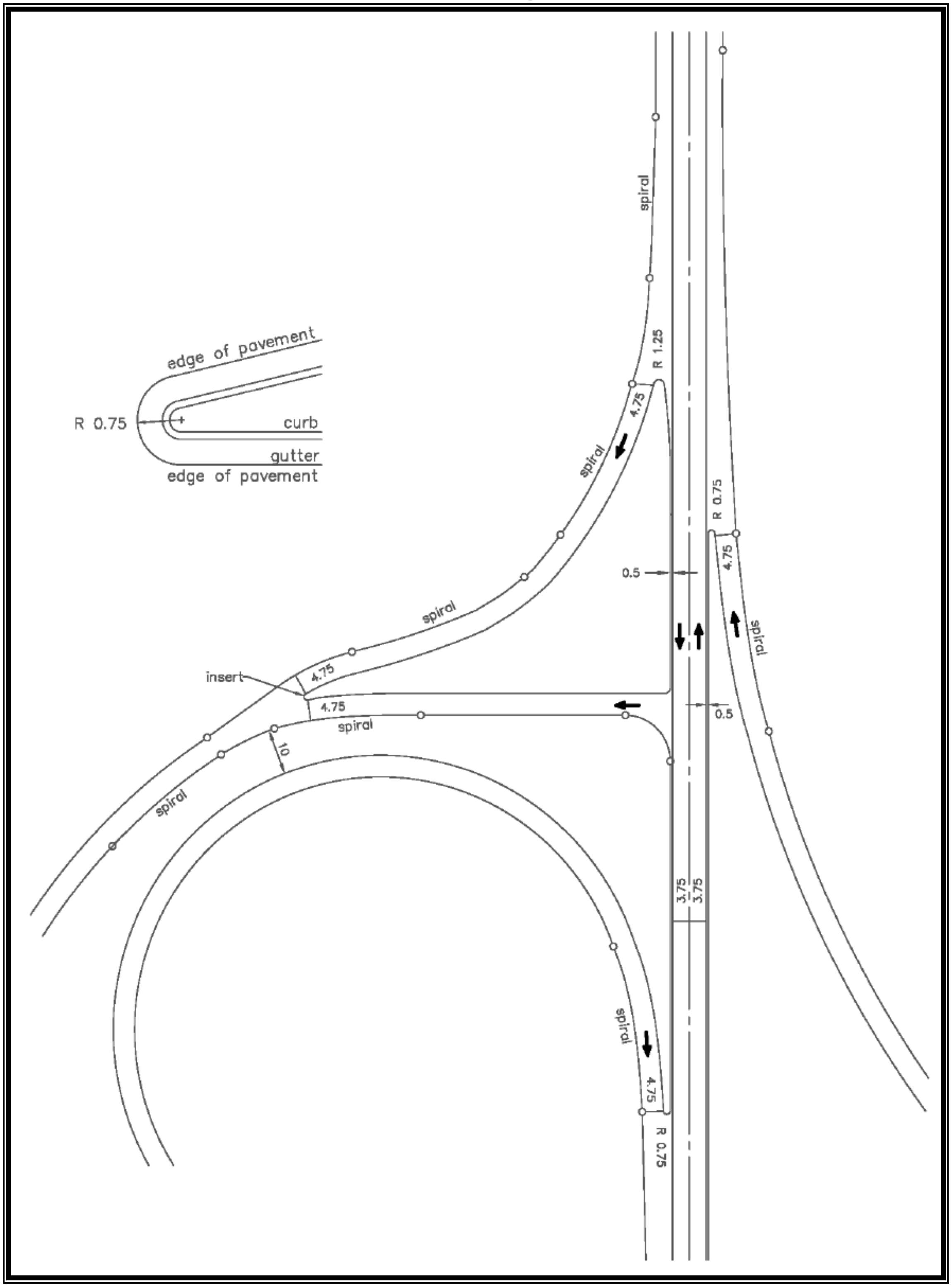


Exhibit-10AK

Parclo B-4 Crossing Road Terminal



ADDITIONAL GUIDANCE

The following additional Guidance regarding Collector-Express and Transfer Lane configuration is Applicable for Chapter 10 – Interchanges:

COLLECTOR LANES

General

Collector lanes are separate from and parallel to the express lanes and perform the function of collecting and distributing traffic between arterial roads and the express lanes. Collector lanes in terms of classification are freeways, having full control of access, no at-grade intersections and interchanging with crossing arterial roads with normal freeway-arterial type interchanges. Geometric design features and characteristics are essentially those of a freeway, however, distribution to and from the through lanes is via transfer lanes which generate a number of left exits and entrances on the collector lanes.

A separated highway system using the express and collector lanes aims to allow for more efficient use of the highway which helps to lower overall emissions through efficient travel. Express lanes allow vehicles to remain at more constant speeds without weaving in and out of traffic. This can lead to less braking and speed variability in those lanes and hence the reduction of emissions from the vehicles in express lanes. Collector lanes aim to accommodate vehicles entering or exiting the highway and serve the same purpose of allowing for more efficient travel in the express lanes.

Benefits

Collector lanes normally have two or three basic lanes in each direction, which when added to a normal three or four basic lane in each direction on the express lanes, provide a total capacity of five to seven basic lanes in each direction. Spreading large numbers of basic lanes on separate roadways instead of a single roadway has some advantages.

Traffic on roadways of not more than four basic lanes is always within one lane of a shoulder in case of emergency. With five or more basic lanes, traffic has to change at least two lanes to reach a shoulder for an emergency stop. This is hazardous both for the vehicle requiring the shoulder and other traffic on the roadway.

Traffic on the express lanes of an express-collector system is through traffic on relatively long trips. Transfer lanes to and from the collector lanes are relatively infrequent and therefore, the through traffic is comparatively uninterrupted by entering and exit traffic. Weaving manoeuvres associated with entering traffic and exiting traffic are confined to the collector lanes.

Design Features

Design speed and other design criteria for collector lanes are the same as for the adjacent express lanes. Geometric design features of alignment, profile and cross section elements should meet the same standards as those for the express lanes. The principles of good lane balance, maintenance of basic lanes and the dimensions of ramps terminals should be applied.

Collector lanes are separated from the express lanes carrying traffic in the same location by an outer separation. An outer separation is similar to a median in design but different in function, in that it separates traffic travelling in the same direction. Outer separations normally contain two shoulders and a barrier to prevent traffic crossing between the two roadways or at least a fence to discourage it. Because collector lanes have left exits and entrances to transfer lanes, lane continuity is an important consideration. This is defined and discussed in *Chapter 3 – Alignment and Lane Configuration* and the design of collector lanes should be carefully checked to ensure that continuity of basic lanes is maintained. Where continuity is lost, it can usually be corrected by the application of auxiliary lanes between successive entrance and exits, illustrated in *Figure 3.7.1 of Chapter 3 – Alignment and Lane Configuration.*

The complexity of roads entering and exiting collector roads from both right and left, makes proper signing critical to the successful operation of these facilities. Before finalizing the location of transfer lanes, interchanges and ramps, it should be checked to ensure that it can be adequately signed and readily understood by the driver, particularly the unfamiliar driver. Advance signing well ahead of exits is essential for the smooth operation of collector roads.

Transfer Lanes

Transfer lanes between collector roads and express lanes are similar to ramps between freeways, in that they carry traffic between two controlled access facilities. Transfer lanes are relatively short and level unless they are part of a basket weave configuration between collector lanes and express lanes. Like ramps they consist of three elements, the exit terminal, the entrance terminal and the section between the two bullnoses or transfer lanes proper.

Whereas the design speed of a ramp is normally less than that of the associated freeway, the design speed of a transfer lane should be the same as that of the freeway, since the driver travelling between the two roadways does not adjust speed to make this manoeuvre.

Transfer roadways normally have two lanes. Although design volumes may indicate that one lane is sufficient, it is generally considered that two lanes are required to provide the necessary degree of flexibility to accommodate a variety of traffic patterns, for traffic moving between collector and express lanes. Transfer lane widths are the same as those of through freeway lanes and shoulders on both sides of the transfer lanes should be maintained.

Alignment and profile geometrics should be consistent with design speed, discussed above. Visibility to exit bullnoses on transfer lanes is important and decision sight distance to exit terminal bullnoses suggested in *Section 10.6.3.4 of Chapter 10 – Interchanges* applies.

Transfer lanes are usually preceded by or followed by a weaving section on the collector lanes. This is illustrated in **Exhibit 10-AL**. Since the transfer lanes are in effect left exits and entrances, the weaving induced on the collector lanes is more intensive than under the more common condition in which a right entrance is followed by a right exit.

In the case weaving is between the two ramp movements and the through freeway traffic is not part of the weaving manoeuvre. In the case of the transfer lanes on the collector lane much, if not all, of the traffic on the transfer lane is weaving with the through collector lanes traffic. This calls for additional weaving length over that of the normal right entrance/right exit condition. These weaving sections merit detailed analysis applying the techniques provided in *Provincial Engineering Memorandum; HSBM DCSO # 2016-05 dated March 31, 2016 for Capacity Analysis Manual – January 2016.*

Typical designs for the transfer roadways are shown in **Exhibit-10AM** and **Exhibit-10AN**.

Basket Weaves

A basket weave consists of a pair of transfer lanes crossing each other and separated vertically. The successful operation of the basket weave depends on the geometrics of the alignment and profile. Drivers expect to be able to maintain speeds close to the freeway speeds when transferring between express lanes and collector lanes in a basket weave. For this reason, design speed in the basket weave should be not less than 10 km/h less than the design speed of the express and collector roads.

Exhibit-10AL
WEAVING ON COLLECTOR LANES DUE TO TRANSFER LANES

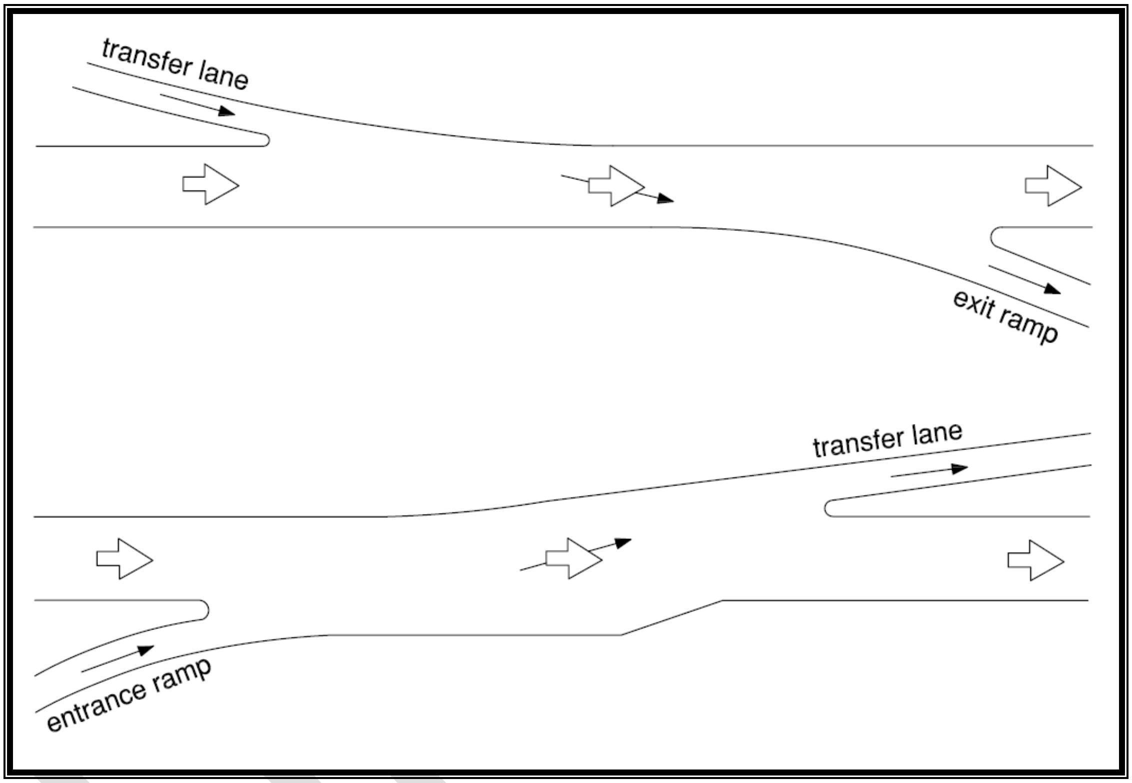


Exhibit-10AM

TRANSFER ROADWAY: COLLECTOR TO EXPRESS LANES

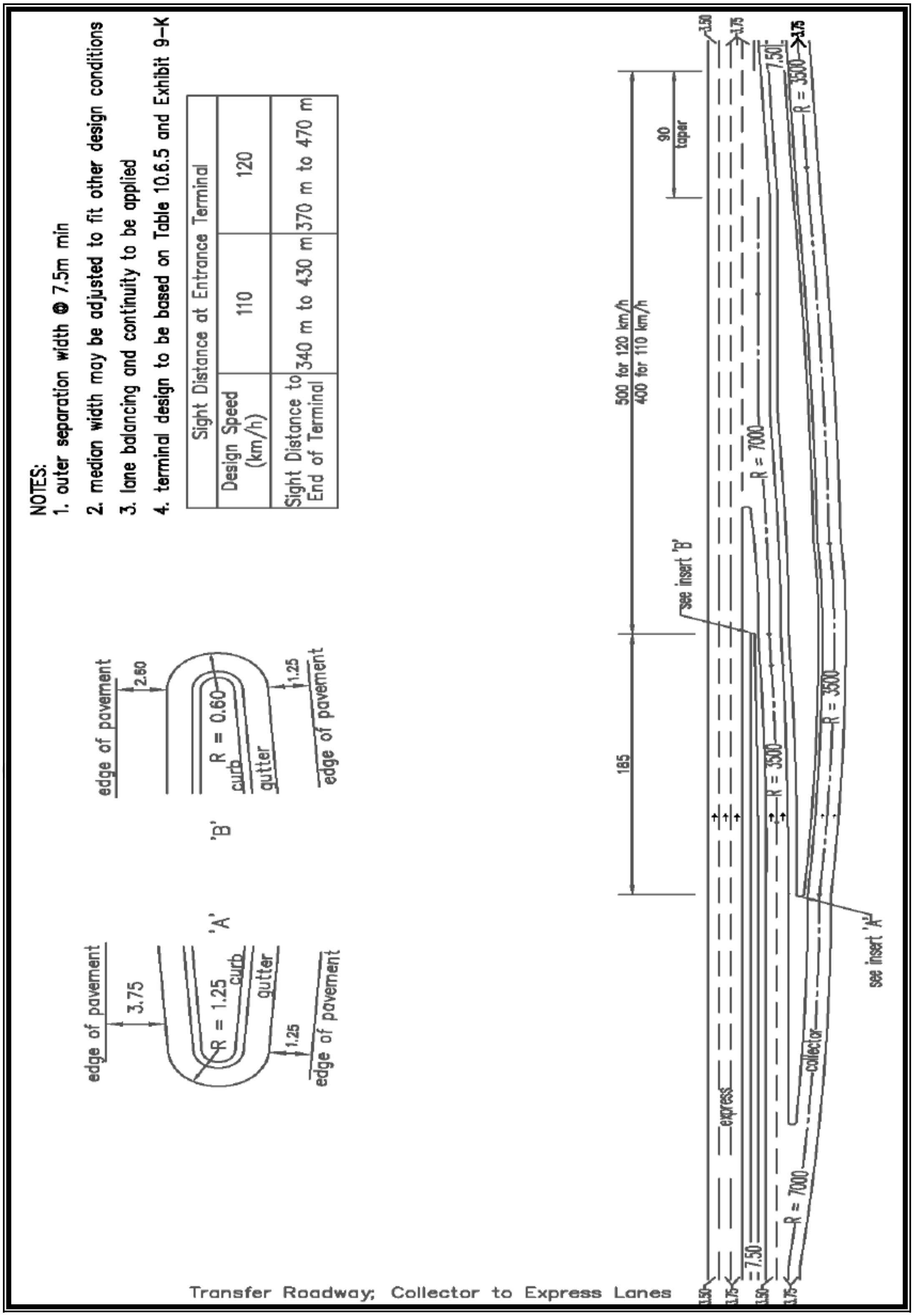
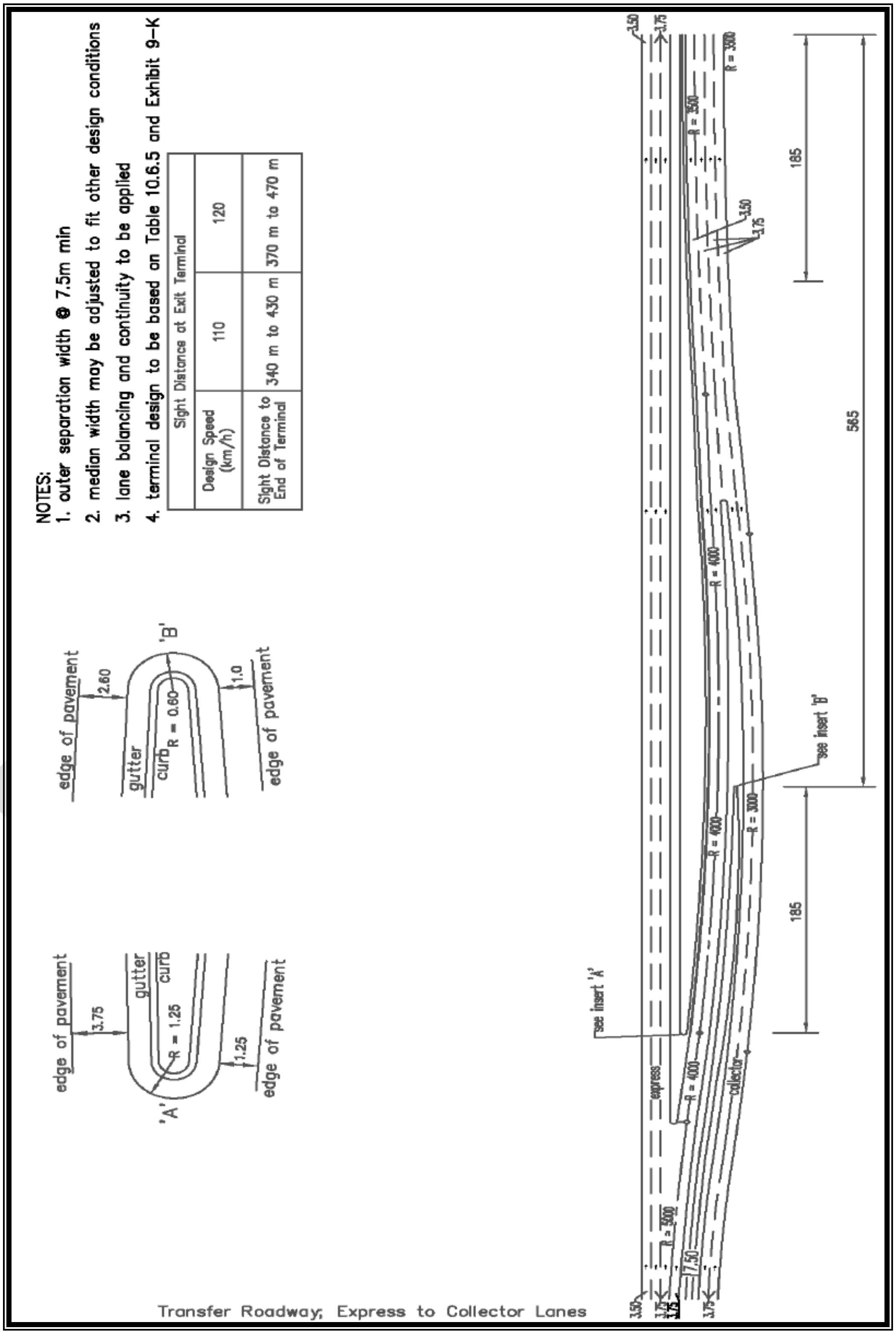


Exhibit-10AN

TRANSFER ROADWAY: EXPRESS TO COLLECTOR LANES



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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 11 for Chapter 11

Special Roads

June 2023

MTO Design Supplement
Appendix 11 for Chapter 11
Special Roads

This chapter is applicable with the following additional Guidance.

- All information contained within the chapter is only to be considered for roadways with AADT ≤ 200. For roadways with AADT > 200 see Chapters 1 to 10 of TAC GDG along with Appendix 1 to 13 except 11 as applicable.

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Appendix 12

Managed Lanes

June 2023

All of the following material is additional guidance as the TAC GDG does not contain a chapter on Managed Lanes.

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12.1 Introduction and Organization of Chapter

The transportation system in Ontario is rapidly changing due to traffic demand constantly increasing. When traffic demands cannot be accommodated by the existing roadways, travel times and the cost of congestion increase, the air quality worsens, and more greenhouse gas emissions are released. Meanwhile, the space required to expand the transportation network and government funds are limited. Incorporating managed lanes into transportation planning is a useful strategy to address some of the issues faced by corridors with heavy congestion.

Transportation is one of the largest sources of emissions in Ontario. Reducing transportation emissions through influence of mode choices and encouraging the transition of existing drivers to transit, carpooling, cycling and walking, highlights an important role of the implementation of managed lanes to alleviate congestion on the highways.

The purpose of this chapter is to present technical guidance and recommended practices for managed lanes to assist transportation professionals as they consider planning and the implementation of managed lane-facilities within highway corridors.

The chapter is organized in eleven (11) sections and additionally contains a list of references reviewed during the preparation of relevant material included in this chapter. Below is a brief summary of the topics covered in each section:

- Section 1 primarily includes definitions and types of managed lanes,
- Section 2 outlines managed lane strategies for Ontario,
- Sections 3 and 4 include planning and operational considerations for the implementation of managed lanes, including HOV alternatives,
- Section 5 outlines specific design guidelines for different types of managed lanes,
- Section 6 addresses the safety implications of managed lane cross-sections,
- Section 7 includes traffic control systems for the implementation of managed lanes and/or toll lanes,
- Section 8 includes performance monitoring and enforcement of managed lanes,
- Sections 9 and 10 include illumination and maintenance aspects for managed lanes,
- Section 11 discusses the provisions of transit facilities within managed lane corridors.

12.1.1 Managed Lanes Overview and Definitions

12.1.1.1 Managed Lanes (ML)

Managed lanes are designated lanes within the highway right-of-way where traffic is managed to improve congestion by restricting vehicle eligibility, limiting facility access, or in some cases, collecting variably priced tolls. Examples of managed lanes include High Occupancy Vehicles (HOV), High Occupancy Toll (HOT), Express Toll, Bus Only Lanes or Bus Reserved Lanes and Truck Only Lanes (**Section 12.1.1.3**).

12.1.1.1.1 Benefits of Managed Lanes

- Provide more reliable and predictable travel times for all vehicles in managed lanes, including buses.
- Offer drivers a choice of travel options, including using carpool lane with a toll that is set according to how heavy traffic is, or use of carpool lane for drivers with two or more people.
- May increase safety by removing commercial motor vehicles and transit vehicles from main traffic flow.
- Improve air quality by reducing the time vehicles idle on freeways.
- Create better highway connectors and transitions to move vehicles more efficiently.
- Could provide toll revenue.
- Encourage transit and carpool use.

12.1.1.1.2 Success of Managed Lanes

The important prerequisite condition necessary for managed lane demand to materialize is the presence of recurring traffic congestion. Managed lanes are a congestion management strategy and have benefits that are only fully realized in areas of frequent traffic congestion that causes significant travel time delays and uncertainty over trip time.

There are implicit conditions that should exist for managed lanes to be considered viable. These include:

- Recurring congestion generally defined as level of service [LOS] D or worse, or average travel speeds 40 – 50 km/hr below posted speed limits, within a corridor for a significant period. A volume to capacity (V/C) ratio of 0.85 is selected as an applicable threshold consistent with a highway planning LOS of D (according to the Highway Capacity Manual (HCM)). Corridors with V/C of 0.85 or higher during AM Peak direction can be identified as a qualified corridor for managed lanes.

- The total delay times (from 6am to 9pm) for all vehicles/vehicle occupants or the standardized average delay time for vehicle/vehicle occupant could be used also to select sections of the roadways with the highest potential for improvements and highest potential benefits.
- Lack of available resources (right-of-way, funding and environmental support) to address capacity needs. Interest and ability to minimally increase or alter existing roadways by managing their use for specific dedicated purposes to ensure that a high level of service can be provided as an alternative to recurring congestion.
- Consideration of managed lanes within the overall framework of congestion management and TDM strategies (i.e., managed lanes are not a stand-alone solution)

12.1.1.2 Suitability of Corridors for Managed Lanes

12.1.1.2.1 Congested Corridors

Recurring congestion within a corridor or segment of a corridor during the defined (AM and/or PM) peak periods is a key requirement for considering any type of managed lanes. Recurring congestion is generally defined as a breakdown in traffic flow and a reduction in speed as demand approaches or exceeds capacity resulting in increased air pollution and greenhouse gas emissions.

Given that any qualified section is part of a larger corridor, and the importance of having a ML network, a section of a corridor would be considered qualified even if uncongested, but critical to the continuity and connectivity of the ML network. Adding or removing the connectivity of a ML can impact the operations of the ML network and the overall performance of the corridor or network.

12.1.1.2.2 Vehicle Eligibility

The vehicle eligibility for a ML network option defines the minimum number of occupants required for a vehicle or the vehicle requirements to be allowed to use the ML. For high-occupancy lanes, the key evaluation is to identify whether HOV2+ or HOV3+ should be the governing policy. For example, a threshold of a minimum of 500 vehicles per hour per lane (vphpl) has been used as a minimum volume requirement for HOV lane identified in a several studies in North America.

In Ontario, most HOV lanes can be utilized by vehicles with at least two people (including the driver) in one of these vehicles:

- Cars.
- vans or light trucks.
- commercial motor vehicles less than 6.5 meter long with a gross weight of 4,500 kg or less.
- towing a trailer if the combined vehicle-trailer length is less than 6.5 meters.

Also, the following vehicles have unrestricted access to HOV lanes, no matter how many passengers they are carrying:

- buses of all types.
- licensed taxis and airport limousines (until June 30, 2020).
- emergency vehicles.
- vehicles with Ontario green licence plates
- motorcycles

12.1.1.3 Types of Managed Lanes

Managed Lanes (ML) have become more prevalent on highway facilities with various types as outlined below.

12.1.1.3.1 HOV Lanes

HOV lanes have been the most widely applied form of managed lanes. Incorporating high-occupancy vehicle (HOV) facilities into the freeway system is one means of improving the operational conditions on freeways. HOV lanes help move more people faster on highways by influencing/encouraging people to carpool or take transit. This is important during peak travel times when other lanes are slow and congested. The HOV lanes can also provide a congestion-free bus route, allowing operators to provide faster, more reliable service.

HOV Lanes Benefits to Motorists

- Save time**:** avoid congestion and arrive at destination quicker.
- More reliable commute: avoiding congestion and a more consistent commute time.
- Save money: it costs less to ride a bus or to share a ride than to drive alone.
- Conserve fuel: waste less fuel than sitting in traffic.
- Less stress: letting someone else drive or taking turns.

HOV Lanes Benefits to Highway System

- Manage congestion: HOV lane can handle a lot of growth in demand. Once a general-purpose lane reaches capacity, it becomes congested and moves fewer people.

- Make better use of infrastructure: highway lane capacity varies from 1,500 to 2,200 vehicles per hour. A lane full of buses and carpools moves many more people than a general traffic lane.
- Transit priority: Buses and transit riders have priority. A single transit bus can replace 57 single-occupant cars.
- Provide choices: HOV lanes make carpooling and public transit more effective and reliable choices for commuters.
- Support mobility: Taxis and airport limousines that use HOV lanes can return to duty faster after dropping off or arrive sooner to pick up.
- Support electric vehicles: Vehicles with Ontario green licence plates are allowed on all provincial HOV lanes - even with only one person in the vehicle.
- Lower greenhouse gas emissios in an effort to meet 2030 emission targets.

In December 2005, MTO opened its first HOV Lanes on sections of Highways 403 and 404. By 2031, a network of more that 300 km of HOV lanes are planned on 400-series highways as part of MTO HOV Lane Network for the Greater Golden Horseshoe area.

In Ontario, HOV lanes are designated under the ***Highway Traffic Act***, pursuant to the High Occupancy Vehicle Lanes Regulation. Occupancy and eligibility may be adjusted over time. In Ontario, there are certain exemptions to the multiple occupancy requirements for HOV lanes. These vehicles are permitted to use the lanes regardless of occupancy. Detailed definitions of exemptions are laid out in the ***Ontario Regulation 620/05: HIGH OCCUPANCY VEHICLE LANES.***

Table 12.1.1 HOV Users

User Groups		
Permitted		Prohibited
Toll/Fee	Non-tolled	
• N/A	• Motor vehicles[1] with at least two occupants[2] • Buses • Exempt vehicles[3]	• Motor vehicle with one occupant • Commercial motor vehicles longer than 6.5 metres

[1] Eligible vehicle must be less than 6.5 metres long with a gross weight of 4,500 kg or less.

[2] Occupancy requirements may be adjusted over time to manage congestion

[3] Exempt vehicles include police vehicles on duty, vehicles owned or leased by the Province of Ontario, vehicles engaged in road construction or maintenance activities, vehicles with green licence plates, taxicabs or limousines.

Effective July 1, 2019, HTA was amended to allow single-occupant motorcycles to access High Occupancy Vehicle lanes (HOV).

12.1.1.3.2 HOT Lanes

Typically, HOT Lanes are HOV facilities that allow lower-occupancy vehicles, such as solo drivers, to use the facilities in return for toll payments, which could vary by time of day or level of congestion. Vehicles with more than one occupant could be exempted from the toll. Most HOT lanes are created within existing general-purpose highway facilities and offer potential users the choice of using general-purpose lanes or paying for premium conditions on HOT lanes.

HOT lanes could be created through new capacity construction or converting HOV lanes to HOT lanes. Since both right of way and construction funds are limited, conversion of existing HOV lanes to HOT operation is the most common approach.

Where HOV lanes are seen to be under-utilized, High Occupancy Toll lanes (HOT) may be considered. HOT lanes permit single occupant vehicles (SOVs) to use HOV lane by paying a toll. The HOT lanes concept is a managed lane that combines HOV with pricing strategies to improve overall facility operations. Previous studies on HOT lanes show that they reduce congestion not only in tolled lane but also in general-purpose lanes.

HOT lanes typically are limited-access separated highway lanes. Separation from the adjacent general-purpose lanes can be achieved by treatments that range in cost, permanence and permeability from a simple painted line to concrete traffic barriers.

HOT lanes often utilize sophisticated electronic toll collection (ETC) and traffic information systems that make variable, real-time toll pricing of non-HOV vehicles possible. Information on price levels and travel conditions is normally communicated to motorists via variable message signs (VMS)~~,~~ providing potential users with the facts they need to decide between utilizing the HOT lanes or the parallel general-purpose lanes that may be congested during peak periods.

HOT Lane Benefits

HOT lanes are intended to provide a variety of benefits to multiple user groups. When applied in conjunction with other management tools and provision of additional lane capacity, HOT lanes have the potential to generate significant improvements in congestion level. Also, HOT Lanes may represent an opportunity for transit agencies as they provide faster travel speeds.

HOT lanes also have a wide range of secondary benefits, including:

- Generate revenues that can be used to support construction of HOT lanes themselves or other initiatives, such as improved transit service;
- Traffic service improvements on congested parallel highway mainline lanes and improving corridor-wide mobility;

- Performance reliability compared to general-purpose lanes during peak periods~~.~~;
- Faster highway trips for express transit services such as bus rapid transit (BRT);
- Environmental advantages such as reducing greenhouse gas emissions and air pollution by providing opportunities to encourage carpooling, improve transit service, and move more people in fewer vehicles at faster speeds; and,
- Improving the utilization of HOV lanes and eliminating potential pressure to convert underperforming HOV lanes to general-purpose use.

Table 12.1.2: Users of HOT lanes

User Groups		
Permitted		**Prohibited**
Tolled	**Non-tolled**	
• Authorized single occupant vehicles	• Motor vehicles[4] with at least two occupants[5] • Buses • Exempt vehicles[6]	• Unauthorized single occupant vehicles • Commercial motor vehicles longer than 6.5 metres

[4] Eligible vehicles must be less than 6.5 metres long with a gross weight of 4,500 kg or less.
[5] Occupancy requirements may be adjusted over time to manage congestion.
[6] Exempt vehicles include police vehicles on duty, vehicles owned or leased by the Province of Ontario, vehicles engaged in road construction or maintenance activities, vehicles with green licence plates, taxicabs or limousines (currently exempt until July 2018).
Effective July 1, 2019, HTA was amended to allow single-occupant motorcycles to access High Occupancy Vehicle lanes (HOV).

Figure 12.1.1 Hwy 403/QEW, HOT Lane Pilot Project in Ontario

12.1.1.3.2.1 Ontario HOT Lanes

The Ministry of Transportation (MTO) first launched High Occupancy Toll (HOT) lanes as a pilot project on the Hwy 403/QEW (16.5 km of the QEW, in both directions, from Trafalgar Road in Oakville to Guelph Line in Burlington, (**Figure 12.1.1**) to test a new way to improve traffic flow and encourage carpooling. This pilot project helped the ministry to plan for a more efficient highway network in Ontario. During the pilot, the ministry explored and tested innovative technology to support HOT lanes, including tolling, compliance and performance.

The ministry approved an amendment to the **Highway Traffic Act, Ontario Regulation 620/05** - High Occupancy Vehicle Lanes (HOV) to extend the pilot allowing single-occupant taxicabs and airport limousines to access the lanes. The amendment; **O. Reg. 244/18 to O. Reg. 620/05** - High Occupancy Vehicle Lanes came into force on April 13, 2018.

The HOT pilot program and supporting retail and distribution system was developed and delivered in less than nine months as an online service. MTO and Service Ontario collaborated to simultaneously develop policy, performance measures and program design, including an online digital retail service. MTO partnered with Service Ontario to develop the public facing online application, administrative back-end console, permit fulfillment process and contact center support for customer service functions.

MTO partnered with the Ontario Ministry of Economic Development and Growth in a Small Business Innovation Challenge providing grants to Ontario-based small and medium enterprises for the purposes of developing prototypes that support automated vehicle occupancy detection. There were few viable options in the marketplace for automated vehicle occupancy detection.

Overall, the pilot helped MTO refine HOT lanes implementation to suit Ontario and ensure they are an effective part of the transportation network. This included investigating the opportunity to include HOT lanes in future highway expansions.

Figure 12.1.2 HOT Lanes Pilot Digital Message Signs

12.1.1.3.3 Express Lanes / Limited Access Lanes

An Express Lane (EL) is a type of managed travel lane physically separated from a general-purpose lane or general toll lane within a roadway corridor. Express lanes are limited-access facilities that typically operate adjacent to general use lanes. The separation technique is one of the key design decisions that influence the feasibility, operations, and constructability of an express lane project.

Express lanes can provide a high degree of operational flexibility, which enables them to be used in actively responding to changes in traffic demands. Express lanes can be located within tolled or non-tolled facilities and can be operated as reversible flow or bi-directional facilities to best meet peak demands.

Limited-Access Lanes limit vehicle access over long stretches of the facility. Limiting access and egress points is a strategy used on provincial highways, however in the context of managed lanes in Ontario it will typically be employed along with another managed lane strategy.

Limiting access to certain points can help reduce occurrence of traffic flow disruptions and weaving issues due to merging and lane changes. All express lane facilities should be constructed to the inside (median side) of the general use lanes to reduce costs and maintain general-purpose lane access to cross streets.

12.1.1.3.4 Bus Lane / Bus Only Lane (BOL)

A bus-lane or a bus-only-lane, is more commonly located on a major roadway on a separate right-of-way. It is usually a component of a Bus Rapid Transit (BRT) system and as a result the terms bus-lane, busway, and BRT are sometimes used synonymously. However, there is a distinction between a lane dedicated to exclusive use by buses and BRT, which may include various operational improvements and station design features to provide high quality service for express bus trips.

Bus operation can be integrated into HOV lanes on freeway corridors that experience high levels of congestion and have high use for bus transit services (**Figure 12.1.3**). Bus-lanes on freeway are usually shared with HOVs and other vehicles since buses use little capacity. The purpose of bus lanes and supporting facilities (e.g., transit stations, park-and-ride lots and direct access treatments) is to provide more reliable bus service by cutting down delays that buses would have incurred in congested traffic environment, thereby increasing service efficiency by allowing more peak trips by the same bus and providing patrons a faster trip.

12.1.1.3.5 Part-Time Shoulder Use / Bus on Shoulder (BOS)

Part-time shoulder use is the conversion of shoulders to travel lanes during some hours of day as a congestion relief strategy. This strategy is also known as temporary shoulder use or hard shoulder running and is typically implemented on freeways to provide additional capacity when it is most needed and preserves shoulders as refuge areas during most of the day.

There are many forms of part-time shoulder use or “shoulder running”; that vary in terms of location of shoulder used (left/right options), vehicle-use options [bus only, high-occupancy vehicle (HOV) only, all vehicles except commercial motor vehicles], operating schedule, and special speed controls. In all options, the use is “temporary” for part of the day, and the lane continues to operate as a refuge/shoulder when not being used for these travel purposes.

Figure 12.1.3 Freeway HOV lane – Bus Rapid Transit (BRT) use for HOV (Hwy 403, Mississauga)

Although part-time shoulder use can be a very cost-effective solution, it is not an appropriate strategy where minimum geometric clearances, visibility, and pavement requirements cannot be met, or if it has an adverse impact on safety. The physical (e.g. lane width and lateral offset to obstructions such as median barriers, guardrails, and bridge rails) feasibility of part-time shoulder use should be evaluated to determine if it is an appropriate option for consideration, and if it is consistent with long-term transportation goals and objectives.

Assessment of safety impacts of part-time shoulder use begins with a review of three or more years of historical collision data, considering the collision type, temporal factors (e.g., time of day, day of week), and location. North American experiences indicate that congestion-related collisions, such as rear-ends, occurring during times when the shoulder is open, are reduced as congestion is reduced. Also, collisions related to erratic driver behavior or sub-standard geometry, such as run-off-road, fixed-object, or sideswipe collisions, increase with part-time shoulder use. Collisions related to right-side ramp-freeway may also increase with right part-time shoulder use. The mere presence of collision types that may increase with part-time shoulder use should not prevent the application of part-time shoulder use, but a

preponderance of those collision types would indicate if a given freeway may be a poor candidate for part-time shoulder use.
Overall, there appears to be a link between changes in congestion and changes in safety performance when shoulders are narrowed to implement part-time shoulder use. The application of the HSM freeway crash prediction models indicate reducing congestion (by increasing capacity) can offset the increase in collisions associated with increasing the number of lanes while reducing lane and shoulder width.

Ontario Regulation 618/05 includes designation of Bus By-Pass shoulders on King's Highways describing all parts of highways (example, Highway No. 417 in the City of Ottawa (**Figure 12.1.4**) which is designated as having paved shoulders for use by a bus operated in accordance with a license issued under the **Public Vehicles Act** and an authorization provided by the Ministry. Also, regulations include all signs marking bus by-pass shoulders with text alternatives and dimensions of signs.

Advantages of placing Bus Rapid Transit (BRT) running way on shoulders:

- Transit vehicles can enter and exit the shoulder whenever necessary to leave or enter the general-purpose lane.
- The investment costs to convert a conventional shoulder to a BRT guideway are relatively low, typically limited to upgrading pavement structure on shoulder and adjustment of stormwater inlets.
- Freeway design standards usually permit high BRT vehicle operating speeds.

The disadvantages of having BRT running way on a freeway shoulder:

- Disabled vehicles on shoulder require that all transit vehicles re-enter the adjacent general-purpose lane.
- Upgrading of shoulder pavement structure to accommodate loadings from BRT vehicles may create delays to freeway traffic during construction work, unless there is enough room in the median to permit lanes to be shifted during construction.
- Extra signage and motorist information are required to explain the use of shoulders by buses.
- Transit vehicles may have to merge into the general-purpose lanes in advance of interchange exits if the bus does not exit at that location.
- Consideration needs to be given in operating policies to possible major speed differentials between buses and other traffic on adjacent congested general-travel lanes.

It is desirable that bus-pass shoulders have a minimum 3.35-meter wide travel lane width, with an additional 0.6-meter wide paved shy distance between the edge of the running way and any obstructions, including but not limited to; piers, sign supports, walls, ditch edges or guiderails., In addition, a 0.6-meter buffer zone between shoulders and adjacent general-purpose lanes is desirable.

12.1.1.3.6 Truck Only Lanes

Truck-only lanes are lanes designated for usage of commercial motor vehicles (CMV). The purpose of truck-only lanes is to separate from other mixed-flow traffic to enhance safety and stabilize traffic flow. Truck-only lanes can be separated using physical barriers or operational measures (e.g., rumble strips, signage, and paint striping) and can be operated during specific hours of the day if appropriate.

Truck-only lanes when implemented and operated appropriately, they can increase commercial motor vehicle productivity, improve overall mobility and safety performance of a transportation system, and contribute to the economic development. Although truck-only lanes offer the potential to address multiple transportation issues, insufficient data and lack of experience with their operation make it difficult to determine their impact.

Truck-only lane implementation is currently not that common in North America., and a decision on the potential implementation of these types of lanes in Ontario has not been decided yet. After policy related issues are finalized and these types of lanes have been approved for consideration of implementation, the following design recommendations are to be considered by designers of managed lanes to accommodate commercial motor vehicles:

- Provide full 3.75 m travel lanes and full width shoulders;
- Use low grades on vertical alignment and avoid use of long downgrades;
- Increase lengths of vertical curves to increase sight distance for commercial motor vehicle drivers;
- Lengthen acceleration lanes to provide commercial motor vehicles adequate space to reach mainline operating speeds;
- Lengthen deceleration lanes to allow commercial motor vehicles to exit from mainline;
- Use larger radii on curves to better account for commercial motor vehicles negotiating multi-curve ramp systems;
- Use adequate lane widening in horizontal curves;
- Provide signing and variable message signing in proper placement for better visibility for commercial motor vehicles;
- Use continuous shoulder rumble strips to alert motor vehicle drivers if they leave their designated lane;

- Use concrete barrier (the most effective barrier type for containing trucks); and barrier curve delineation systems on curves

Figure 12.1.4 Bus on Freeway Right Shoulder (Ottawa)

Figure 12.1.5 Bus on Shoulder in Minneapolis

12.1.1.4 Separation Types

Most concurrent-flow MLs are separated from general-purpose lanes (GP) by a painted stripe (double solid white lines) or narrow buffer. As a result of the proximity of GP and ML traffic, increasing congestion levels on GP lanes may have an adverse effect on ML operations.

This adverse effect on ML operations is referred to as frictional effect. The cause of frictional effect is drivers in stripe or buffer separated MLs observing the slow traffic in adjacent lanes and feeling uncomfortable passing congested GP traffic at a high-speed differentials.

In order to increase the capacity and functionality of the ML facility, design considerations which reduce the potential for frictional effect should be considered. These design considerations could include using a concrete barrier between the GP lanes and MLs to reduce the interaction between the two parallel lane groups.

12.2 Managed Lanes Strategies

Vision: To use managed lanes to provide safe, reliable, predictable travel on Ontario's highways as part of an integrated transportation network.

Managed lanes strategies can pertain to one or more of the following:

1. Pricing - using varying or fixed tolls
2. Eligibility (vehicle/user) – permitting or restricting certain vehicles or occupancy
3. Access control – limiting entry to designated locations

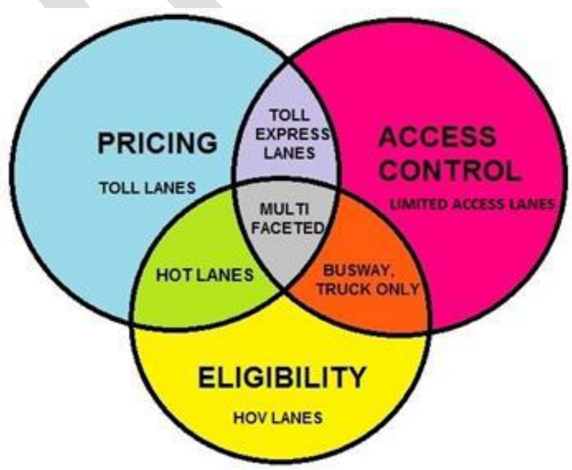


Figure 12.2.1 Managed Lanes Strategy Interdependencies

12.2.1 Goals and Objectives

Goals for the implementation of managed lanes vary by corridor and regional context (**Table 12.2.1**). The following performance goals can help determine conceptual feasibility for both concept designs and operations:

- Sustain or improve mobility, particularly during peak periods.
- Improve roadway efficiency, safety, and reliability.
- Improve air quality and reduce greenhouse gas emissions.
- Promote bus transit and ridesharing.
- Generate revenue.

Table 12.2.1 Managed Lanes Goals and Objectives

GOALS	OBJECTIVES
1) Enhanced Mobility - provide travel options for the efficient movement of people and goods	• Mitigate traffic congestion
	• Optimize vehicle/person/goods throughput
	• Facilitate behaviour change towards more sustainable transport options
	• Provide travel options for all users
2) Integrated program – align with government priorities and plans	• Reduce GHG emissions and improve air quality from mobile sources
	• Increase transit ridership
	• Reduce socio-economic impacts of congestion
	• Foster strong partnerships with communities and service providers
3) Adaptable system – evolve with conditions and environment	• Integrate innovative technologies
	• Optimize traffic flow
	• Provide efficient and intuitive interfaces
	• Adjust to changing trends (e.g., demographics, travel patterns)
4) User-focused service – provide value to users and community	• Provide a positive user experience
	• Prioritize safety for all users
	• Maintain integrity of the network
	• Provide equitable access

12.3 Planning Considerations

Development of managed lanes is one method of improving the efficiency of a road network, by assessing and implementing an inter-connected regional network of multi-purpose reserved lanes that build-on existing plans for high occupancy vehicle (HOV) lanes with potential for high occupancy toll (HOT) lanes. The use of both existing and new lane capacity, as well as shoulders, should be explored, with an emphasis on interconnectivity and more efficient use of available capacity.

12.3.1 Managed Lanes Considerations

Typically, the needs that best characterize managed lane consideration include:

- Manage travel demand growth.
- Support throughout for longer-distance travel.
- Lack of available right-of-way and related resources to meet forecasted demand
- Improving corridor travel mobility and reliability.
- Desire for increased person movement/vehicle throughput.
- More modal choices.
- Increasing access controls.

Historically, managed lane implementation in North America has involved setting aside dedicated lane or lanes, at least during respective peak commute periods, and restricting usage to accomplish desired mobility goals. In Europe, more aggressive lane management is practiced on entire freeways to achieve these same goals for an expanded number of users. Both approaches have distinct advantages and drawbacks from a safety, performance and implementation perspective (**Table 12.3.1**).

12.3.1.1 HOV Lanes

The provision of HOV lanes is a policy decision which stems from the needs of the transportation system and the effectiveness of an HOV lane in helping to resolve those needs. There are sound technical measures which may be considered in the decision-making process, such as cost, time savings, existing usage, etc. However, there are also planning goals, environmental requirements (greenhouse gas reduction & air quality standards) and community interests to be considered.

In this context, the decision to provide an HOV lane could be based on an area wide planning and/or policy commitment to not encourage growth in single occupancy auto travel, or it could be a site-specific response to a congestion situation where an HOV lane is shown to be a better solution than any other alternatives. There is a balance required between an area wide strategy, the needs of the transportation system in that area, and opportunities of a corridor.

Table 12.3.1 Advantages and Disadvantages of Dedicated Lane and Corridor Management

Approach	Advantages	Disadvantages
Dedicated Lanes	• Limited impact to traffic--reserves only a small portion of the roadway to aggressively manage use, and assumes all other lanes may experience congestion regardless of other strategies applied • Keeps at least one lane operating at "free-flow" during congested periods	• Speed differential between segregated traffic streams which often requires physical separation • Not all users can benefit given the limited capacity provided
Managing All Lanes	• Achieves improved mobility benefits for all users • Lower cost than adding new lane capacity	• Requires greater management restrictions (such as more restrictive metering and speed management) and still does not assure a breakdown in LOS during peak demand periods • Can be costly and requires a dedicated and ongoing operation, maintenance and enforcement program

12.3.1.2 HOT Lanes

HOT lanes can be implemented at locations where demand for an existing HOV lane is below its operational capacity and where there is congestion during peak periods on parallel general-purpose lanes. In such cases, additional paying single occupancy vehicle motorists may be allowed to use the facility, with tolls set at levels that maintain desired traffic service standards.

HOT lanes implementation can be a response to the following reasons:

1. HOT lanes assist those carpooling, even if your carpooler cancels at the last minute, you can still pay for its use to make it to work on time.

2. HOT lanes help those riding buses by reducing their travel time and improving transit commute reliability.
3. HOT lanes provide a boost to every driver due to the total highway capacity being increased. A HOT lane moves more vehicles than a standalone HOV lane by ensuring that the lane is more fully used.

12.3.1.3 Part-Time Shoulder Use / Bus On Shoulder

Part-time shoulder use is defined as follows:

- The shoulder is used for travel only during times of day when the adjoining lanes are likely to be heavily congested.
- When not needed as an additional travel lane, the shoulder will be restored to its original purpose as a "shoulder," and the basic physical characteristics of the shoulder are retained and recognizable.

Part-time shoulder use may be used to fulfill any number of "functions," such as:

- Reduce peak-period recurring congestion.
- In lieu of a conventional add-a-lane capacity improvement.
- As an interim treatment while a conventional widening or expansion project works through the planning/design/construction process.
- Increase bus ridership by improving bus travel time and reliability.
- Provide short-term benefits for a minimal cost compared to ultimate solution.
- Mitigate the loss of general-purpose lane capacity if a general-purpose lane is converted to a managed lane such as an HOV lane.

Generally, all these options take advantage of existing shoulders and include a combination of treatments such as left/right shoulder options, vehicle-use options, operating schedules, and special speed controls, as listed below:

Left/Right Shoulder Option

- Right shoulder
- Left shoulder

Vehicle-Use Options

- Open shoulder to transit vehicles only.
- Open shoulder as an HOV lane that permits carpools and transit vehicles.
- Open shoulder as a HOT lane that allows vehicles to pay a toll to use.

- Open shoulder to all vehicles except commercial motor vehicles.
- Open shoulder to slow moving trucks in rural mountainous areas.

Operating Options

- Dynamically open shoulder when certain congestion thresholds are reached (an ATM strategy referred to as “Dynamic Shoulder Use”).
- Statically open shoulder during specified historical peak periods (time of day).

Speed Control Options

- Same speed limit as other lanes (at posted speed limits).
- Same speed as other lanes (at a reduced speed relative to normal posted speed limits).
- Lower speed limit than other lanes.

12.3.2 Freeway Expansion Versus Lane Conversion

Potentially one of the most contentious issues associated with managed lane implementation is whether the managed lane should be a new lane added to the freeway. This question can be answered differently in different situations and a solution appropriate to the specific characteristics of the corridor under study is required.

The options both for and against the "takeaway" approach have strong arguments. The rationale for converting an existing lane includes:

- easily implemented;
- low cost;
- creates greatest ML ‘s incentive; and
- avoids community impact of road widening.

The advocacy for building new ML lanes stems from:

- avoids worsening existing congestion;
- can be more readily designed to desirable standards;
- provides long term capacity to accommodate growth;
- realistically reflects current (and foreseeable) patterns of auto use; and,
- based on previous experience, is politically / publicly more acceptable.

The weighing and balancing of such conflicting concerns require a detailed understanding of the corridor, the community, public attitudes, and the ML market under study. It also requires willingness to compromise and recognition that an "ideal" solution which resolves all concerns will be unattainable.

Currently, there is no specific policy related to lane takeaways for converting general-purpose lanes to Manged Lanes. To create a connected network of Managed Lanes, lane takeaways may need to be considered on certain corridors in the long-term when opportunities no longer exist for new facilities through planned highway expansion.

12.3.2.1 General Purpose Lane Conversion

Creation of HOV and HOT lanes is much more acceptable if it is done by adding capacity to an existing road. Conversion of existing lanes reduces the overall capacity of the roadway, thereby increasing congestion on the remaining general lanes. The greatest public acceptance is obtained by adding a lane for HOV use rather than conversion of an existing mixed flow lane.

12.3.2.2 HOV to HOT Conversion and Extensions of Existing Facilities

The conversion of an existing general-purpose or HOV lane to HOT lane use is less complicated from a design point of view if the prior design is found to support tolled traffic without safety ramifications,the pavement is already in place and it is likely that little or no additional widening or right-of-way acquisition would be necessary. However, to maintain premium traffic service levels and discourage toll violations, HOT lanes generally require access control.

Converting existing HOV lanes to HOT lanes should be considered only if the HOV lanes are significantly underutilized to begin with. If an existing HOV lane is so heavily used by HOVs during peak hours that it is near the capacity it can handle while maintaining high speeds, converting it to a HOT lane may reduce the highway efficiency. Such conversion would allow some Single Occupancy Vehicles onto that lane during peak hours, and tolls might drive some HOVs away. That would reduce the total number of persons using these lanes in peak hours.

When converting an existing HOV lane to HOT lane, some operational changes may occur that are reflected in design changes, for example:

- Changing signing and pavement markings.
- Changing or restricting access and adding weave lanes
- Enhancing design treatments that help enforcement.
- Modifying utilities—providing power to tolling equipment and telecommunications back to office.
- Reconfiguring project limits and transitions/termini.
- Providing maintenance access.

12. 3. 3 Use of HOV / HOT Lanes by Trucks

Congestion on highways also creates delay for commercial freight vehicles. This delay could lead to increases in transportation costs, which may in turn drive up costs to consumers. One potential method for reducing this cost and possibly reducing congestion for all vehicles is to provide trucks with alternate routes or separate (preferential) lanes that allow them to bypass congestion, while freeing up space in general purpose lanes.

Allowing commercial motor vehicles to access managed lanes during non-congested (non-peak) periods of the day, when there may not be much demand for the congestion-free managed lanes, could also provide an opportunity to make better use of unused capacity. As with shared-use vehicles (carpools, buses), large trucks have special needs and may warrant preferential treatment considering their importance to the economy. **Table 12.3.3** outlines few pros and cons of allowing commercial motor vehicles to use ML. The facility must be constructed with consideration of trucks, and it features full 4.5 m (15-footwide) lanes and 3 m (10-foot) shoulders on each side. The lengths of weaving areas are to be extended and horizontal curvature at entry points to be adjusted to accommodate trucks.

Table 12.3.3 Pros and Cons of Allowing Commercial Motor Vehicles in Managed Lanes.

Pros	Cons
Increased revenue potential	Operational performance impacts
More reliable travel times for freight partners in nearby port	Driver expectations and comfort
	Increased capital cost
	Higher design standards

In Ontario, commercial motor vehicles must have two or more people in vehicle and less than 6.5 m in total length with a gross weight of 4,500 kg or less to use HOV lanes and can use HOT lanes for free if there are at least two people in the vehicle. More specifically, in Ontario, trucks more than 6.5 m in length are not permitted to operate on the left (median) lane of any King's Highway of three or more lanes per direction (**R.R.O. 1990, REGULATION 608**).

Benefits to efficiency of highway networks can be achieved by allowing commercial motor vehicles to access managed lanes during non-congested (non-peak) periods of the day, when there may not be much demand for the congestion-free managed lanes. Moreover, providing congestion-free alternatives for freight vehicles could present an economic development opportunity because shippers may decide to locate freight terminals, distribution centers, and related businesses near managed lane facilities.

Several issues need to be considered to allow heavy trucks access to managed lanes:

Safety

Trucks are slower to start and stop, are less flexible in maneuvering, and often maintain maximum speeds regulated by equipment installed on the vehicle. There is evidence that significant speed differentials among vehicles can lead to more collisions. Furthermore, for most managed lane facilities, slower-moving trucks would need to use the left-most freeway lane to access the managed lane, which could cause safety and traffic flow problems near access points since trucks would have to interact with light vehicles in the passing lane of the freeway, which typically has the highest speeds.

The main source of concern for safety is the traveling speed difference between light vehicles and heavy trucks, and there is evidence that a significant speed differential leads to more collisions. Speed differential can be exacerbated in a managed lane situation because passenger cars already in the managed lane may be moving significantly faster than vehicles in the congested general use lanes. At access areas along the corridor, heavy trucks would have to first change lanes to the far-left lane to be able to enter the lane. This type of lane changing in the general use lanes could cause collisions and increase congestion. Once near the access point, the truck would have to merge from near standstill congested conditions into a fast-moving managed lane. With two-lane managed lane facilities, this type of merging would be less problematic.

Other safety issues arise due to the infrastructure of the managed lane. Some lanes are separated by pylons along the length of the corridor or at the access points. Trucks, due to their size and slower lane changing, would be more likely to damage these pylons, thus posing a safety and maintenance problem due to debris in the road. Some managed lanes have signs mounted on the center concrete median, which truck mirrors may be more likely to strike. Even in facilities that have been built for trucks, the breakdown lanes on shoulders must be wide enough for trucks. In areas under bridges and other structures, the vertical clearance over the shoulder must be high enough to allow a truck to park there.

Operations and Maintenance

The operations and maintenance of the facility would likely need to be adjusted to allow use of managed lanes by commercial motor vehicles. The signing required to communicate access rules and restrictions for a managed lane that also includes trucks should be adjusted to avoid last-minute lane changes.

Additionally, emergency response, traffic collision clearance, and enforcement activities could be affected by having commercial motor vehicles in managed lanes. In the event of an incident, enough shoulder width is required to allow large trucks to safely slow down, get out of the travel lane, and speed back up again. Commercial Motor Vehicles also create more pavement wear, so it is likely that the lane would have to be closed more frequently for pavement repair and maintenance if large ot heavy trucks were allowed.

Highway Design

Many highway design features are calculated differently for trucks and cars. If a facility is being considered for commercial motor vehicle use, many design features might have to be modified. These include but are not limited to highway and ramp curvature, underpass/overpass height, shoulder width, pavement thickness, and roadside barriers.

12.3.4 Reserved Bus Lane Versus Occupancy Rates of 2+ / 3+ Lane

The establishment of a minimum vehicle occupancy rate for an HOV lane is a corridor-specific decision, but one which must be taken in the context of the project goals, the market to be served, and the needs and characteristics of the surrounding area.

On the freeway system, current bus usage is, due to congestion, generally relatively low and therefore this issue focuses more on operational needs of a lane design. The complex interaction of vehicle movement on a right side HOV lane at an interchange may produce a desire to minimize the number of vehicles contributing to the conflict by designating the lane for buses only (i.e. Reserved Bus Lane). In that same corridor, a median HOV lane could be designated for 2+ and operate smoothly and effectively. There are therefore no "rules" which apply to every HOV project with respect to eligibility; the appropriate designation will remain corridor-specific and subject to detailed analysis and iterative study.

12.4 Operational Considerations

Establishing a ML facility requires implementation of specific occupancy requirements and involves various other activities as indicated in the following sections.
For example, priority HOV treatments on highways involve much more than the provision of physical facilities dedicated to HOV use; a series of decisions must also be made as to what constitutes a viable HOV project in the context of both facility under study and area-wide HOV system. The decisions centre on determining the most effective and beneficial use of the HOV facilities available. These involve striking a balance between:

- moving as many people in HOVs as possible;
- avoiding congestion in the HOV lane itself and at its points of interaction with mixed flow lanes; and
- ensuring the lane is adequately used, both relative to a non-HOV alternative and in the

view of the public.

12.4.1 Eligible Vehicles

In Ontario, eligible vehicle types in managed lanes and facilities are outlined in **Table 12.1.1** and **Table 12.1.2.**

12.4.2 Vehicle Occupancy

The core of the HOV issue is the definition of a minimum auto occupancy rate; if too restrictive, few travellers will be able to take advantage of the incentives offered to HOV users, and the public may become dissatisfied with and disrespectful of the program; if too open, the priority facility may become congested, and limits will be placed on its ability to move significantly more people than a mixed-flow lane.

12.4.3 Operational Capacity

Like all freeway traffic lanes, an HOV lane under ideal conditions has the physical capability of accommodating a peak period vehicular flow of up to 2,200 vehicles per hour. However, one of the requirements of an effective HOV lane is that a consistent, reliable, unimpeded trip be provided, to maximize the incentive to use and switch to HOVs. The lowest "Level of Service" for mixed flow traffic which maintains stable, high-speed flow is "C", which corresponds to only approximately 1,500 vehicles (passenger car equivalents) per hour. Beyond that point, traffic tends to slow down and be immediately influenced by small changes in flow characteristics. It must be considered that HOV lanes will be used by local buses and that there will be no ability under most circumstances to overtake a vehicle while in the lane, rendering the operation even more influenced by a slower vehicle or an isolated constraint.

The design year traffic volume projection for a single HOV lane should not exceed 1,500 vehicles (auto equivalents) per hour in the peak period. If necessary, the HOV criteria or operating strategy can be modified at that point to maintain LOS "C" flow. Raising occupancy restrictions during peak periods, expanding HOV capacity, and enhancing transit/rideshare marketing and incentive programs are some of the techniques available in that situation.

12.4.4 Minimum Lane Usage

The key measure of effectiveness is whether the HOV lane carries an adequate number of vehicles. For a typical concurrent flow HOV lane the minimum figure is likely to be in the 500-600 vehicle per hour range.

Additional experience-based observations include:

- The minimum number depends to some extent on the vehicle mix in the HOV lane; a lower figure is generally acceptable for an HOV lane dominated by bus use, since each bus is readily perceived by motorists as moving more people.

- The minimum number depends on the facility operation: fewer HOVs are required to make a contraflow HOV lane perceived to be adequately utilized than for a concurrent flow lane.

- The presence of a well-used HOV lane will generate public awareness and support for other subsequent contiguous or nearby HOV facilities which may have less usage.

- Acceptance of lane usage levels can be significantly affected by education/marketing campaigns, by the presence of a widespread program of HOV priority for all parts of the trip, and by the presence in the community of a strong, heavily utilized municipal transit system.

- Acceptance depends somewhat on the level of congestion in the adjacent mixed-flow lanes; the more severe the congestion the greater the HOV use required to dispel the perception of inequitable distribution of freeway capacity.

- Visible and effective enforcement is essential to generating and maintaining respect for the lanes; if lanes are under-utilized the temptation for ineligible vehicles to use them rises, and if a high level of violation occurs the remaining public will become less tolerant of the HOV lane.

- A lower level HOV lane usage may be acceptable for an initial or designated "pilot project" period, but this must be communicated effectively to the public.

Thus, the issue of minimum lane usage sweeps across the entire HOV spectrum and must be resolved to the satisfaction of the freeway operator, HOV users, the local community, and all other freeway users in the area. Underlying this concern is the fact that HOVs make up a relatively small proportion (less than 10% for 3+, less than 20% for 2+) of the current traffic stream - far lower than the physical proportion of a freeway to be set aside for their exclusive use (e.g. 25% of an 8-lane freeway; 33% of a 6-lane freeway).

12.4.5 Access

Vehicle access should be limited to certain locations for all managed lane facilities. Continuous access to the express lanes is prohibited. Vehicle ingress and egress points will be determined based upon considerations for traffic safety, traffic volumes, the surrounding roadway network, areas of congestion, and interchange spacing. Further details on vehicle access and design elements for access/egress are outlined in Section 12.5.4

Limiting access has traditionally been applied to HOV and express lanes as a means of regulating entry and exit movements. Restricting access reduces friction caused by entering and exiting traffic and discourages shorter distance travel. Access restrictions may also help alleviate specific traffic bottlenecks where short-distance trips cause a lane to exceed its capacity. Access can be restricted by design or dynamically managed by (a) metering demand at entrance ramps via the use of traffic signals or gates, (b) limiting access at specific ramps to selected users like HOVs, or (c) limiting the number of entrance and exit ramps so that free-flow is ensured.

Access control is associated with concurrent flow managed lanes located next to the median barrier where access is provided every 1 to 3 Km. Access control is not required for electronic tolling or variable pricing; however, restricting access makes toll collection easier to manage by having fewer toll zones than might otherwise be required.

Figure 12.4.1 illustrates a facility with limited access where vehicles can enter or exit the managed lane in certain designated locations only. This type of access is a cost-effective design when compared with other access types such as direct grade-separated access. However, it requires the general-purpose on-ramp traffic to weave across multiple general-purpose lanes and this cross-weave actions may cause significant frictions on general-purpose lane traffic depending on cross-weave demand, the distance available to complete the cross-weave maneuvers and the general-purpose lane density.

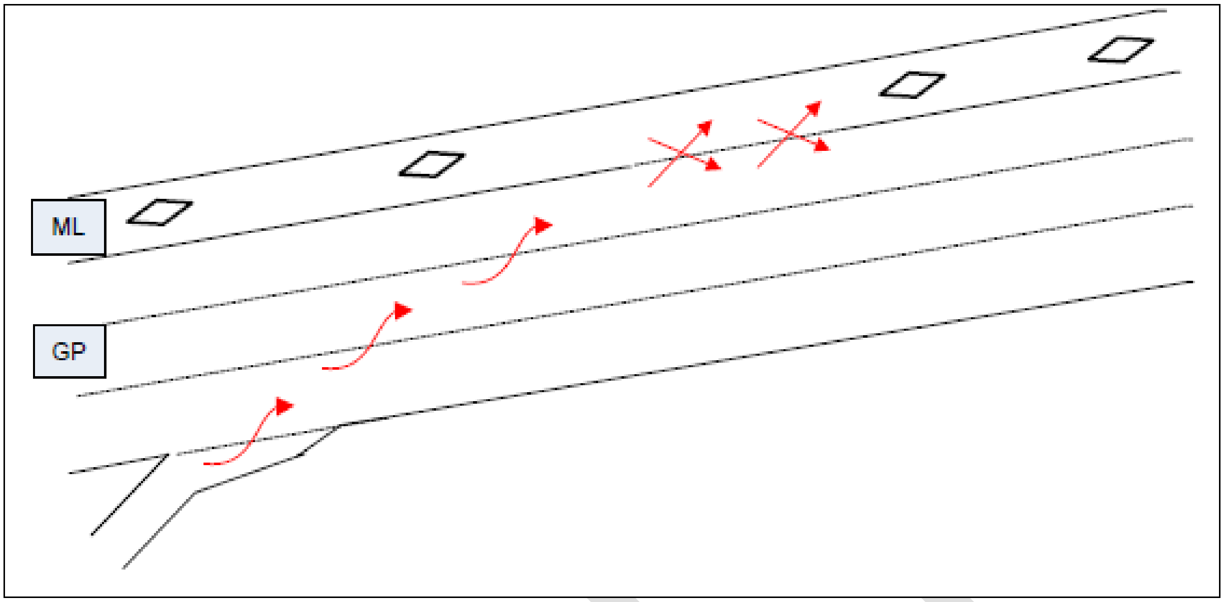


Figure 12.4.1 At Grade Access with Limited Access Points

12.4.6 HOV Lanes Alternatives

For an HOV lane on a limited access facility, consider the following operational alternatives:

- Inside (desirable) or outside HOV lane
- Lane conversion
- Use of existing shoulder—not recommended for permanent operations
- HOV direct access ramps
- Queue bypasses
- Flyer stops
- Hours of operation

When evaluating alternatives, designer would consider a combination of alternatives to provide the optimum solution for the corridor. Also, incorporate flexibility into the design in order not to preclude potential changes in operation, such as changing an outside lane to an inside lane or a reversible facility to two-way operations. Access, freeway to- freeway connections, and enforcement will have to be accommodated for such changes.

12.4.6.1 Inside or Outside HOV Lanes

The inside (left) HOV lane is most appropriate for a corridor with long-distance trip patterns, such as a freeway. These trips are characterized by long-distance commuters and express transit service. Maximum capacity for an effective inside HOV lane is approximately 1,500 vehicles per hour. When HOVs weaving across the general-purpose lanes cause severe congestion, designers may consider providing HOV direct access ramps, separated HOV roadways, or a higher-occupancy designation.

The outside (right) HOV lane is most appropriate for a corridor with shorter, more widely dispersed trip patterns. These trip patterns are characterized by transit vehicle routes that exit and enter at nearly every interchange. The maximum capacity for an effective outside HOV lane is reduced and potential conflicts are increased by heavy general-purpose lanes congestion and large entering and exiting volumes.

12.4.6.2 Conversion of a General-Purpose Lane

The use of an existing general-purpose lane for an HOV lane is an undesirable option; however, conversion of a lane to an HOV lane might be justified when the conversion provides greater people-moving capability on the roadway. Use of an existing freeway lane as an HOV lane will be considered only with a Design Analysis.
Given enough existing capacity, converting a general-purpose lane to an HOV lane can provide additional people moving capability in future without significantly affecting existing roadway operations. The fastest and least expensive method for providing an HOV lane is through conversion of a general-purpose lane. Restriping and signing are sometimes all that is needed.

12.4.6.3 HOV Direct Access Ramps

Direct access ramps allow buses, carpools, vanpools, and motorcycles to directly access the high occupancy vehicle (HOV) lanes in the center of freeway. They come down from above the mainline, or up from below, and merge into the HOV lane from inside the median.

Direct access ramps are open only to carpools, vanpools, buses and motorcycles 24 hours a day, seven days a week. This is true even when HOV lanes are open to all traffic. The cost of constructing direct access ramps is substantial because they require separate structures above or below the freeway.

Direct access ramps improve safety, reduce congestion, save time, and increase travel time reliability for both HOVs and general-purpose freeway traffic. High occupancy vehicles may have hard time merging left through general purpose lanes to gain access to HOV lane during congested periods, creating a safety problem for all freeway users. When buses, particularly articulated (extra-long) buses attempt this merge, they can cause congestion in the lanes they pass through for quite a distance back. By enabling carpools, vanpools, buses, and motorcycles to connect directly with HOV lanes, these vehicles avoid the need to weave across other lanes of traffic.

Direct access ramps work much like other left-side on- and off-freeway ramps, except they are restricted to HOVs. Vehicles access the ramps from an adjacent park-and-ride facility or surface street. They merge into the left side of the freeway and enter the HOV lane. As with other left-side on- and off-ramps, drivers enter traffic to their right. Visibility is limited so ramp users should use extra caution when merging into a freeway HOV lane from a direct access ramp (**Figure 12.4.2**).

When using a direct access ramp to exit the freeway, HOV drivers should watch for signs and then exit to the left where indicated. This takes them up (or down) the direct access ramp and into a park-and-ride lot or to an intersection with a local street.

12.4.6.4 Use of Existing Shoulder

Shoulder-use managed lanes are permitted where buses can travel and bypass congestion. Consideration of shoulder conversion to an HOV lane is valid when traffic volumes are heavy, and the conversion is a temporary measure. Another alternative is to use the shoulder as a permanent measure to serve as a transit-only or queue bypass lane during peak hours and then revert to a shoulder in off-peak hours.

The use of shoulder requires special signing that clearly defines the use of the shoulder and to establish special operations to clear the shoulder for the designated hours.
The existing shoulder pavement is often not designed to carry heavy volumes of vehicles, especially transit vehicles. As a result, repaving and reconstruction of the shoulder might be required.

Figure 12.4.2 Aerial View of HOV Direct Access Ramps

12.4.6.4.1 Part-Time Shoulder Use / Bus Bypass Shoulder

Part-time shoulder use is the conversion of shoulders to travel lanes during some hours of day as a congestion relief strategy (**Figure 12.4.3 and Figure 12.1.4**). This strategy is also known as temporary shoulder use or hard shoulder running and is typically implemented on freeways. Part-time shoulder use is a transportation system management and operations strategy that uses shoulders to provide additional capacity when it is most needed and preserves shoulders as refuge areas during rest of the day.

Vehicles can travel on paved shoulders (also known as part-time shoulder use or dynamic shoulder lanes) under specific conditions. A left shoulder may be converted and posted for part-time shoulder use operation using a variety of traffic control devices. Other right shoulders are conditionally used by transit buses whenever congested speeds fall below a given threshold.

Bus-on-shoulder operations are known as "bus bypass shoulder" (BBS). They are a low-cost strategy allowing buses to travel at or near free-flow speeds through congested freeway routes.

Bus-on-shoulder is typically used only where roadway congestion is significant and traveling on the shoulder improves on-time reliability and even decreases overall trip time.

A variety of part-time shoulder use options exist. All of these options take advantage of existing shoulder infrastructure and include a combination of treatments such as left/right shoulder option, vehicle-use option, operating schedule, and special speed controls, as listed below:

- Left/Right Shoulder Option
  - Right shoulder
  - Left shoulder
- Vehicle-Use Options
  - Open shoulder to transit vehicles only
  - Open shoulder as an HOV lane that permits carpools and transit vehicles to use it
  - Open shoulder as a HOT lane that allows vehicles to pay a toll to use it if they don’t meet HOV occupancy requirements
  - Open shoulder to all vehicles except trucks
  - Open shoulder to all vehicles
  - Open shoulder to slow moving trucks in rural mountainous areas
- Operating Options
  - Dynamically open shoulder when certain congestion thresholds are reached (an ATM strategy referred to as “Dynamic Shoulder Use”)
  - Statically open shoulder during specified historical peak periods (time of day)
- Speed Control Options
  - Same speed limit as other lanes (at posted speed limits).
  - Same speed as other lanes (at a reduced speed relative to normal posted speed)
  - Lower speed limit than other lanes.

Figure 12.4.3 Bus-On-Shoulder (BOS) Operations in Chicago

Figure 12.1.4 Bus on Freeway Shoulder (Ottawa, ON)

12.5 Design Guidelines

The intended purpose of a facility has some effect on selection of certain design criteria, particularly for the design of access as well as requirements of potential toll collection accommodation. Primary considerations are cross-sectional elements such as lane and shoulder widths, buffer width, median width, drainage, cross-slope, and traffic control devices, particularly if the facility is separated by buffers or barriers. Other important design elements include sight distance, horizontal curve design, and vertical clearance under toll gantries, sign bridges, and overpasses.

Design criteria for managed lane facilities that are part of general-purpose freeway corridors are the same as for the general-purpose lanes. These criteria apply to vertical and horizontal alignment, cross-slope, and lane and shoulder widths. When proposed design elements do not meet these criteria, approval for a design exception or deviation process is required (Section 12.5.5). Also, managed lane design should match driver expectancy established by the presence of design elements and traffic control devices on nearby facilities.

Ramps are one of the critical geometric aspects to consider in making a managed lane facility safe and functional with other facilities. The important aspects in the design of ramps are ramp orientation (left versus right), type, and spacing. These guidelines typically vary by traffic level and appropriate design speed. Understanding both current and future traffic impacts of the facility is important to ensure geometric adequacy both at time of construction and in future years of operation.

Other aspects of geometric criteria include establishing techniques for separation of managed lanes from adjacent general-purpose lanes and consistent orientation and treatment for access, as well as consideration of enforcement, incident management, and maintenance of traffic control devices and performance of the tolling systems.

12.5.1 Design Elements

There is a variety of elements that need to be considered in development and design of managed lane facilities. The following are key design elements:

12.5.1.1 Design Speed

For managed lanes that are part of a general-purpose freeway corridor, it is recommended to use a design speed that is the same as the adjoining freeway. A suggested design speed for ramp connections for managed lanes is approximately 0.7 times the mainline design speed. This criterion is applicable to flyover ramps and connecting drop ramps. At-grade access locations can use this criterion if dedicated weave lanes are provided, or they may be designed at a higher speed based on the specific location and operating characteristics of freeway through lanes.

12.5.1.2 Cross Section and Alignment

Number of Lanes

Most managed lanes are designed to fit within available right-of-way, which is often quite constrained. For the majority of ML projects, retrofit means adding one lane in each direction. The designer should consider the constraints of the corridor and trade-offs to provide the best possible balance of managed lanes, shoulders, and separation in conjunction with lanes and shoulders in the general-purpose facility.

Lane Orientation

Almost all managed lanes are located on the left side next to the median such that long distance travel with limited access is facilitated. The traffic volumes, right-of-way, existing roadway infrastructure and cost considerations generally dictate the design of dedicated facilities. A left side orientation results in fewer conflicts with mixed traffic since there are few locations were left side ramps intervene. A right-side orientation frequently conflicts with local on and off-movements with the main lanes, so therefore, either the usage of right-side orientations needs to be low to mitigate the magnitude of conflicts, or usage must be restricted to selected drivers and vehicles such as buses only.

Lane Width

The recommended lane width for a managed lane facility is 3.5 – 3.75 m, just as with any other freeway lanes. For a managed lane facility that includes a buffer of 0.6 m – 1.25 m width, in constrained areas the designer may allow up to 0.3 m of lane width to be considered as part of this overall buffer dimension where full buffers and lane widths would not fit as the managed lane driver perceives this space as part of the overall width used for horizontal sight distance. **Figure 12.5.1** provides examples of cross sections for barrier-separated two-way HOV facilities (s*ource:* Guide for HOV facilities ASSHTO 2004). Also, the ASSHTO Safety Manual provides information of trade-offs by lane width for freeways.

Shoulders Width

Ideally, managed lane shoulders should follow the TAC Geometric Design Guidelines and the MTO Design Supplement for the shoulder width of the general lane to provide clearance for disabled vehicles, enforcement activities, and emergency response. In practice, many retrofit applications have narrower shoulders so that the lane width is maintained and, to the extent possible, a shoulder width of at least 2.5 m is maintained. For concurrent directional lanes, shoulders should be to the left, next to the median barrier. Shoulder space with a width between 1.2 m to 2.5 m should not be striped because drivers on a concurrent flow lane can misconstrue the space as wide enough to stop in, leaving their vehicles exposed to high-speed traffic that may not be able to negotiate around the exposed vehicles. **Figure 12.5.2** shows examples of shoulder width options as per FHWA.

Median Width

Medians on managed lane facilities should be designed in the same manner as other freeway medians. When right-of-way is constrained, the median should be designed with enough width to accommodate the pedestals and bases for gantries and traffic control devices, the median barriers, and any enforcement activities that will be required for the facility so that vehicles can travel in the leftmost lane or the left shoulder without their path being infringed upon.

Buffer Width

Managed lane drivers are expected to shift away from the pylons placed in the buffer; however, a wider buffer can offset the impacts on lateral position.

Horizontal Clearance

For managed lane facilities within other freeways, the horizontal clearance may be affected by right-of-way constraints, but it should be enough to prevent vehicle from colliding with signs, guardrails, and other roadside apparatus. For stand-alone facilities, the MTO Roadside Design Manual should be applied.

Vertical Clearance

The facility should have the necessary vertical clearance for the design vehicle to pass under toll gantries, sign bridges, and overpasses without striking them. It is recommended that for facilities within other freeways, the vertical clearance provided be the same as that provided on the general-purpose facility.

12.5.1.3 Separation Between Managed Lane and General-Purpose Lanes

There are multiple ways to provide separation between managed lanes and general-purpose lanes of a freeway. Each approach reflects different operational goals and requirements. While all can be effective, selection of separation type should take into consideration the design setting, business rules, design vehicles, and level of anticipated demand. Barriers, buffers, pavement markings, and separate facilities are all used, and some facilities may have a combination of separation types (e.g., a mixture of buffer separation and pavement marking separation where cross section is limited). Each option has its own potential advantages and disadvantages, and these should be considered early in the design of managed lane facility to determine which treatment is best suited for that location.

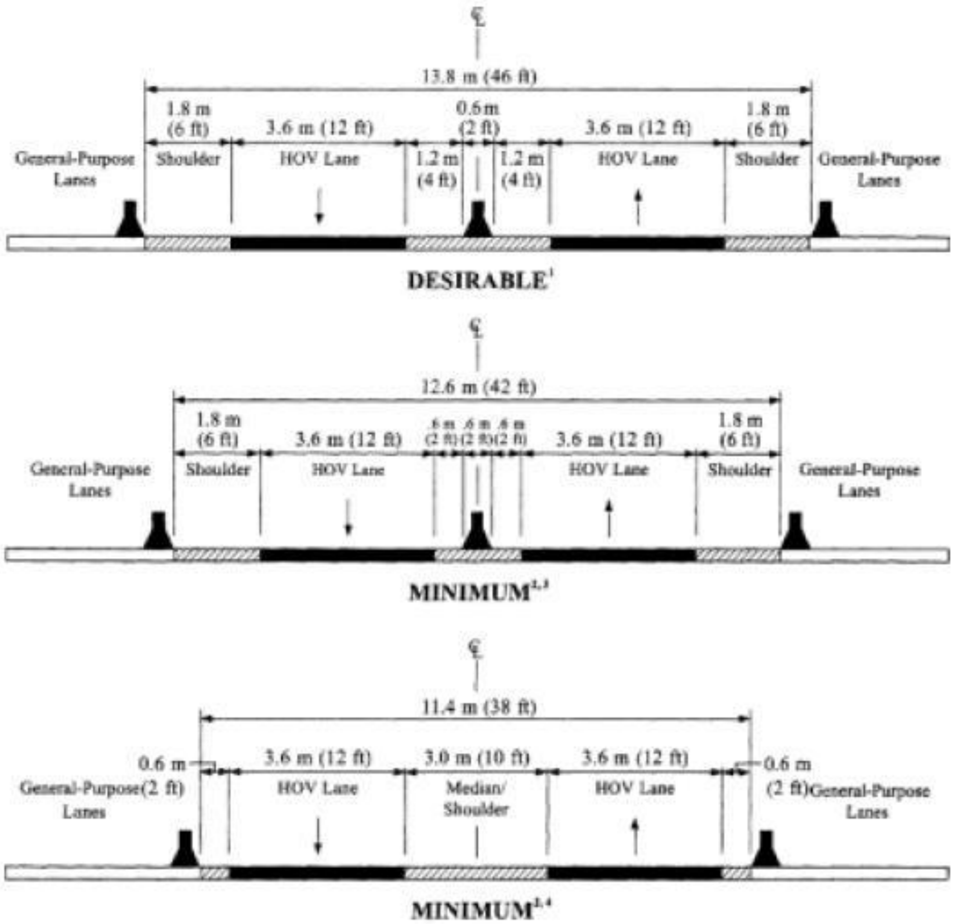
If the project has adequate right-of-way (ROW) and a requirement to accommodate future corridor growth or future phasing, express lane configurations using a wide buffer separated system can provide room for future pavement when an additional lane is required.

A buffer is a physical space between managed lanes and general-purpose lanes operating in the same direction that provides separation without a barrier. A buffer is defined by pavement markings providing guidance to the driver, and access points are defined by changes in those markings.

Buffers promote more efficient traffic flow where travel speed differentials in adjacent lanes can be substantial but where a barrier is not a practical or desired solution. Buffers are less costly than barriers; however, depending on the width of buffer provided, they may require additional right-of-way.

A 1.25-meter buffer is commonly recommended, though wider buffers can sometimes provide additional benefits in terms of drainage, snow storage, capability to expand the number of lanes in future, and visual separation. **Figure 12.5.3** shows cross-sections for buffer-separated HOV lanes. However, a buffer that is too wide may encourage drivers to use it as an additional travel lane. Conversely, 0.65 m buffers have been used to provide a measure of separation where a wider buffer is not possible due to cross-section constraints.

Some literature indicates that operational performance of MLs may impact, and be impacted by, operations of adjacent general-purpose lanes (GPs), despite some degree of physical separation. Such operational co-dependence may especially exist between the GP lane adjacent to the separation buffer and the ML lane.



[1] HOV envelopes in one direction over 6.7 m (22 ft) may invite passing. A full breakdown shoulder is not provided although vehicles can still maneuver around disabled vehicles. Enforcement of this facility is performed at the ends and access locations.

[2] Operational treatments should be incorporated if the minimum design cross sections are used. The minimum cross section should be used as an interim project or over short distances. Increased enforcement and incident management programs should be implemented to successfully operate the facility.

[3] The width of this cross section provides the minimum space required for a bus to pass a disabled bus at slow speed.

[4] Shared median minimum cross section should only be used for two-way ramps, short connector sections, low-volume HOV lanes, or other lower speed facilities.

Figure 12.5.1 Example of Cross Sections for Barrier-Separated Two Way HOV Facilities

Source: Guide for HOV facilities ASSHTO 2004

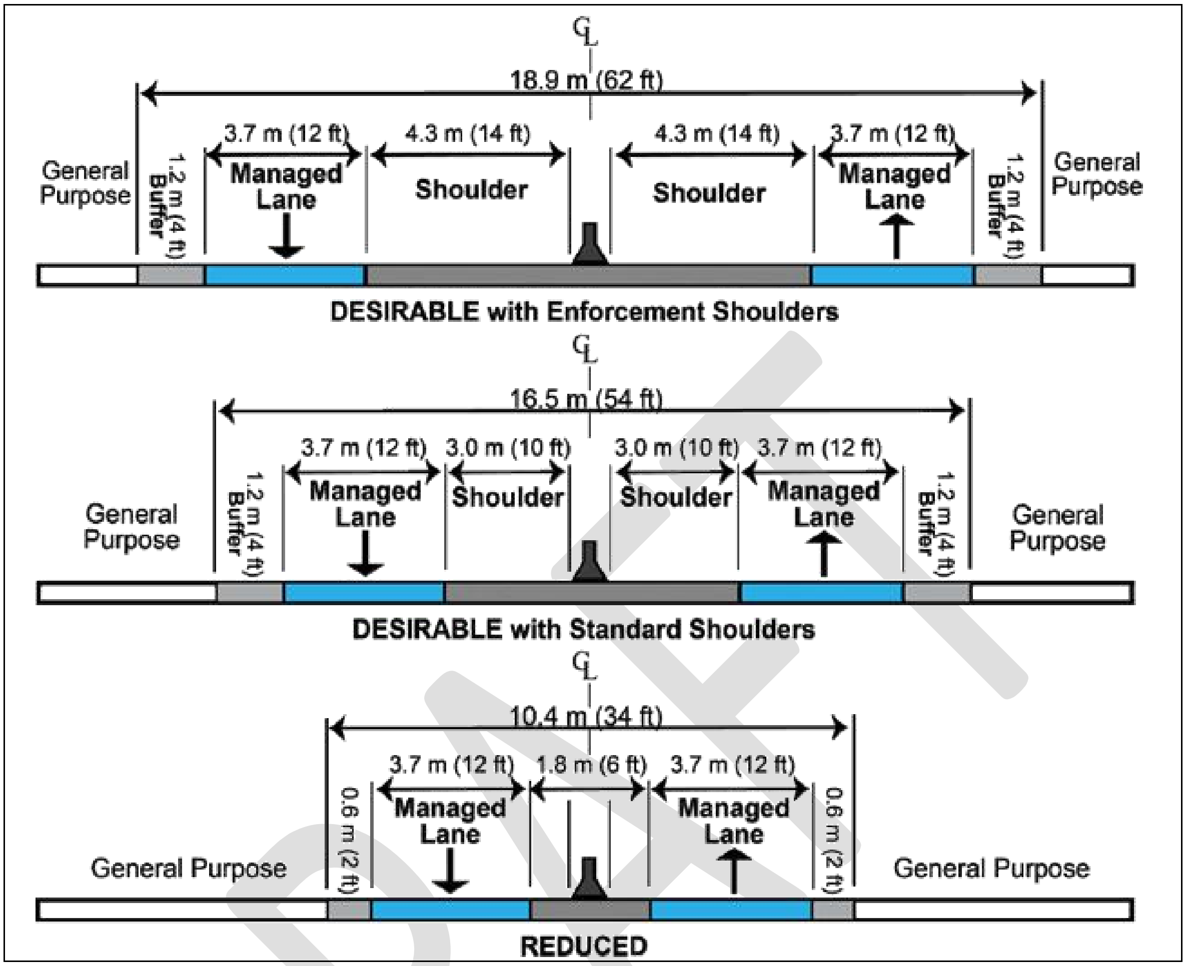


Figure 12.5.2 Example of Managed Lane Shoulder Width / No Shoulder (FHWA)

12.5.1.3.1 No Separation (Pavement Markings Only)

For most constrained rights-of-ways and for projects that only operate during peak periods and revert to general purpose operation at other times, the separation between managed and general-purpose lanes could be only a single-line pavement marking. At a minimum, the separation requires to be a pavement marking that is wider than a typical lane line. While this treatment is the least costly option for separation, it is also the least restrictive and may be hardest to enforce when compared to other options. For tolling purposes, it may require more frequent toll readers to be installed.

12.5.1.3.2 Buffer Separated

12.5.1.3.3 Barrier Separated

Concrete barrier separation provides the most positive separation between managed lanes and general-purpose lanes which makes it the easiest to enforce among managed lane facilities. It also leads to the fewest opportunities for collisions between vehicles in the managed lanes and vehicles in the general-purpose lanes because access is physically limited.

Barrier separation is a costly separation treatment because of requirements for duplicate shoulders as well as additional width of the barrier. Enough shoulder width to be provided within the managed lane envelope to accommodate an emergency, a disabled vehicle, or other special event. It is also the least flexible treatment, which makes changes to access points for the managed lanes difficult.

Figure 12.5.4 illustrates recommended cross-sections for barrier-separated median HOV lanes. Few urban freeways in Ontario have preserved adequate median width to allow retrofit of barrier-separated lanes.

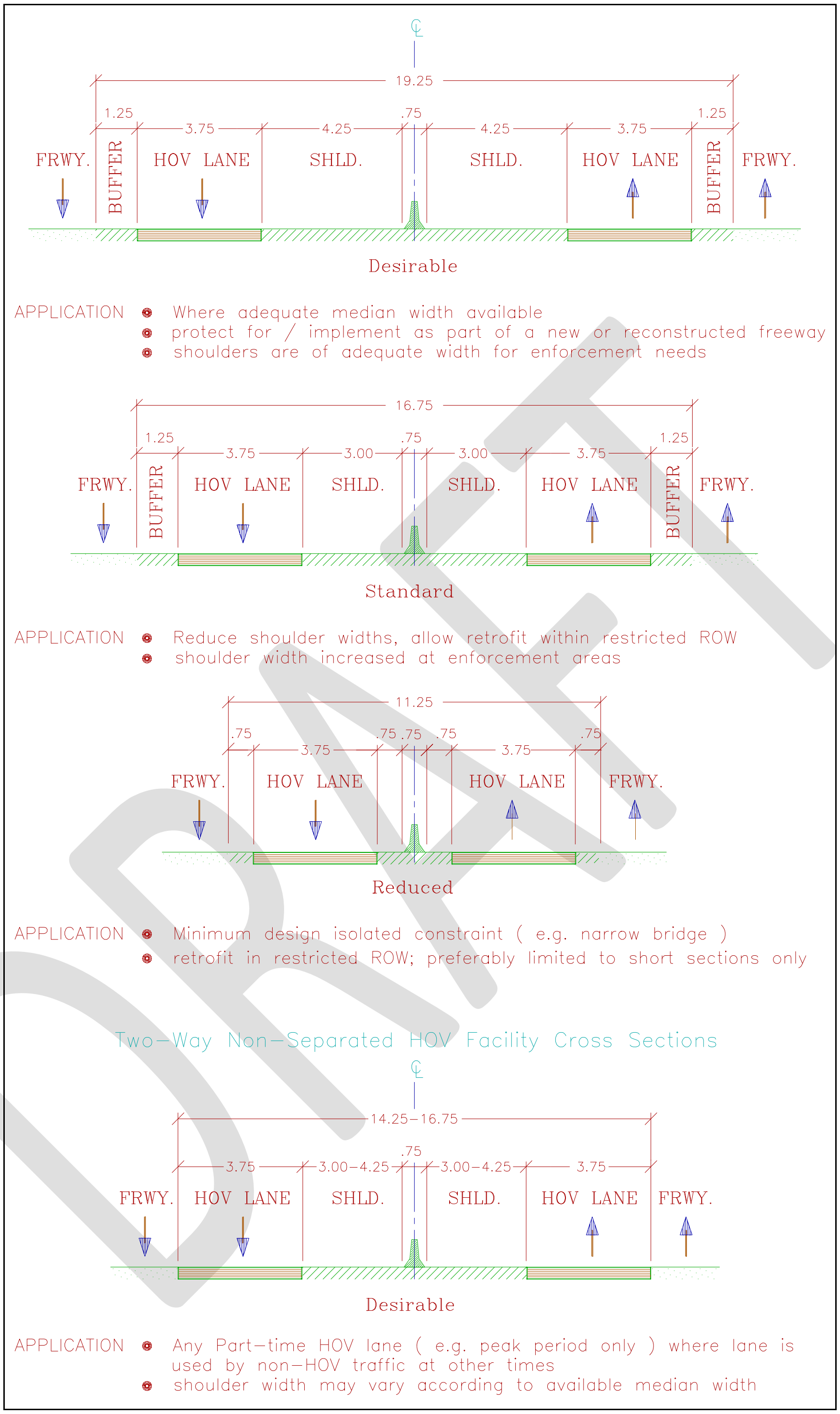


Figure 12.5.3 Examples of Cross Sections of Buffer Separated HOV and Non-Separated HOV

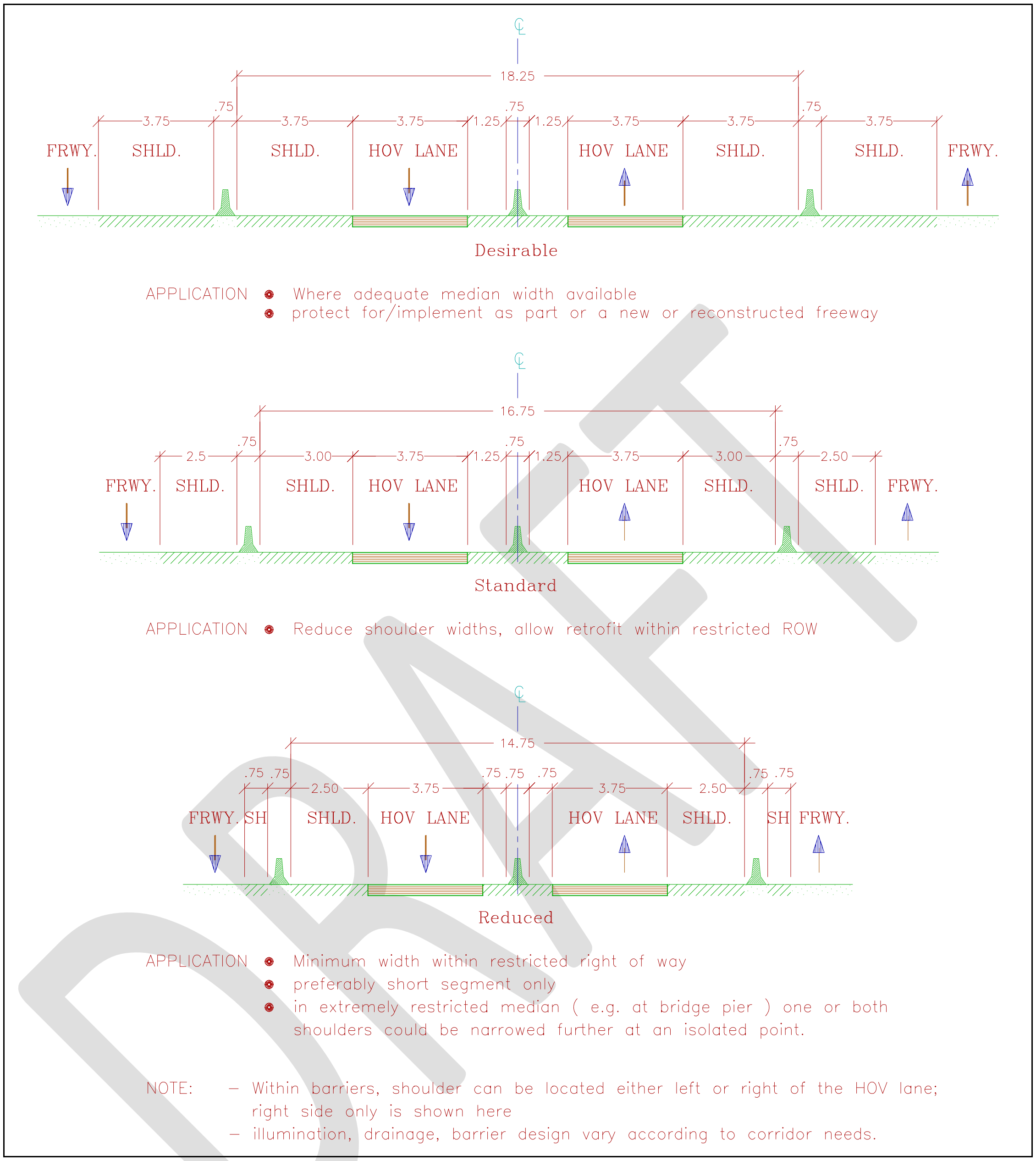


Figure 12.5.4 Examples of Cross Sections of Barrier Separated HOV Facility

12.5.1.4 Access and Egress Consideration

Access into and out of a managed lane facility is an important design element for the managed lane facilities. Drivers must be able to make their way safely into and out of the ML. The location of managed lane access points should avoid creation of short weaving distances between upstream and downstream right-side ramps and left-side managed lane access. It may be difficult to find appropriate locations for managed lane access on older freeways with frequent on and offramps. Studies recommended a design domain of 120 m to 500 m per lane change for spacing between general-purpose ramps and managed lane access, depending on traffic volumes and other conditions with 300 m being desirable (300 m is a common recommendation in literature). These distances are typically applied to passenger vehicles, so the weaving distance provided for buses should be longer (**Figure 12.5.7).**

12.5.1.4.1 Types of Access Configurations

There are 3 types of access configuration (**Figure 12.5.5**:

- At-Grade Access (Type A)
- At-Grade Ramp Access (Type B)
- Grade-Separated Ramp Access (Type C)

For the first type of At-Grade Access, managed lane traffic enters the general-purpose lanes through a conventional on-ramp from the right. This access is common for concurrent managed lane facilities. Access between the managed lane and general-purpose lanes is sometimes constrained to specific location, which affects weaving intensity. This type of access requires a cross-weaving movement through general purpose lanes prior to access point (**Figure 12.5.5**)

For the second type of At-Grade Ramp Access, traffic weaves across multiple general-purpose lanes but the entrance to or exit from the managed lane is confined to an at-grade on-ramp or off-ramp. The managed lane operations are impacted by cross-weaving maneuvers from and/or to access points at ramps. This type of access configuration requires a cross-weaving movement across general-purpose lanes prior to access point and a ramp movement to get from general purpose into the managed lane (**Figure 12.5.5**).

For the third type of Grade-Separated Ramp Access, the managed lanes access occurs on a grade-separated structure (i.e. flyover, bridge, or underpass). The operational impact to general-purpose lanes is minimal as cross-weaving movement is eliminated entirely. This type of access configuration does not require any cross-weaving across general-purpose lanes (**Figure 12.5.5**).

FIGURE 12.5.6 includes examples of Ingress / Egress Barrier Separated HOV Facilities and **Figure 12.5.8** illustrates weaving distances at buffer separated HOV facilities as referenced in the Caltrans HOV Guidelines (Caltrans January 2018). Further description for HOV/HOT access configuration is outlined in **Section 12.5.2.7**.

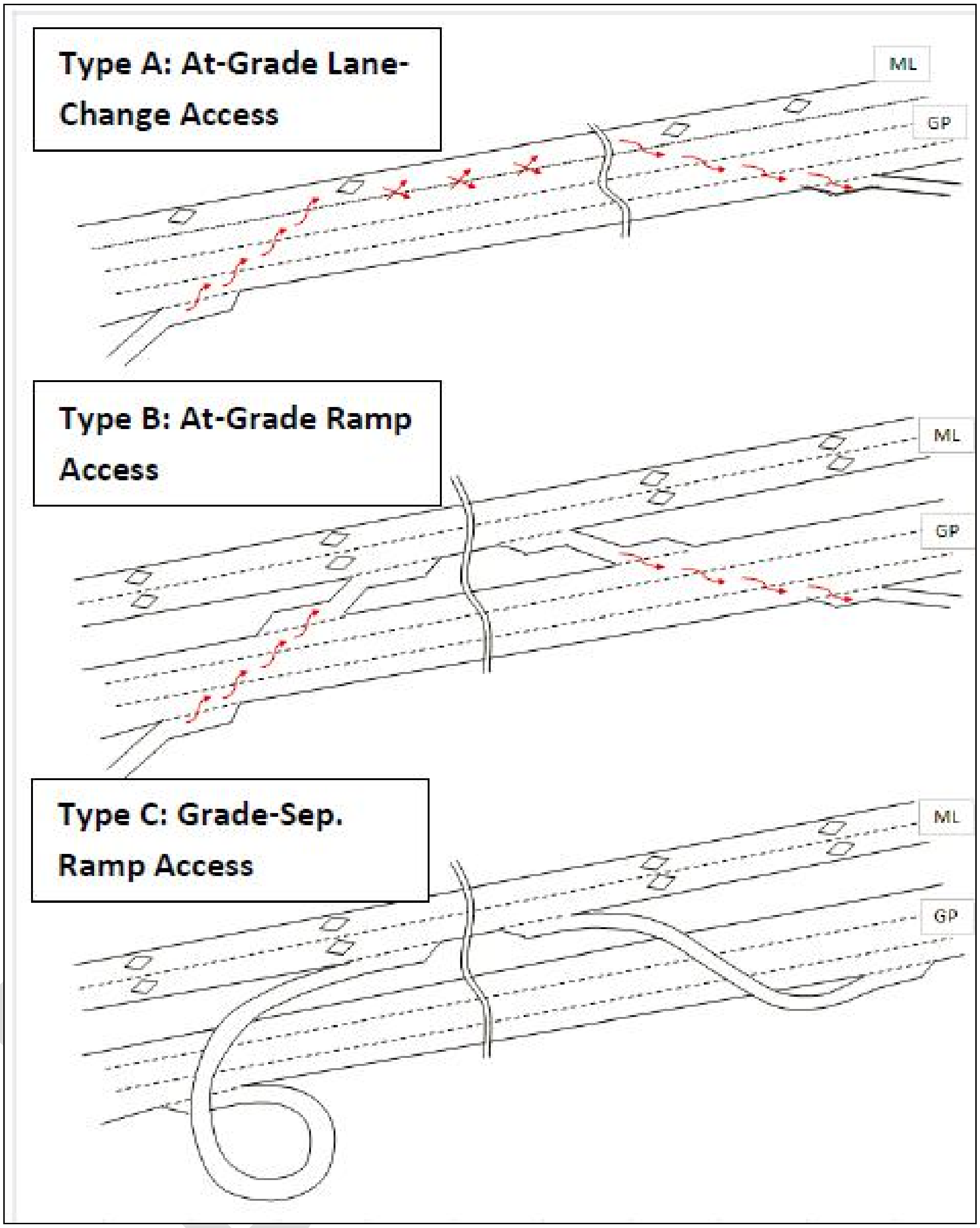


Figure 12.5.5 Types of Access Configurations

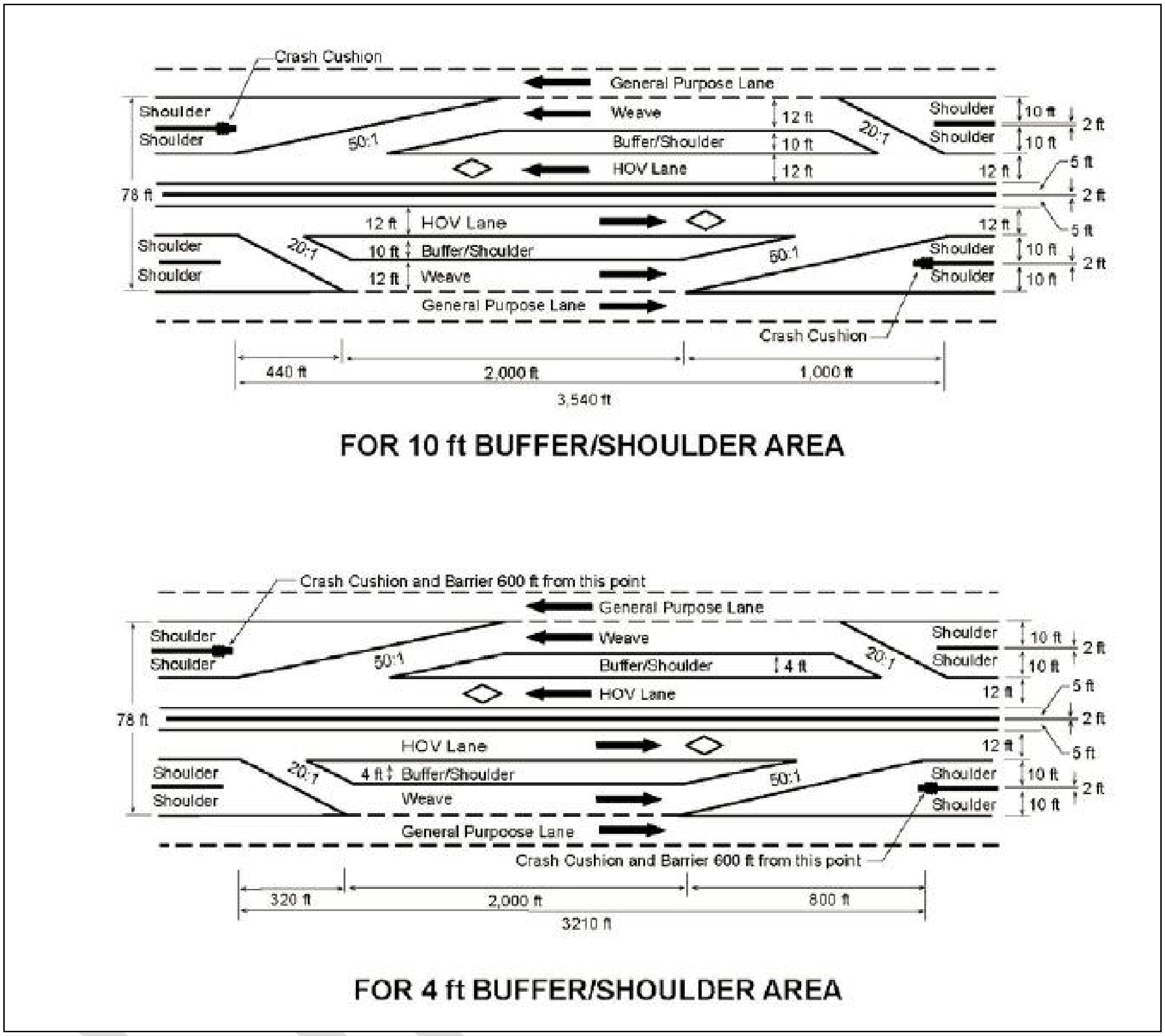


Figure 12.5.6 Ingress / Egress Barrier Separated HOV Facilities
Source HOV Guidelines Caltrans January 2018

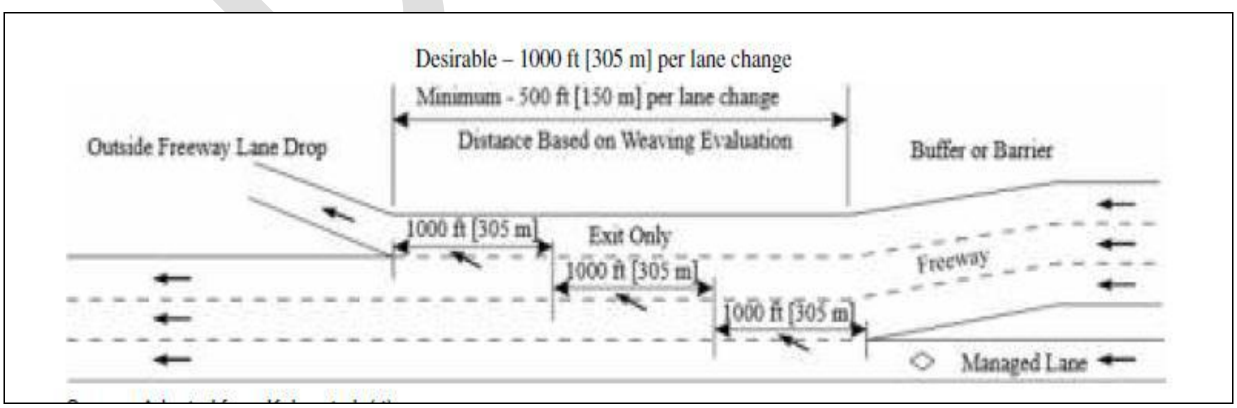


Figure 12.5.7 Termination of Managed Lane with 1000 ft (305 m) per Lane Change.
Source NCHRP 815 – Guideline of Implementing Managed Lanes (2016)

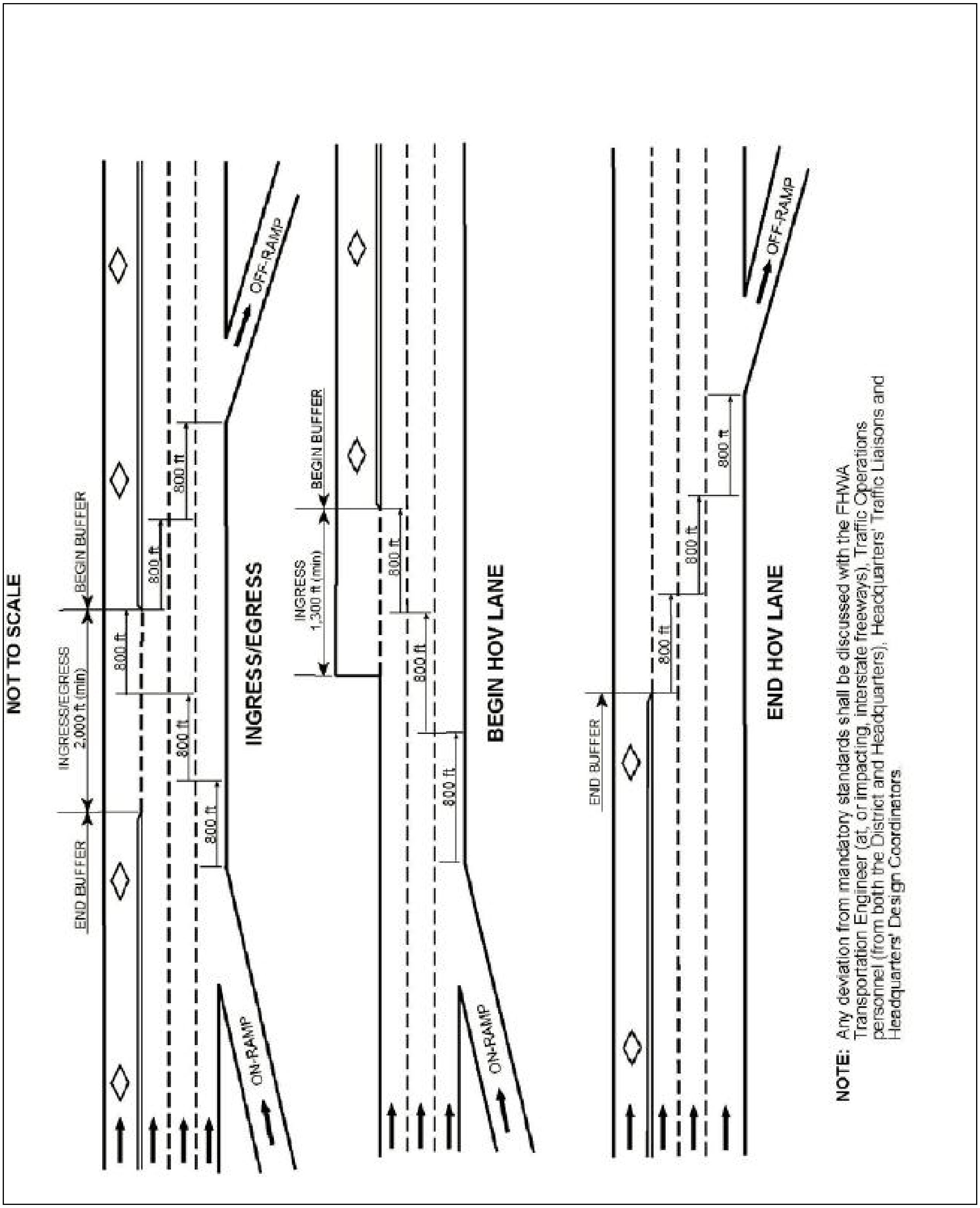


Figure 12.5.8 Weave Distance at Buffer Separated HOV Facilities

Source HOV Guidelines Caltrans January 2018

12.5.1.4.2 Consideration of Limited Access Versus Continuous Access

Provision for intermediate access is typically provided unless a facility is designed to allow access at only the beginning and end. This is accomplished through either continuous access, in which eligible vehicles may enter the facility at any location, or a limited- or restricted access approach, in which selected locations are designated for ingress, egress, or both.

The choice of access type is based on a general evaluation of performance and management benefits for the entire freeway as well as the capital costs of building and operating the managed lanes. If a proposed access point or series of points causes bottlenecks or does not allow managed lane drivers to use their desired general-purpose entrance and exit ramps, then the access is not serving its purpose and the effects of other factors may not be fully appreciated. This suggests a level of analysis that looks not only at the entire corridor’s travel patterns (specifically including the desired origins and destinations for managed lanes users) but also at the immediate area surrounding each proposed access point or driver decision point.

Continuous access and restricted access do not have to be mutually exclusive, in that a managed lane designer does not have to choose either one or the other for the entirety of a managed lane facility. Within a given facility, restrictions on access can be applied to certain parts of the facility while continuous access is provided in other parts of the same facility.

12.5.1.4.3 Frequency of Restricted-Access Points

The defined access points are provided at regular intervals or logical locations; restricted-access points are not intended to serve every general-purpose entrance and exit ramp. Depending on the purpose of facility, designers would determine where access could be provided.

The location of managed lane access points should avoid creation of short weaving distances between upstream and downstream right-side ramps and left-side managed lane access. It may be difficult to find appropriate locations for managed lane access on older freeways with frequent on- and off ramps. This can be one reason that managed lanes on freeways would operate with more open access, so that weaves are not constrained.

A survey of managed lane practitioners found that spacing for access openings on existing facilities produce a design domain between **1.6 km to 4.8 km** (1 and 3 mi), though the reasons for providing access in a specific location vary, ranging from policy decisions to safety or operational considerations.

12.5.1.4.4 Beginning and Ending of Managed Lanes

Design for both beginning and termination treatment locations must consider proximity to existing or planned ramps from the right side. A minimum of 245 m (800 feet) “per-lane change distance" must be provided between ramps and beginning/termination of managed lanes (**Figure 12.5.9**)

12.5.1.4.4.1 Treatment for Beginning of a Managed Lane

Typically, the managed lane begins on left side of general lane number one with a full width. For the buffer-separated facility a minimum of approximately 600 m (2000 ft) of dashed white line should be on the right. The beginning of the buffer should begin no earlier than approximately 250 m (800 ft) distance per lane change required entering managed lane from the nearest on-ramp (**Figure 12.5.9**).

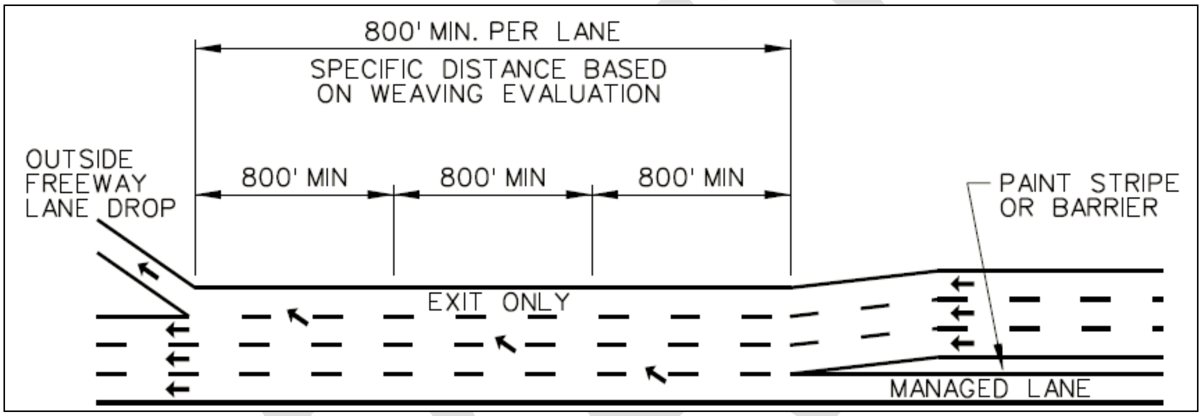


Figure 12.5.9 Terminating a Managed Lane as a General Lane

12.5.1.4.4.2 Treatment for Ending of A Managed Lane

Managed lanes should end in a continuing lane which enables traffic to continue without a merge. If the managed lane has to merge back into the freeway traffic, a minimum of approximately 600 m (2000 ft) of dashed white line should be provided before the end of the managed lane taper begins. No less than approximately 250 m (800 ft) per lane change should be provided from the end of buffer to the next off-ramp or connector (**Figure 12.5.9**).

12.5.1.4.4.3 Treatment for Barrier Separated Managed Lane

The at grade ingress and egress from general-purpose lanes to a barrier-separated ML facility can be achieved with at grade channelized openings in the physical barriers. The at-grade opening can be accomplished with the use of a weave lane to assist merging of the ML traffic with the general-purpose lane traffic. The preferable length of the weaving area for ingress and egress designs is approximately 600 m (2000 ft).

12.5.2 HOV / HOT Lane Design Concepts

The essential principle of a High Occupancy Vehicle (HOV) facility is to give the HOVs priority over non-HOVs from the mixed traffic flow so that they operate in an efficient high-speed manner. The application of HOV lanes depend directly on traffic demands, physical context, operational circumstances, and planning goals of the corridor under study; the decision depends on detailed corridor-specific analysis and it cannot be generalized that all freeway HOV lanes in Ontario should be of one type or another.

In this Section, each design concept is outlined, examples of operational applications elsewhere are cited, typical design standards for basic cross-section elements are illustrated, and some comments are made as to appropriate applications in the Ontario context.

12.5.2.1 Concurrent Flow – Median Lane

The most common HOV lane type is the concurrent flow lane, whereby the HOV traffic flows in the same direction as the adjacent general traffic. Differences in configuration stem from the degree of separation of HOV traffic from adjacent freeway lanes, and the HOV lane's position on either the left (median) or the right side of general traffic lanes.

Median HOV lanes are suited to long commuter trips and express bus services; operational difficulties arise when there are frequent interchanges and a significant amount of HOV weaving between the entrance/exit ramps and the median lane. In high volume areas such as bus stations and park and ride lots, direct "drop ramps" between the median HOV facility and crossing bridges may be used, "Tee" ramps to/from adjacent transit centres can be introduced, and HOV flyover ramps can be provided between two intersecting HOV routes.

The nature of median HOV lanes varies depending on degree of separation provided from adjacent general traffic lanes by utilization of one of these methods; a physical barrier, a painted buffer zone, or a simple painted line.

12.5.2.1.1 Barrier Separation

Operationally, the most desirable strategy is provision of a continuous physical barrier (e.g. Ontario Tall Wall concrete barrier), with either direct access/egress ramps from flyovers or designated controlled entry zone.

12.5.2.1.2 Buffer Separation

The buffer provides a delineation and controls access between managed lane and general-purpose lanes to improve operations. Having no barrier between the manged and general-purpose lanes, improves maintenance and snow removal operations. The ability to designate managed lane for operation only during peak periods (or other specified times) and allow mixed traffic to use the lane when it would otherwise be under-utilized are also protected by non-separated option.

Experimentation with a variety of buffer widths has led to the conclusion that a **1.25 m** wide painted (double white stripe) buffer between managed lane and adjacent mixed flow lane is a preferred design. The buffer clearly provides a margin of comfort which reflects typically high-speed differential between the lanes yet minimizes overall cross-section requirements. It is recommended that a buffer of more than 1.5 m width not be provided, as it could be perceived as a place of refuge for stopped or stalled vehicles, with potential safety consequences. Cross-sections for buffer-separated HOV lanes are shown in **Figure 12.5.3**

12.5.2.1.3 Non-Separated

Non-separated managed lanes operating in the same direction and immediately adjacent to general-purpose lanes, can be located either to the left (desirable) or to the right of general-purpose lanes. Non- separated managed lanes are normally less expensive and easier to implement, and they provide more opportunity for frequent access. However, the ease of access could create problems for enforcement and a greater potential for conflicts.

At many locations, managed lanes operate successfully with only a normal (or doubled) dashed white stripe pavement marking as a separator, relying on pavement markings and overhead signage to delineate the managed lane, this non-separated approach is suited to peak period only managed lanes or in severely constrained rights-of-way. In this situation, managed lane operation will tend to be slower and less relaxing due to driver uneasiness about proximity of slow-moving or stationary traffic and adjacent mixed-flow lane. This may yield to some reduction in managed lane capacity (**Table 12.5.1**), and in the extreme case, may place an upper limit on speed differential between managed lane and adjacent mixed flow lane in the order of 40 km/h. It is important to note that a managed lane which is utilized during peak periods only and reverts to mixed flow use at other times should appear to be a "typical" lane, with no buffer zone or solid stripe between it and other mixed flow lanes. **Table 12.5.2** provides potential tradeoffs for contiguous and barrier-separated concurrent-flow lanes respectively.

Table 12.5.1 Width Factors Used in Capacity and Level of Service Calculations

Distance from Edge of Travelled Way to Obstruction (m)	Width Factor* fw (x capacity)	% Reduction in Theoretical Capacity	HOV Lane Separation Characteristic
^{3} 2.0	1.0	0	wide buffer
1.5	0.99	1	proposed 1.25 m narrow buffer Ontario Standard
1.0	0.98	2	
0.5	0.96	4	non-separated lanes 0 - 0.5 m paint line(s)
0	0.90	10	

*** Assumptions**

· 3.75 m wide travelled (HOV) lane

· two mixed-flow freeway traffic lanes per direction

· Obstruction on one side of HOV lane; adequate shoulder (^{3} 2 m wide) on other side of lane

Table 12.5.2 Trade-offs for Contiguous Concurrent-Flow Lanes

Suggested Sequence	***Cross-Section Design Change***
1	Reduce the 4.30 m median shoulder (for continuous enforcement) to no less than the desirable criteria. Provide designated enforcement areas instead.
2	Reduce median shoulder to the minimum criteria as per Standards
3	Reduce outside (right) shoulder to a typical minimum width as per Standards.
4	Reduce the median shoulder to 0.6 m. *
5	Reduce the managed lane to 3.35 m. *
6	Reduce general-purpose lanes to 3.35 m, starting from the left and moving to the right as needed. The outside (right) lane is to remain at 3.65 m. *
7	Transition barrier shape at columns to vertical face.
*Requires design exception.	

Source: Nevada Department of Transportation, ML Design Manual December 2013

12.5.2.1.4 Variability

The implementation of managed lanes as added lanes on existing freeways involve, in many cases, geometric compromises to utilize existing structures or minimize impact and cost. For this reason, a range of alternative cross sections have been illustrated in **Figures 12.5.10** and **12.5.11** with alternative shoulder widths for barrier separated ML facility and buffer separated ML facility.

An illustration of a typical constrained situation at a median bridge pier is shown in **Figure 12.5.12** where it requires alternative cross section for HOV barrier and buffer separation from the general-purpose lane.

When faced with a restricted envelope or section of a corridor within which to retrofit an HOV facility, the designer may be faced to deviate from standards and should consider first the least essential cross-section elements. **Tables 12.5.2, 12.5.3 and 12.5.4** provides general practice.

HOV lanes are governed by general freeway design standards, and exceptions to the standards will need a sound justification and senior level approval (**Section 12.5.5**).

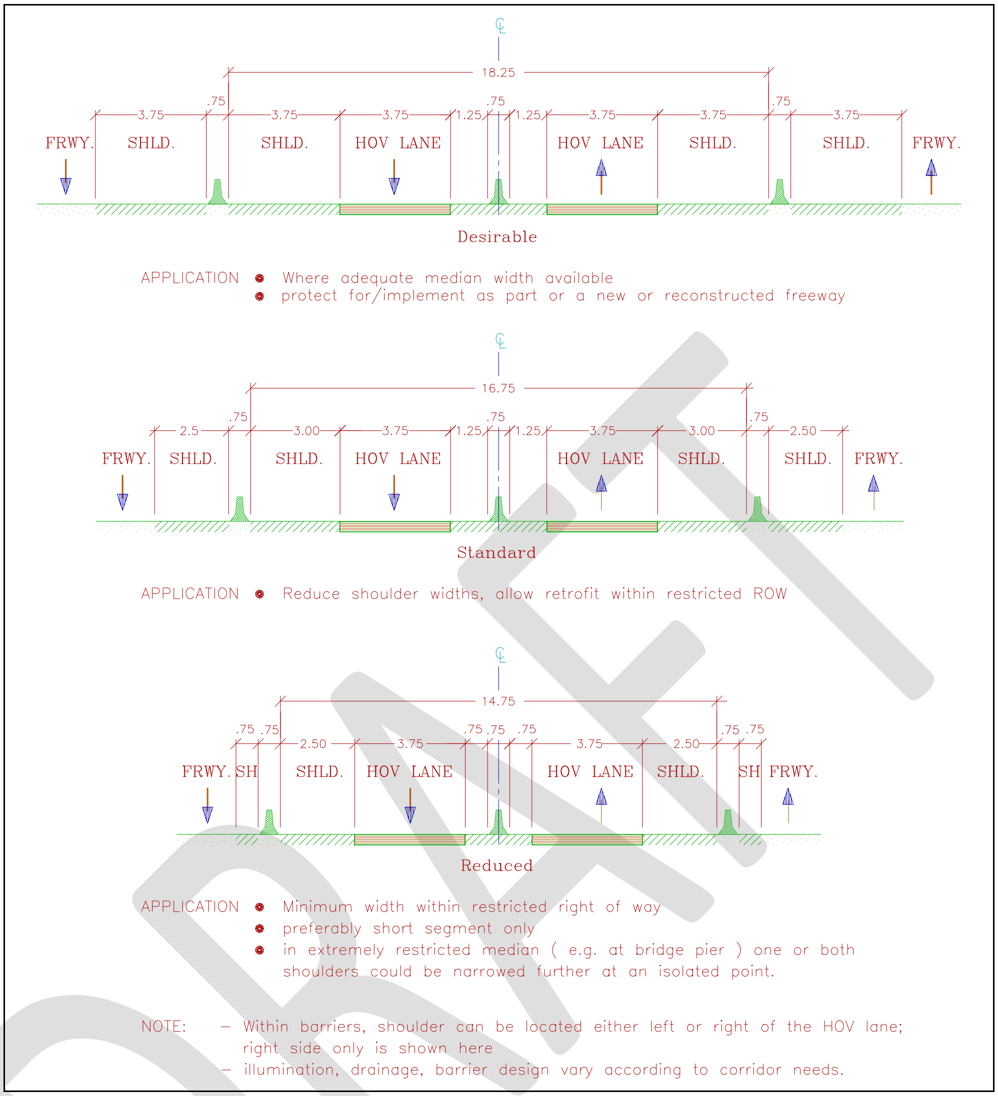


Figure 12.5.10 Two-Way Barrier-Separated HOV Facility Cross-Sections

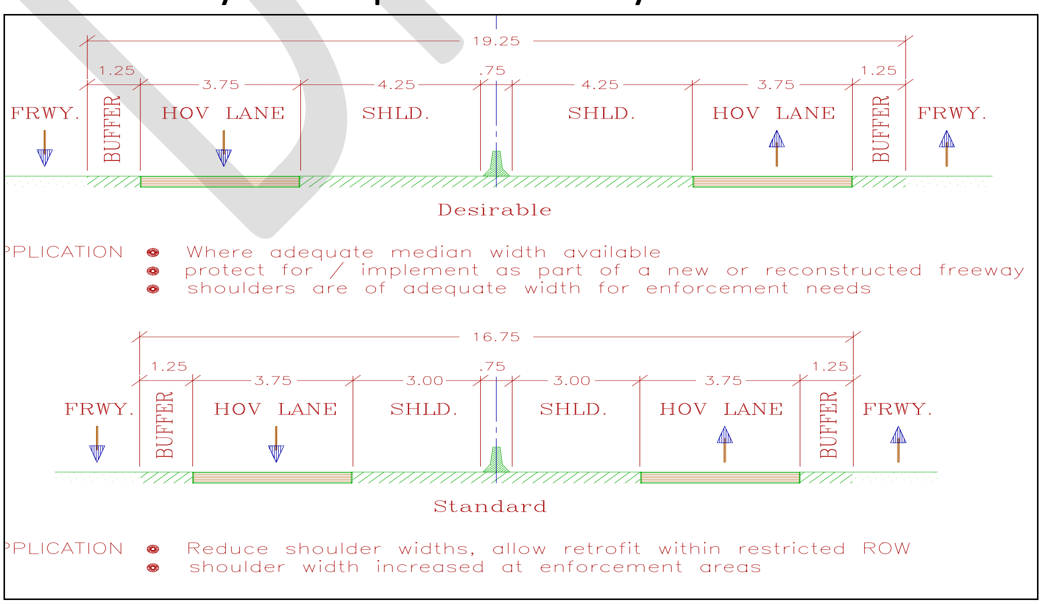


Figure 12.5.11 Two-Way Buffer-Separated HOV Facility Cross-Sections

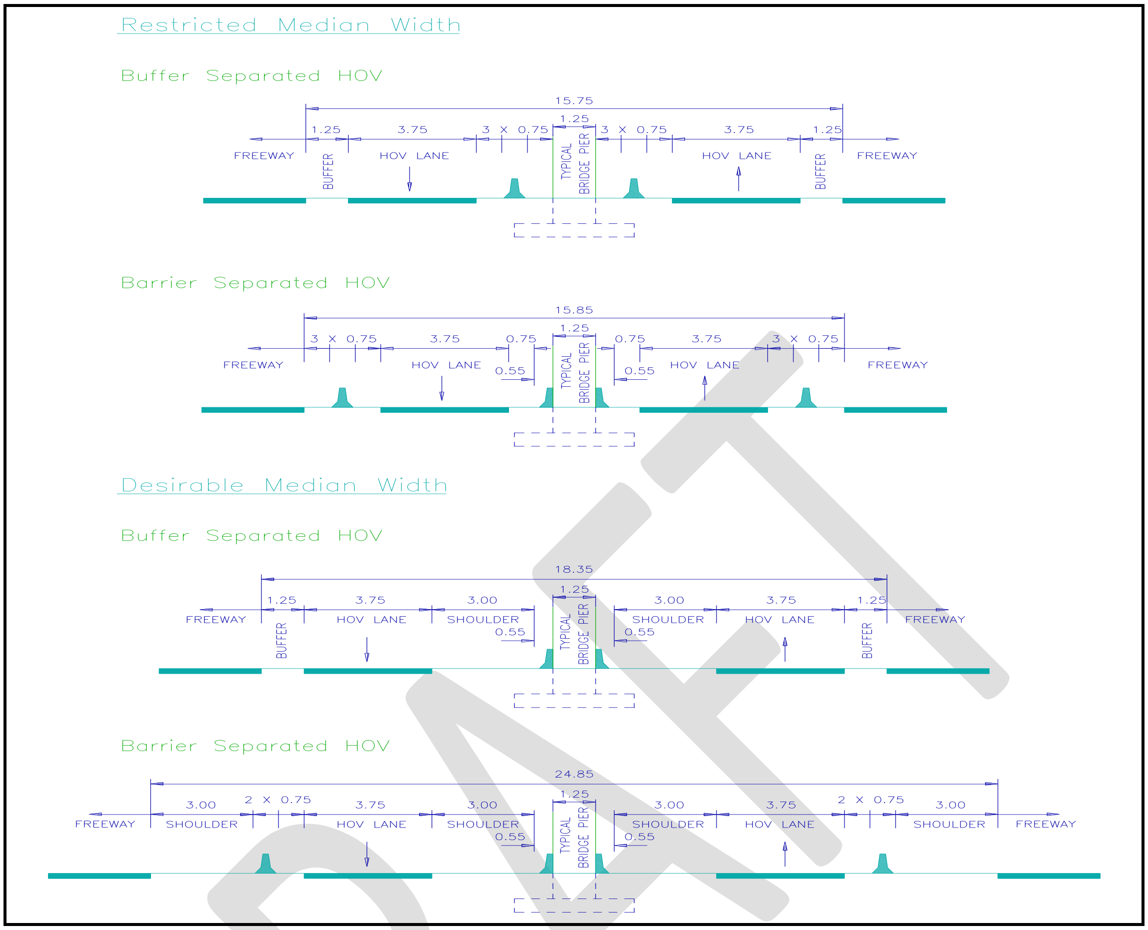


Figure 12.5.12 HOV Lanes at Median Pier

Table 12.5.3 Guidelines for Restricted Section to Retrofit a Median ML Facility (Concurrent Flow)

Compromise	**ML Lane Type**	
	Two-Way Barrier-Separated	Two-Way Buffer-Separated
First	Reduce left ML lane lateral clearance to no less than 0.6 m	Reduce left ML lane lateral clearance to no less than 0.6 m
Second	Reduce right ML lane lateral clearance to no less than 2.5 m	Reduce freeway right lateral clearance (shoulder) from 3 m to no less than 2.5 m
Third	Reduce freeway left lateral clearance to no less than 0.6 m	Reduce buffer width to no less than 0.3 m
Fourth	Reduce freeway right lateral clearance (shoulder) from 3 m to no less than 2.5 m	Reduce ML lane width to no less than 3.35 m (consider reversing fourth and fifth steps when buses are projected to use the HOV facility)
Fifth	Reduce ML lane width to no less than 3.35 m (consider reversing fifth and sixth steps when buses are projected to use an HOV facility)	Reduce selected mixed-flow lane widths to no less than 3.35 m (leave at least one 3.65 m outside lane for trucks)
Sixth	Reduce selected mixed-flow lane widths to no less than 3.35 m (leave at least one 3.65 m outside lane for trucks)	Reduce freeway right lateral clearance shoulder from 2.5 m to no less than 1.25 m
Seventh	Reduce freeway right lateral clearance shoulder from 2.5 m to no less than 1.25 m	Transition barrier shape at columns to a vertical face or remove buffer separation between ML and mixed-flow lanes.
Eighth	Convert barrier shape at columns to a vertical face.	

Note that this list is provided as ***an example and is not intended to supersede engineering judgment in specific design applications.***

Table 12.5.4 Pros and Cons of Managed Lane Facility Cross-Section Trade-offs

Design Elements	Pros	Cons
3.75 m travel Lane	- Matches typical guideline for general-purpose travel lanes on freeways - Ample for accommodation of buses and trucks	-May be difficult to achieve in a retrofit without taking width from other elements in the managed lane or general-purpose facilities
3.65 – 3.75 m Shoulder	- Matches typical guideline for general-purpose travel lanes on freeways - Provides refuge space for disabled vehicles - Provides space for enforcement activities - Provides space for temporary storage of snow removed from the travel lane - Provides option for throughput during incidents in the travel lane	- May be difficult to achieve in a retrofit without taking width from other elements in the managed lane or general-purpose facilities
3.35 m travel Lane	- Easier to provide in a retrofit than 3.65-3.75 m lane, though there are safety trade-offs - May be acceptable if associated with a wider buffer	- Narrower than typical freeway lane - Less-than-minimum width in some guidelines; not always allowed or recommended - Associated with higher number of crashes
3.0 – 3.35 m Shoulder	- Can accommodate passenger vehicles and most heavy vehicles - Easier to provide in a retrofit than 3.65 m shoulder	- Narrower than typical freeway shoulder - Reduces the available space to store and/or attend to disabled vehicles and to store snow - Restricts ability of enforcement officers to conduct activities outside of the travel lane
2.4 – 2.7 m Shoulder	- Can accommodate most passenger vehicles - Easier to provide in a retrofit than 3.65 m shoulder	- Not suitable for heavy vehicles - Very restrictive for refuge and enforcement - Minimizes usefulness in snow storage

		and incident management
Shoulder less than 2.4 m	- Provides a measure of lateral clearance for drivers compared to no shoulder	- Not suitable for heavy vehicles - Not wide enough to store a passenger vehicle without encroaching on the travel lane - Not suitable for maintenance, enforcement, snow storage, or incident management - Can restrict sight distance in curves - Associated with higher number of collisions
1.2 m or wider buffer	- Provides separation between managed lanes and general-purpose lanes - Provides additional accommodation for vehicles to shift laterally within the lane in horizontal curves	- May be difficult to achieve in a retrofit without taking width from other elements in the managed lane or general-purpose facilities - Depending on width, may be seen as an additional travel lane for passenger vehicles or motorcycles without additional delineation or separation devices
Buffer less than 1.2 m	-Provides a measure of separation between managed lanes and general-purpose lanes -Easier to provide in a retrofit than a wider buffer	- Reduces distance between traffic streams that could be traveling at greatly different speeds - May not be allowed in some jurisdictions

Source: Texas A&M Transportation Institute (TTI).

This list provides **an example and it is not intended to supersede engineering judgment in specific design applications.**

12.5.2.2 Concurrent Flow – Right Lane

12.5.2.2.1 Right Lane Use

The location of managed lanes on the outer (right hand) lanes of a freeway can effectively resolve some issues associated with a median managed lane alternative. However, it poses new operational challenges, particularly at interchanges. A right-side managed lane conflicts with local on and off-movements with the main lanes, so therefore, either usage of right-side orientations needs to be low to mitigate conflicts, or usage must be restricted to select drivers and vehicles such as buses only. In the context of frequent on-off patterns, right lane managed lane may address the transit needs and short distance trip patterns at lower cost than median managed lanes. Severe physical constraints, inadequate right-of-way, or structural requirements may effectively preclude a median managed lane, forcing an outside lane option. Another application of right-side managed lanes is a low-cost and easily implemented temporary or pilot project facility, or as an early stage towards a more permanent managed lane. The most common use of right-side managed lanes has been as a queue bypass for priority vehicles (particularly buses) in situations such as a bridge/tunnel approach, ferry dock, or toll plaza where either a right side or left side managed lane could apply equally well.

For freeway conditions, the right-side managed lane operation is constrained by the interaction between HOVs and non-HOVs at entry and exit interchange ramps. The most effective right side HOV lanes are those with few vehicles in them; to achieve the person-movement volumes which justify provision of an HOV lane while minimizing the number of vehicles involved, bus-only operation may be the most appropriate designation. Unless grade separated at the interchange, right-side HOV lanes exhibit lower operating speeds (and Level of Service) than median HOV lanes; the capacity of a right-side HOV lane is correspondingly lower, at approximately **1100 vehicles/hour** rather than 1500 vehicles/hour. There is also greater risk of motorist confusion with respect to signing and pavement markings due to the weaving manoeuvre at ramps. Right-side HOV lanes have proven to be more difficult to enforce than median facilities, due to frequency of violators claiming that they were bound for the next exit ramp. With bus-only use however, proper use of the lane becomes easier to enforce.

The right-side managed lane can be separated from adjacent mixed flow lane by either a narrow buffer (±1.25 m) or paint lines; the approach does not lend itself to barrier separation due to the transitions which must be made at interchange ramps. If the lane is always used by moving traffic (i.e. it does not convert to shoulder use in off-peak periods) a standard permanent shoulder should be provided. In this respect the right-side managed lane design standards are identical to those for any freeway lane. **Figure 12.5.12** illustrates a typical cross-section.

12.5.2.2.2 Right Shoulder Use

A right shoulder may be utilized as a managed lane on a temporary or peak period basis. Rather than permanently occupying the right lane of a freeway, a right shoulder can provide priority lane when most beneficial and revert to its "typical" usage at other times.
The pavement must be strong enough to allow daily usage by transit vehicles with depth equivalent to adjacent lanes. For shoulder use by buses only, **3.50 m is the design width**, while if other HOVs are to use the lane an additional 0.35 m in width is recommended (**Figure 12.5.13)**. Associated with the change in function of the shoulder, requirements should be considered for reinforce, extend, or provide guiderails, since moving traffic would shift 3.5 m closer to any obstacle or slope.

As is the case for any temporary - use managed lane, signage must be frequent, concise, and clear regarding the proper use of the lane. If the shoulder is to be used for HOVs in peak periods only, the provision of an additional "shoulder" beyond the 3.75 m paved shoulder would be desirable but not essential. The shoulder could be used by a stopped vehicle in the event of an emergency, in which case the HOVs would have to merge with mixed flow to bypass the obstacle; a premium is therefore placed on the implementation of an effective Incident Management Strategy aimed at removing any stopped vehicles as quickly as possible.

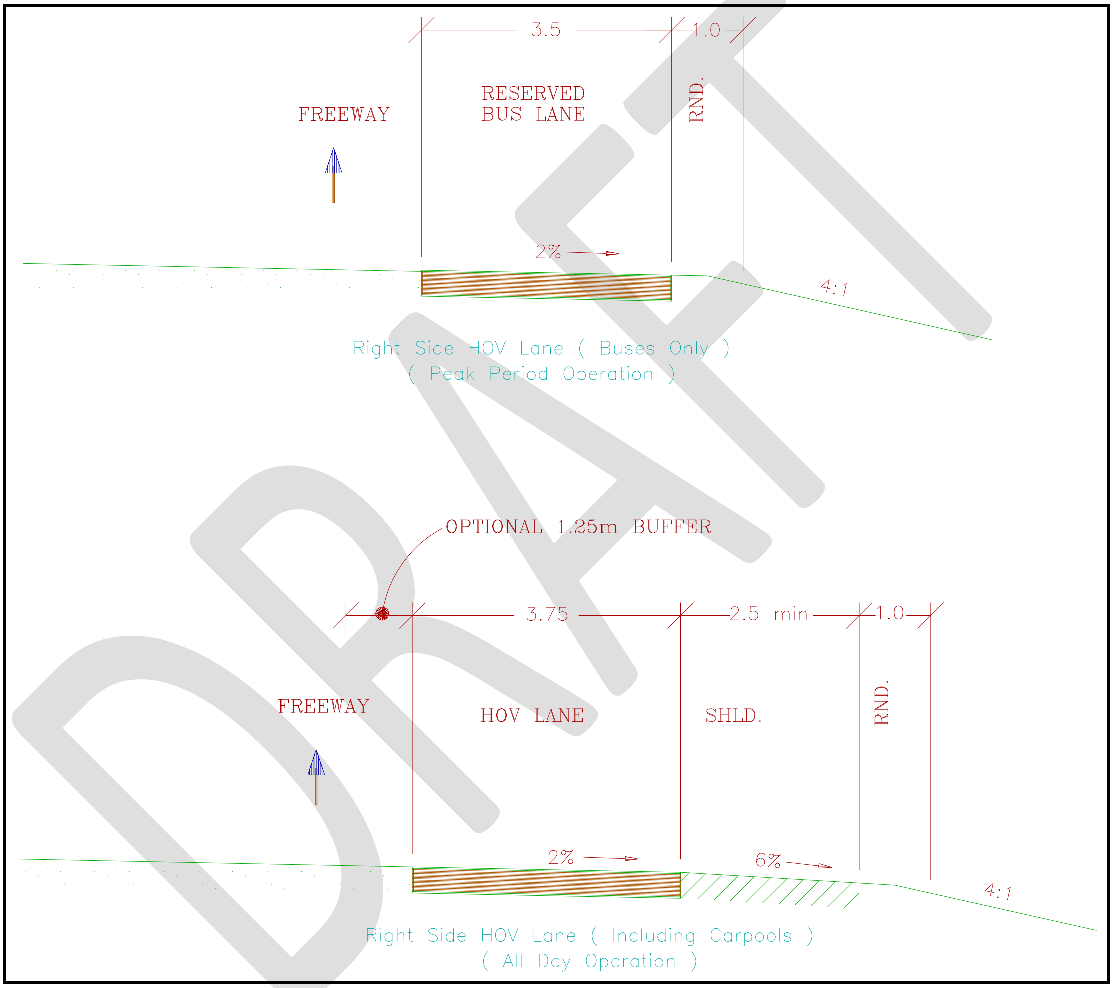


Figure 12.5.13 Right Side HOV Lane

12.5.2.3 Reversible Flow

A reversible flow HOV lane is suited to a corridor where there is a high directional split in the peak period (at least 65% of all traffic travelling in the peak direction) and is often used in a corridor where extreme physical constraints preclude designation of more than a single lane for HOV use. A two-lane reversible facility is used to accommodate extremely heavy peak direction demand (potentially both HOV and mixed flow).

A reversible lane must be in the median of the freeway to allow access to it from both directions at different periods of the day. Reversible HOV lanes, once installed, cannot readily be adapted to other operational approaches, and are only appropriate when corridor demand directionality is a permanent characteristic.

Reversible lanes add additional capacity to the peak flow lanes, which helps to ease congestion and optimize passenger mobility. However, reversible flow lanes pose a unique set of operational challenges and opportunities. These lanes work well when isolating managed facility users from general-purpose lanes by use of barriers between the two systems to improve operational performance. The ability to provide access to/from reversible lane is normally restricted and infrequent; as with any barrier-separated lane, therefore, a premium is placed on focusing carpools and buses at key nodes at either end of the corridor or at a limited number of points along the corridor where access can be provided.

Reversible flow lanes require set hours of operation in each direction. Additional operational measures must be put in place to ensure traffic is routed into and out of the facility at set times to ensure maximized flow and standardized periods of operation. Reversible lanes require additional inputs of signage and safety features to ensure vehicles can easily and safely access the facility during off hours. Raising public awareness to their operation and safety features should be a prime component of any reversible facility implementation plan.

Specialized signage, access designs, and daily operational requirements are additional factors which should be considered for a reversible lane. The median location of reversible HOV lanes demands separation of HOV traffic from general freeway flows by physical barriers. Consequently, a shoulder must be provided between barriers in order that the lane not become blocked by a stalled or stopped vehicle. The provision of direct reversible median drop ramps between crossing roads and the median HOV lane(s) is a typical feature of many reversible facilities. Recommended cross-sections for reversible HOV lanes are shown in **Figure 12.5.14**

As with concurrent flow, a reversible HOV lanes may be applied in extremely constrained retrofit situations, where inadequate width is available for the optimum design.

Reversible flow lanes require additional study to determine the amount of time required to clear out the lanes prior to switching directions compared to bi-directional systems with continuous flow in both directions. Clearance and resetting times vary by corridor length, speed limit and congestion. Efficient planning is necessary to determine system-wide clearance times in multi-facility and radial reversible managed lanes systems to ensure a safe transition for flow from one direction to the other.

Reversible facilities require a signage system to be clearly established to inform travelers of hours of operation for reversible facilities in their direction of travel. Highly visible gates should be developed and installed to prevent flow from the off-peak direction into the reversible managed facility during periods of opposite flow.

Table 12.5.6 summarized key advantages and disadvantages of Reversed Managed Lane facilities.

By maximizing the utility of managed lanes, reversible facilities can serve peak demands while keeping costs at a minimum. While bi-directional facilities may serve off-peak demand in both directions, these facilities require an investment in both directions. Reversible facilities are less expensive than bi-directional facilities primarily due to the construction of one facility in place of two separate unidirectional facilities.

Reversible Lane Application in Ontario

The applicability of reversible HOV lanes to Ontario freeways appears to be limited, for two main reasons:

- Few Ontario freeways exhibit a directional split as high as 65% during the peak period, particularly when projected over the long term (20 years).
- Most freeway crossing bridges in Ontario have centre piers, conflicting with a centred median lane. Also, high mast light standards and sign support footings utilize the median.

Table 12.5.5 Guidelines for Restricted Section to Retrofit a Median HOV Facility (Reversible Flow)

Compromise	Cross-Section
First	Reduce single-lane HOV envelope to no less than 6 m, or two-lane envelope to no less than 8.5 m.
Second	Reduce freeway left lateral clearance to no less than 0.6 m.
Third	Reduce freeway right lateral clearance (shoulder) from 3 m to no less than 2.5 m.
Fourth	Reduce HOV lane width to no less than 3.35 m (consider reversing fourth and fifth steps when buses are projected to use the HOV facility).
Fifth	Reduce selected mixed flow lane widths to no less than 3.35 m (leave at least on 3.65 m outside lane for trucks).
Sixth	Reduce freeway right lateral clearance shoulder from 2.5 m to no less than 1.25 m.
Seventh	Convert barrier shape at columns to a vertical face.

Ontario Examples: Lane controls and no (or minimal) physical separation:

- The **Peace Bridge** between the U.S. and Canada, connecting Fort Erie, Ontario to Buffalo, New York. Three lanes total, all marked reversible, one reversed in the direction of rush hour flow with the possibility of all lanes flowing in the same direction based on traffic needs.

- The **Queenston-Lewiston Bridge** connecting Niagara-on-the-Lake, Ontario to Lewiston, New York. Five lanes total, all marked as reversible, one to four lanes marked daily in the same direction, depending on traffic needs. In addition to the directional signals, special signals are also fitted to specify what type of vehicle may use the lane.

Table 12.5.6 Advantages and Disadvantages of Reversible Managed Lane Facility

Information Source Georgia Department of Transportation, Jan 2010

	Operational Issues		Cost		Safety	
	Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Reversible	●Efficient for moving vehicles longer distances ●Isolation from GP lanes improves flow ●Maximizes V/C ratio utility by putting lanes in the direction of greatest flow	●Not well known to drivers ●Complex operations ●Requires studies to determine optimal hours of operation ●Some proportion of demand will not be served ●Less suited to short trips	●Potentially less expensive than bi-directional facility ●May require less ROW ●May require less overpass, bridge and interchange construction	●Trade-off between cost and total access	●Requires a barrier separated system which reduces the risks due to traffic speed turbidity	●Requires additional signage and gates to prevent access to vehicles during off hours ●Requires more enforcement ●Requires extra development to ensure safety at system-to-system interchanges
Bi-Directional	●Can allow for buffer or alternate lane separation ●Can be operational 24hr/day ●Can be designed for short or long trips	●Provides more facility than demand requires in most off-peak hours	●Trade-off between cost and total access	●More expensive than reversible facility ●More overpass bridge and interchange construction often required ●Requires more ROW	●Never utilizes the same corridor for flow in opposite directions	●Does not require barrier systems which can reduce the risk of collision due to traffic speed turbidity

	Transferability		Environmental		Social	
	Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
Reversible	●During system-to-system transfers between facilities with similar hours of operation and flow directions, the negative impacts are negligible, but the costs and operational improvemen-ts remain in place	●System-to-system interchanges may require additional engineering due to variations in peak hour directional flow ●Transference onto a radial corridor may not be possible ●Variations in hours of operation can complicate access	●May require less ROW ●May provide air quality improvemen-ts ●May reduce greenhouse gas emissions	●Does not maximize potential air quality benefits from both directions of traffic flow in locations with lower directional splits	●May require less ROW ●May have less impact on neighbouring land uses ●Shorter construction period has less impacts on surroundings	●Provides access in only one direction at a time
Bi-Directional	●No hours of operation or one-way flows ●Normal routing and directional conditions ● Allows for continued access and transference along the managed lanes regardless of corridor shift	●System-to-system interchanges may require more system connections than reversible system interchanges	●Potentially maximizes air quality improvemen-ts ●May reduce greenhouse gas emissions	●May require more ROW	●Provides access in both directions at potentially all hours	●May require more ROW ●May have higher impact on neighbouring land uses ●Longer construction periods could lead to adverse impacts on surroundings

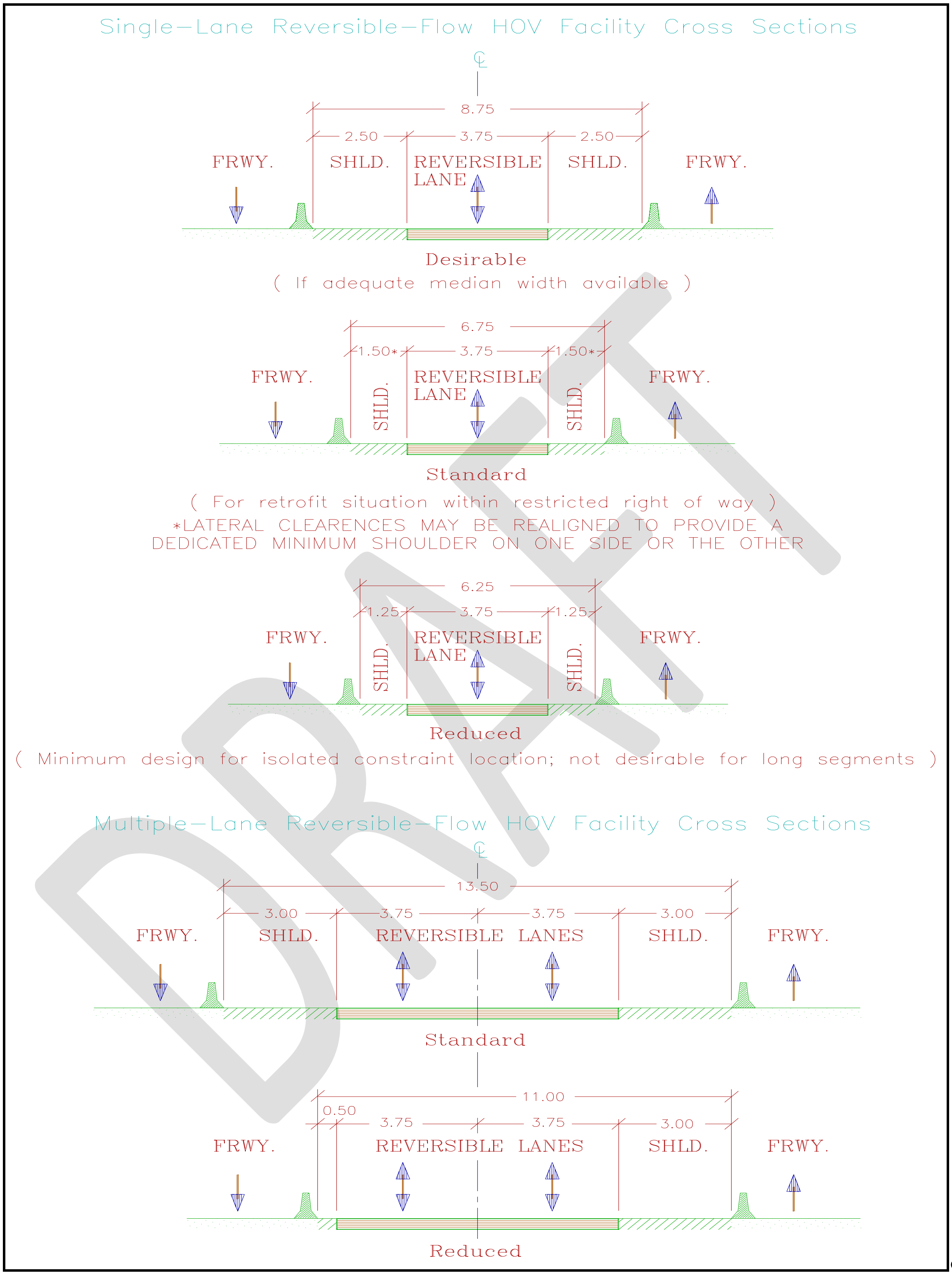


Figure 12.5.14 Reversible HOV Lanes

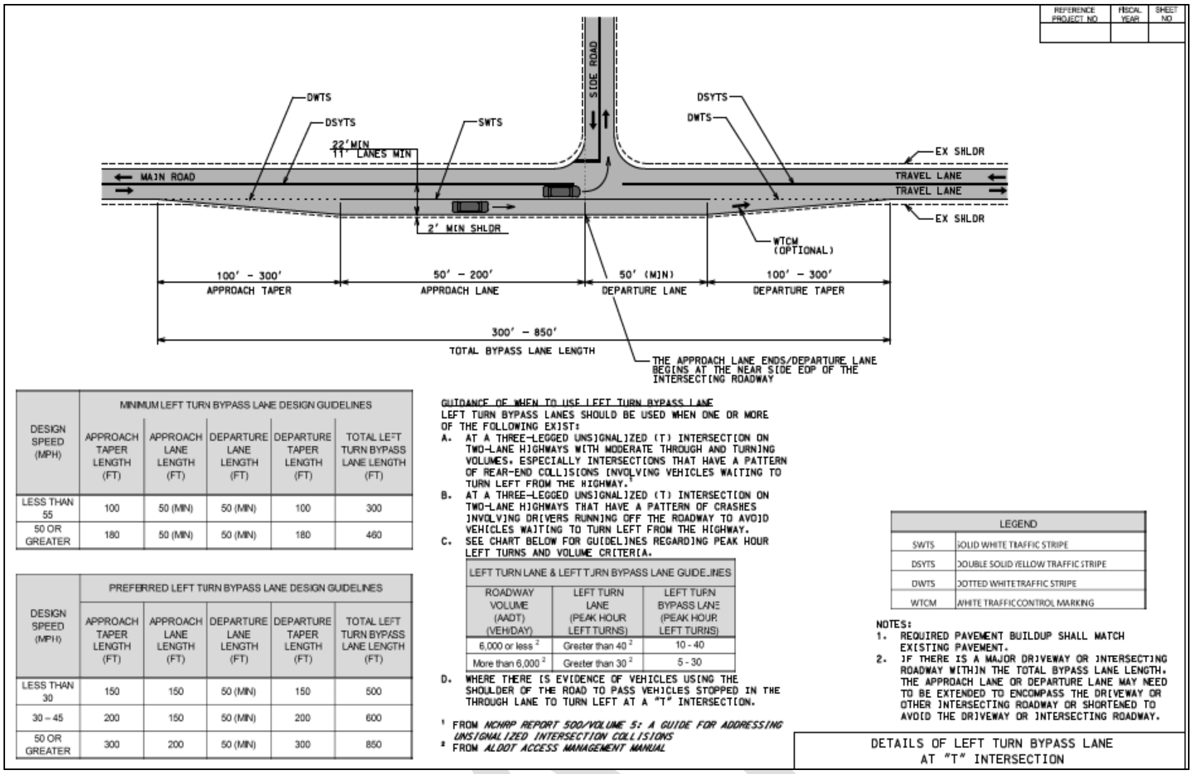
12.5.2.4 Queue Bypass – Main Line

In some circumstances, recurring queues develop on the provincial freeway system; examples include international border crossings/customs areas, toll plazas, ferry docks, exit ramp terminals, or constrained merging areas. Opportunities may exist to give HOVs "head of the queue" priority treatment through a provision of a short right side or left side lane segment which bypasses the constriction and/or the resulting queue of vehicles.

A short, dedicated lane can be implemented around a point specific traffic bottleneck. This bottleneck may be operational or geometric in nature. The most common queue bypasses exist on approaches to bridges and tunnels, approaches to toll plazas, and metered entrance ramps. The bypass may be functional only for a time period that a queue typically forms, and some queue bypasses are now tolled at a differential rate from other lanes if implemented at a toll plaza.

An HOV bypass may be created by widening an existing ramp, constructing a new ramp where right of way is available, or reallocating the existing pavement width (provided the shoulders are full depth). Ramp meter bypass lanes may be located on the left or right of metered lanes. Typically, bypass lanes are located on the left side of the ramp (See Figure 9.17.9: Left-Turn Slip Around Design – Tangent Alignment of TAC GDG -2017 and Figure 12.5.15 below)~~**Figures 12.5.15 – 12.5.17**).~~

Any of the treatments described previously (reversible and concurrent lanes) can be used, in conjunction with a site-specific assessment of constraints and physical opportunities. Where HOVs are required to merge with or weave across other traffic (e.g. at exit ramp terminals) careful operational review is required.



DESIGN SPEED (MPH)	MINIMUM LEFT TURN BYPASS LANE DESIGN GUIDELINES				
	APPROACH TAPER LENGTH (FT)	APPROACH LANE LENGTH (FT)	DEPARTURE LANE LENGTH (FT)	DEPARTURE TAPER LENGTH (FT)	TOTAL LEFT TURN BYPASS LANE LENGTH (FT)
LESS THAN 55	100	50 (MIN)	50 (MIN)	100	300
50 OR GREATER	180	50 (MIN)	50 (MIN)	180	460

DESIGN SPEED (MPH)	PREFERRED LEFT TURN BYPASS LANE DESIGN GUIDELINES				
	APPROACH TAPER LENGTH (FT)	APPROACH LANE LENGTH (FT)	DEPARTURE LANE LENGTH (FT)	DEPARTURE TAPER LENGTH (FT)	TOTAL LEFT TURN BYPASS LANE LENGTH (FT)
LESS THAN 30	150	150	50 (MIN)	150	500
30 – 45	200	150	50 (MIN)	200	600
50 OR GREATER	300	200	50 (MIN)	300	850

LEFT TURN LANE & LEFT TURN BYPASS LANE GUIDELINES		
ROADWAY VOLUME (AADT) (VEH/DAY)	LEFT TURN LANE (PEAK HOUR LEFT TURNS)	LEFT TURN BYPASS LANE (PEAK HOUR LEFT TURNS)
6,000 or less [2]	Greater than 40 [2]	10 - 40
More than 6,000 [2]	Greater than 30 [2]	5 - 30

LEGEND	
SWTS	SOLID WHITE TRAFFIC STRIPE
DSYTS	DOUBLE SOLID YELLOW TRAFFIC STRIPE
DWTS	DOTTED WHITE TRAFFIC STRIPE
WTCM	WHITE TRAFFIC CONTROL MARKING

~~**Figure 12.5.15 Details of Left Turn By-Pass Lane at "T" Intersection**~~

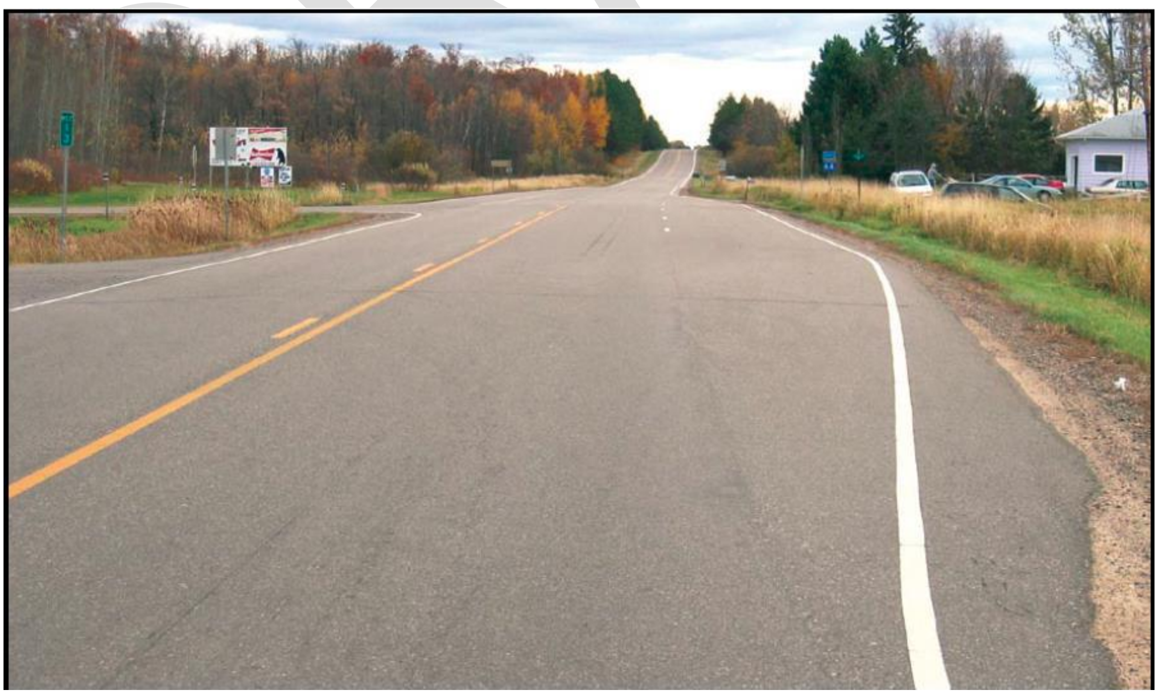
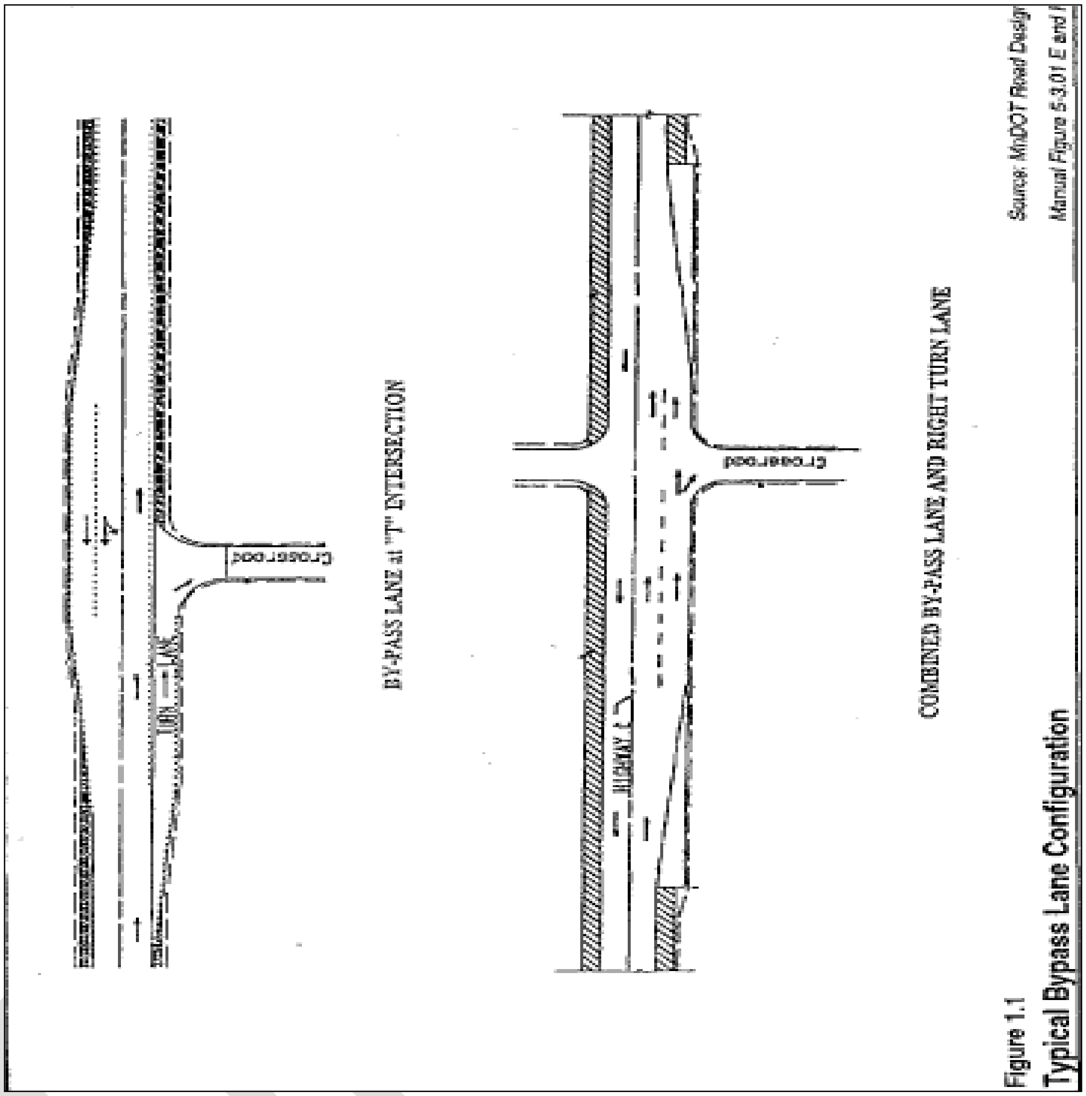


Figure 12.5.15~~16 –~~ Queue By-Pass Lane- In Ontario a Slip-Around



~~**Figure 12.5.17 Typical By-Pass Lane Configuration (*Source MnDOT Road Design*)**~~

12.5.2.5 Metered Freeway Entrance Ramps

A key element of many Freeway Traffic Management Systems is ramp metering regulating the rate of vehicle entry onto the freeway. This process is normally applied only during peak periods on a set of freeway entry ramps, resulting in a queue of vehicles being created on the on ramp upstream of the meter signal. This peak period recurring queue provides an ideal opportunity for HOV bypass lanes, allowing HOVs to save up to several minutes. Where a main line freeway bus service exits the freeway to intercept local passengers then re-enters the freeway via metered ramp, a ramp meter bypass lane is essential to avoid repeated delays to the bus. Ramp meter bypass lanes may be provided in association with, or independent of, mainline freeway HOV lanes.

HOV ramp meter bypass are typically low-volume operations with relatively little risk of conflict between vehicles; HOV-only access ramps could be considered where a two-lane ramp is physically infeasible or if high HOV volumes result in safety concerns that cannot be resolved otherwise. It is recommended that all metered ramps by provided with HOV queue bypass lanes where physically feasible **(Figure 12.5.16~~18~~).**

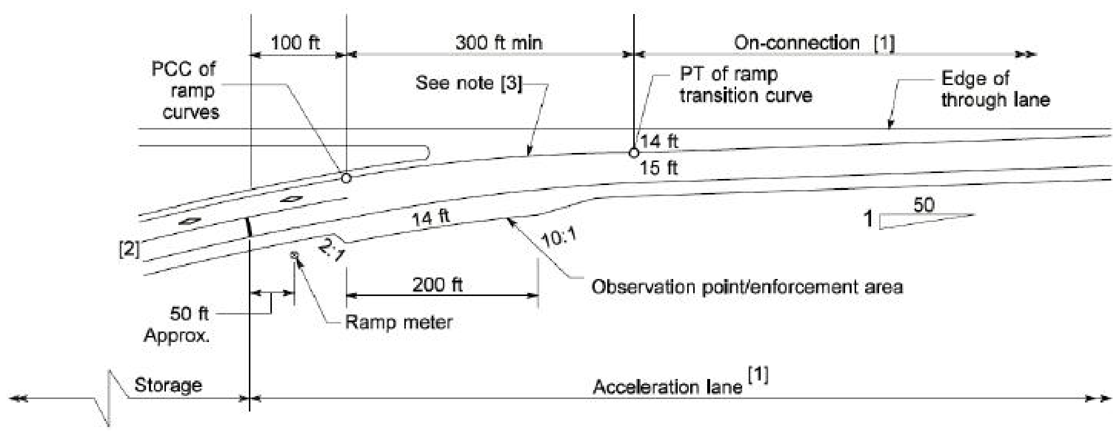


Figure 12.5.16~~18~~ Two-lane Ramp Including a Single Lane Ramp and a Single Metered Lane with an HOV Bypass (*Source: WSDOT Design Manual June 2009)*

12.5.2.5.1 General

HOV Bypass Design

1. The HOV bypass is designed to operate only during the time when the ramp is being metered. During off peak times, all traffic should use the main portion of the ramp. For this reason, the approach to bypass should be designed such that a conscious effort has to be made by the driver entering the bypass, see **Figure**s **12.5.17~~19~~ and 12.5.18~~20~~**

2. A raised island up to 2.5 m (8 ft) wide with curb shall separate the HOV bypass from the main portion of ramp.

3. Free right turns adversely affect entrances to HOV bypasses. If practical, designers should consider eliminating the free right turn when an HOV bypass is constructed. Where double left turn lanes (to the on-ramp) and an HOV bypass are present, free right turns shall not be allowed. **Figure 12.5.16~~18~~** shows an HOV bypass lane when double left turn lanes are present.

4. The Traffic Office should be contacted for input regarding queue length and storage.

5. If the projected peak traffic storage demand is such that an overflow from the storage area will block the entrance to the bypass lane, the storage length should be increased and additional lane width, striped as a diamond lane, should be provided (**Figure 12.5.17~~19~~ note 8)**.

6. The minimum recommended length of a ramp is approximately 400 m (1300 ft). This length would allow entering vehicles to approach mainline speeds.

During periods of metering, the left side or outside lane will permit smooth bus re-entry onto entrance ramps from bus interface locations. During periods of no queues on entrance ramps, buses re-entering from interface locations may turn directly into the right metered lane to avoid possible merging conflicts downstream.

Bypass lanes shall be designed such that the configuration can be easily modified to standard ramp lanes if their use by high occupancy vehicles (HOV's) is discontinued at the interchange.

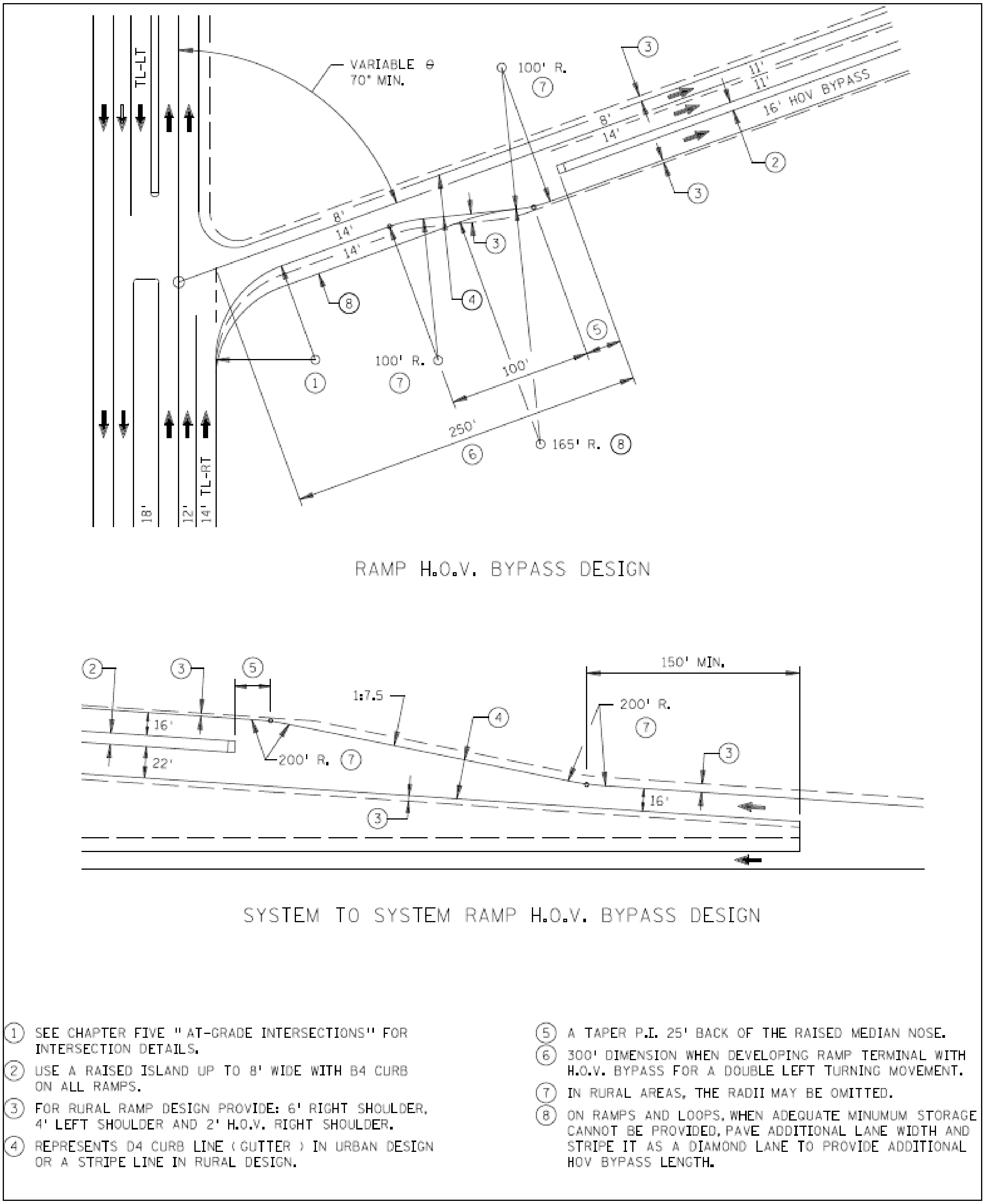


Figure 12.5.17~~19~~ Ramp HOV Bypass

Source MnDOT Road Design Manual

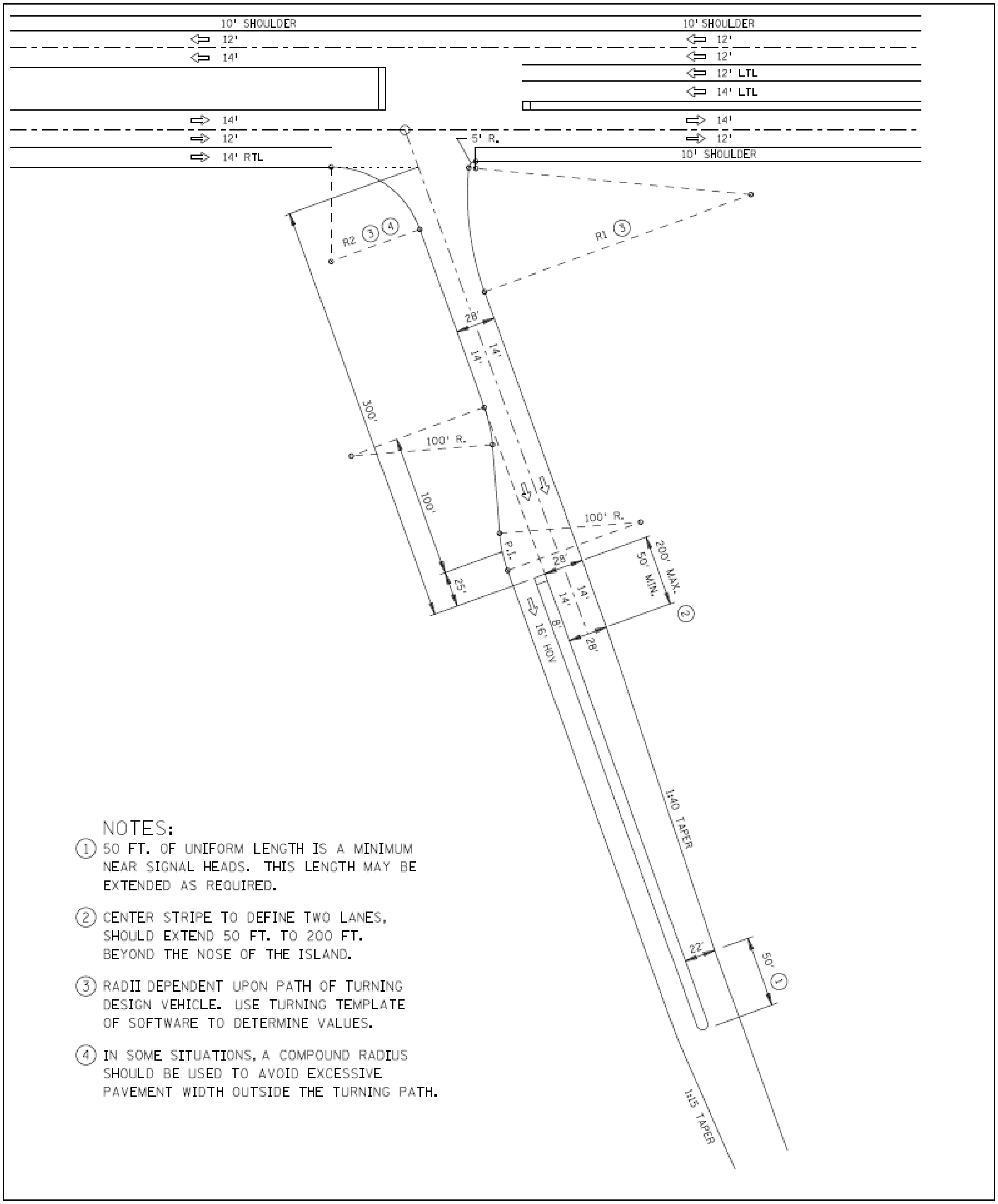


Figure 12.5.18~~20~~ Double Left Turn on Ramp with HOV Bypass Lane

Source MnDOT Road Design Manual

12.5.2.5.2 Crossing Road Exit Terminal and Transition Zone

Details of exit terminal design at the crossing road, illustrated in **Figure12.5.19~~21~~**and **12.5.20~~22~~**are found in **Chapter 10**, up to the bullnose. Downstream of bullnose, a diverging taper shall be introduced on outside or left side of the ramp. Start of taper should be at the bullnose and the length of taper should be adjusted to minimize the deflections created by the taper. Details of the taper are found in **Chapter 10.**

If more storage for ramp metering is required, then a two-lane crossing road exit may be considered, provided traffic control concerns are addressed, and approval is given by the Traffic Office.

At no point along the ramps shall the offset between the crossing road and the left edge of pavement on the ramp be less than 3.5 metres.

12.5.2.5.3 Freeway Entrance Terminal and Transition Zone

Details of entrance terminal design at the freeway, depicted in **Figure 12.5.21~~3~~** are found in **Chapter 10**, downstream of the bullnose.

Upstream of bullnose, a merging taper shall be introduced on outside or left side of the ramp no less than 70m in length measured from the bullnose. The length of taper should be adjusted to minimize the deflections created by the taper. It is important that safe merge conditions be designed however ramp metering queue length is diminished as the taper is extended. Location of the metering station is normally dependent on the taper and shall be no less than 100m from the bullnose. The parallel lanes of the ramp shall be no less than 30 m between the metering station and the start of taper.

At no point along the ramp shall the offset between the freeway edge of pavement and the left edge of pavement on the ramp be less than 3.6 m with curb and gutter or 4.6 m without curb and gutter.

12.5.2.5.4 Ramp Cross-Section

The entrance ramp between transition zones shall be designed to an ultimate two lanes with shoulders. Paved shoulder should be provided on the right or inside of the ramp through the freeway terminal transition zone to permit possible merging vehicle runout. In cases where bypass lanes are not to be constructed initially, grading should be undertaken to satisfy ultimate two-lane design. Surfacing should be undertaken to provide single lane and appropriate shoulders.

The two-lane ramp shall have a paved width of no less than 7.75 m wide, however design widths indicated in **Chapter 4** should be used depending on radius of inner edge of pavement and traffic condition.

12.5.2.5.5 Safety Measures

A longitudinal barrier (double steel beam or concrete median barrier) shall be located along the outside of an inner loop ramp if unprotected clearance between inner loop and outer loop ramp is less than 10m. Design of the barrier shall be in accordance with the **MTO Roadside Design Manual** . An anti-glare screen may also be required.

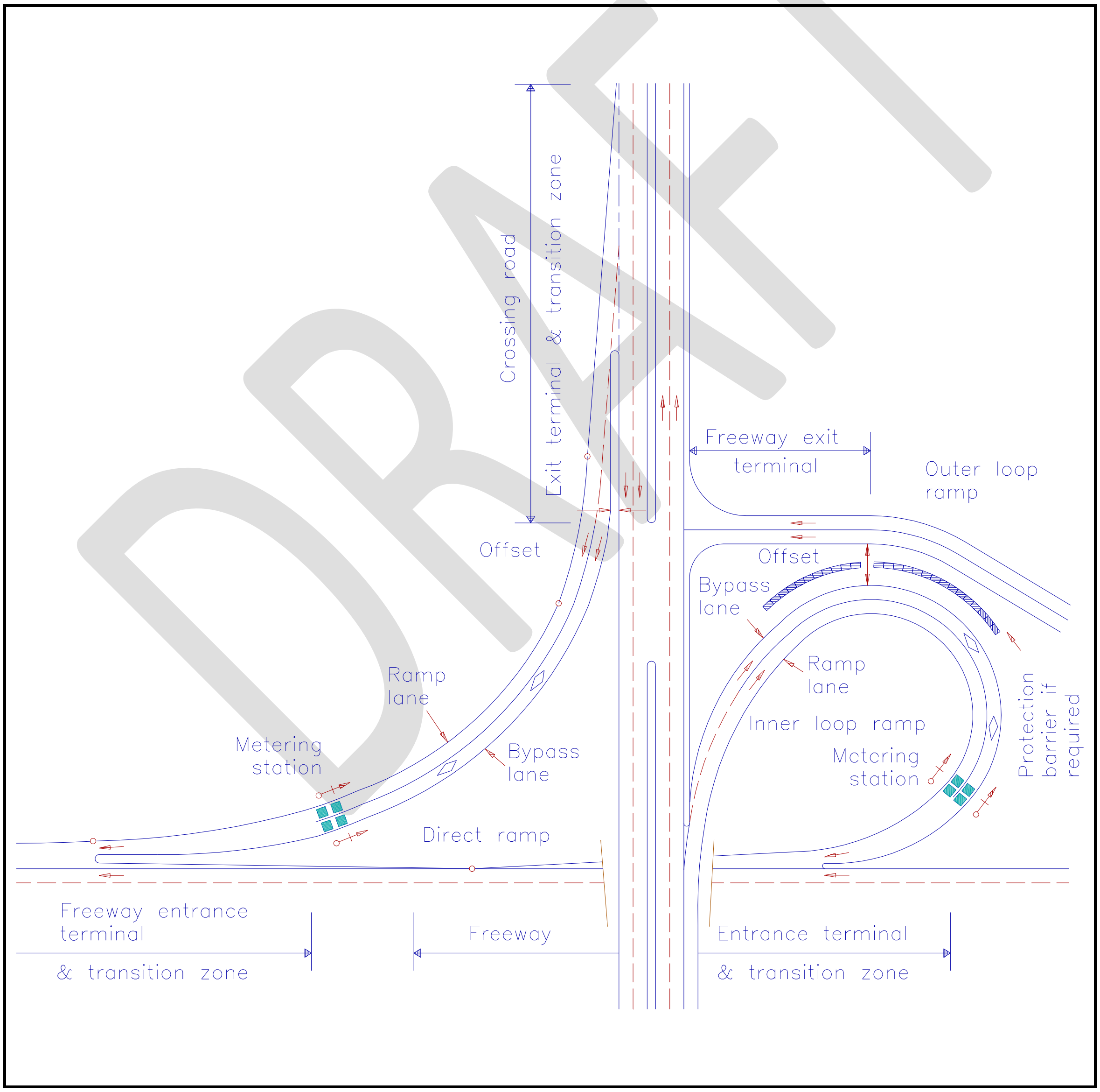


Figure 12.5.19~~21~~ "Parclo A" Interchange with Bypass Lanes

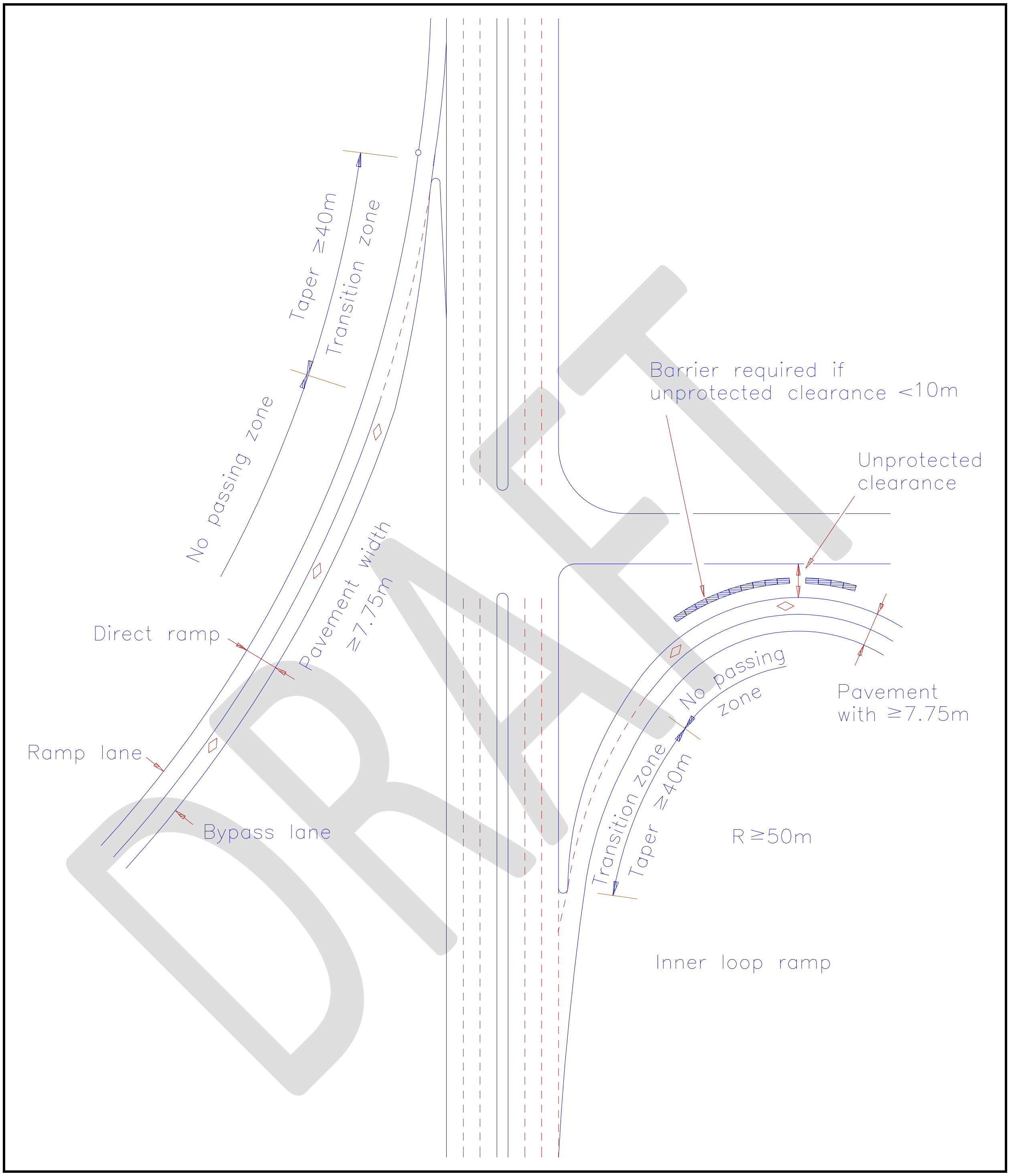


Figure 12.5.20~~22~~ Crossing Road Exit Terminals at "Parclo A" Interchanges

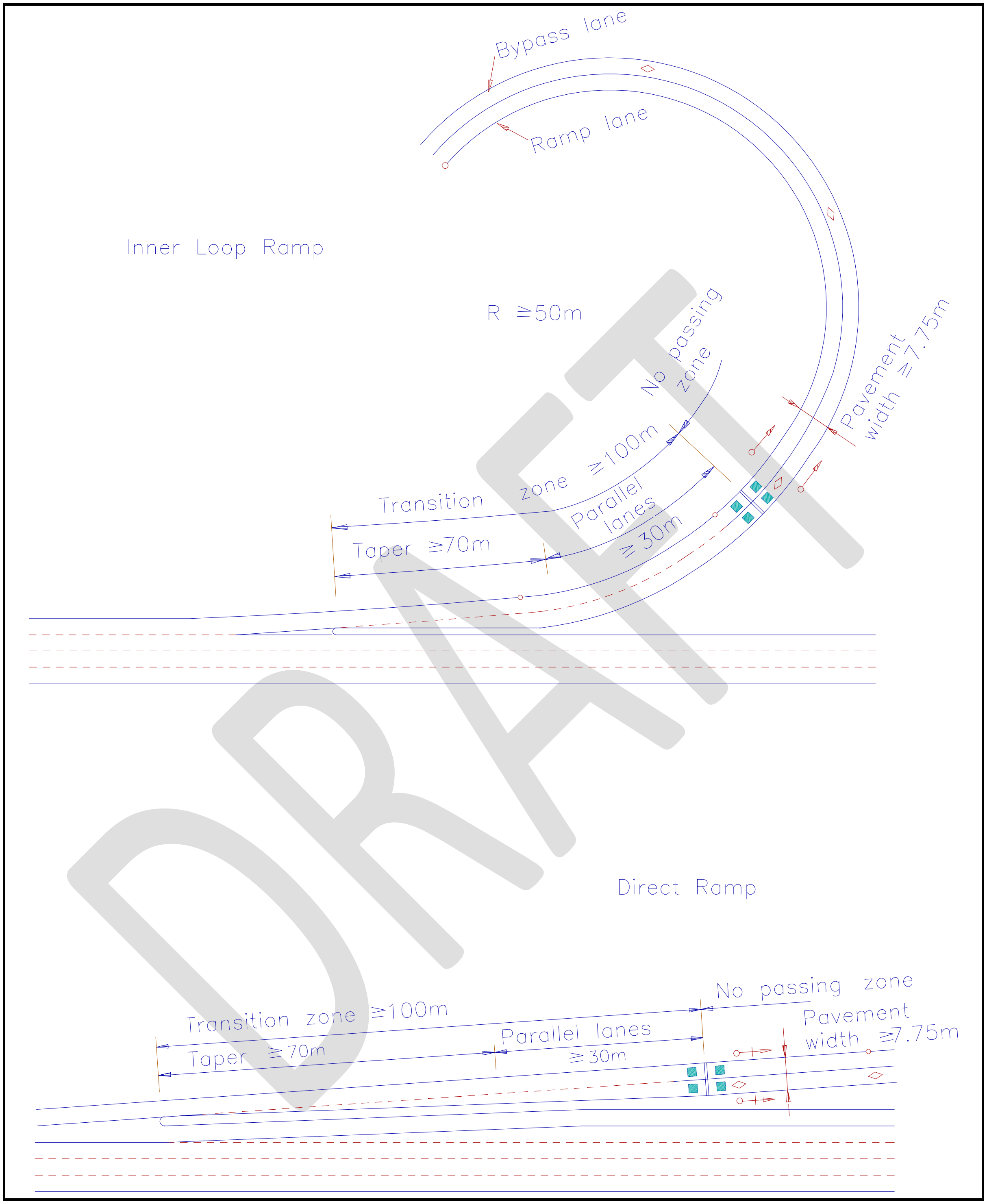


Figure 12.5.21~~23~~ Freeway Entrance Terminals with Bypass Lanes

12.5.2.6 Separate HOV Roadway

A separate roadway dedicated to HOV use can be applied where there is a very high volume of HOVs, where a freeway facility is physically incapable of accommodating necessary HOV provisions, where desired operational characteristics require off-line facilities, or where a barrier-separated exclusive access facility can be provided within a freeway right-of-way.

The Transitways planned to date in Ontario have not considered the potential use of the facility by other HOVs, notably carpools, vanpools and/or taxis. The planning principles for an HOV roadway open to carpools and vanpools would be like those used for the Ottawa or Mississauga Transitways but several design details would require modification in order to make the facility safe and suitable for all HOVs. Key design issues have been outlined in **Table 12.5.7.**

Table 12.5.7 Key Design Issues for Separate HOV Roadways

Design Element	Busway Standard (Typical)	HOV Standard (Desirable)
Design Speed for Vertical and Horizontal Main Line Alignment	80 km/h	120 km/h
Median Treatment	Solid Painted Line	Physical Barrier
Entrance Ramps	Direct Entry / Intersections	Acceleration Lane / Free Flow

Since the higher design speed for an HOV facility could act as a significant constraint in this development and design (e.g. a minimum horizontal radius of 650 m is required for 120 km/h operation, while only 250 m radius is required for 80 km/h operation), it must be considered in the local context. Since the intent of the facility is to provide a faster overall trip time for HOVs compared to the mixed flow alterative, use of a higher design speed would be appropriate in an area where the HOV route parallels, or is an alternative to, a freeway. The reduction of design speed in an area of physically constrained right-of-way may also be acceptable if it would be safe and would not eliminate the benefits of HOV.

12.5.2.7 HOV / HOT Lane Access / Egress

Access to a HOV/HOT lane facility and the extent to which it is controlled, are fundamental issues in the design and operation. Cost, operational, safety, and enforcement trade-offs associated with the different levels of access control must be considered. There are multiple approaches to providing access to HOV/Hot lanes: continuous, restricted at-grade access, and grade-separated access.

The need for various access types depends on the traffic patterns and physical opportunities present in a corridor. They further depend on the HOV lane type being considered and its operational characteristics, **Table 12.5.8** provides a brief overview of the situations in which various access provisions may be considered.

There has been interest in continuous access where motorists can enter or exit priced managed lanes (HOT) at any point. The use of continuous access for priced lanes has implications on the number of tolling points, ETC installations and enforcement practices. While tolls are often collected downstream of access points, additional access points in intermediate locations are now also common on newer priced managed lane facilities.

Table 12.5.8 Application of HOV Lane Access Provisions

Access/Egress Type		HOV Lane Type				
		Concurrent Flow				Reversible Flow
		Median			Right Side	
		Barrier	Buffer	Non-Separated		
At-Grade	Continuous (unrestricted)	No	No	Yes	No	No
	Designated Weaving Zone	No	Yes	Yes	Yes	No
	Dedicated Weaving Lane	No	Yes	No	No	No
	Designated Access Point(s)	Yes	No	No	Yes	Yes
Grade-Separated	Direct Ramp From Crossing Road	Yes	Yes	No	No	Yes
	"Tee" Ramp at Off-Line Node	Yes	Yes	No	No	Yes

12.5.2.7.1 At-Grade Access – Median HOV Lane

For at-grade (weaving) provisions, the following elements may be present:

- no buffer, buffer, or barrier between the HOV and mixed flow lanes
- continuous access, designated weaving zone, or dedicated weaving lane
- one-way weave or two-way (access and egress) weave

Additional factors which affect the type and location of weaving manoeuvre include:

- volume of traffic in HOV lane, in mixed-flow lanes, and performing weaving manoeuvre
- location of weaving zone relative to right side freeway ramp entrances and exits
- width of buffer or barrier
- number of freeway lanes and Level of Service on mixed-flow lanes
- available cross-section width/configuration
- sight distance
- separate mixed-flow weaving/merging conditions

12.5.2.7.1.1 Continuous Access

The simplest means of providing access to/from the HOV lane is across a standard or double dashed lane marking from the adjacent mixed flow lane. This is the recommended approach when the HOV lane is used only during peak periods and is open to all users at other times; in such a case, the lane should appear similar to a mixed flow lane and designation relies on signage.

If an HOV lane is a permanent installation, it is preferable to restrict access to designated locations or zones; lack of acceleration/deceleration areas, relatively high-speed differential between HOV lane and adjacent traffic, and improved safety and enforcement characteristics which follow from segregation of traffic flows militate against the use of continuous access in such a situation.

12.5.2.7.1.2 Designated Weaving Zone

The experience to date with design and operation of weaving zones has been that they should be a minimum of 300 m and a maximum of 450 m in length. The guidelines strike a balance between providing adequate merge/diverge length and minimizing the risk/incentive for congested mixed flow traffic to use the HOV lane as a passing lane.

Where a solid painted line demarcates HOV lane and where a buffer zone separates the lane from adjacent mixed flow lanes, the recommended strategy is to designate defined zones for access to/from the HOV lane by introducing a dashed pavement marking in an appropriate location. **Figure 12.5.22~~2~~4** illustrates one application and provides guidelines regarding weaving zone design and location.

In most circumstances, two-way (access and egress) moves can be accommodated within a weaving area. HOV lane volumes are limited, the number of HOVs entering or exiting the lane at any one point would generally be 500 per hour or less, and in most locations the weaving manoeuvre would emphasize either access or egress; therefore, the risk of HOV weaving manoeuvre itself operating at a poor level of service is low. If these conditions were not met in a particular case, one-way (access only or egress only) operation could be assessed, but enforcement would be an issue not easily resolved.

The location of ingress/egress zones should be subject to careful corridor-specific study, considering HOV traffic origin and destination patterns as well as physical fit and feasibility. It is neither necessary nor appropriate to attempt to serve every freeway entry and exit ramp with an at-grade HOV lane access zone; prime consideration should be reserved for: freeway-to-freeway connections, transit needs, ramps with a high volume of car/vanpools, ramps serving major park and ride/park and pool facilities and isolated interchanges.

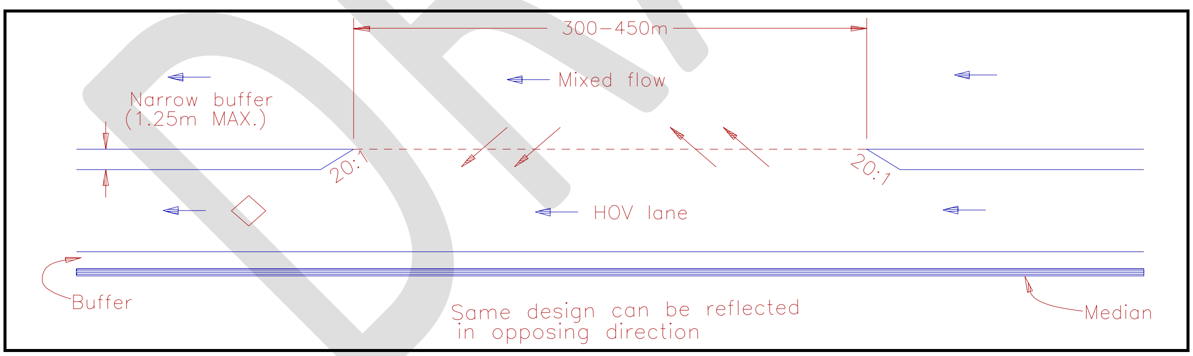


Figure 12.5.22~~2~~4 Designated Weaving Zone for Buffer Separated HOV Lanes

The placement of an HOV lane weaving zone must consider weaving condition introduced to freeway as HOV users entering at a right-side ramp weaves across congested mixed flow lanes to access HOV lane via the weaving zone. A site-specific weaving analysis for a variety of operational situations is required; the "worst case" situation is not necessarily the peak hour, as weaving may in fact be more difficult in the "shoulder" periods where high volumes are combined with high speeds.
As noted above, the weaving zone location is flexible, and can be adjusted by simple restriping

in response to field observation of traffic operations. As a planning guideline, however, the following guidelines have emerged from experience elsewhere as shown in **Table 12.5.8**

The distances are intended to maintain a Level of Service "D" for the weaving manoeuvre. The greatest distance for an "exiting" weave reflects provisions for buses which find it more difficult (due to visibility) to shift lanes to the right.

In Ontario, two sequential entry ramps from Parclo "A" type interchanges are common; for HOVs from both ramps to have the ability to access the HOV lane, the weaving zone location should be based on the downstream entry ramp's bullnose.

For a corridor where several interchanges are located, interchange spacing may determine location of weaving zones. If interchanges are too close together to accommodate entry weave, weaving zone, and exit weave (i.e. 1000 m - 1800 m between interchange ramp bullnoses), there should not be a weaving zone provided. This will prevent one or the other weaving manoeuvre being "forced" into too short a distance.

For interchange spacing greater than the minimum and up to approximately 2500 - 3000 m, a single weaving zone should be used (if both interchanges serve key HOV routes). Consideration should be given to skewing weaving zone location within the envelope so as to give greater weaving distance to higher volume move, or to tying the weaving more closely to the more significant crossing road. Beyond that spacing, two weaving zones should be provided if both interchanges are to be served.

12.5.2.7.1.3 Dedicated Weaving Lane

Consideration should be given to the provision of dedicated weaving lanes where there are high volumes (>500 vph) of HOVs entering or exiting a median HOV lane or where a new or reconstructed freeway project offers adequate right of way or where operational concerns with designated weaving zones are present,

Table 12.5.9 Guidelines for HOV Lane Weaving Zones

HOV Volumes	No. of Mixed Flow Lanes	Distance from Right Side Entry Ramp Bullnose to Start of Weaving Zone	Distance from Start of Weaving Zone to Right Side Exit Ramp Bullnose	
			"Must Exit" at Bullnose	"Choice" at Bullnose
< 250 vph	2	300 m	600 m	400 m
	3	400 m	600 m	400 m
250 - 500 vph	2	400 m	800 m	600 m
	3	500 m	800 m	600 m

The basic parameters regarding length and location relative to interchanges are like those for a designated weaving zone, as outlined in **Section 12.5.2.7.1.2.** Illustrations of dedicated weaving lanes are included in **Figure 12.5.23~~25~~ and Figure 12.5.24~~26~~.**

A dedicated weaving lane provides optimum conditions for at-grade access to a buffer-separated median HOV lane, providing a clearly defined area where acceleration or deceleration matching the speed of merging traffic to occur safely and without interference.

Within a single corridor, access types could include both zones and lanes, applied as appropriate relative to the HOV and mixed flow traffic conditions and demands. The addition of a weaving lane can force realignment of mixed flow lanes if in a retrofit narrow median situation; the associated costs and impacts may be significant.

Dedicated weaving lanes are less flexible than other at-grade options and should be considered carefully where uncertainty regarding demand is present. It may be more appropriate to begin with a weaving zone and upgrade to a dedicated lane if and as needed, based on operational experience. Similarly, such lanes could be protected for in new highway construction.

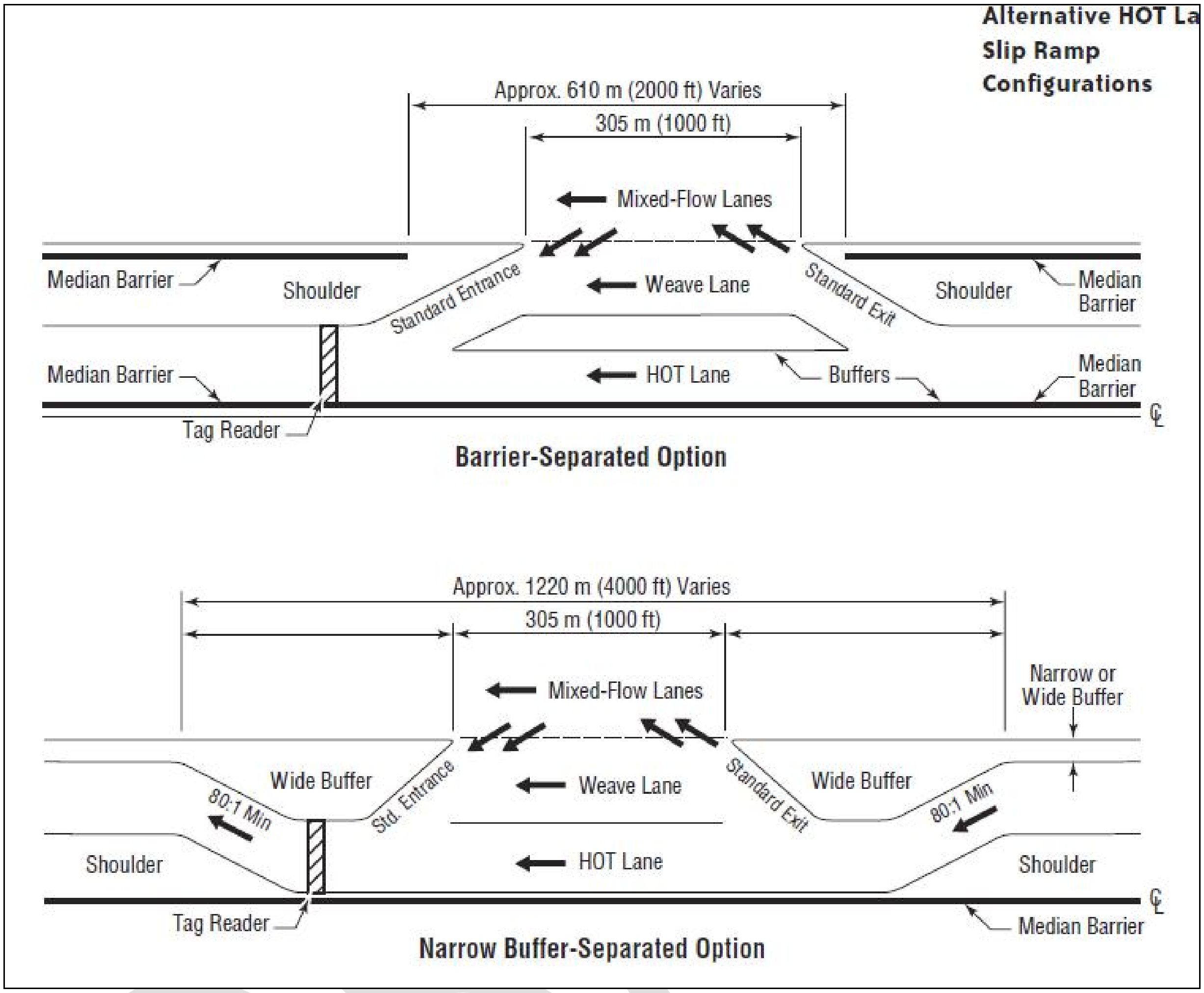


Figure 12.5.23~~25~~ Alternative Hot Lane Slip Ramp Configurations

Source: FHWA "A Guide for Hot Lane Development"

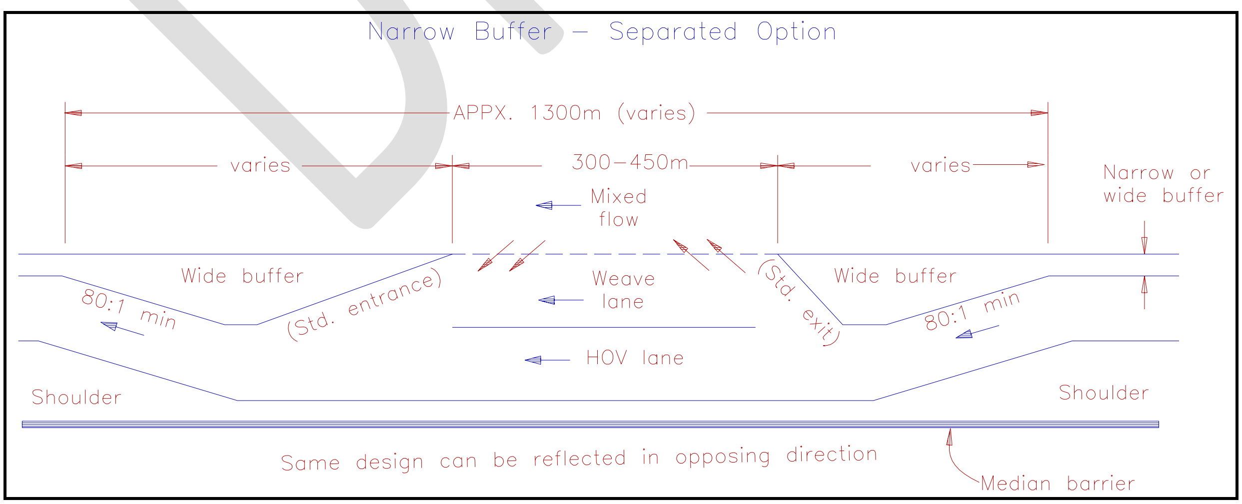


Figure 12.5.24~~26~~ Dedicated Weaving Lane for Narrow Buffer-Separated HOV Lane Access

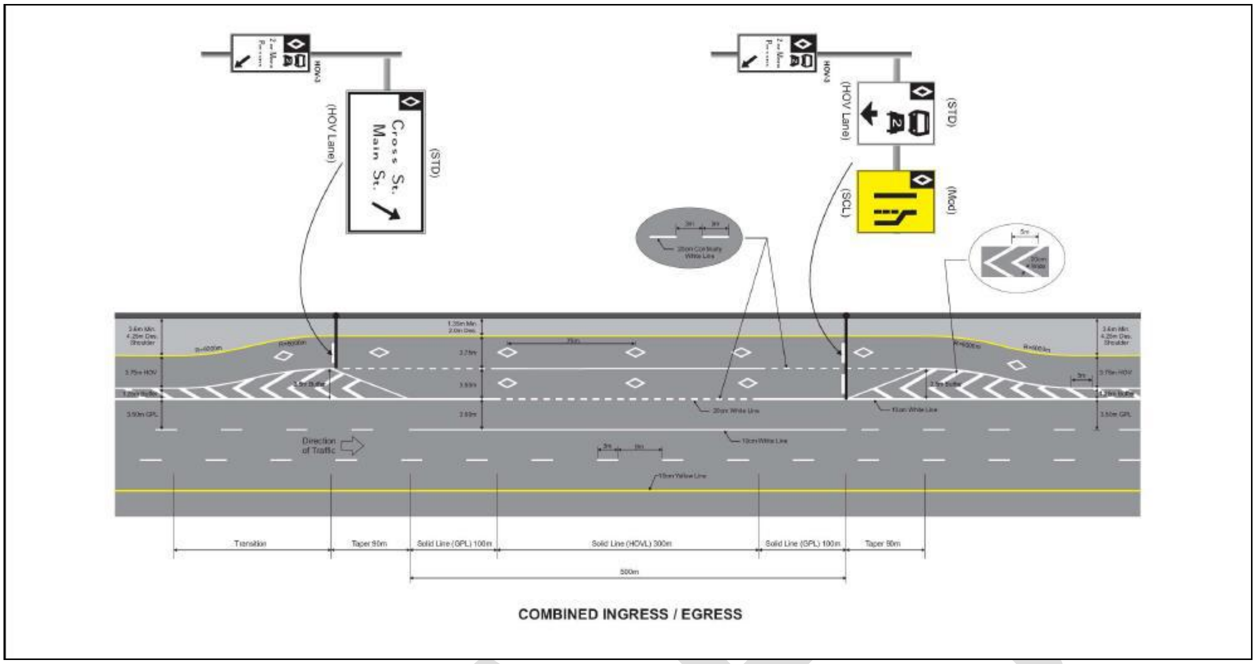


Figure 12.5.25~~27~~ HOV Transfer Lane Application in Ontario Accommodating Access and Egress Movement Simultaneously
Source: Access / Egress Lanes for HOV Facilities, MTO Study "Dedicated at Grade Transfer Lanes for Freeway HOV Facilities", June 2009

12.5.2.7.1.4 Designated Access Point

Figure 12.5.26~~28~~ illustrates that access to a barrier-separated HOV lane is best provided by designated access points rather than by weaving zones along its length (since the latter inherently involve elimination of the barrier for several hundred metres). A designated access point therefore tends to be at the end of an HOV lane or at a key point such as a freeway-to-freeway interchange. Such a design is usually site-specific; typical layouts are shown on **Figure 12.5.26~~28~~**.

Key issues are signage, safety (the introduction of a barrier between two concurrent flow lanes is a concern), and enforcement (a pull-over shoulder, with the ability to return ineligible vehicles to mixed flow traffic and it should be located downstream of the entry point).

12.5.2.7.2 At Grade Right Side HOV Lane

The provision of access and egress for right side HOV lanes is relatively simple, yet complex operational issues arise and potentially unacceptable in their impact. The issues are mainly a result of the need for mixed flow vehicles entering or exiting the freeway at interchanges to cross the HOV lane to/from right side ramps.
While there are several ways of resolving the resultant weaving conflict, the costs and impacts involved may negate whatever gains the HOV lane is intended to provide.

Examples of such measures include:

- grade separation with entry ramps: high cost and conflict with short term / temporary right-side opportunities;

- consolidation of entry ramps (e.g. merging loop and direct on ramps to a single freeway entry point): focuses traffic to create an even more severe weaving condition;

- ramp metering: must occur corridor-wide and has minimal impact on hourly volume;

- restriction of HOV lane usage (by raising minimum occupancy rates, bus-only designation, etc.): conflicts with goal of moving more people more conveniently and with minimum acceptable lane usage criteria; or

- provision of adequate specialized merge / weave area: potential physical impact on interchange, structure, and area.

Due to these concerns, right lane application to date has been restricted to areas where there are no such conflicts, to low-volume Reserved Bus Lanes, or to locations where both HOV lane and interchange ramp volumes are relatively low.

A design which provides for the weaving of entering or exiting traffic across HOV lane is shown in **Figure 12.5.27~~29~~,** based on the layout of a typical urban Parclo "A" type interchange in Ontario. Basic signage, lane lengths, and lane marking concepts are shown; development of more detailed design standards is required.

In some cases, a right side HOV lane can still be effective if it does not pass through an interchange. A bus-only lane used by buses exiting and re-entering freeway at each interchange via a transit interface or by buses traveling only between interchanges, can provide a queue-jump time saving. Such a lane would physically appear little different from an auxiliary lane or paved shoulder, with exception of a solid paint lane line, a buffer zone and special signage. Access / egress would occur on the interchange ramps, as shown in **Figure 12.5.28~~30~~.**

12.5.2.7.3 Spacing Between Access / Egress Zones

For facilities that do not provide continuous access, defined access points are provided at regular intervals or logical locations; restricted-access points are not intended to serve every general-purpose entrance and exit ramp. The spacing between access openings on existing facilities, has a design domain between **1.6 km to 4.8 km** (1 and 3 mi). The reasons for providing access of a particular type or in a specific location vary, ranging from policy decisions to safety or operational considerations. Each agency determined which factors were most important to a given facility, and the factors chosen varied from one facility to another. Similar considerations of applicable policies and safety or performance goals must be made when planning for new or revised access points.

12.5.2.7.4 Grade Separated Access

As described in **Section 12.5.2.7.1,** reliance on at-grade access for median HOV lanes yields several operational issues and may place constraints on effectiveness and attractiveness of HOV lanes. Furthermore, in some locations of high demand, the freeway / interchange configuration, or physical constraints may virtually preclude use of at-grade measures.

If grade separated access / egress provisions can be well-located, physically feasible, and cost-effective with respect to the demands, they can provide many benefits: high capacity, good level of service, safety, control of traffic flow, time savings / HOV priority, elimination of need for at-grade weaving zones / lanes, enforceability and visible HOV priority, with marketing / public impression benefits.

Grade separated access ramps take two basic forms: "drop ramps" from crossing roadways, and "Tee ramps" serving adjacent off-line nodes. Other unique configurations may occur at freeway-to-freeway interchanges; as shown in **Figures 12.5.39~~41~~, 12.5.40~~42~~ and 12.5.41~~43~~.**

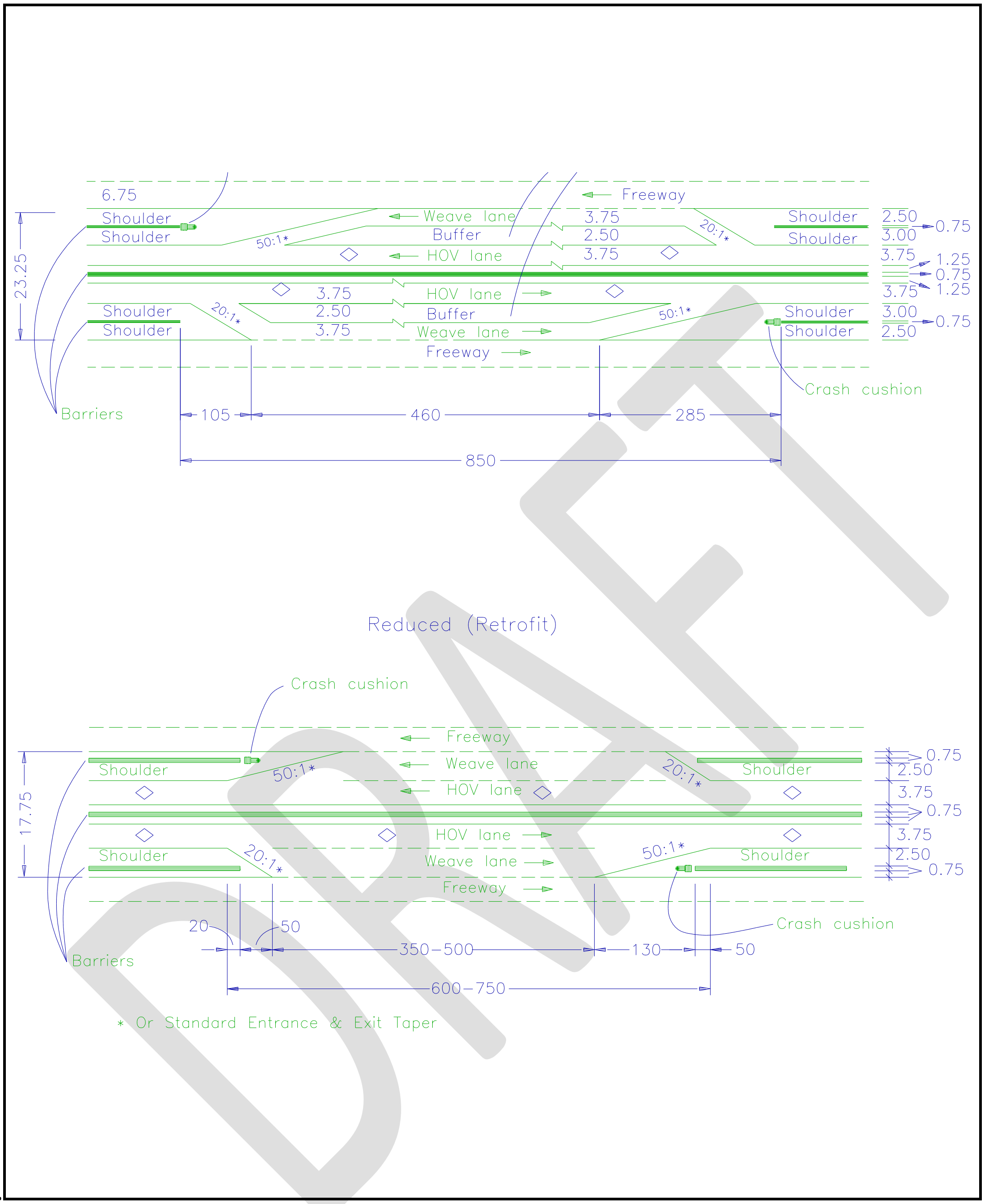


Figure 12.5.26~~28~~ Dedicated Weaving Lane for Barrier-Separated HOV Access

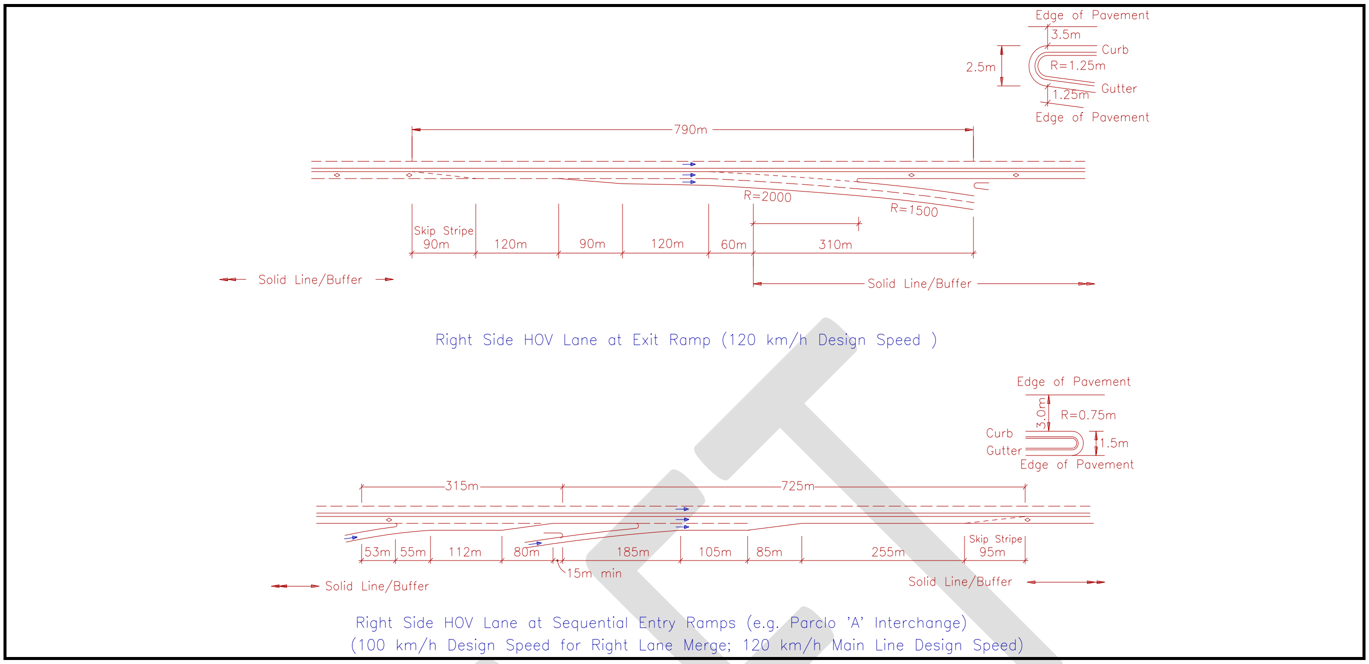


Figure 12.5.27~~29~~Right Side HOV Lane Through Treatment at Interchange Ramps

12.5.2.7.4.1 Direct Ramp from Crossing Road

Direct access ramps improve safety, reduce congestion, save time, and increase travel time reliability for both HOVs and general-purpose freeway traffic. High occupancy vehicles can have a hard time merging left through general purpose lanes to gain access to an HOV lane during congested periods, creating a safety problem for all freeway users. When buses, particularly long ones, attempt this merge, they may cause congestion in the lanes they pass through for quite a distance back.

A direct ramp may be two-way, one-way or reversible, and may feed either a buffer separated or barrier-separated median HOV lane. As with any HOV infrastructure investment, operational decisions must be made prior to considering a direct ramp. If HOV lane is only to operate during peak periods, or if it is a "test case" which may be abandoned after a trial period, direct ramps should not be provided as the cost of constructing direct access ramps is substantial because they require separate structures above or below the freeway.

Figure 12.5.29~~31~~ illustrates a general design outline for a two-way ramp**; Figures 12.5.30~~32~~, 12.5.31~~33~~, 12.5.32~~34~~ and 12.5.33~~35~~** show typical cross-sections for various median widths ranging from "optimum" to "minimum", for two-way and single lane (reversible) ramps respectively. Also, **Figure 12.5.34~~36~~** provides examples of direct ramp applications.
A key issue in consideration of a direct ramp is whether the crossing roadway already has an interchange with the freeway. In many retrofit situations, the provision of a direct ramp may

not be desirable, but it could be essential, or it may be the best of the available alternatives. **Figures 12.5.35~~37~~, 12.5.36~~38~~ and 12.5.37~~39~~** outline the implications and configurations of several design situations, using interchange layouts typically found in Ontario.

Several structural issues may be posed by introduction of a new mid-span connection; rather than raising the direct ramp on a structure per se, it would generally be preferable to provide a walled ramp of earth fill, thereby reducing costs and structural complexity at the ramp's upper end. Another important factor is the ability, at an existing structure, to widen the freeway to allow new median lanes (two ramp lanes, two main line HOV lanes, and associated shoulders) while maintaining pre-existing number of lanes through the available span opening.

For these reasons, it is often preferable to introduce direct HOV ramps only at either a new / future crossing road or at an existing structure with an adequate span and no other interchange ramps. In such case, an integrated design, or at least protection for a later introduction of a direct ramp (through adequate deck width for mid-span turning lanes, etc.) would yield benefits.

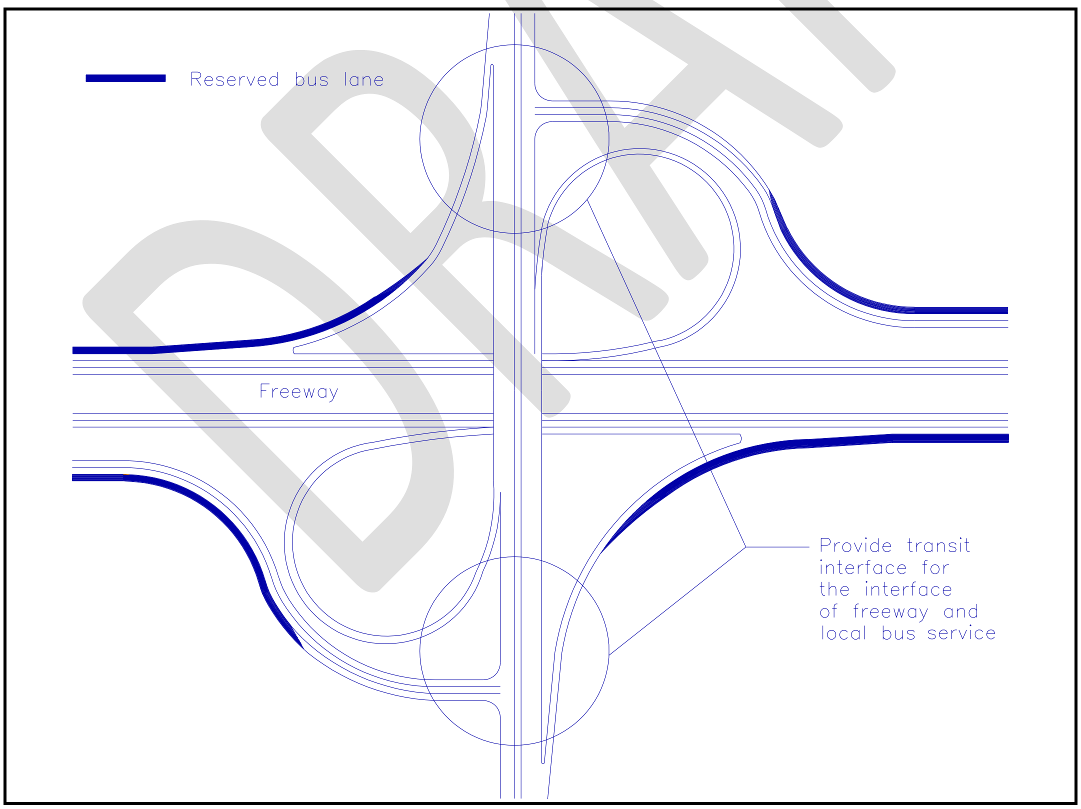


Figure 12.5.28~~30~~ Right Side HOV Lane Access/Egress at Interchange Ramps

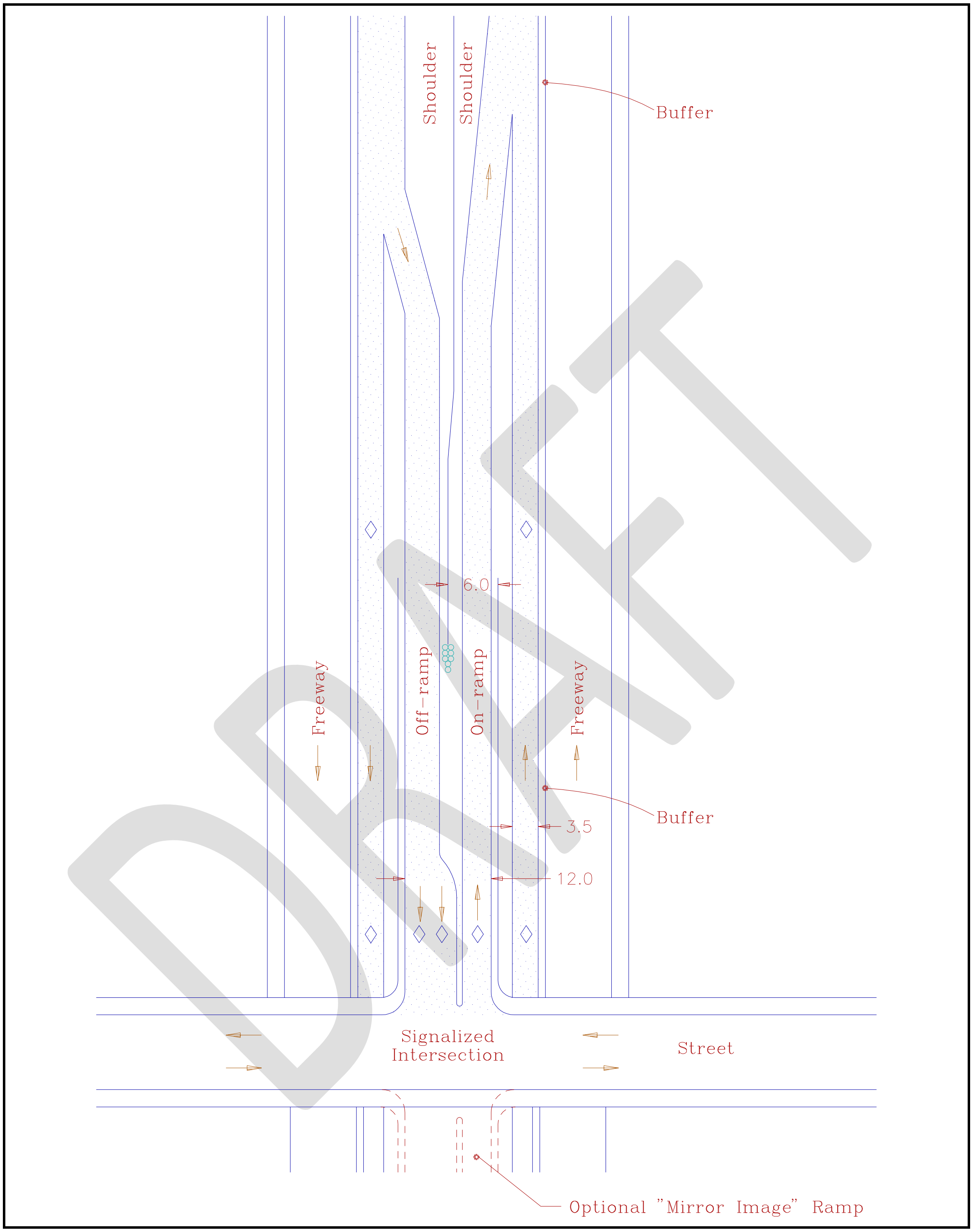


Figure 12.5.29~~31~~ Two-Way Median Ramp for a Buffer-Separated HOV Facility

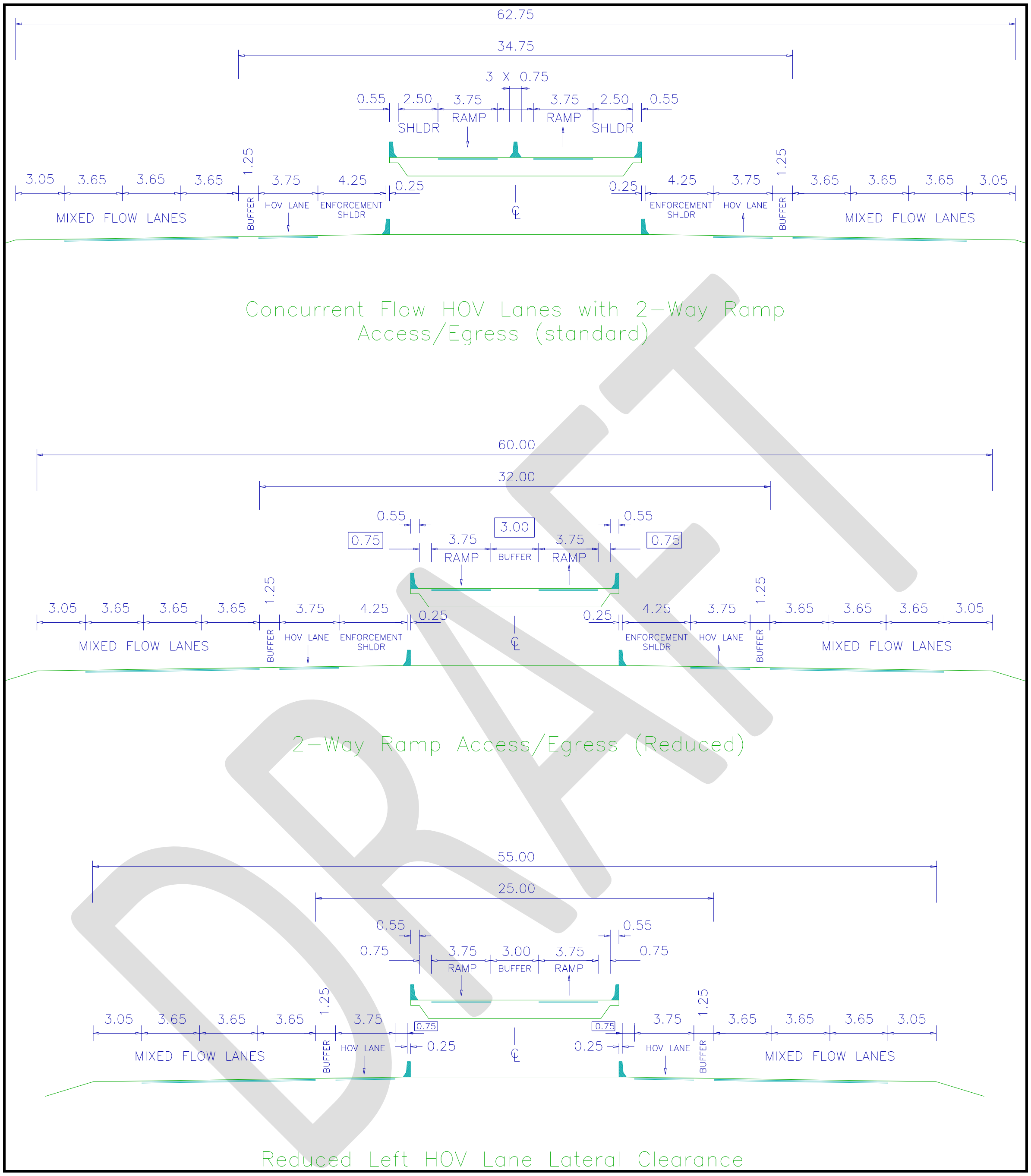


Figure 12.5.30~~32~~ Median HOV Two-Way Ramp Cross-Sections

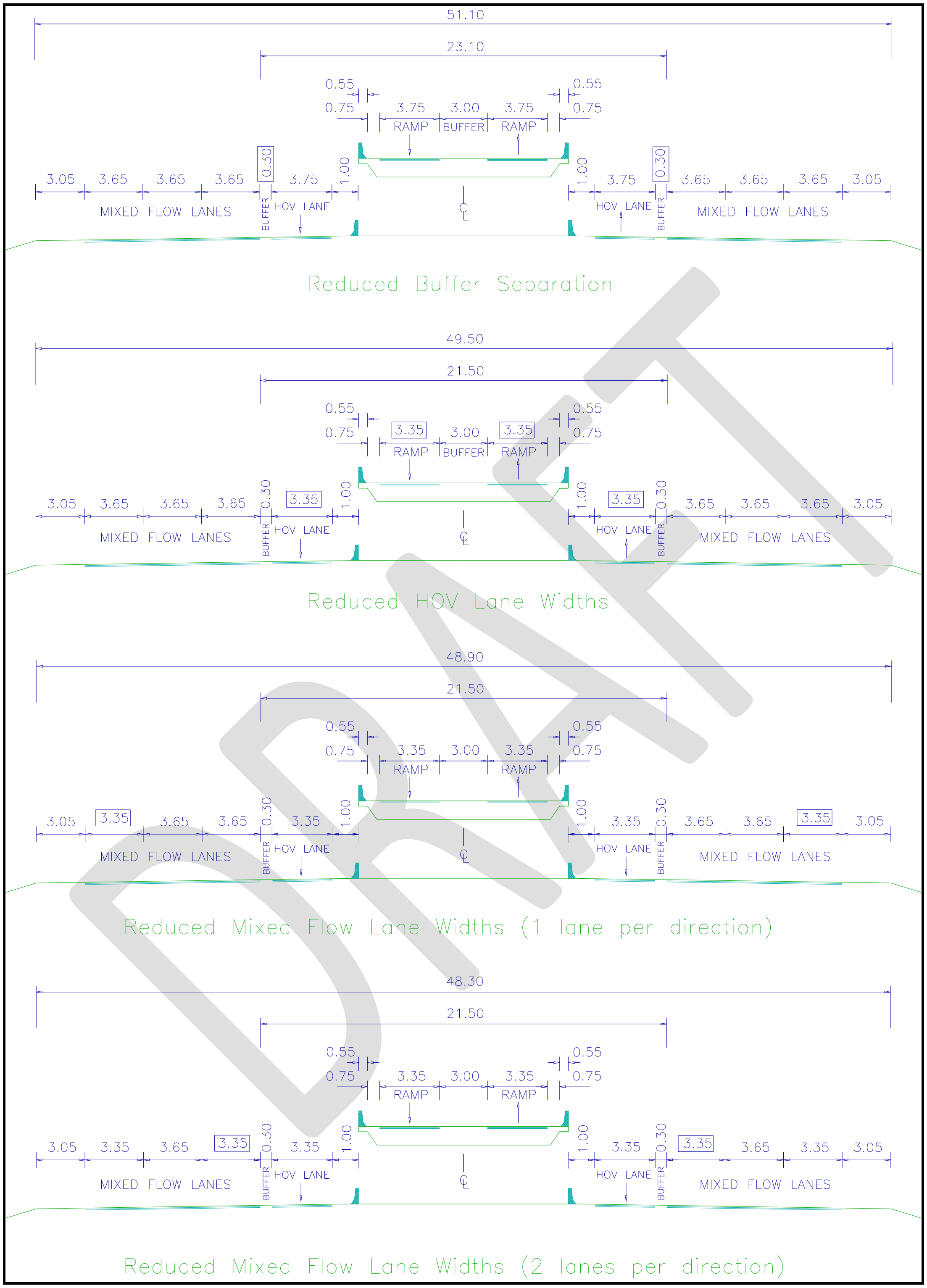


Figure 12.5.31~~33~~ Median HOV Two-Way Ramp Cross-Sections

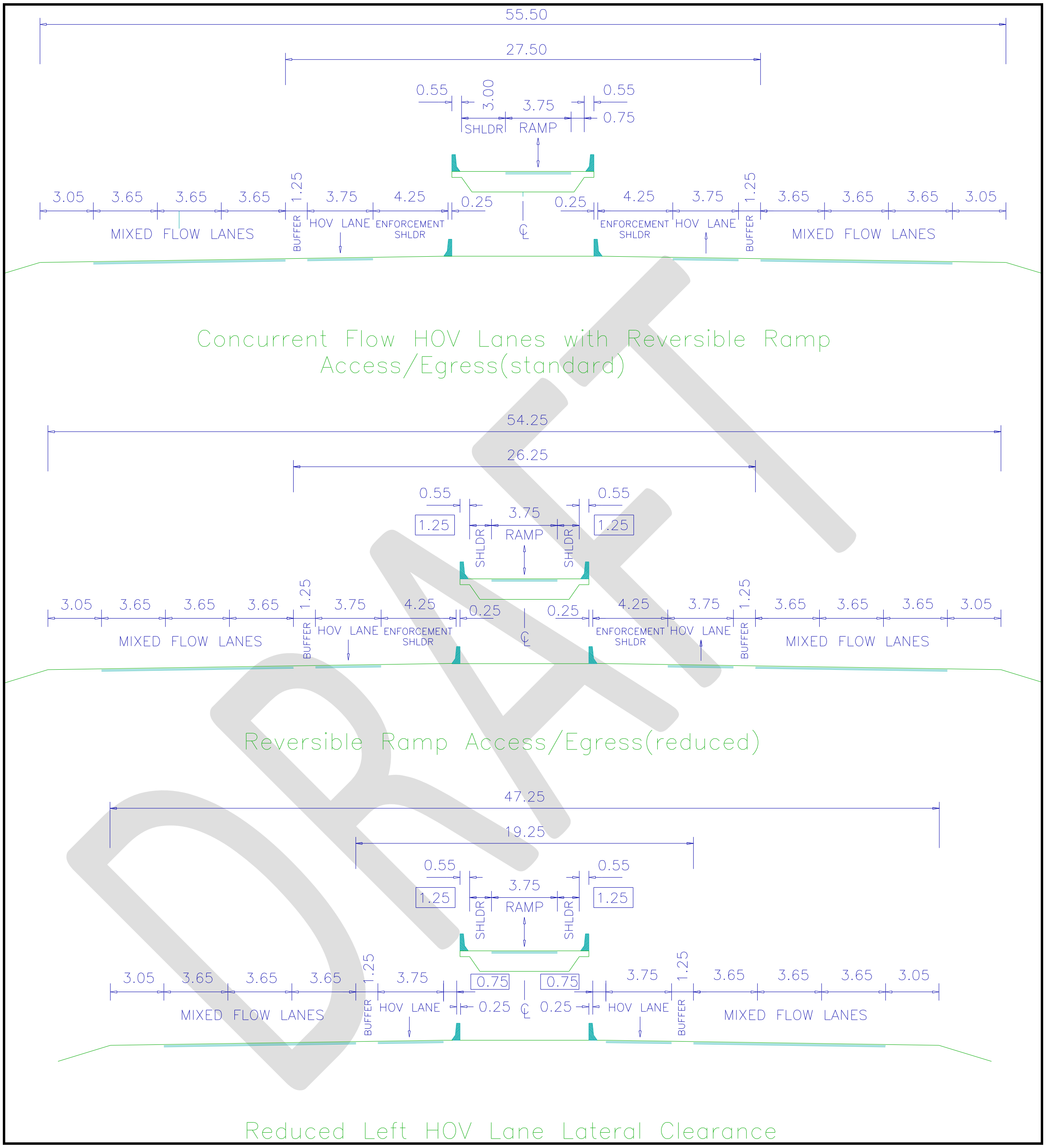


Figure 12.5.32~~34~~ Median HOV Reversible Ramp Cross-Sections

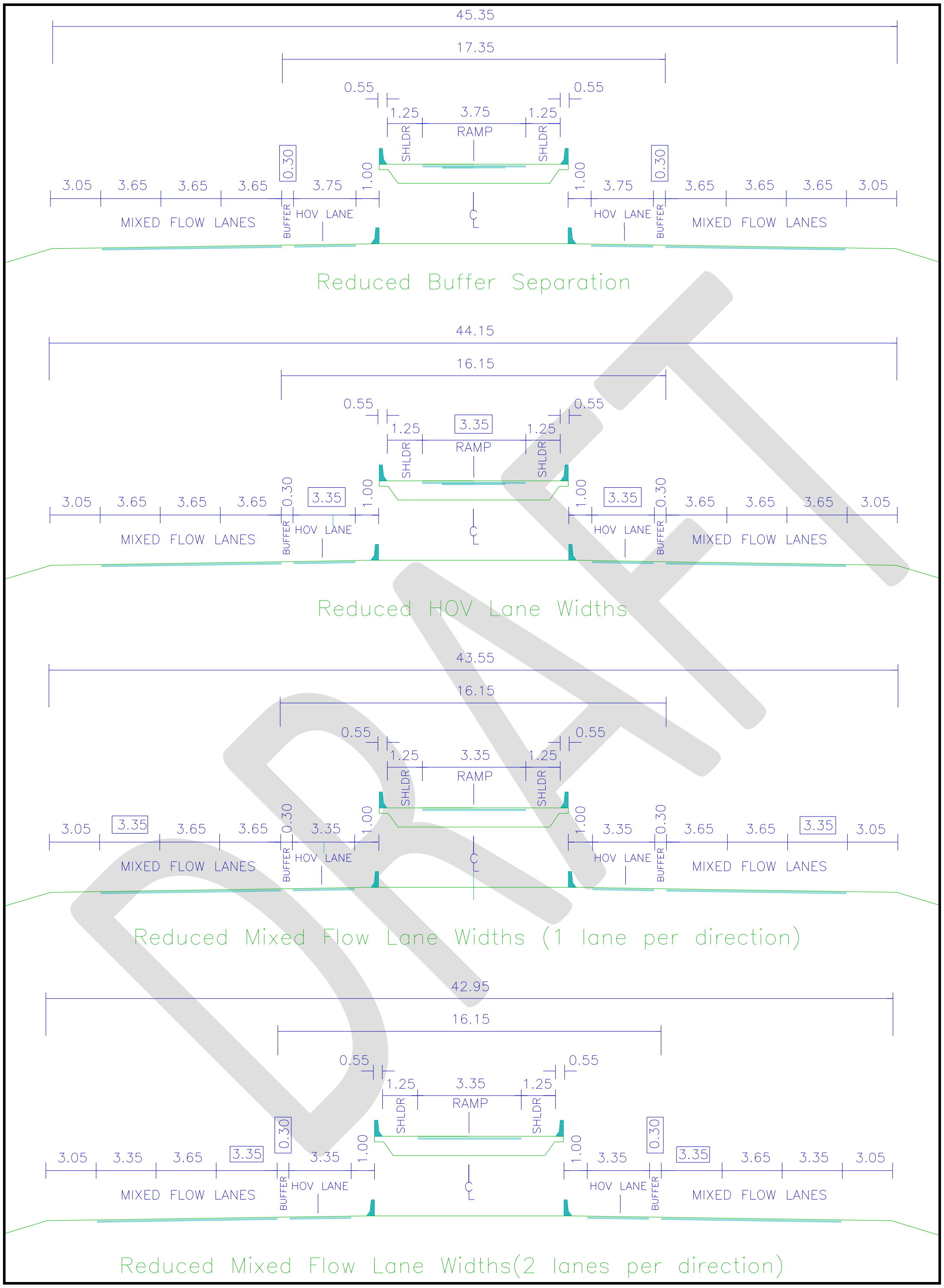


Figure 12.5.33~~35~~ Reduced Median HOV Reversible Ramp Cross-Sections

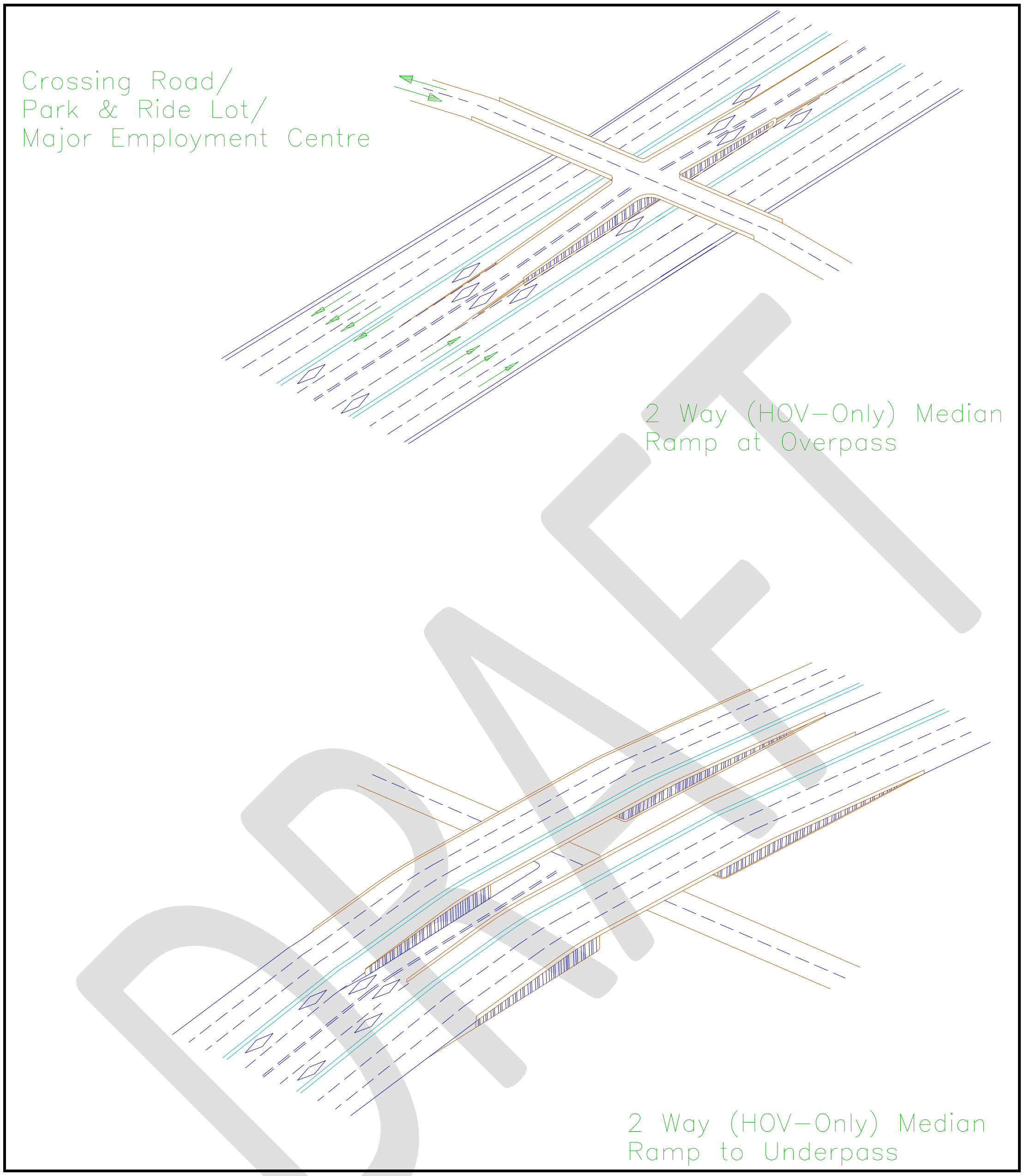
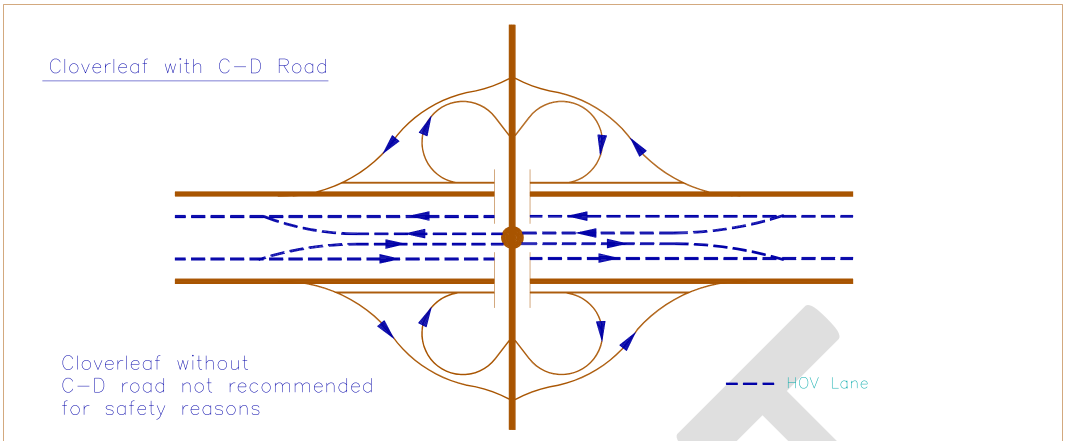
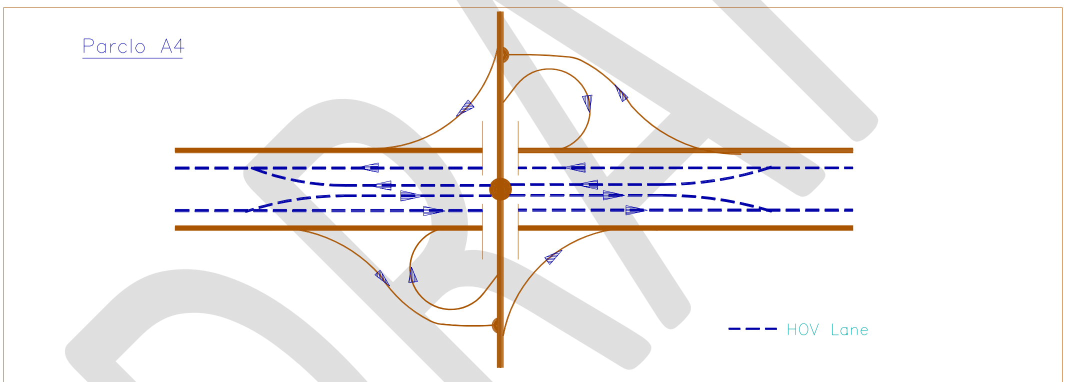


Figure 12.5.34~~36~~ Direct Median Ramp at Crossing Roads

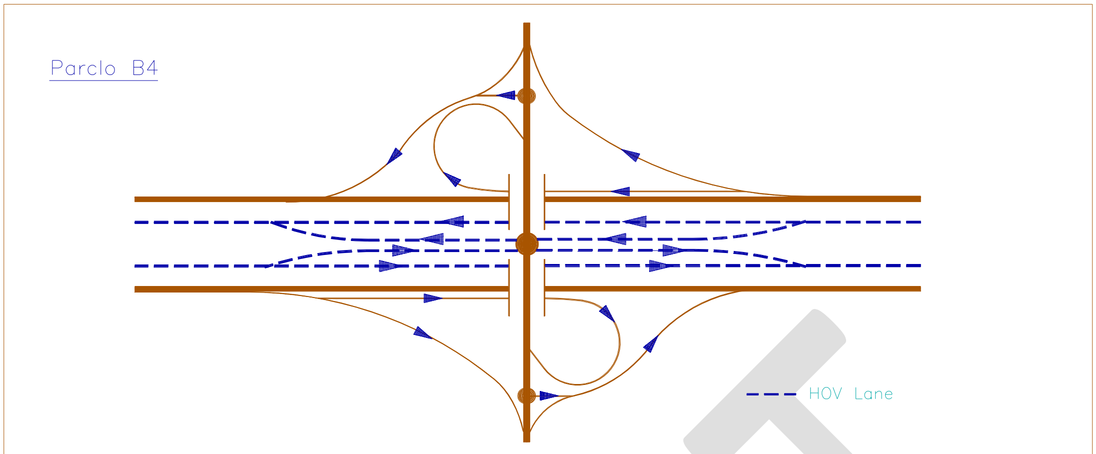


BENEFITS	DISADVANTAGES	APPLICATIONS
Free flow of most freeway and arterial traffic.	Difficult to retrofit to parclo interchange due to property and structural requirements.	New interchange plans where property available.
Minimum impact on arterial operation.	Potential weaving concerns on C–D road and arterial.	Low – moderate volume interchanges.
Can prioritize HOV signal without synchronization problems.	Higher cost for arterial structure.	High volume directionally skewed "tidal flow" interchanges where entry/exit weaving is minor.



BENEFITS	DISADVANTAGES	APPLICATIONS
Conventional interchange layout.	Signal synchronization on arterial is key issue.	Retrofit to existing parclo interchange if traffic conditions on arterial permit.
Can be readily retrofit to existing I.C.	Turning moves and queue storage on bridge structure (esp. if retrofit).	New interchange plans, esp. if one signal can be eliminated.
No weaving		
Moderate cost		
Allows HOV service/interface in existing demand corridor.		

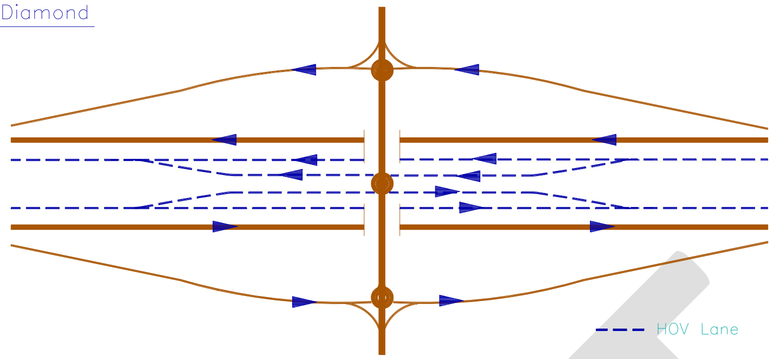
Figure 12.5.35~~37~~ HOV Direct Ramp/Interchange Combinations (Parclo A4)



BENEFITS	DISADVANTAGES	APPLICATIONS
If mixed flow left turns to entry ramps physically protected, layout has a maximum of two stops and less synchronization need.	Weaving between arterial HOV's and loop traffic. "Unexpected" signal for free – flow loop move. Left turns and queues conflict with through arterial traffic; parclo 'A' removes conflict.	Retrofit to existing parclo 'B' interchange. New freeway where property/ environmental constraints preclude parclo 'A' and where traffic patterns permit.

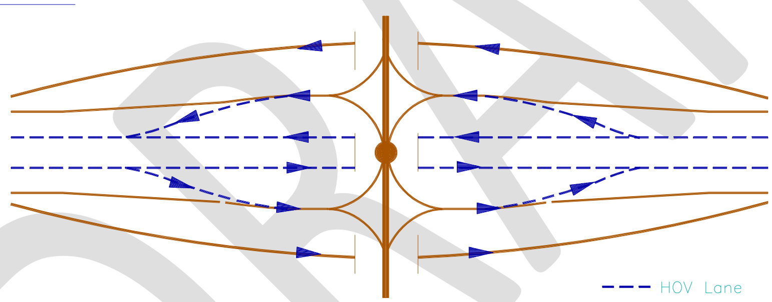
Figure 12.5.36~~38~~ HOV Direct Ramp/Interchange Combinations (Parclo B4)

Simple Diamond



BENEFITS	DISADVANTAGES	APPLICATIONS
Minimal right of way requirements. Efficient transit interface opportunity. Can be retrofit in constrained area. Conventional freeway operations.	Signal synchronization and vehicle storage made difficult by signal proximity. Additional left turns introduced on arterial(compared to parclo).	Where signal synchronization can be accomodated either by operational measures or by adequate intersection spacing. In constrained right of way where access is essential.

Point Diamond



BENEFITS	DISADVANTAGES	APPLICATIONS
Right of way requirements minimized. Can be retrofit in constrained area. Single signal on arterial; synchronization not an issue. Freeway buses can interface with arterial buses by using freeway – grade bus turnouts.	Heavy demand on single intersection. Weaving/merging on ramps. Double ramp structures required. Unconventional left side freeway exits/entrances.	Where traffic conditions/demands on arterial allow effective signal operation. In severely constrained corridor where access is essential.

Figure 12.5.37~~39~~ HOV Direct Ramp / Interchange Combinations (Simple Diamond)

12.5.2.7.4.2 Ramps to Parallel Routes / Off Line Nodes

A new HOV-only crossing structure could be provided where there is no reasonable way to provide HOV lane access at a major node through use of an existing structure, or where no structure exists or planned. Such ramps are costly, but can be designed to optimum standards and, if serving a major HOV generator or providing an essential link, would cost-effective than other alternatives. In some cases, a single direct ramp alone could provide 5 - 10 minutes time savings and such ramps may also eliminate an unacceptable at-grade weaving operation. Since these ramps tend to be site-specific in design, the HOV-related guidelines have cross-sections and design criteria identical to mixed flow ramps. **Figures 12.5.38~~40~~, 12.5.39~~41~~, 12.5.40~~42~~, 12.5.41~~43~~ and 12.5.42~~44~~** provide examples of such cases and possible design applications at Parclo "A" interchanges.

12.5.2.7.5 Terminal Points

12.5.2.7.5.1 Start of HOV Lane

An HOV lane can start as a new lane on the left side of the left-most mixed-flow lane. Entry to the HOV lane should require conscious movement by HOVs; the HOV lane should not begin as a direct continuation of a mixed flow lane from which non-HOVs are directed to exit. Consistency with intermediate weaving zones should be maintained: a 300 - 600 m long dashed white line located at least 300 - 500 m (as appropriate depending on HOV volume and freeway width) downstream of the nearest right-side freeway entry ramp bullnose should be used to designate the access area. A dedicated weaving lane is not required for this entry-only manoeuvre, although consideration should be given to protecting the ability to provide such a lane if the HOV lane is to be extended upstream in future.

12.5.2.7.5.2 End of HOV Lane

The preferred means of terminating an HOV lane is as a direct continuation into a free flow mixed-flow lane. If the HOV lane must physically end, a left side lane drops after a minimum 750 m (1000 m desirable) merging zone is adequate. Alternatively, the right-side mixed flow lane could be dropped at an interchange or downstream of the end of HOV designation on the left lane. If possible, the lane drop should be in an area where a high-volume right side mixed-flow ramp relieves traffic volumes on the freeway. The introduction of mainline congestion due to merging HOV lane traffic is to be avoided.

As with any weaving zone, a minimum of 200 m per lane change should be provided between the end of buffer / barrier and the next downstream right-side exit ramp. A dedicated weaving lane is not required for this egress-only move, however, future downstream extension of HOV lane may warrant protection for the later provided extra lane.

12.5.2.7.6 Freeway-To-Freeway Interchanges

For HOVs to transfer between freeway corridors, mixed flow ramps must generally be used, along with appropriately located weaving lanes / zones. If there are HOV lanes in both freeway corridors, an ultimate network plan may warrant provision of a direct HOV-only ramp between the two, as shown in **Figure 12.5.43~~45~~**.

Due to the complexity of most freeway-to-freeway interchanges, only one or two HOV-only moves can be provided within the interchange itself. There may be a restricted design speed on the HOV ramp to retrofit it into the area; it would obviously be preferable to protect for such a connection in the design stage.

Another impact is that, in order to introduce the ramp, the freeway main lines may require widening around the ramp terminus. As with any such complex situation, the design solution will be site-specific.

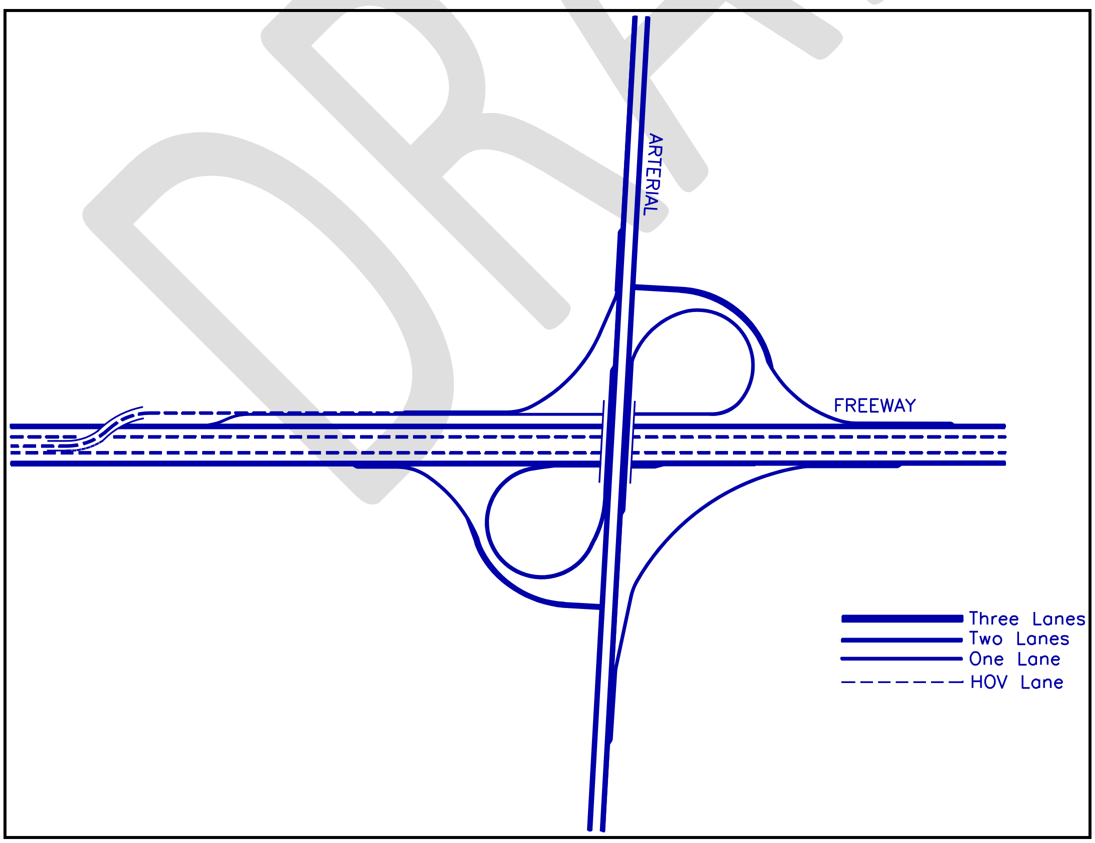


Figure 12.5.38~~40~~ Direct Ramp from Parclo "A" Entry Ramp to Median HOV Lane

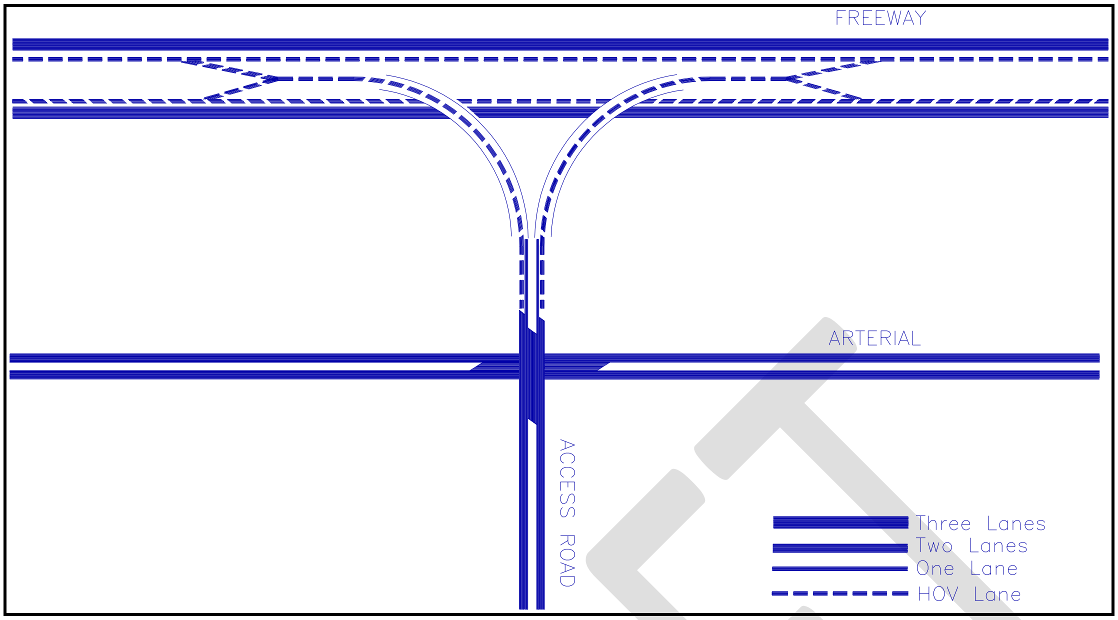


Figure 12.5.3941 In / Out Ramp Between Median HOV Lane and Off-Line Activity Centre

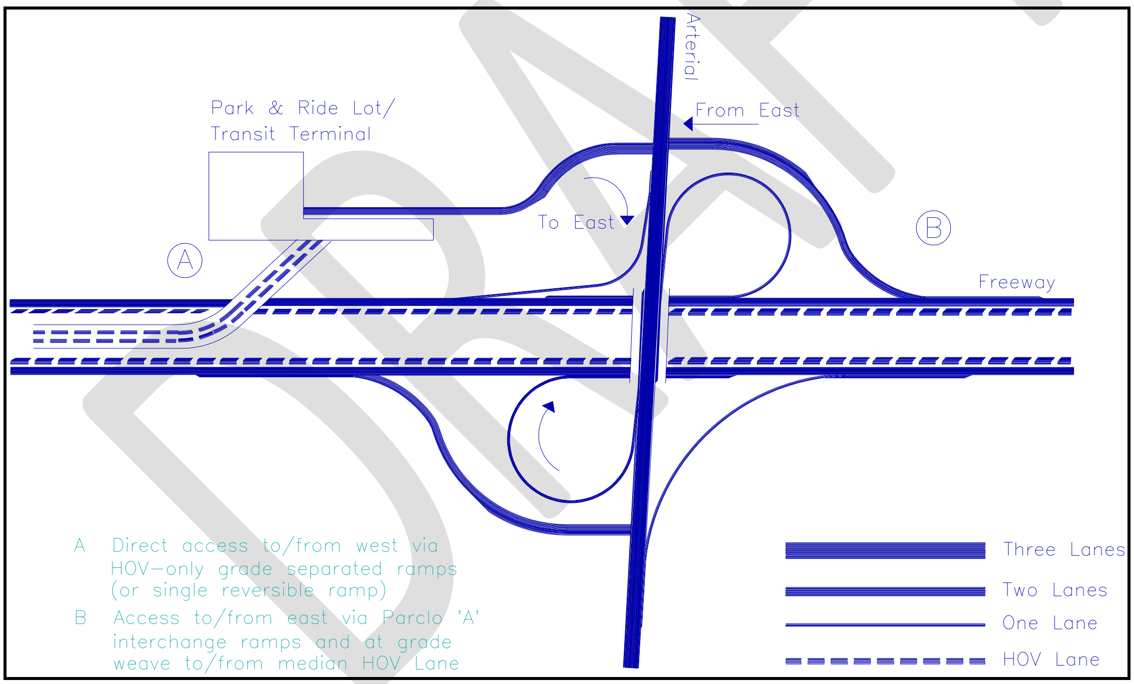


Figure 12-5.4042 Direct Ramp to Off-Line Parking / Transit Node at "Parclo A" Interchange

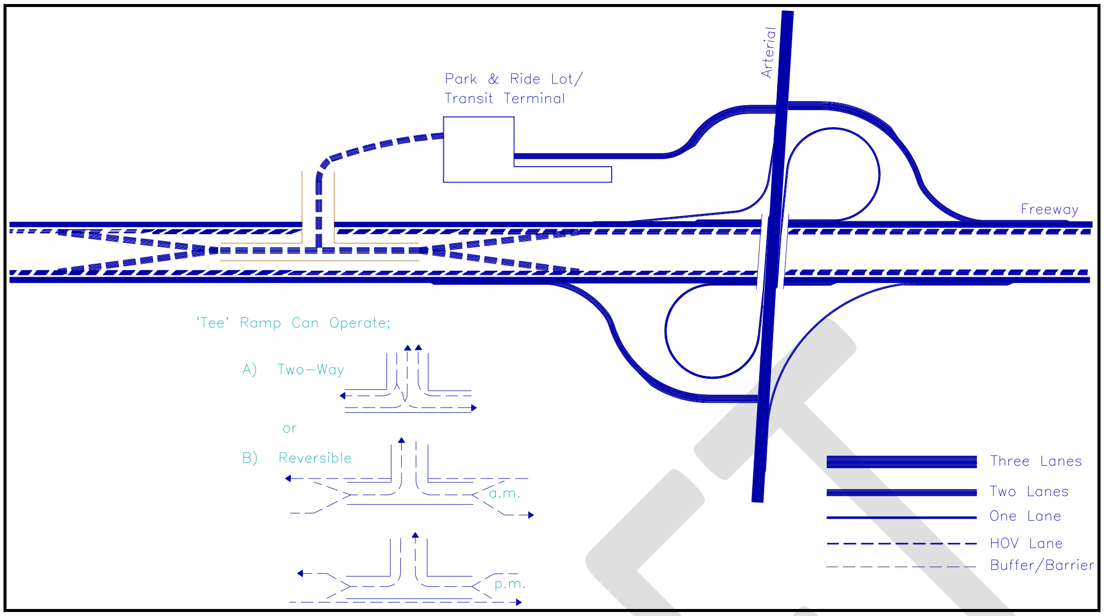


Figure 12.5.41~~43~~ "Tee" Ramp for Direct Access Between Median HOV Lane and Off-Line Facility

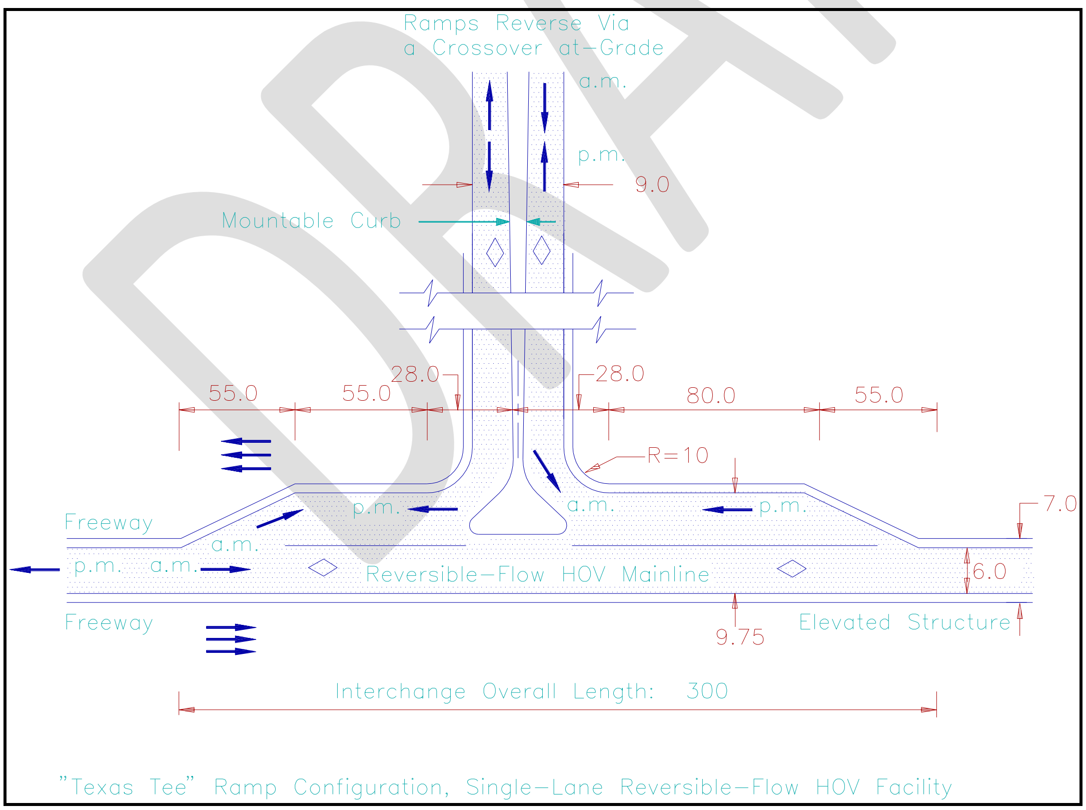


Figure 12.5.42~~44~~ Reversible Median "Tee" Ramp

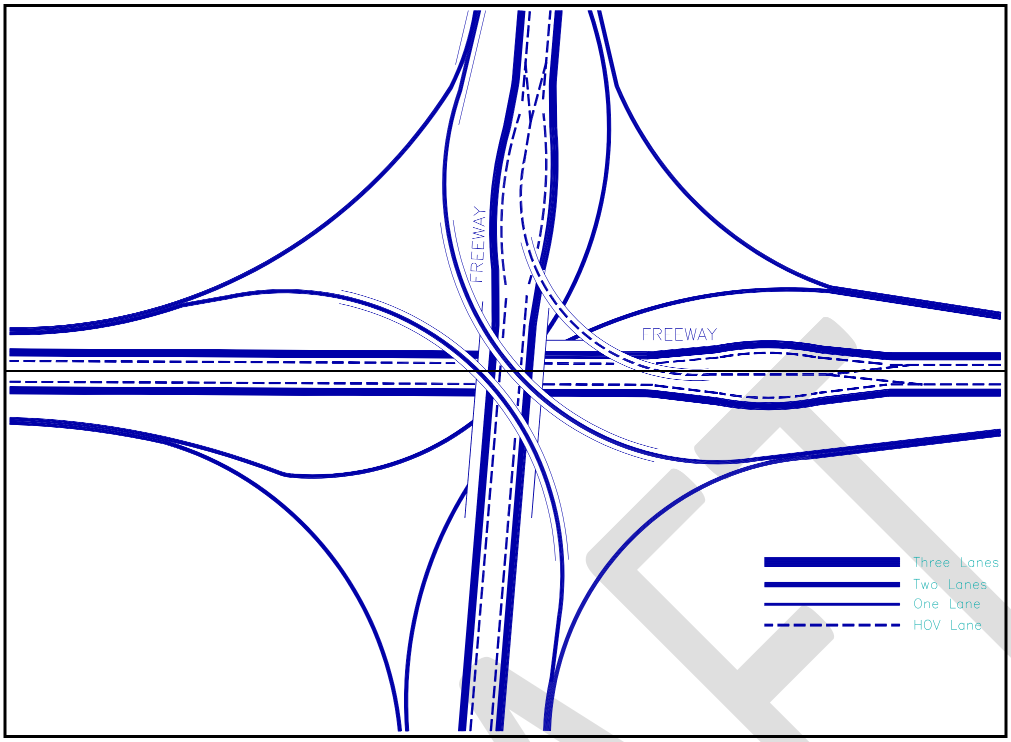


Figure 12.5.43~~45~~ Freeway-to-Freeway Interchange with Direct HOV Lane Connection (Major Move Only)

12.5.3 Bus Lane / Bus Only Lanes (BOL) Design

Within freeways, there are often opportunities to construct busways between the median barrier and the general-purpose traffic lanes.

The design speed of the median busway should match the design speed of the adjacent freeway to avoid differences in alignment geometry between the busway and the freeway. As a result, the geometry of the busway should meet geometric design guidelines.

The median busway should be designed with at least a 0.6 m (2 foot) paved shy distance between the edge of median barrier and edge of the bus lane. The bus lane should be at least 3.5 m (11.5 feet) wide, with a preferred width of 3.65 m (12 feet). The median busway does not require a horizontal separation between the bus lane and the adjacent general-purpose traffic lane, although 0.6 m of painted marking separation is desirable unless speed differential regulation applies in which case greater separation may be required.

The unobstructed vertical clearance over the busway should desirably be a minimum of 5.0 m (16.5 feet). The minimum recommended clearance is 4.7 m (15.5 feet). This will allow other vehicles, such as maintenance and emergency vehicles, to utilize the busway.

Lane designation signs should be installed at the start and end of the median busway. Overhead signs designating the busway should also be installed at intervals of about 15 seconds based on traveling at the posted speed. The maximum spacing of the signs should not exceed 30 seconds.

Pavement markings would consist of a solid white pavement marking between the bus lane and the general-purpose traffic lane and the words "Bus Only" painted in the busway cross-section, similar to HOV standard markings.

12.5.4 Part-Time Shoulder Use / Peak-Use Shoulder Lane

Part-time shoulder use or peak-use shoulder is the conversion of shoulders to travel lanes during some hours of day as a congestion relief strategy. This strategy is also known as temporary shoulder use or hard shoulder running or peak-use shoulder lane is typically implemented on freeways. This construction approach allows to add more space for travelers in a quicker and more cost-effective way than expanding highways. Drivers may use the designated shoulder in specific areas as an additional lane during times with heavy congestion. It is a transportation system management and operations strategy that uses shoulders to provide additional capacity when it is most needed or when general-purpose lanes are closed for construction or incidents. When an additional travel lane is not needed, the shoulder will be restored to its original purpose and the basic physical characteristics are retained.

There are no occupancy requirements for the vehicles to use the peak-use shoulder lane, and the speed limit is the same as the rest of the roadway. However, Part-time shoulder may not be an appropriate strategy where minimum geometric clearances, visibility, and pavement requirements cannot be met, or it may have an adverse impact on safety.

In the event of an emergency or blocking vehicle during lane operations, the peak-use shoulder will be closed (in the case of the dynamic lanes, using the overhead lane control signs) until the problem is able to be cleared.

12.5.4.1 Design Elements of Part-Time Shoulder

Beginning and End Segments

Part-time shoulder use can begin and end along segments or at ramps. If the beginning or end of a static or dynamic shoulder use segment falls along a basic freeway segment, then it would desirably be located such that it is highly visible and easily comprehended to approaching drivers. Horizontal curves crest vertical curves, and overpasses may limit a driver's visibility of a downstream roadway, and dropping any type of lane, including a shoulder open to part-time travel, within or immediately beyond these features should be avoided if possible. Likewise, dropping any type of lane in or immediately beyond an area with extensive, complex signing or other features contributing to high driver workload should be avoided, if possible. The desirable locations for lane drops are also desirable locations to begin shoulder use.

Part-time shoulder use on freeway segments should include pavement markings at the beginning of the area designated for shoulder use that guide drivers from the adjacent general-purpose lane onto the shoulder but also maintain continuity of the general-purpose lane. Shoulder use ends along freeway segments are designed like shoulder use adds. A solid edge line is typically used to transition traffic from the shoulder back to the adjacent general-purpose lane. Carrying part-time shoulder use through system interchanges is more complex due to conflicts with exiting and entering traffic. At major forks, the shoulder lane can be carried onto one of the forks. This is desirable if the ramps downstream of the fork have more lanes than the freeway approaching the fork.

Lane Width

For shoulders designated for part-time travel, a width of 3.65 m (12 feet) or more is generally preferred. Narrower shoulders may be adequate depending upon the type of vehicles using the part-time shoulder lane, the available lateral offset to obstructions beyond the pavement edge, and if speed restrictions will be used when the shoulder is open. If trucks are prohibited from using the shoulder, then widths as narrow as 3.35 m (10 feet) may be adequate. Shoulders less than 3.35 m (11 feet) wide are not recommended for part-time shoulder use.

A 3.35 m (11 feet) shoulder may be inadequate for part-time shoulder use if the lateral offset to obstructions is less than 0.5 m (1.5 feet) or a high volume of larger vehicles such as buses is anticipated. Opening the shoulder only when congestion is present and reducing the speed limit when the shoulder is open will likely improve the safety of a narrow shoulder designated for part-time use.

Shoulders less than 3.65 m (12 feet) wide typically requires a design exception if they are designated for part-time shoulder use. If an entire roadway is repurposed, and general-purpose lanes are reduced to less than 3.65 m (12 feet) wide to accommodate part-time shoulder use (for any shoulder width), a design exception is also required.

Shoulder Width

It is desirable to leave 0.5 m of pavement beyond the portion of the shoulder designated for part-time shoulder use to decrease the likelihood of vehicles departing the roadway and decrease pavement maintenance needs. Part-time shoulder use will require a design exception, since the remaining paved shoulder (beyond the portion of the shoulder designated for part-time shoulder use) will not meet the minimum width requirements.

12.5.4.2 Assessing Safety of Part-Time Shoulder Use

Experience to date has not identified major safety issues with part-time bus, static, or dynamic shoulder use that led implementing agencies to discontinue part-time shoulder use due to poor safety performance. Before/after collision studies of part-time shoulder use in the U.S. and internationally have not consistently indicated whether part-time shoulder use has a positive or negative effect on collision frequency.

Part-time shoulder use would likely reduce congestion-related collisions occurring during the operational hours of part-time shoulder use. Collisions related to erratic driver behavior or driver confusion may increase with part-time shoulder use.

Assessment of the safety impacts of part-time shoulder use on a given facility should begin with a review of three or more years of historical collision data. The review should consider the collision type, temporal factors (e.g., time of day, day of week), and location. Congestion-related collisions such as rear-ends occurring during times a shoulder would be open to travel, may potentially decrease with part-time shoulder use if congestion is reduced. Collisions related to erratic driver behavior or suboptimal geometry, such as run-off-road, fixed-object, or sideswipe collisions, may increase with part-time shoulder use.

Collisions related to right-side ramp-freeway may increase with part-time use of the right shoulder. The mere presence of collision types that may increase with part-time shoulder use should not prevent the application of part-time shoulder use, but the occurrence of those collision types indicates a given freeway may be a poor candidate for part-time shoulder use.

The 2014 Supplement to the Highway Safety Manual (HSM), 1st Edition, provides collision prediction models for freeways and ramp terminals, but does not explicitly model part-time shoulder use. The HSM models would have limited utility in evaluating projects that involve only adding part-time shoulder use. For this guide, HSM models were used to conduct a comparative analysis of freeways with typical lane widths and shoulder widths and freeways with an additional lane in each direction, but narrower shoulder widths (and in some cases narrower lane widths). The HSM freeway collision-prediction models indicate that implementing freeway part-time shoulder use could have the following influence on crash frequency and severity:

- Reduce property damage only (PDO) crashes
- Slightly increase fatal and injury (FI) crashes when converting existing 4- or 6-lane freeways
- Have little to no effect on FI crashes when converting existing 8-lane freeways

Overall, there appears to be a link between changes in congestion and changes in safety performance when shoulders are narrowed to implement part-time shoulder use. The application of the HSM freeway collision prediction models indicate reducing congestion (by increasing capacity) can offset the increase in collisions associated with increasing the number of lanes while reducing lane and shoulder width.

The empirical studies show that additional variables not specifically accounted for in the HSM prediction models could increase collisions associated with part-time shoulder use. Those factors include any differences between narrow general-purpose lanes and a narrow part-time "lane" on a shoulder, speed differential, influence of ramps, and upstream/downstream bottlenecks. Changes in barrier offset difference with and without part-time shoulder use can be modeled in the HSM. There may be greater changes in collision frequency with part-time shoulder use if barriers are present and they cannot be moved further back from the roadway when part-time shoulder use is implemented.

12.5.4.3 Bus Riding on Shoulders

In many urban areas, traffic congestion commonly delays bus services and adversely affects schedule reliability. Bus use of highway shoulders to bypass congestion has been in operation in Ontario on portions of Highway 403, 417, Highway 8 and Highway 401. **ONTARIO REGULATION 618/05** outlines the designation of Bus-By-Pass shoulders on Kings Highways.

BOS operation represents a low-cost and relatively quick strategy to improve bus running times and reliability without requiring costly expansion of the highway right-of-way. Because the bus shoulder operations can be implemented within the highway right-of-way, minimal disruption and traffic impacts result. The shoulder bus operations also facilitate the development of rail transit-like "station stopping" service, because buses can easily enter and exit the highway.

From a highway operations and safety viewpoint the BOS use operations raise a number of concerns. These concerns encompass the loss of basic functions that shoulders are intended to provide (removal and storage of disabled vehicles, emergency vehicle access, and highway maintenance staging), traffic safety risks, and the added costs for maintenance and enforcement. The traffic safety concerns include:

- Conflicts at on- and off-ramps;
- Sight distance adequacy, particularly at on-ramps;
- Conflicts for motorists pulling onto the shoulder;
- Loss of safe evasive movement shelter area;
- Need for bus driver training;
- Speed differential;
- Impact on adjacent lane motorists;
- Return merge distance adequacy;
- Shoulder area debris hazards;
- Reduced clearance for buses at bridge abutments; and
- Highway drainage.

Clearly, with proper operating rules and prudent upgrades to shoulder facilities, the bus use of shoulders bypass congestion would be a success strategy.

Implementation of adequate shoulder width, shoulder pavement strength, proper signage, sufficient lateral clearance of obstruction adjacent to shoulder, modifications to drainage inlets and pavement edge rumble strips would contribute to safe and successful operation of BOS use.

12.5.4.4 Traffic Control Devices Design

The requirement of signing and pavement marking varies depending on type of part-time shoulder use. BOS is typically implemented as unobtrusively as possible with minimal signing and no pavement marking. Extensive signing and pavement marking are detrimental to overall BOS operation because it leads some passenger car drivers to believe the shoulder is also open to them.

Dynamic part-time shoulder use requires changeable signs to notify drivers when the shoulder is open. Static part-time shoulder use has been successfully implemented in the states for decades with static signs, but dynamic signs are becoming increasingly common on these facilities and have been added to several established part-time shoulder use facilities that previously had only static signs to give a higher degree of acknowledgement to drivers of the current operating condition on the shoulder.

Pavement marking needs for dynamic part-time shoulder use is no different than static part-time shoulder use. In both cases, pavement markings need to provide sufficient guidance to drivers when the shoulder is open and when it is closed.

Dynamic part-time shoulder use requires electronic lane-use control signals to display whether the shoulder is opened or closed to traffic or, optionally, transitioning from being open to closed Static part-time shoulder use facilities can benefit from LCS as well, as they allow occasional deviation from operating hours due to disabled vehicles, off-peak special events, or other nonrecurring events.

In addition to lane control signs, changeable message signs (CMS) can be used to reinforce the open/closed status of shoulder or provide other information to drivers. High volume, urban freeways on which part-time shoulder use is typically implemented often already have CMS signs.

12.5.5 Standards and Design Exceptions

Design Variances and Flexible Design Philosophies

For retrofit facilities, trade-offs and accommodations may need to be made in comparison to applicable guidelines for affected design elements (e.g., lane width, shoulder width, lateral clearance). As mentioned earlier in **Section 12.5.5.1.4,** the implementation of HOV lanes could involve, in many cases, geometric compromises to utilize existing structures or minimize impact and cost.

HOV lanes are governed by general freeway design standards, and exceptions or deviation from the standards would require sound justification and senior level of approval (see Chapter 1)

The designer needs to know what trade-offs to consider, and what protocols must be followed. As a North American example, Nevada DOT utilized a series of possible trade-offs for designing the cross section for a concurrent flow HOV lane (**Table 12.5.10)**.

12.6 Safety of Managed Lanes

Managed lanes are intended to provide faster travel speeds and better reliability than the adjacent general-purpose lanes.

Collisions on managed lanes can be related to access, congestion, and sight distance. These factors are compounded by failure to appreciate driver expectancy that differs for ML as compared to GP lanes. Adequate attention to placement of traffic control devices can help. In addition to collisions near access points, collisions also occur within a managed lane facility. Common types of collisions within a facility include:

- Rear-end collisions due to congestion.
- Sideswipe collisions due to passing on two-lane facilities or within access zones.
- Collisions caused by drivers making unexpected maneuvers at the point where access restrictions apply or to avoid debris or disabled vehicles that may block the highway.

Table 12.5.10 Suggested Design Sequence of Trade-offs for Concurrent Flow HOV lanes

Suggested Sequence	Cross-Section Design Change
First	Reduce the 14-ft median (left) shoulder (for continuous enforcement) to 8 ft. Provide designated enforcement areas instead.
Second	Reduce median shoulder to typical minimum width as per Nevada DOT Standard Plans.
Third	Reduce median shoulder to 2 ft.*
Fourth	Reduce outside (right) shoulder to typical minimum width as per Nevada DOT Standard Plans.
Fifth	Reduce managed lane to 11 ft.*
Sixth	Reduce general-purpose lanes to 11 ft starting from left and moving to the right as needed. The outside lane should remain 12 ft.*
Seventh	Transition barrier shape at columns to vertical face.

*Requires design exception. (Source: Nevada DOT).

Note: that this list is provided as an example and is not intended to supersede engineering judgment in specific design applications.

12.6.1 Safety Implications of Managed Lanes Cross-Section

Research work in 2013 reported on an evaluation of the relationship between cross-section design (i.e., lane width, shoulder width, and buffer width) and safety performance for HOV lanes. Three years of collision data for 13 Southern California segments totaling 153 miles were analyzed. The segments were buffer separated between HOV lanes and GP lanes. Collisions included those that occurred on median shoulder, in HOV lane, or in adjacent GP left lane. Independent variables included geometric attributes and annual average daily traffic (AADT). It was found that wider HOV lane width and wider shoulder width were associated with lower collision frequencies. For that study, buffer width and width of the lane next to HOV lane were not found to be statistically significant. The authors also provided case study of preferred cross-section allocation if converting a section from an HOV lane and left shoulder to a section having a buffer, HOV lane, and left shoulder. The authors recommended inclusion of a buffer by reallocating some of shoulder width to buffer.

Another study in Florida (2015) developed collision prediction equations for freeway facilities with HOV and HOT lanes by number of freeway lanes. Segment length and AADT were found to be significant and included. For most of models, left shoulder width was the only other significant variable. An increase in left shoulder width was associated with decreases in collisions. The inclusion of a 2- to 3-ft buffer was associated with fewer fatal and injury collisions.

The findings from safety literature along with guidance in ***Highway Safety Manual*** are clear in that a reduction in a freeway left shoulder width is associated with an increased number of collisions.

Research work in California and Texas (FHWA-HOP-16-076 December 2016), California included freeways with three or four GP lanes while the Texas freeways had three to five GP lanes, indicated that reduction in a freeway left shoulder width is associated with increased number of collisions. Safety studies for GP freeway lanes found that reduction in lane width is associated with more collisions.

- Safety improvement associated with increased left shoulder width is a reduction of collisions by 5% per additional foot of left shoulder, when there are no changes to other model variables.
- Safety improvement associated with increased right shoulder width is a reduction of collisions by 9% per additional foot of right shoulder, when there are no changes to the other model variables.
- There is a safety improvement associated with each additional lane width (see **Table 12.6.1**).

Other research work indicated that increase in collisions associated with reductions in freeway lane and shoulder widths may be offset if reductions are done to increase number of freeway lanes. Also, research results indicated that reductions in ML widths (shoulder, lane, and buffer width) are associated with more collisions. It was found that narrow buffer widths (equal or less than 3 ft) appear to be associated with more collisions as compared to 4-ft to 6-ft buffers. Wider envelopes are associated with a reduction of 2.8% (in Texas) or 2.0% (in California) in total freeway collisions (all severities) for each additional foot of width. In California, wider envelopes are associated with a reduction of 4.4% in ML related collisions (fatal and injury severity levels) for each additional foot of envelope width.

Table 12.6.1 Safety Benefit of Additional Lane

Safety of lane width (Fatal and serious injury collisions). Number of Lanes	Fatal and Serious Injury Collision Reduction of a 12-ft Lane Compared to 11-ft
2	5%
3	7%
4	10%
5	12%

12.6.2 Collisions at Access Points

Access points are common sites for collisions just as at intersections on surface streets. Collisions near access points can involve vehicles entering or leaving the managed lanes (e.g., sideswipe, striking separation device, etc.), and collisions can involve vehicles that are not changing facilities (e.g., rear-end collisions caused by drivers braking to avoid a vehicle entering the facility in front of them). Volume of traffic, type of access and separation provided, and proximity of ML access to GP lane entrance and exit ramps may all influence collisions and these effects may vary from one facility to another.

12.6.3 Safety Benefits of Converting HOV To HOT Lanes

Safety benefit is a major component of benefit-cost analysis of transportation projects. Conceptually, conversion of HOV to HOT lanes could offer safety benefits. First, the underused HOV lanes may motivate solo drivers on general purpose lanes "cheat." Illegal users of HOV lanes may be more likely to make a sudden entry when they are frustrated by large speed differential between HOV lane and general-purpose lanes and may make sudden exits when they realize the presence of police surveillance. It is evident that intermediate access and lane changes by illegal users on concurrent flow HOV lanes increased collision rates.

Truck traffic has significant impact on traffic operations and safety. Safety concerns due to truck traffic continue to draw increasing attention of transportation engineers and policy makers who are proposing a few practical strategies such as lane restrictions and exclusive facilities. The key aspect of all these strategies lies in separating trucks from cars to create more homogeneous traffic conditions.

Researchers and practitioners have been exploring various remedial countermeasures to tackle these problems. Different truck traffic control strategies have been proposed as a mean to reduce their operational and safety impacts. A wide range of research results in favor of these strategies based on their operational performance. However, there is still very limited consensus on their safety impact. Despite some empirical findings on collision reduction, very few of them specifically examined the outcomes of the collisions in terms of collision severity.

Table 12.6.3 Operational Impacts of Physical Design Options

Source Conversions of HOV to HOT Guidebook – FHWA 2007

<table>
<tr><th colspan="2">Physical Design Options</th></tr>
<tr><td>Concrete Barrier
Benefits:
• Reversible lane concept
• Safety from general purpose lanes
• Easier to enforce compliance
Issues:
• Users have feeling of confinement
• No way-out during accidents unless removable rail or gates are installed</td><td>Flexible Delineators (Pylons)
Benefits:
• Inexpensive and achieves visible separation
• Easy removal
• Have a way out
Issues:
• Frequent maintenance / replacement
• Safety due to vehicles able to drive through delineators
• Possible flying hazard when hit by vehicles at speed</td></tr>
<tr><td>Buffer Separated
Benefits:
• Inexpensive
• Vehicles have a way out
• Easy removal
• Easy to install
Issues:
• Safety due to vehicles cutting in and out
• Extra right-of way requirements</td><td>Non-Buffer Separated (Pavement Markings)
Benefits:
• Inexpensive
• Vehicles have a way out
• Easy removal
• Easy to install
Issues:
• Safety/enforcement issues of vehicles cutting in and out</td></tr>
<tr><td>Non-separated Shoulder
Benefits:
• Provides extra capacity without adding a lane
Issues:
• Confusion over lane use
• Lack of emergency pull outs for disabled vehicles
• May have to be rebuilt if transit buses are allowed to use.</td><td>Grade Separation
Benefits:
• Exclusive use
• Safest
Issues:
• No way out
• Lengthy construction/Expensive
• Users have a feeling of confinement
• Easier enforcement</td></tr>
</table>

12.6.4 Safety Impact of Commercial Vehicle Separation from Traffic

A large percentage of commercial vehicles, both in rural and urban areas, can degrade the speed, comfort, and convenience experienced by passenger car drivers. Some jurisdictions, to minimize these safety and operational effects, have implemented truck lane restrictions. The most common type of lane restriction addresses truck traffic. These restrictions can take the form of time-of-day restrictions, peak period bans, or route restrictions.

The dual-dual roadway consists of parallel inner lanes for autos only and outer lanes for mixed traffic. Collision data from major highway sections with dual-dual roadways for several years was examined. Comparative analysis showed that the severe collisions occurred in different lanes were different. Surprisingly, the proportions of injury collisions occurred along the dual-dual roadways were higher compared with other sections of the highway. Results also confirmed that collisions on the dual-dual roadways were more likely to be injury collisions. As a general comment, results of deployment dual-dual roadways with car-only lanes has statistically significant impact on collision severity, indicating higher risk of having injury collisions in dual- dual lanes compared with regular mix traffic lanes. The finding suggests that other than considering collision frequency as a measure of safety, collision severity should be considered to fully assess the performance of the truck-auto separation strategies.

Other research work showed different results indicating that mixed-use lanes (cars and trucks) had a higher collision rate than car-only lanes and that truck related collisions were the biggest contributor in the mixed-use lanes. The speed difference between cars and heavy trucks is the main source of safety concern. Significant speed differential leads to more collisions.

The **Highway Safety Manual (HSM)** now includes crash predictive methods for freeways. The researchers found that reductions in lane widths and inside (left) shoulder widths are associated with increased collisions. The proposed collision modification factor for the HSM along with the findings from other recent work is shown in **Figure 12.6.1** for lane width and **Figure 12.6.2** for inside (left) shoulder width. The range of shoulder widths included in the study was (0.6 m to 3.6 m) 2 to 12 ft. An inside shoulder width of 6 ft was assumed as the base condition. Some agencies avoid inside shoulder widths greater than 4 ft and less than 8 ft because of concerns that drivers may attempt to seek refuge in a space that does not have sufficient width to accommodate a typical vehicle (6 ft) plus clearance (desirably 1 ft to 2 ft).

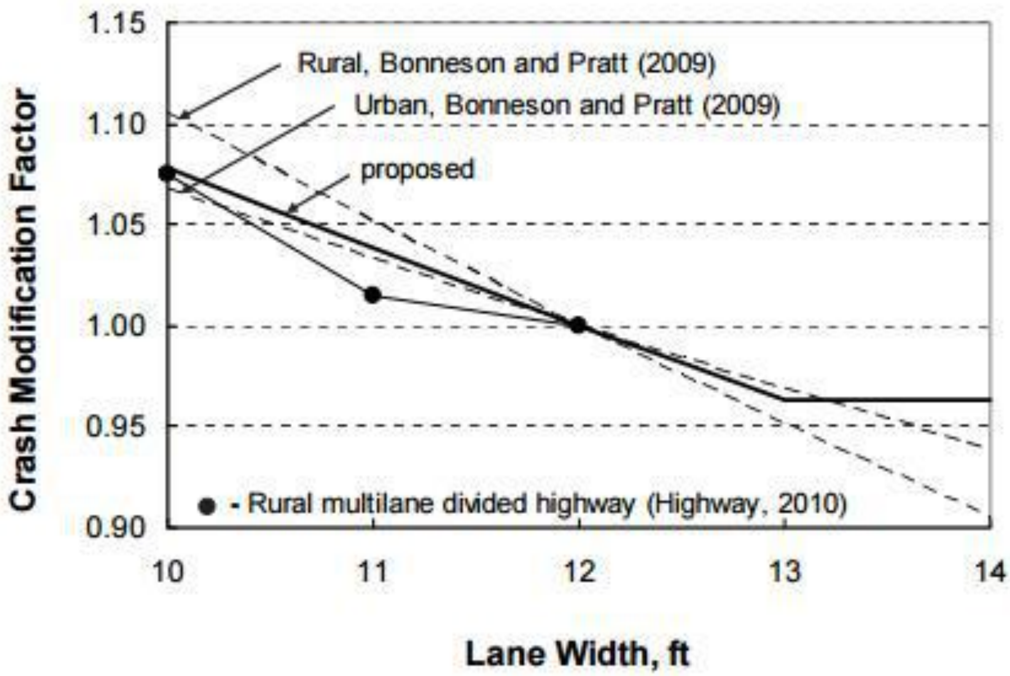


Figure 12.6.1 Proposed Crash Modification Factor for Lane Width.
Source: Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges (NCHRP Project 17-45, online final report).

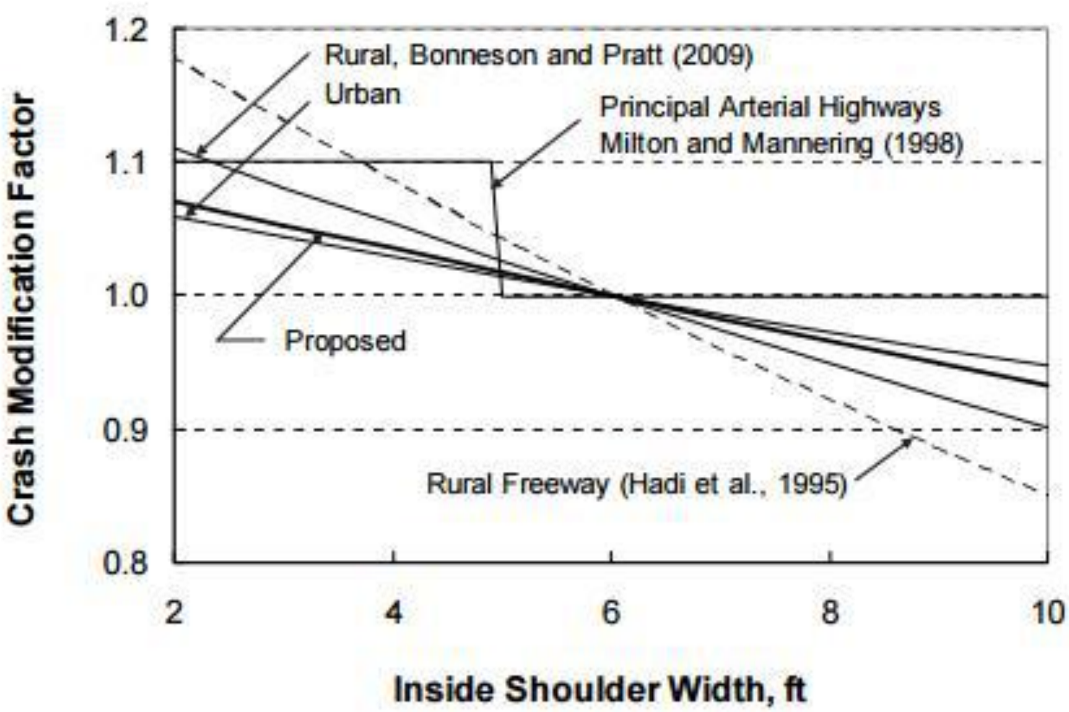


Figure 12.6.2 Proposed Crash Modification Factor for Inside Shoulder Width.
Source: Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges (NCHRP Project 17-45, online final report).

12.7 Traffic Control System for Managed Lanes

12.7.1 Advanced Traffic Systems (ATS) Applications

As managed lanes become more common, road agencies have been working to develop new standards and guidelines for the traffic control devices for these new facilities. Surveys have been conducted to investigate drivers' comprehension of signs for toll and managed lanes facilities. Some aspects revealed are:

- Advanced destination signing is an important determinant of whether drivers will use a managed lane or not. Distance – Destination signs and Interchange Sequence Signs should be provided in advance of all access points to and from managed lanes.
- Interchange sequence signs for managed lane exits requires to be made more distinct to avoid confusion with signing for the general-purpose lanes.

Managed lane facilities are among the segments of the highway system which exhibit the greatest potential for FTMS/IVHS related applications and benefits:

- The intent of FTMS is to make the highway system operate more efficiently, more safely, and with less congestion; these goals are shared with managed lane applications.
- FTMS/IVHS strategies are normally applied in those corridors exhibiting significant recurring congestion to maximize potential benefits; these are also conditions suited to ML application.
- Managed lane has the potential to operate with great flexibility and maximum efficiency through increased awareness of mixed flow conditions and flexible electronic signage and gate controls; some types of managed lanes could operate only when and as needed to avoid congestion, for example at various points throughout the day or with varying minimum occupancy rates depending on the overall freeway level of service. However, if not tied to a schedule, enforcement and driver expectations could have problems due to inconsistency.
- Managed lane is in most cases a more controlled environment than several mixed flow lanes and is used by a select group of vehicles (no trucks); management of the flow within the lane to achieve optimum efficiency will be far easier than application of IVHS on a large scale to the entire freeway system.
- One of the major HOV-related issues at present is the determination of vehicle eligibility (i.e. occupancy); advanced registration and/or electronic monitoring techniques hold some promise to resolve this problem.
- Ramp metering, and preferential treatment of HOVs at metered ramps, holds significant potential to become more efficient and effective, with monitoring and control of

upstream lane volumes and gap availability.
- IVHS plans are likely to be fist applied to buses and commercial fleets before extending to the entire automotive spectrum; since bus use is a major factor in achieving the potential of an HOV/HOT facility, any technique which improves bus service is supportive of the HOV/HOT concept.
- Ridesharing and transit information will become more readily available and accurate, thereby making HOV/HOT use and carpool formation more convenient.

In summary, managed lane facilities and operation will potentially be among the most significant and easily-applied components of an advanced Traffic Management/IVHS plan for a freeway corridor.   HOV/HOT use is itself one of the most effective means of reducing congestion, it is essential that HOV/HOT operation maintain a good level of service and that use of HOV/HOTs - both carpools and buses - be made as convenient and attractive as possible.

12.7.2 Incident Management

As essential element in a Freeway Traffic Management and Operations plan is Incident Management, both in reducing the risks of disruptive incidents occurring and in minimizing the consequences of incidents of traffic flow when they do occur. Since two of the key features associated with managed lanes priority treatments are travel time improvement and reliability, incident management plays a major role in managed lanes system operations.

Typical non-recurrent incidents include traffic accidents, disabled vehicles, spilled loads, driver gawking, and adverse weather conditions. Other irregular activities which may affect flow include freeway maintenance (including snowploughing) and construction while unusual situations such as traffic diversion from blocked parallel routes, VIP transfers, and larger scale emergencies can also occur. Together, all these departures from "normal" operation represent the cause of the delay experienced on freeways in Ontario's urban areas.

An Incident Management Strategy, involving defined actions and responsibilities, should be developed for a corridor prior to the introduction of HOV/HOT lanes; involved agencies should include the MTO, provincial/regional police, all emergency service providers, tow truck operators, and the affected municipalities.

A Freeway Traffic Management System (FTMS) plays a large role in identifying and removing incidents while informing area motorists of the situation; some HOV/HOT -specific design features related to incident management are also appropriate:

- Adequate shoulder width, continuous throughout HOV/HOT project, for both HOV/HOT

and mixed flow lanes (see **Section 12.5** for relevant design guidelines).
- widened shoulders where necessary for enforcement purposes (**Section 12.8.3.2**).
- physical barriers between opposing traffic flows and, where adequate right-of-way exists, between adjacent HOV and mixed traffic lanes.
- adequate geometric provisions for lane access, egress, and termination.

Barrier-separated managed lanes have been shown to have lower collision rates than non-barrier-separated lanes.

Given that an HOV/HOT lanes effectiveness are predicated on a fast, reliable travel time, and that during peak periods they will carry a disproportionate number of persons, there is some justification to developing an incident management strategy which places highest priority on maintaining smooth HOV/HOT lane operation.

In the extremely unusual event of emergency or construction conditions requiring use of the HOV/HOT lane by non-HOV/HOT users (e.g. during closure of the mixed flow lanes), consideration should be given to maintaining HOV/HOT priority to the extent possible, and to ensuring that the facility is operationally compatible (e.g. reversible lane) with the demands being placed on it. Limiting such use to off-peak periods and using temporary or electronic signage to define the condition is highly desirable.

12.7.3 Signs and Markings

12.7.3.1 Signage

Clear, concise communication of managed lane -related facilities and regulations to all freeway users is a substantial challenge. In addition to the normal entry, exit, and directional signage associated with any freeway lane, the specification of: a) vehicle eligibility; and, b) time of managed lane operation are required. Furthermore, the dynamic nature of many managed lane applications provides opportunities for use of changeable signs.

O. Reg. 620/05: HIGH OCCUPANCY VEHICLE LANES, October 2018, includes description of the static signs for HOV lanes.

Also, for the HOT lanes pilot project (16.5-kilometre section of the QEW, in both directions, between Trafalgar Road in Oakville and Guelph Line in Burlington) signs:

- HOT lane signs marking the far-left lane
- Markers painted on the road, including diamond markers and a striped buffer zone that separates the HOT lane from other lanes

12.7.3.2 Pavement Markings

Use of standard pavement markings and colours is recommended for managed lane facilities. For example, the HOV pavement markings are white for concurrent flow and yellow for lines separating opposing flows; solid stripes where vehicles are not permitted to cross and dashed stripes where crossing is allowed.

A buffer zone between a concurrent flow HOV lane and a mixed flow lane should be delineated by solid white stripes. If no access restrictions are placed on the HOV lane or if it reverts to mixed flow usage during part of the day, elimination of the buffer and use of standard white dashed striping should be used; in such a case, lane designation will rely entirely on signage.

In the Ontario context, the use of diamond symbol as a pavement marking would be appropriate, however, only for full-time HOV lanes (O. Reg. 620/05: HIGH OCCUPANCY VEHICLE LANES, October 2018).

12.7.3.3 Changeable Message Signs

A changeable message sign (CMS) is a traffic control device that is displaying one or more alternative messages and can have a blank mode when no message is displayed. CMSs can be used to change speed limit for traffic or ambient conditions for managed lanes. CMSs are most appropriate when travel conditions change or where operational approaches are varied throughout the day, week, or in real time. A CMS may be used to supplement, substitute, or be incorporated into preferential lane regulatory signs. Also, CMSs can display tolling information that varies by time of day and type of vehicle.

When locating pricing signs, the designer should consider appropriate distance needed between the sign and the access point to provide drivers with ample time to make their decision about whether to enter the priced lane. Driver workload is high near access points due to lane changing, weaving, and speed maintenance. For this reason, pricing signs should not be placed immediately at the gore point of the access point. Pricing signs should be placed upstream, so driver has time to decide whether to enter and then has adequate time to complete the vehicle maneuvers to do so. Drivers must be able to rely on information provided by the CMS.

12.7.3.4 Advanced Warning System

An Advance Warning System (AWS) was successfully commissioned with the HOV lane opening on December 13, 2005 for Highway 404 High-Occupancy Vehicle (HOV) tunnel. The AWS is an automated system designed to improve tunnel safety, reduce the potential for both primary and secondary collisions, and to reduce incident response times (**Figure 12.7.1**).

The AWS is fully meeting and exceeding the original goals for improved motorist safety and incident management. The warning messages provided on the signs has exceeded the degree of safety of a multi-million-dollar geometric realignment, however at a fraction of the cost. This system is the first of its kind in North America and will set the new standard for exceptionally safe and efficient freeways in Ontario.

The AWS field equipment consists of eight double-loop Vehicle Detector Stations (VDS), four stationary colour Closed Circuit Television (CCTV) cameras, one Video Imaging Processing (VIP) analyzer, two Variable Message Signs (VMS) and two Advanced Traffic Controllers (ATC), refer to **Figure 12.7.2.**

Figure 12.7.1 Highway 404 Tunnel Automated Warning Message

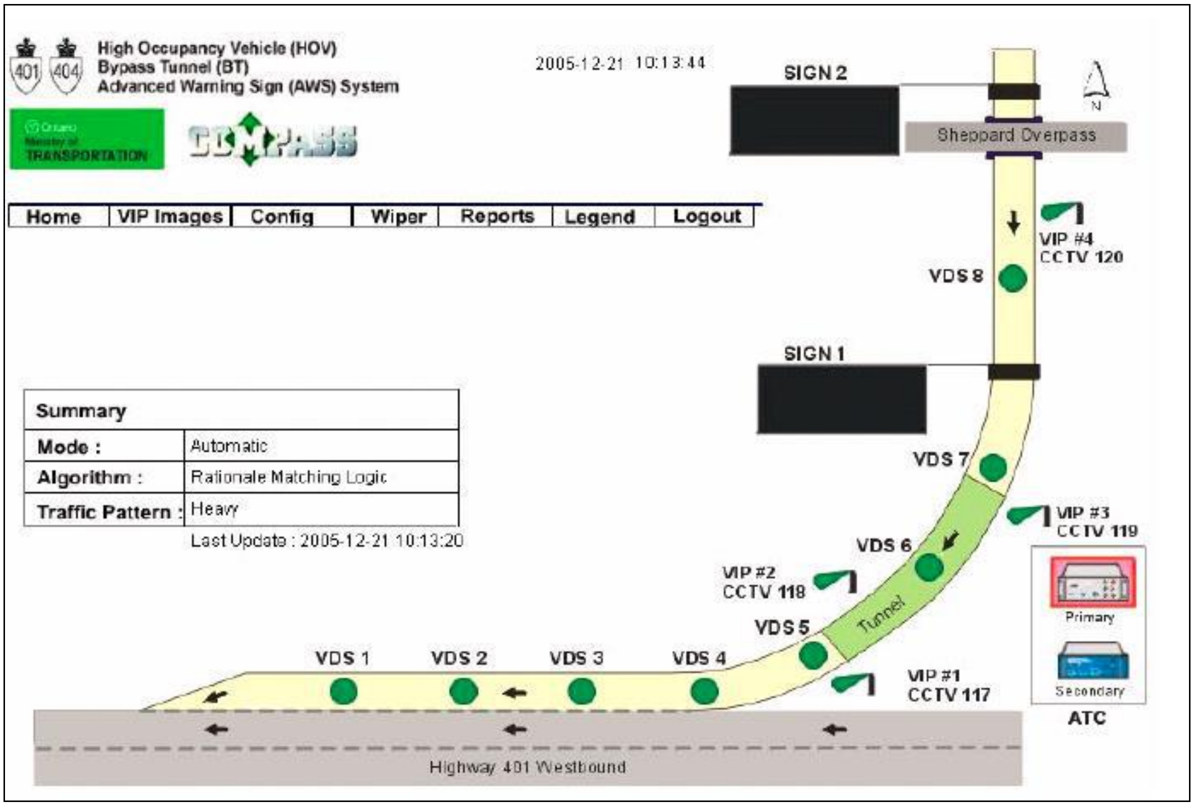


Figure 12.7.2 Schematic Map of Hwy 404 AWS

The eight double-loop Vehicle Detector Stations (VDS) are located before, within, and after the tunnel. A total of three VDS locations are spaced every 40 meters within the tunnel and the remaining five VDS are spaced from 50 to 100 meters outside the tunnel (**Figure 12.7.1 and Figure 12.7.2**).

All VDS within the tunnel use rectangular preformed loops installed below the tunnel's concrete floor and span from wall-to-wall to capture vehicles both within the lane and the right shoulder. The VDS outside the tunnel use MTO COMPASS standard diamond loops in the base asphalt centered within the lane. All VDS loops are connected to the AWS single roadside traffic cabinet and provide vehicle presence indications concurrently to two Advanced Traffic Controllers.

The Advance Warning System technological solution improves the operational management of incidents within the tunnel via the addition of the automatic video-based incident detection system. Traffic problems can be detected quickly, and the digital video recording feature enables detailed information for incident response and analysis and emergency services can be notified soon, potentially resulting in saved lives.

The AWS is designed to ensure that motorists are aware of imminent congestion conditions or traffic problems in the tunnel, thereby minimizing rear-end collisions and secondary collisions. The system operates reliably and consistently with the light and heavy traffic algorithms based on loop technology, as well as with the seamlessly integrated off-the-shelf video detection equipment. The VIP cameras improve the AWS by detecting slow or stopped vehicles quicker and more effectively than traditional loops.

Since the commencement of operations on December 2005 to April 2008, more than 200 confirmed incidents have occurred within the Advance Warning System limits. Only one of these incidents was a single vehicle collision due to speeding. The system was credited for significantly improving motorist safety and effectively reducing the potential for rear-end collisions (**Figure 12.7.3**).

12.8 Performance Monitoring and Enforcement

Attention should be given to continual monitoring and evaluation after opening of a managed lane facility. Public and stakeholder attention to the facility will be more acute during the first year of operation, with answers desired for the following questions:

- How many people are using the managed lanes?
- Have the managed lanes improved traffic in the general-purpose lanes?
- What is the effect on carpools?
- If priced, what is the highest toll price? How much is the average toll?
- How often do account holders use the lanes?

Monitoring technology used successfully today includes vehicle sensors, automatic vehicle identification, license plate recognition, and user information systems. Each of these components has demonstrated that it is integral in ensuring effective operation of a facility. Likewise, more comprehensive, historical data can be collected and analyzed to determine if adjustments to the overall operating strategies should be made.

Based on the experiences reviewed for many areas across North America with some form of HOV monitoring and evaluation, it found out that there are limited procedures for monitoring varying for each area.

Key elements to be considered in effectively managing and operating managed lane facilities include performance monitoring, incident management, enforcement and ongoing consideration of enhancements. Real-time monitoring of freeways and ML through closed-circuit television cameras (CCTV) and other technologies is an important component of proactive management and operation of transportation system.

Figure 12.7.3 Highway 404 and Highway 401 VMS at Tunnel Entrance

Performance Monitoring: ATMS provides real-time monitoring, incident detection, and rapid response capabilities. MTO conducts ongoing monitoring and performance evaluations of HOV facilities. These efforts combine to enhance day to-day operation of HOV and freeway facilities and provide information required for operational changes.

Incident Management: Managing accidents and incidents on ML lanes and freeways is a key part of operational management. Elements of an incident management program include detecting a problem, responding appropriately, clearing the incident and returning the facility to normal operations, and communicating necessary information to motorists to help manage the situation.

Enforcement: Enforcement of vehicle-occupancy requirements and other policies are critical to the successful operation of ML / HOV facilities. ML enforcement programs help ensure that operating requirements, including vehicle-occupancy levels, are maintained to protect HOV travel time savings, to discourage unauthorized vehicles, and to maintain a safe operating environment. Visible and effective enforcement promotes fairness and maintains the integrity of the ML / HOV facility to help gain acceptance among users.

Ongoing Consideration of Enhancements: A key part of operational management philosophy is continually looking for opportunities to enhance performance of ML and freeway facilities. Information from performance monitoring programs can be used to help identify possible areas for improvements or changes. Examples of possible enhancements include new or expanded bus services, innovative rideshare programs and public outreach activities, motorists service patrols, ramp metering and HOV bypass lanes, and special treatments for HOVs at major destinations. The use of new technologies, techniques, and strategies should also be considered on an ongoing basis. These approaches may include advanced transportation management systems, variable message signs, advanced traveler information systems, and other techniques.

There are few components that make up the framework for performance monitoring. These components include outlining a set of performance measures to correspond with objectives and identifying a methodology regarding the gathering of both HOV and GP lane operation data.

Evaluating HOV lanes is in some ways similar to evaluating other highway facilities – safety, vehicle volumes, and level of service are generally evaluated on both types of facilities. HOV evaluations also examine impacts on person movement (how many people, as opposed to how many vehicles, use the lane) modal shifts (how many people changed their travel behavior to take advantage of the HOV lane), and travel time savings are all important indicators of HOV lane performance.

12 8.1 Performance of HOV Lane

Establishing a program to monitor and evaluate the performance of HOV lane can help determine if the facility meets its goals and objectives. The results of the performance evaluation provide basis for making revisions to improve the operation of the HOV system or specific lanes. The performance of an HOV lane is governed by many factors including:

- length of facility;
- design; access and other design treatments;
- rates of HOV violations;
- presence of / coordination with transit services;
- availability of park-and-ride lots supporting the different modes; and
- Supporting programs and services including rideshare matching, preferential parking and related services.

Measures of Effectiveness

Consideration of periodic monitoring of HOV lanes to determine if the improved travel time and trip time reliability, safety and satisfaction incentives are maintained, and to measure effectiveness of future improvements.

Total Person Throughput: A measure of how many people move past a point in a given period. Traditionally transportation agencies measure only the number of vehicles, but on HOV lanes they measure the number of vehicles, number of people per vehicle, and the number of people using transit. Increased person throughput and higher average vehicle occupancy are the goals.

Travel Time: To determine how long it takes HOVs, single occupant vehicles (SOVs) and freight vehicles to travel on roads with HOV lanes. No increase in travel times during the afternoon rush hour is a goal.

Safety: Collision and incident rates on sections of highway before and after HOV lanes are established. No increase in incident and collision rates is a goal.

Enforcement: A qualitative measure of how enforceable HOV lane is. Tracking the number of tickets issued and HOV lane violation rate is an indicative of police enforcement. Minimal violation rate and maximum perception that users obey HOV rules are goals.

Air Quality: Less air pollution resulting in healthier air quality is the goal.

Greenhouse Gas Reduction: A decrease in greenhouse gas emissions is the goal.

Beginning and Ending Transitions: The beginning and ending of HOV lane can create weaving movements or other traffic flow problems. Agencies monitor traffic operations to evaluate how HOV lanes affect traffic flow.

Traffic Diversion: There is a concern that excessive delays in general-purpose lanes may cause traffic to divert to parallel routes. Traffic counts to be taken before and after HOV lanes are established to determine if significant traffic is diverted. The goal is to minimize traffic diversion.

HOV Lane Utilization: A measure of how many vehicles are using the HOV Lane in a given period, and how this compares with their maximum capacity.

Transit Ridership: Agencies track how many people ride transit during peak periods when HOV lane is in service.

Increase in Transit Service: Agencies measure the increase in transit service and compare it to increase in transit ridership. This would help understand the increase in transit ridership due to the HOV project compared to normal increases in ridership that result from an increase in transit service (without an HOV lane).

Number of People per Vehicle: Observation of traffic to determine the number of people per vehicle during peak periods.

Park-and-Ride Use, Van Pools and Employer Programs: Tracking the use of Park-and-Ride and vanpools.

Public Perception: Survey commuters and compare responses before and after HOV lanes.

Access Points: are common sites for collisions just as collisions can commonly be found at road intersections. Collisions near access points can involve vehicles entering or leaving the managed lanes (e.g., sideswiping another vehicle, striking separation device, etc.), and collision can involve vehicles that are not changing facilities (e.g., rear-end collisions caused by drivers braking to avoid a vehicle entering the facility in front of them). Traffic volume, type of access and separation provided, and proximity of managed lane access to general-purpose entrance and exit ramps may all influence collisions, and these effects may vary from one facility to another.

A study completed in California (2013), identified three performance measures for HOV performance evaluation as follows:

Speed Differential: (Speed in HOV Lane – Average Speed in GP Lanes). Speed differential is a proxy for travel time savings. For example, if traffic in the GP lane moves faster than that in HOV lane then the speed differential is negative. If traffic in HOV lane travels at slower speeds than that in GP lanes, the HOV facilities do not provide travel time savings.

VMT Ratio: ((segment length × traffic flow in HOV lane) / {(segment length × traffic flow in HOV lane) + (segment length × average traffic flow in GP lanes)}). This ratio measures utilization level of HOV lane by vehicle-miles but is calculated on a relative basis in comparison to GP lanes. If the ratio is greater than 0.5, it means that HOV lane carries more vehicle-miles than the average GP lane.

PMT Ratio: ((segment length × average vehicle occupants in HOV lane × average traffic flow in HOV lane) / {(= segment length × average vehicle occupants in HOV lane × average traffic flow in HOV lane) + (segment length × vehicle occupants in GP lanes × average traffic flow in GP lane)} This ratio measures the utilization level of HOV lane by person-miles, also on a relative basis in comparison to the GP lanes. If the ratio is greater than 0.5, it means that HOV lane serves more person-miles than average GP lane. One of major objectives implementing HOV lanes is to carry more passengers with fewer vehicles. Thus, PMT ratio should be given a high-priority consideration in addition to VMT ratio in terms of evaluating operational performance of HOV facilities.

Combining the VMT and PMT measures, there would be the following four possibilities:

i) **VMT Ratio < 0.5 and PMT Ratio < 0.5**: HOV lane serves fewer vehicles and people than average GP lane, which implies the potential of not optimally utilized HOV facilities. Although in this category, the HOV lane may still meet the minimum requirement by serving more than 800 vph or 1800 persons per hour according to the HOV guidelines.

ii) **VMT Ratio < 0.5 and PMT Ratio >= 0.5**: HOV lane serves fewer vehicles but move the same or higher numbers of people than an average GP lane.

iii) **VMT Ratio > 0.5 and PMT Ratio < 0.5**: HOV lane serves more vehicles but fewer people than 2 average GP lanes. This situation is unlikely due to the nature of multiple occupancy requirements in HOV lanes, but it may occur when average occupancy of GP lane traffic is greater than that of HOV lane traffic.

iv) **VMT Ratio > 0.5 and PMT Ratio >= 0.5**: HOV lane serves more vehicles and move more people than the average GP lane, which implies the possibility of highly utilized HOV facilities. If an excessive large number of vehicles travel in the HOV lanes, however, it may begin to cause the speed differential to become negative, thus resulting in a deterioration of operations in the HOV lane.

Another North American study suggested performance measures of HOV lanes as follows:

- **Person Throughput**: Average vehicle occupancy × number of vehicles, captured using automatic traffic recorders or other surveillance technologies by vehicle class
- **Vehicle Occupancy**: Captured through manual sampling methods, with quarterly manual counts for the HOV lanes and annual manual counts for the general-purpose lanes on a site rotational basis.
- **Travel Time Savings**: General purpose - HOV travel times; captured using surveillance technologies, will undergo internal quality control reviews and will be supplemented with manual travel time runs.
- **Travel Time Reliability**: Expressed as the percent of time HOV lane speed drops below LOS or specified average speed; captured using surveillance technologies, will undergo internal quality control reviews and will be supplemented with manual travel time runs.
- **Violations** Captured through enforcement records (i.e., citations, warnings) and reflected through average vehicle occupancy trends in the HOV lanes.

It should be noted that each type of HOV configurations can offer different advantages. Contiguous-access configuration provides flexibility for accommodating concentrated demand during peak hours while relaxing the restriction for the remaining hours. Meanwhile, limited-access configuration provides a clear separation of flows and isolates roadways users from frequent lane-changing maneuvers except at designated access areas. In addition, at certain freeway junction locations, limited access configurations can also prevent or discourage last-second traffic weaving maneuvers so that traffic flows can be channelized safely.

12.8.2 Performance of HOT Lanes

Effective enforcement policies and programs are essential for the successful operation of a HOT lane facility. Several strategies can be used to provide enforcement with the type of enforcement chosen largely depending upon the type of design. Buffer-separated facilities require a different enforcement strategy than a barrier separated facility.

Typical enforcement on HOT lanes often requires dedicated enforcement areas, which are usually located immediately adjacent to the HOT lane facility and downstream of a tolling location. This configuration allows enforcement personnel to monitor the facility as well as pursue and apprehend violators to issue appropriate citations. Where separate HOT/HOV lanes are provided (I-25 in Denver, Colorado) the tolling can be enforced with photo enforcement technology.

Enforcement areas can be classified as low-speed or high-speed and usually by type of separation from the general-purpose lanes. The following descriptions and guidelines are provided by NCHRP Report 414—H*OV Systems Manual* 1998

Performance measurement for HOT projects accomplishes four interrelated purposes:

- To ensure that the projects are functioning as efficiently as possible and to enable adjustments to operational policies if they are not.
- To quantify and validate the different benefits these facilities deliver.
- To document the application of congestion pricing as a meter on traffic demand.
- To ensure that the projects follow operational requirements placed on the facility.

HOT facilities, separation type has the most significant impact on explaining the intensity of the frictional effect, as paint-separated ML facilities are readily affected by congestion in adjacent GP lanes.

Building upon recommended practices proposed in various national guidance documents for general freeway performance monitoring and evaluation the following is an overview of performance evaluation of HOT lanes:

- Similar to HOV lanes, value-priced and HOT lane performance depends upon the ability to encourage mode shift to higher occupant vehicles through reduced travel times, increased travel reliability, and enhanced safety. This mode shift is reflected in increases in person throughput and average vehicle occupancies.

- Unlike HOV lanes, value-priced and HOT lanes also benefit from revenue generation and rely on achieving a temporal shift to encourage eligible toll vehicles (SOVs or HOVs not meeting standard eligibility requirements)

  (1) to pay a high-rate toll to take advantage of the potential travel-time savings during peak periods and/or

  (2) to alter trip times to take advantage of lesser tolls during the shoulders of the peak periods when additional excess capacity is available (i.e., peak spreading). One challenge is separating the performance of the value-priced and HOT lane effects from standard HOV lane effects.

12.8.3 Enforcement Requirements for Managed Lanes

Enforcement is a necessary part of HOT/HOV lane operations to catch violators to maintain the operational integrity of the facilities. This is a manually intensive effort and can create a traffic safety hazard. Typically, the Law Enforcement officer first monitors HOT/HOV lane entrance points to wait for vehicles by driving within, or next to, the HOV/HOT lanes where a transponder signal is not received from the passing or entering vehicle in the lane, and then catches up and drives alongside the vehicle to pear into the windows to check for passengers.

Barrier-separated facilities, because of the limited access, are the easiest facilities to enforce. Shoulders provided to accommodate breakdowns may also be used for enforcement. Reversible facilities have ramps for the reverse direction that may be used for enforcement. Gaps in the barrier may be needed so emergency vehicles can access barrier-separated HOV lanes. Buffer-separated and non-separated HOV lanes allow violators to easily enter and exit the HOV lane.

The role of an HOV enforcement program is to protect the integrity of the facility by deterring possible violators and promoting safe and efficient use of the managed lane (e.g. HOV lanes). Enforcement requirements reflect the need to preserve the function and safety of the facility as well as its public support/acceptance. These enforcement needs are in addition to the normal safety, emergency, and operational duties associated with any urban freeway. Although managed lanes can, to some extent, be designed to reduce the potential for use by ineligible vehicles, enforcement agencies still need to monitor the following functions:

- Vehicle eligibility (occupancy rate, vehicle type)
  Safety (particularly lane access/egress)
- Traffic operations (speeding, following distance, etc. in both HOV and mixed flow lanes)

Enforcement on Ontario’s 400-series highway HOV lanes is critical to their success. A key component in developing design and operational practices is the consideration of enforcement provisions. Currently, enforcement is conducted manually by police officers. Providing strategically located enforcement areas and observation points are keys for efficient enforcement. The impact on safety and visibility for the overall facility during planning and design of enforcement areas and observation points should be considered.

In addition to these specific features dedicated to enforcement use, the design of the priority lane itself can affect the violation rate, and in the level of enforcement effort and associated facilities required. A contraflow lane dedicated to bus-only operation, for example, will by its very nature attract fewer violators than a non-separated concurrent flow lane, and could be considered virtually self-enforcing.

For both operational safety and ensuring the use of the managed lane only by eligible vehicles, there are benefits from limiting or controlling the access to the lane. Even in the case of non-separated concurrent flow facility, marking the pavement so as to focus transfer moves to limited zones can minimize unexpected moves. For barrier-separated managed lanes, provisions for enforcement should be focused on the entry points, allowing the apprehension and removal of ineligible vehicles before the lane is used.

A second situation in which a stationary observation and enforcement position is effective is immediately downstream of a ramp meter or queue bypass. Both non-HOV queue jumping and ramp metering violators can be enforced in this way, although the latter requires the provision of a meter signal head that is visible to the enforcement officer.

Examples of recommended practice for concurrent flow HOV lane enforcement areas are illustrated in– **Figure 12.8.1 - 12.8.7** Enforcement zones for other types of HOV application (reversible flow, ramp meter bypass, etc.) can be developed in a site-specific manner.

12.8.3.1 Role of Enforcement

When enforcing HOV lane usage, enforcement officers must deal with both drivers who violate the HOV restrictions unwittingly (unaware of signage, unsure of eligibility, etc.) and those who intentionally use the HOV lane in an ineligible vehicle to bypass congestion.

Both province-wide and area-wide consistency in these areas will support the effectiveness of any enforcement strategy, and are important in ensuring public awareness, understanding and compliance.

12.8.3.2 HOV Enforcement Areas

Enforcement of Ontario's 400-series highway HOV lanes is critical to their success. A key component in developing design and operational practices is the consideration of enforcement provisions. It is decided to provide dedicated enforcement areas as well as a left shoulder to carry out the enforcement of the HOV lanes. These enforcement areas consist of an observation pocket and enforcement bay.

There are three major requirements for enforcement-related facilities associated with a freeway HOV/Bus lane:

- a place to observe traffic operations and lane violators;
- a place to pull over violators (preferably incorporating a means of sending apprehended

vehicles back into the mixed flow); and
- a safe refuge for accident/incident investigation.

In addition to these specific features dedicated to enforcement use, the design of the priority lane itself can affect the violation rate, and in the level of enforcement effort and associated facilities required.

A contraflow lane dedicated to bus-only operation, for example, will by its very nature attract fewer violators than a non-separated concurrent flow lane, and could be considered virtually self-enforcing.

For reversible flow HOV lanes, a moveable physical barrier is required at each end of the priority section to preclude any vehicle gaining access to the lane in the wrong direction. In association with such moveable barriers there is normally a pocket area suited to use by enforcement vehicles for observing entering traffic. A pair of enforcement officers, with one observer and one downstream officer to pull over the observed violator, is effective in this situation.

In Ontario, it was agreed upon with OPP that the preferred enforcement provision is to provide a continuous left shoulder. In urban cross-sections that have a median barrier the desirable left shoulder width is 4.25 m and a minimum of 3.6 m. In rural cross sections where there is a grassed median and no median barrier, a minimum left shoulder of 3.0 m is acceptable.

Where physical constraints preclude the ability to provide a continuous wide left shoulder, localized median shoulder widening would be undertaken to create an enforcement area.

Enforcement areas are to be a minimum of 400m long and a desirable length of 500m is preferred to allow for enough opportunity for vehicles to re-enter the HOV lane. Enforcement areas are to be located approximately every 3km.

Highway designers should avoid locating the dedicated enforcement areas in advance of a downstream curve or within the limits of an access / egress zone.

Consultation with OPP representatives is recommended on HOV lane design projects to examine the unique enforcement needs of HOV facilities.

Alternative Enforcement Areas:

- Continuous paved median 4.25 m or wider in both directions for the length of the HOV facility. If space is available, additional enforcement areas may be built in conjunction with the 4.25 m median.
- When 4.25 m continuous paved median shoulders are not possible, paved bi-directional enforcement areas spaced 3.2 km to 4.8 km apart should be built. A separation in the median barrier should be provided for CHP motorcycle officers to patrol the HOV facility in both directions of travel.
- Where median width is limited, some combination of 1 and 2 should be included.
- Paved directional enforcement areas spaced 3.2 km to 4.8 km apart and staggered to accommodate both directions when space limitations do not allow any of the above outlined considerations.
- Where space is limited, directional enforcement areas located wherever right of way is available.

New HOV facilities should be built to provide adequate enforcement areas. Also, consideration should be given to adding enforcement areas to existing facilities where violation rates are consistently above 10%.

Figures 12.8.5 – 12.8.6, 12.8.7, 12.8.8, 12.8.9 and 12.8.10 illustrate North American practices for enforcement areas for different design conditions

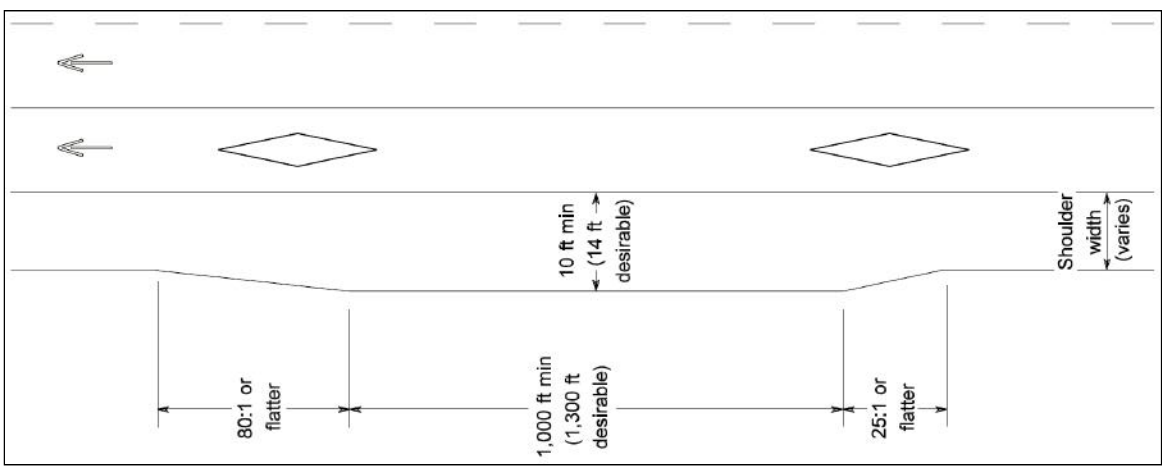


Figure 12.8.1 Enforcement Area one direction only

Source: WSDOT Design Manual July 2018

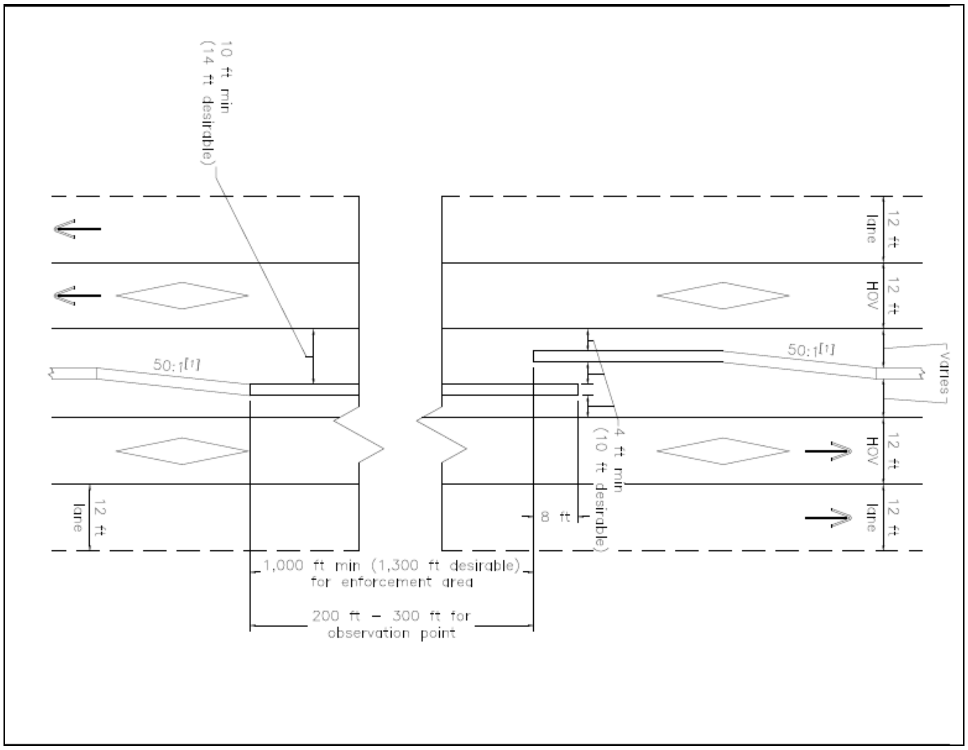


Figure 12.8.2 Enforcement Area Median

Source WSDOT Design Manual June 2009

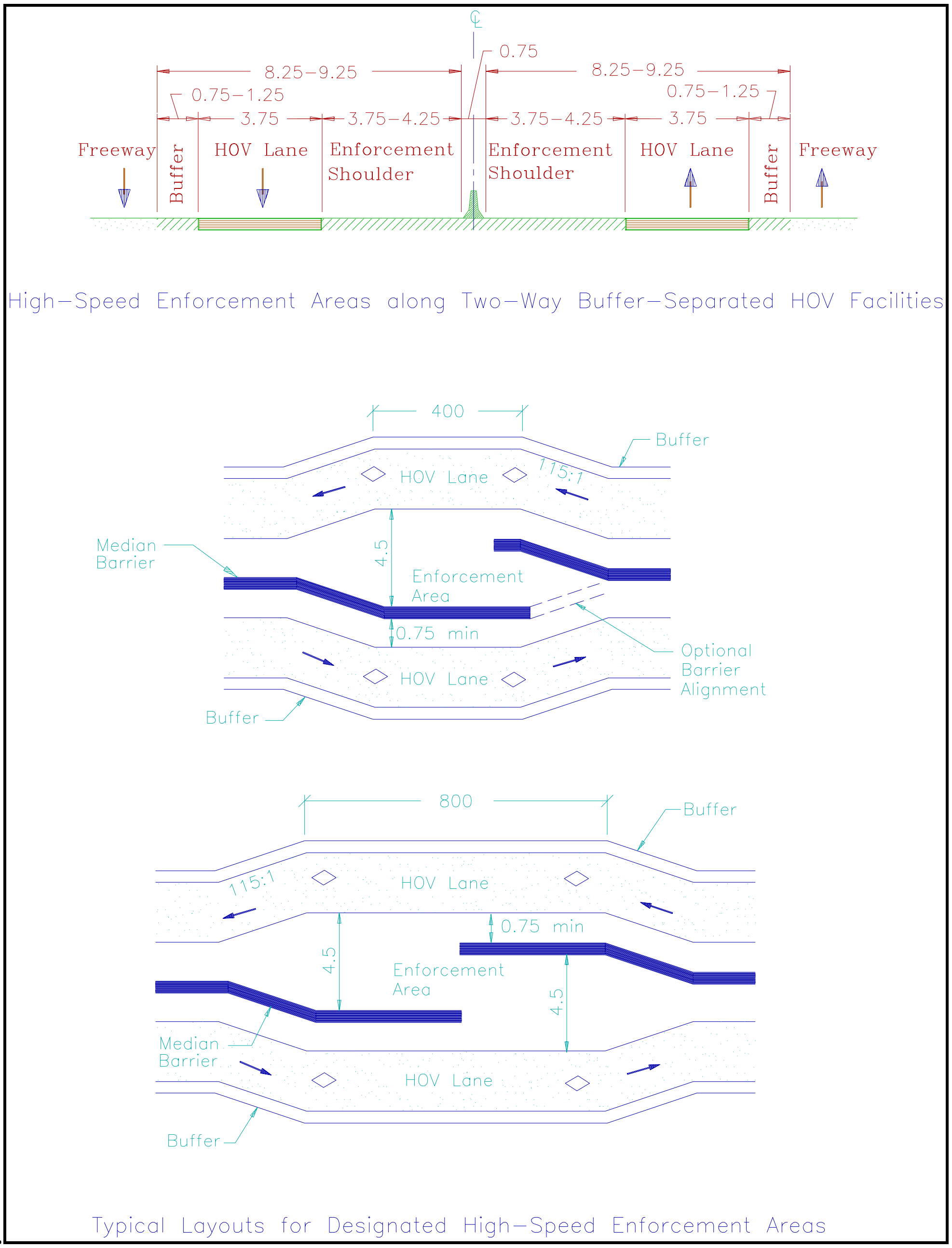


Figure 12.8.3 High-Speed Enforcement Areas

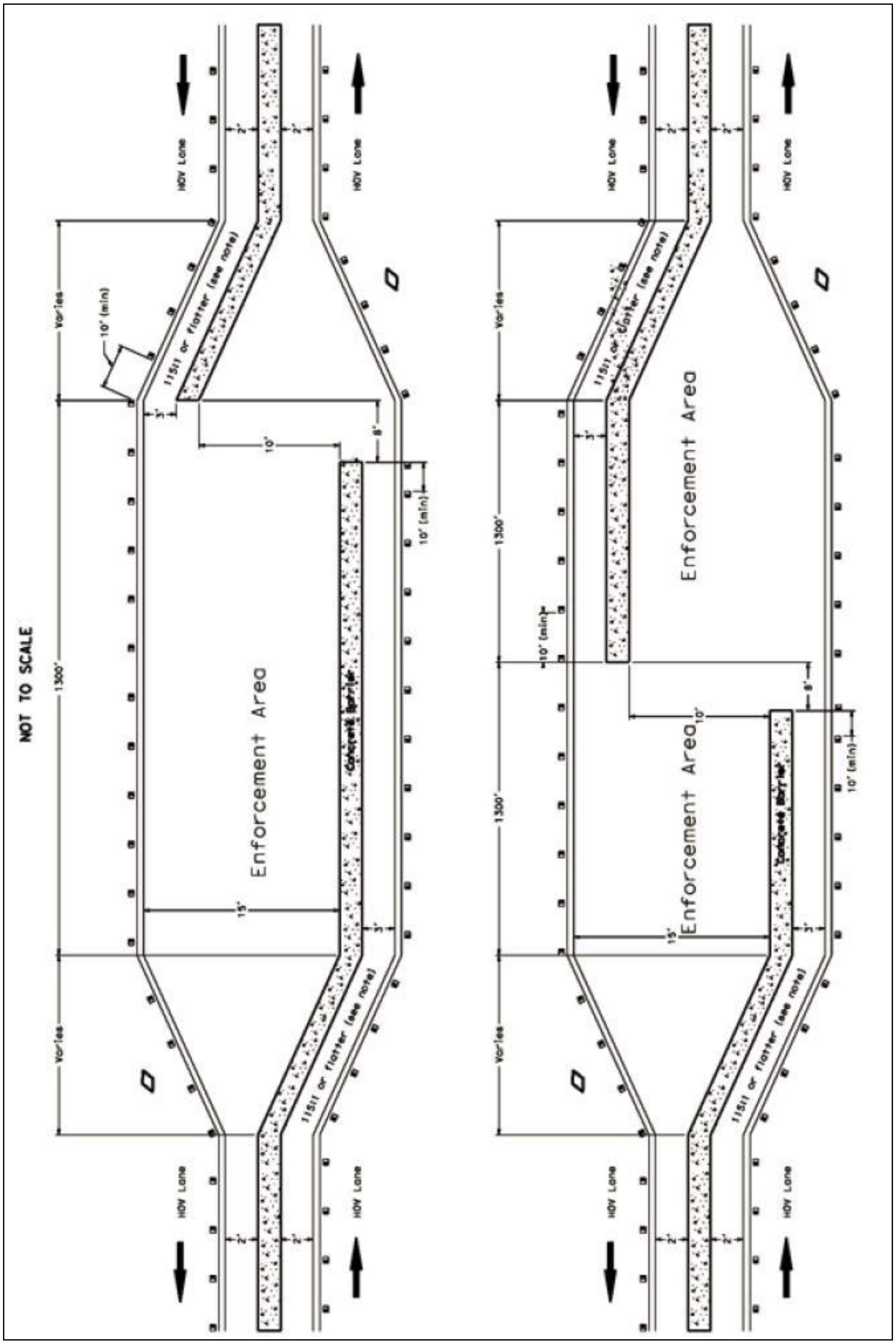


Figure 12.8.4 Directional Enforcement Areas for Narrow Medians

Source: HOV Guidelines California Jan 2018

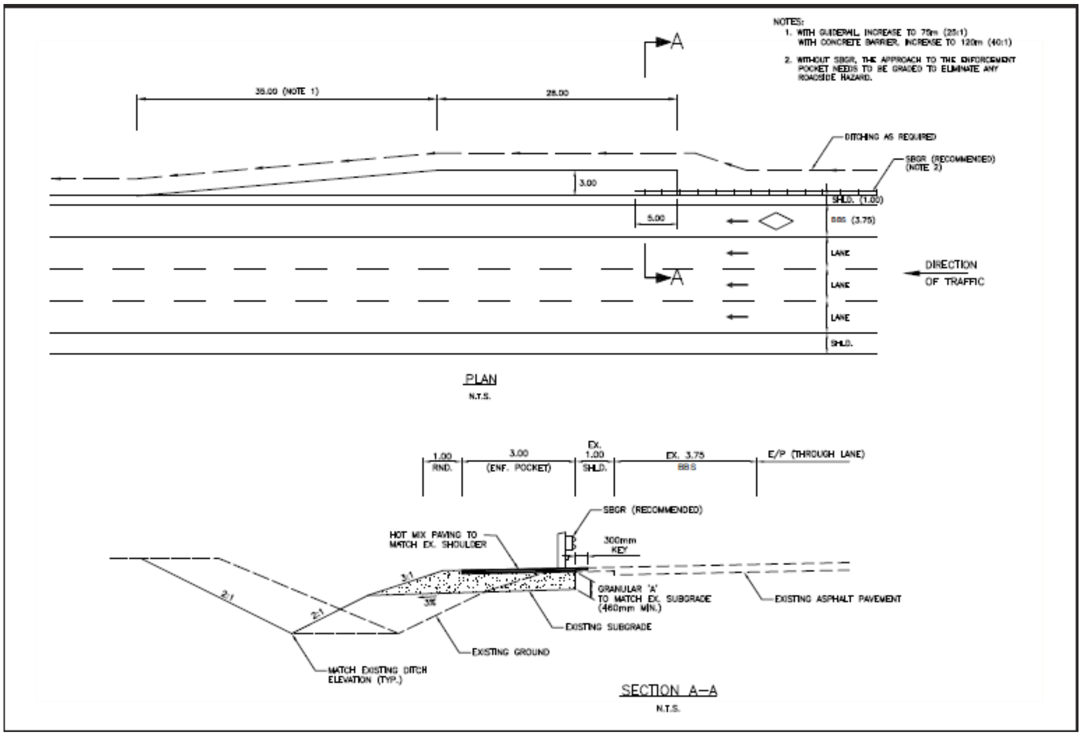


Figure 12.8.5 Observation Pocket for Bus Bypass Shoulder (MTO Best Practice)

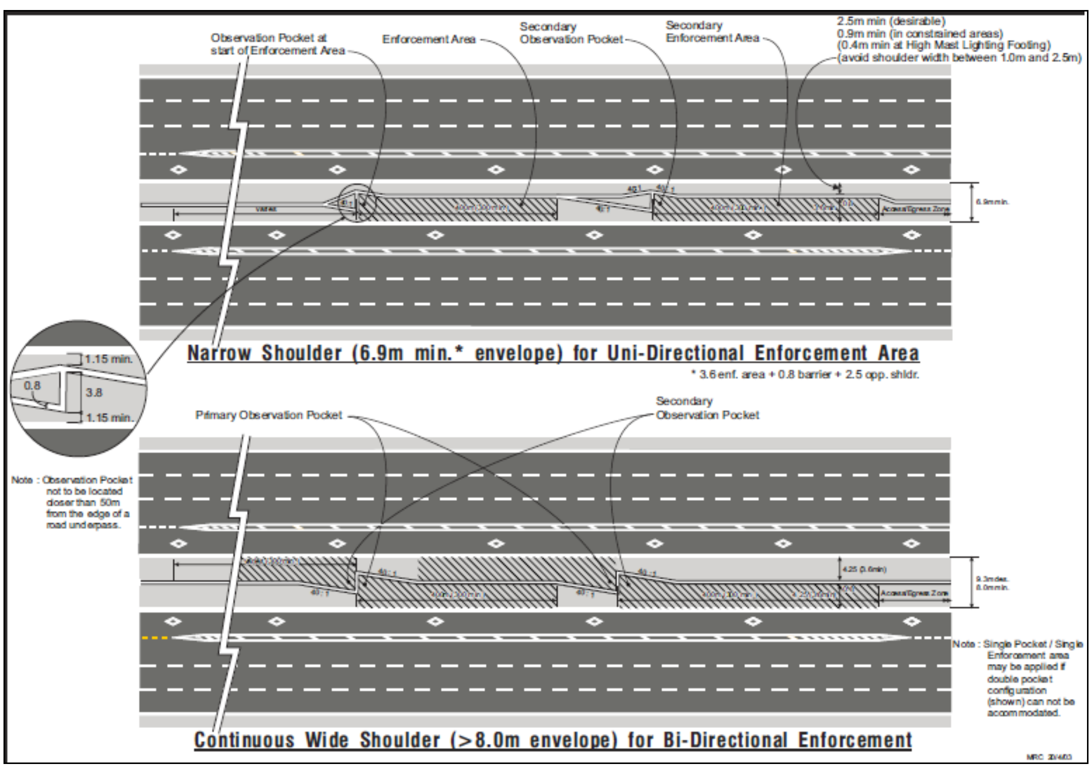


Figure 12.8.6 Double Observation Pocket and Enforcement Area Design for Median HOV Lanes *(MTO Best Practices)*

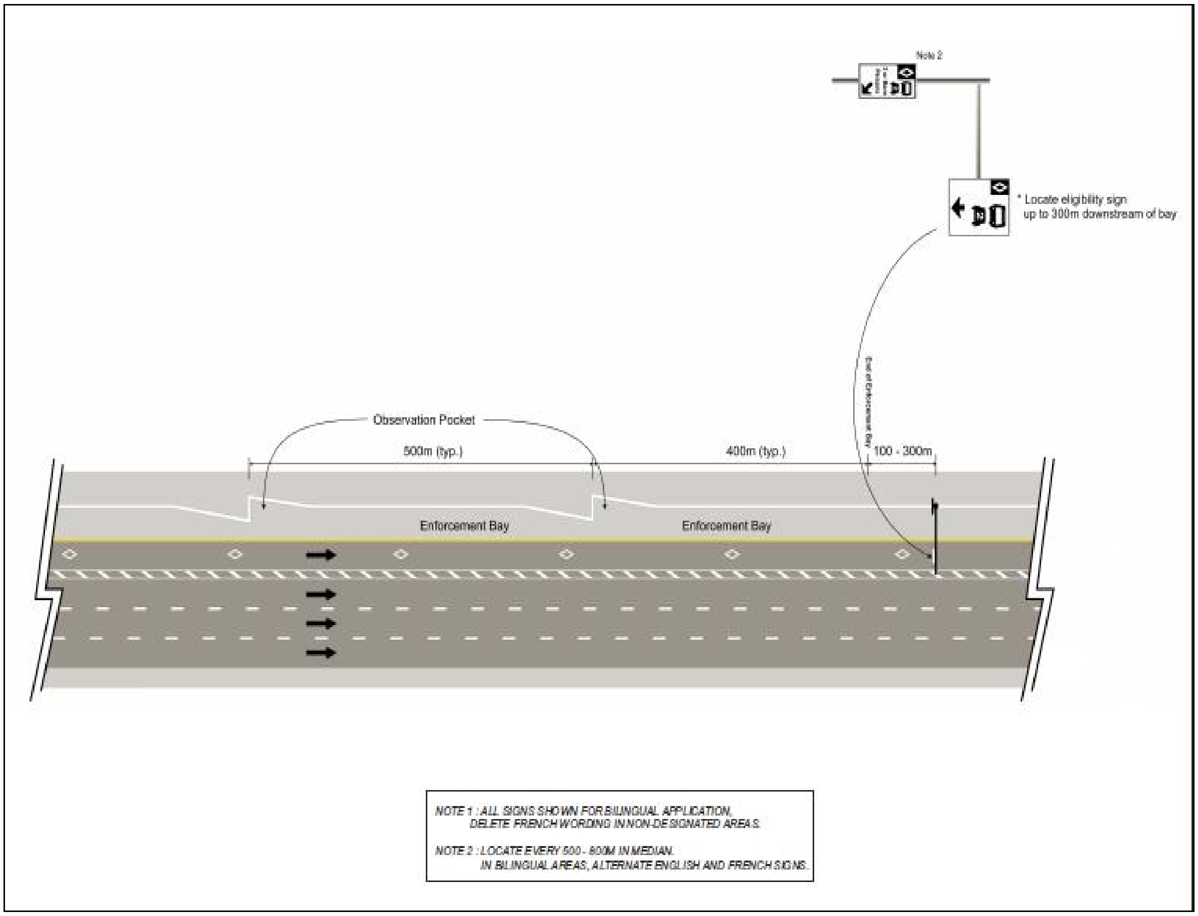


Figure 12.8.7 HOV Signage at Enforcement Area (MTO Best Practices)

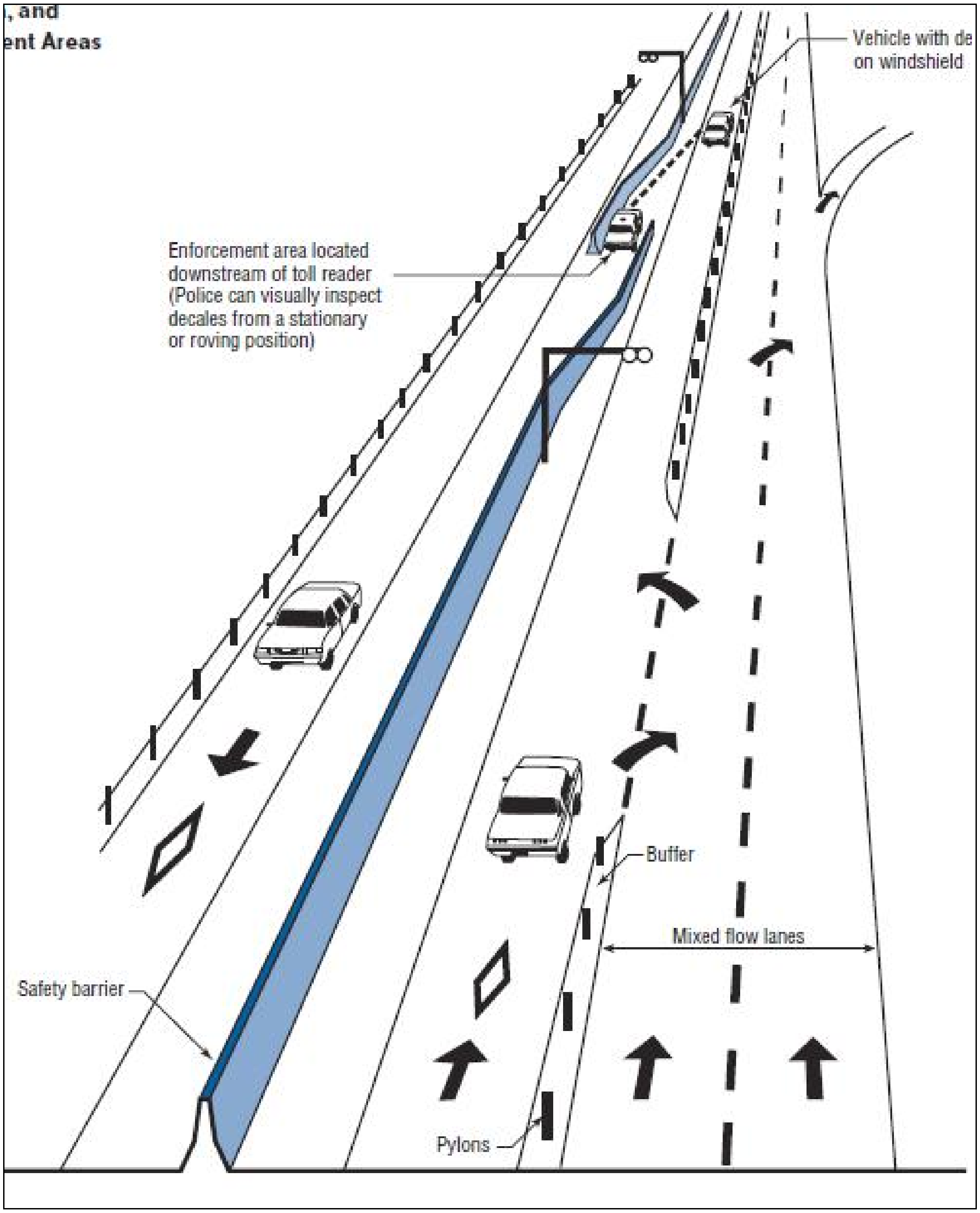


Figure 12.8.8 HOT Lane Access, Electronic Toll Collection and Enforcement Area

Source: FHWA A Guide for HOT Lane Development

12.8.3.3 HOV Violation Rates

The percentage of HOV lane users who commit violations on the Highway stretches that contain such lanes during the peak period, are required to be monitored. There are two violations that are of focus and these are Buffer Zone Crossing Violations and Vehicle Occupancy (VO) Violations.

A Buffer Zone Crossing Violation is one where a motorist changes lane in to, or out of, an HOV lane at an improper location. There are pavement markings that indicate inappropriate locations to change lanes; the Buffer Lane marking. These locations are not suitable for ingress, or egress, into the HOV lanes. Drivers who ignore these lane markings are in violation.
A Vehicle Occupancy Violation is one by which a driver who does not have a minimum of two occupants (including him or herself) in the vehicle, makes use of the HOV lane.

12.8.4 Enforcement Shoulder and Observation Pockets

All enforcement shoulders or zones should be at least 4 m wide (13 feet) as shown in **Figure 12.8.5 - Figure 12.8.7** in order to allow a safe movement within the area; length, including access and egress tapers, should be designed in accordance with the entering and exiting vehicles speeds. The optimum design is a full width breakdown shoulder extending the length of the facility; where adequate right-of-way is not available, periodic shoulder widening to the necessary width is required (in concurrent flow median lanes the widened shoulders can alternate between one direction and the other within a constrained width median). Enforcement areas should not take the form of a wide buffer between HOV and mixed flow traffic. One effective deterrent to would-be violators can be the provision of a turnaround, if space is available, to release the apprehended vehicle in the opposite direction.

Examples of the design of physical facilities related to enforcement activities are illustrated in **Figures 12.8.9 to Figures 12.8.11 for** Bi-directional Enforcement Area for Wide and Narrow Medians.

12.8.4.1 Enforcement for Part-Time Shoulder Use

The success of part-time shoulder use depends on the extent to which drivers comply with posted hours of operation or lane-use controls, as well as any vehicle restrictions. Enforcement of Bus on Shoulder (BOS) lanes is focused on use of the shoulder by non-buses, and enforcement of static and dynamic part-time shoulder use is more focused on use of the shoulder outside of hours of operation.

With increased likelihood of vehicles on the shoulder, including violators when the shoulder lane is closed, police conducting routine enforcement would target areas with downstream pull over opportunities such as exit ramps, emergency turnouts large enough for two vehicles, and so forth. Ultimately, law enforcement personnel should be engaged in planning and design of shoulder lanes and design needs for enforcement elements should be incorporated.

On dynamic part-time shoulder use facilities, lane control technology would include mechanisms for providing real-time information to police officers in the field about the status of the shoulder, when it is opened / closed, and the current lane assignment displays.

On BOS facilities, shoulders can still be used by police to pull over vehicles, and bus drivers are trained to re-enter general purpose lanes when a shoulder is obstructed.

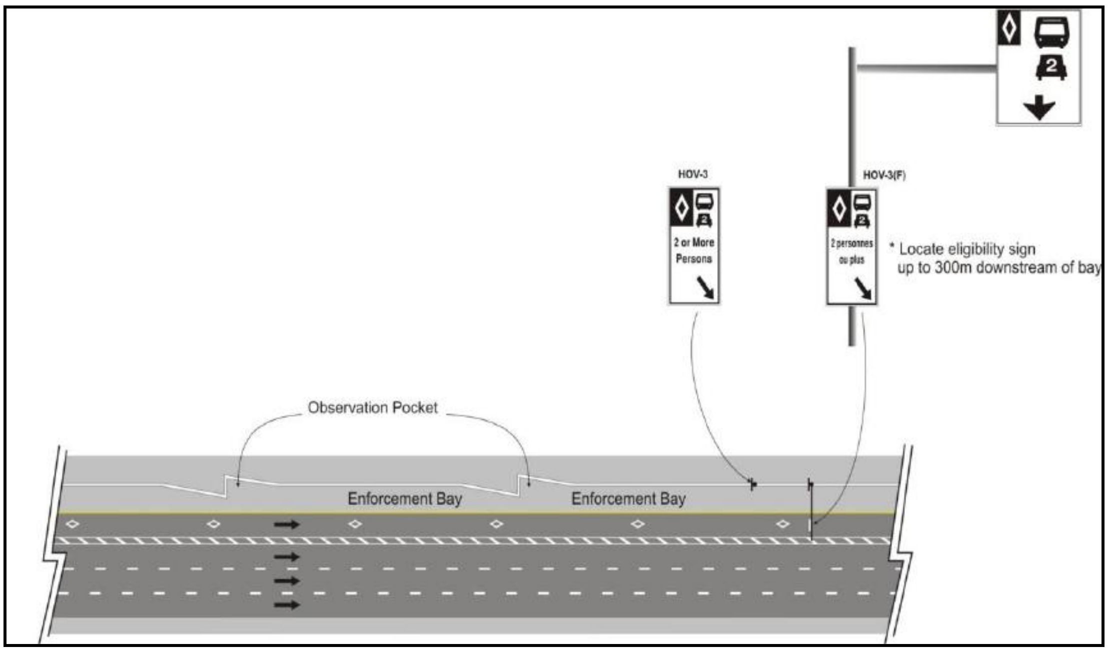


Figure 12.8.9 Signage at the Enforcement Bay and Observation Pocket

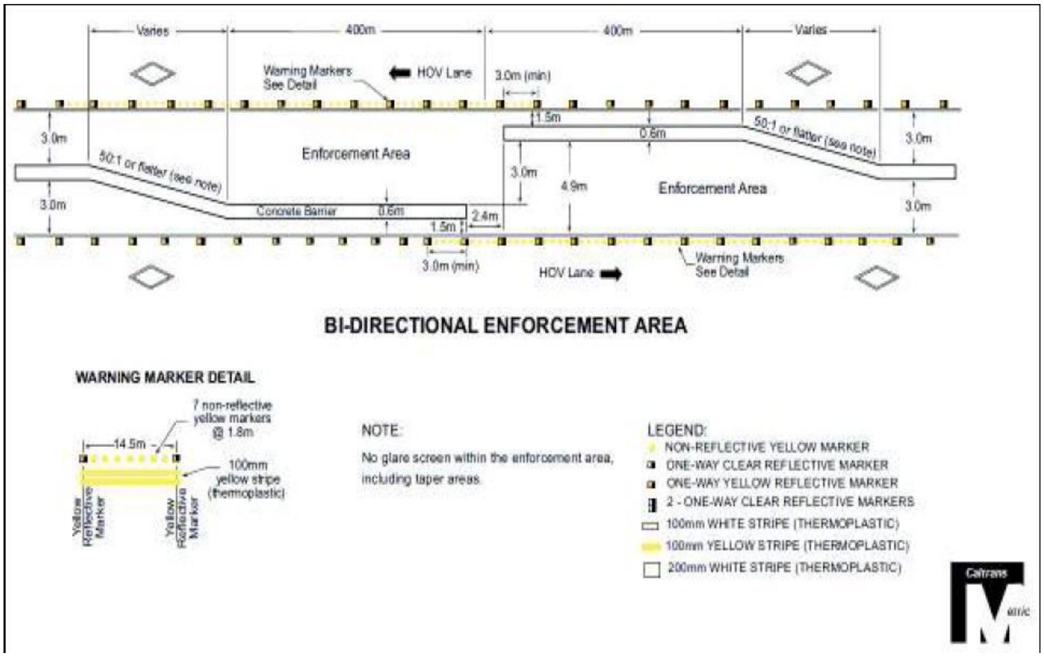


Figure 12.8.10 Bi-directional Enforcement Area for Wide Median

Source: Caltrans (*53*). This figure is solely intended for use in the California Department of Transportation's ("Caltrans") High-Occupancy Vehicle Guidelines as examples of high-occupancy vehicle lanes used within California. It is neither intended as, nor does it establish, a legal standard for use in other environments. The figure is for the information and guidance of the officers and employees of Caltrans. The figure is not a substitute for engineering knowledge, experience, or judgment. The examples given herein are subject to amendment as conditions and experience may warrant.

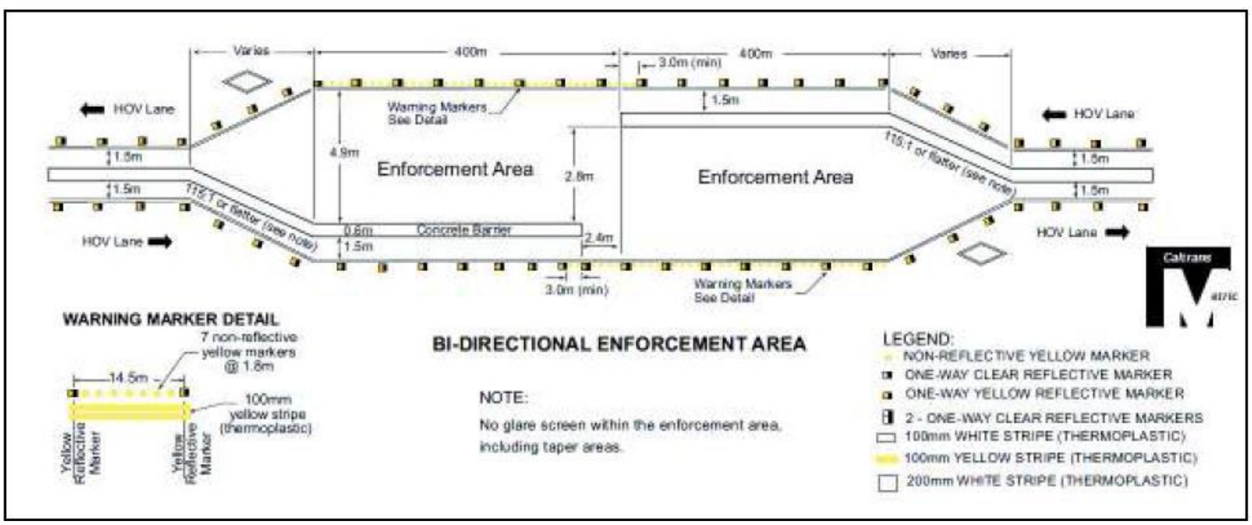


Figure 12.8.11 Bi-directional Enforcement Area for Narrow Median

Source: Caltrans (*53*). This figure is solely intended for use in the California Department of Transportation's ("Caltrans") High-Occupancy Vehicle Guidelines as examples of high-occupancy vehicle lanes used within California. It is neither intended as, nor does it establish, a legal standard for use in other environments. The figure is for the information and guidance of the officers and employees of Caltrans. The figure is not a substitute for engineering knowledge, experience, or judgment. The examples given herein are subject to amendment as conditions and experience may warrant.

12.8.4.2 Opening and Closing Part-Time Shoulder Use Facilities

Opening and closing of part-time shoulder use facilities is a largely manual process. The shoulder should be inspected prior to each opening by “sweeping” (driving) the length of the facility or viewing CCTV if there is full camera coverage of the facility. Any debris or disabled vehicles should be cleared prior to the scheduled opening time of the shoulder. If dynamic lane use control signs are present, then they can be used to keep the lane closed past the scheduled opening time if additional time is needed to clear the shoulder.

If an incident occurs while the shoulder lane is open, then it should be closed as soon as possible if dynamic lane assignment signs are present. Interagency agreements should be prepared prior to implementation of part-time shoulder use to determine which agency has the authority to close the shoulder.

BOS lanes do not need to be inspected before opening, and if buses encounter obstructions on the shoulder, then they can merge into traffic to avoid them, and dispatchers can alert buses on part-time shoulder use routes of known obstructions.

Road agencies should be cautious with introducing too much variability into the operating hours of dynamic part-time shoulder use. For example, if a shoulder needs to be opened in the morning peak period for congestion reduction purposes nearly every weekday, it will be more predictable to drivers if it is opened at the same time every weekday (such as 7 a.m.) rather than different times based on minor variations in traffic from day to day. In this case, the benefits of dynamic over static part-time shoulder use would still be realized by the ability to extend the operating hours if high traffic volume was still present at the end of the typical a.m. peak period or occasionally open the shoulder at other times such as weekends.

12.8.5 Automated Enforcement

The current methodology of Ontario enforcement is based on a manual approach by visual inspection by patrol officers to the vehicles using the HOV lane. Manual enforcement is labor-intensive, costly, and sometimes has negative safety implications. With the emerging shift from HOV to HOT (high-occupancy toll) lanes, enforcement becomes more complex, because vehicles can be in the lanes legally either by meeting an occupancy requirement or by paying the electronically charged toll.

Several studies were conducted to explore the feasibility of using new technologies/techniques to improve the effectiveness of violation enforcement and to evaluate the capability of a novel image sensor device to automate detection of in-vehicle occupants to flag law enforcement of

HOV/HOT lane violators. Experiments were conducted to determine this capability across varied conditions and scenarios to assess detection segmentation algorithms of vehicle passengers and drivers. Although occupancy detection through vehicle glass could be achieved in many cases, improvements were suggested to be made to such a detection system to increase robustness and reliability as a law enforcement tool. Other studies were completed on automated occupancy enforcement using roadside infrared systems. It is a costly technique and could produce image only front-seat passengers.

HOT lanes networks would likely require at least 2-person occupancy for zero or reduced-rate tolls. The in-vehicle detection approaches would rely on using data from airbag deployment systems. Those systems are required and being planned only for front seats, and there are legal and policy reasons making it unlikely that such data can be transmitted from the vehicle to use for enforcement purposes.

Both roadside and in-vehicle occupancy verification systems raise serious privacy concerns. Declaration transponders could be a more promising approaches, but still relies on patrol officer enforcement.

Other alternative approach relies on two policy changes—transponders for all HOT lane users and registered carpools, to simplify the occupancy verification and enforcement problem for HOT lanes. It aims to reduce enforcement requirement to the same used for electronic toll collection, by requiring all eligible carpools to be registered and have transponders. The toll collection software would be written to charge the zero or reduced-rate toll to vehicles identified as registered carpools when their transponder is detected in the lanes during peak periods.

12.9 Illumination

The Ontario policy for highway illumination Directive **(PLNG-B-05)** specifies the warrants for Continuous / Full illumination of provincial highways.

As with any other freeway element, safety of operation is essential for an HOV lane. Particularly with barrier-separated facilities, the use of lighting at access and egress locations is desirable to help drivers at night to identify and navigate these areas of weaving traffic. Therefore, partial lighting of these areas is warranted when continuous highway lighting is not warranted.

The presence of lighting in corridors where Closed-Circuit Television monitoring is used as an element in a Freeway Traffic Management System aids in monitoring and in incident management.

The most significant HOV-related illumination requirement is the provision of adequate lighting in enforcement areas to allow monitoring of vehicles occupancies (recognizing that peak periods during the winter months occur during darkness in Ontario). HOV ramp meter bypass lanes and HOV lane access zone, are key locations in this regard.

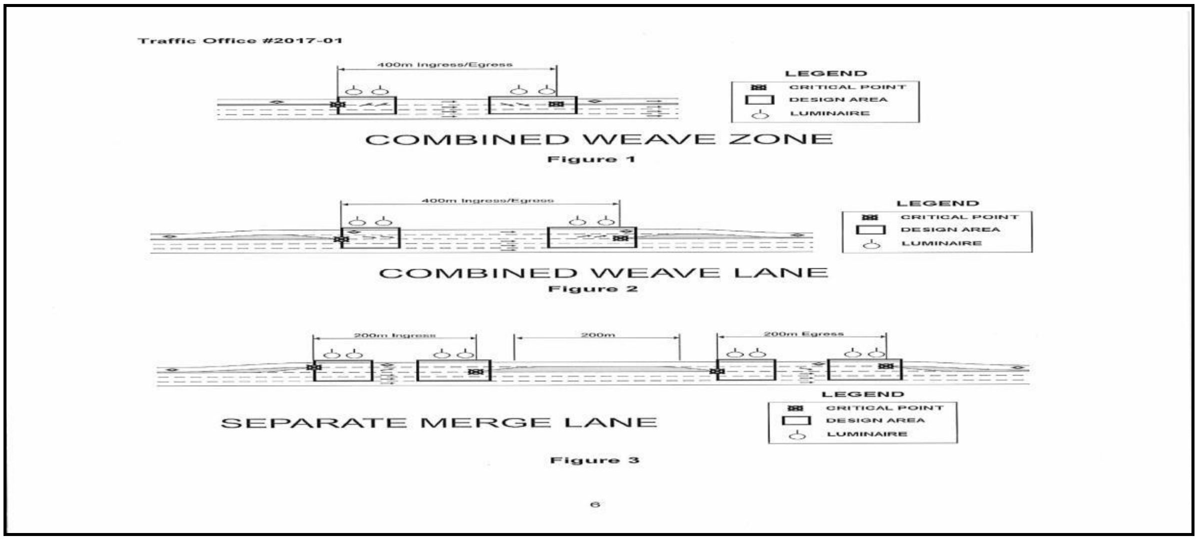
Partial Illumination

In general, where continuous lighting is not warranted on provincial highways, partial lighting of HOV/HOT ingress and egress zones is required.

A minimum of two lights are required at each end of the HOV/HOT ingress and egress zone. If HOV/HOT ingress zone and egress zone are separated, additional lights may be required as follows. HOV/HOT ingress and egress zones should be lighted to the same minimum maintained lighting levels as specified in the MTO Electrical Engineering Manual for other partial lighting applications.

The selection of the partial lighting pole location should be coordinated with the placement of managed lane tolling system and also coordinated with the placement of static signs and typical Intelligent Transportation System (ITS) elements.

Note: distances in the following **Figures 12.9.1 and 12.9.2** are for illustration purposes only and may vary per location. The figures show lighting poles in the median (preferred), alternatively the lighting poles may be placed on the outside of the highway, rather than the median, provided that the required lighting levels are achieved.



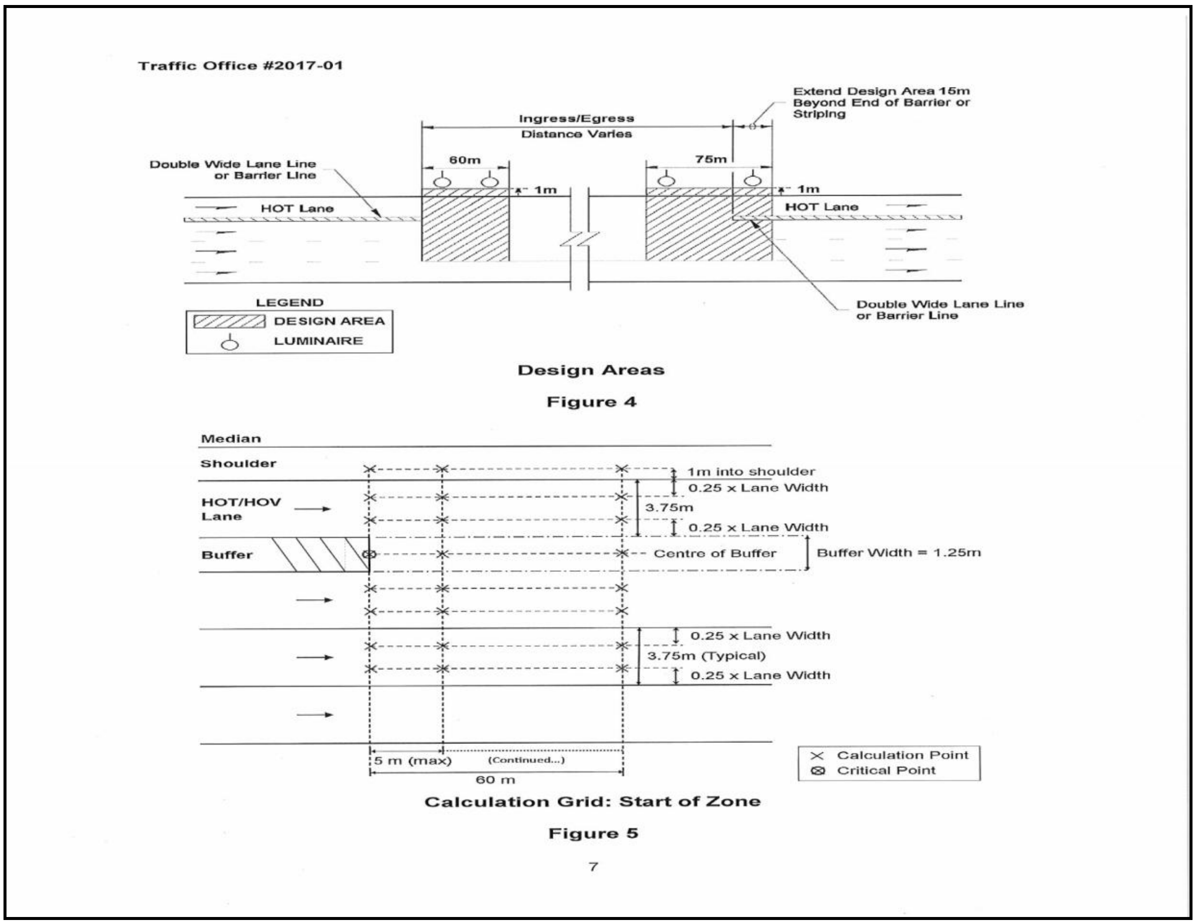


Figure 12.9.1 Illumination of Managed Lanes

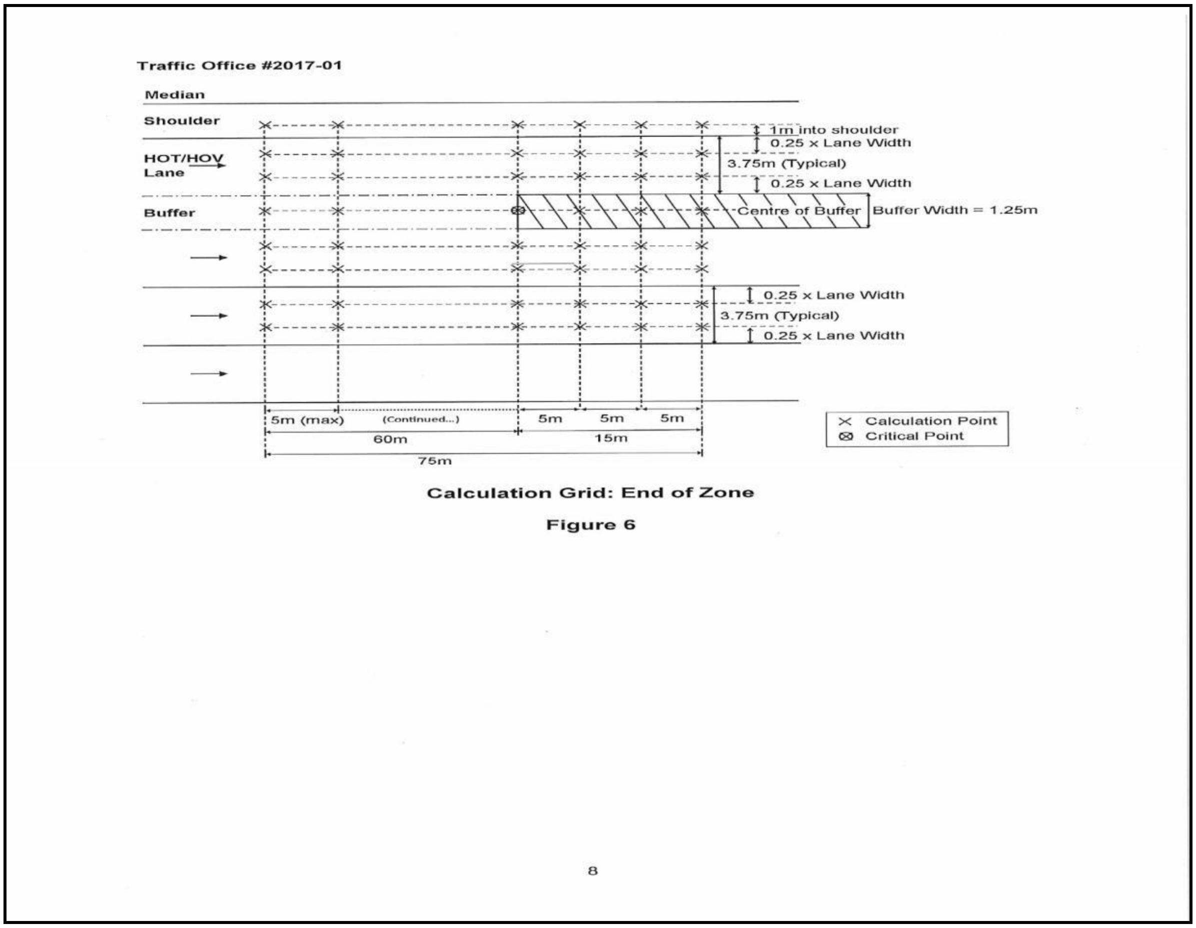


Figure 12.9.2 Design Areas for Illumination of Managed Lanes
Source: CR, Provincial Engineering Memorandum Traffic Office #2017-01, April 2017 (Appendix A)

12.10 Maintenance

The ability to carry out regular freeway maintenance activities in a matter which ensures the safety of maintenance crews and minimizes disruption to traffic flow should not be affected by the presence of an HOV facility. Some HOV designs have inherent additional operational costs; the daily placement of barriers or pylons on contraflow lanes, for example, or the shifting of barriers to allow reversible operation.

The presence of adequate shoulders, use of advance signage (including Chargeable Message Signs), and restriction of activities to off-peak periods are typical effective strategies.

In Ontario, the removal of snow from the freeway system is a crucial maintenance activity; in this respect, concurrent flow non-barrier-separated facility design is favoured over barrier-separated lanes. In the presence of barriers, the consideration of the reduction of shoulder width in constrained areas from a standard 2.5 - 3.0 m should take into account snowploughing and snow storage needs. The use of a reduced shoulder for an extended length is highly undesirable and should only be considered if an acceptable snow removal strategy can be applied.

Assigning a high priority to HOV lanes for both snow removal and litter removal is desirable, given that the lanes rely on smooth peak period operation to carry a disproportionate share of freeway users.

In the long term, HOV lane pavement resurfacing or reconstruction can be a significant challenge; again, non-barrier-separated lanes are more flexible, in that the adjacent freeway lane can be designated for HOV use on a temporary basis during the construction period. If the work can be accomplished on a weekend (in the nearly three days between the Friday and Monday peak period peak direction flows) it would be desirable to do so, and to limit the impact on peak period peak direction weekday HOV flow.

For reversible lanes, and in particular those with heavy volumes of buses, wheel rutting in the single lane can develop over time to create a problem, especially when combined with snowplowing and reconstruction constraints as cited above. The pavement of such a facility should be designed for strength and longevity.

Since HOV lanes are located in either the median or right-side lanes, maintenance of a clear path for surface water drainage across the lane is essential; in the case of barrier-separated lanes, drainage slots in the base of the barrier are required.

Maintenance of lanes designated for part-time shoulder use is similar to maintenance of general-purpose lanes. It is beneficial to keep part-time shoulder at the same level as general-purpose lanes. Conducting maintenance on part-time shoulder use segments that requires maintenance vehicles to stop on the shoulder will need to be conducted at times the shoulder is closed to traffic. On high volume freeways where, part-time shoulder use is most commonly used, there may already be restrictions on maintenance during peak period when the shoulder lane would be open.

After snowfall, part-time shoulder use is typically plowed after all general-purpose lanes on the freeway have been plowed. This creates the potential for the shoulder to be closed during a period when it is scheduled to be open, although this usually has little effect on traffic operations due to reduced traffic volume during snow. It is beneficial to open the dynamic part-time shoulder use segment throughout the duration of a snowstorm because vehicles driving in the shoulder help to distribute salt that has been spread there.

Maintenance of toll equipment, software, traffic sensing, and related toll enforcement systems for priced managed lanes requires specialized attention, which may be specific in nature to the technology deployed by the tolling integrator and systems vendor for each facility. This technology may also be employed in other lanes of the roadway. Maintenance on toll collection equipment is usually conducted at night during periods of low utilization when lanes can be closed. These tightly integrated systems require a high level of reliability and preventative maintenance. Performing preventative maintenance helps avoid unforeseen equipment outages. Every attempt should be made to provide maintenance access off the roadway to equipment cabinets so that access to devices does not requiring lane closures.

12.11 Transit Facilities

The provision of transit stations where passengers and/or buses may gain access to the managed lanes is essential in corridors where transit service forms a significant element of the managed lanes user market. Location of Transit Facilities stations along managed lanes help improve transit ridership and improve the productivity of the lanes in terms of passengers or passenger kilometers of travel carried. Such facilities may be as simple as a bus bay and shelter on a right side HOV lane or as complex as a multi-level multimodal transportation gateway astride the freeway. The standards for transit stations in the managed lanes context are still evolving, and in any case will tend to be site-specific and not readily standardized in application.

The design of online and offline bus stations along managed lanes should consider the following:

1. Locating stations adjacent to major activity concentrations, park-and-ride facilities, and interchanging bus lanes.
2. Maintaining the speed, reliability, and safety of the managed lanes by providing adequate spacing between stops, acceleration and deceleration lanes, and separate lanes for buses entering, exiting, and stopping at stations.
3. Providing adequate station platform capacity that conforms to Accessibility for Ontarians with Disabilities Act and its standards.

The Transit way can have one of three forms:

- **Median Busway:** A dedicated bus facility in the median area, usually separated physically from other forms of traffic and with free-flow ramps to and from other types of BRT running ways (**Figure 12.11.3)**

- **HOV/HOT Lanes:** A running way shared with high-occupancy vehicles on either the median side or the outer lanes of the freeway and not necessarily separated physically from the general traffic lanes.
- **Shoulder:** Permitted use of the outside shoulder of the general traffic lanes by Transit vehicles. Sometimes limited to peak hour periods or congested conditions and usually with various operating constraints, such as maximum operating speed.

Figure 12.11.1 Freeway HOV Lane (Highway 403, Mississauga, ON)


Figure 12.11.2 Bus on Freeway Shoulder (Ottawa, ON)


Figure 12.11.3 Freeway Median Busway (Interstate 45, Huston, Texas)

HOT lanes represent a new opportunity for transit agencies with many potential benefits, including increased funding, faster travel speeds, more riders, and greater community visibility. However, these benefits do not emerge automatically. Transit agencies need to work closely with HOT lane developers to realize these positive externalities and avoid negative ones, such as access conflicts, increased traffic congestion, and ridership losses.

The Transit Facility location can also be Off-Line / Interchange

- interface at Parclo A interchanges
- Transitway stations
- Park and Ride lots

12.11.1 On-Line Stations

One of the most difficult tasks facing the planner of a managed lane facility is to reconcile its inherent tendency to be more beneficially located in the freeway median with the need for excellent transit vehicle and passenger access through interface with crossing roads. The goal is to allow express (through) buses to use the managed lane without having to divert off line to pick up passengers, and for local transit users to gain direct access to the lanes without having to weave across congested mixed flow traffic.

The optimum solution may be to provide a transit station, elevated (or depressed) at the cross-street level, with direct managed lane access / egress ramps. There are two fundamental drawbacks, however: the physical requirements of such a facility (if feasible) are significant, leading to high cost and potentially enormous retrofitting problems; and a passenger interface in the middle of a freeway presents a generally hostile environment to the passenger, particularly for the desired walk-in movement from surrounding development, for example in winter conditions. Such a facility may also be unable to address the Park and Ride or Park and Pool components of the managed lane market.

Center island platforms are used to minimize platform space since both directions share a common area for patrons that are removed as much as possible from freeway operations. They require only one set of vertical pedestrian access points. Because doors on buses are usually on the right-hand side, the center platforms require channelized crossovers on each end for bus drivers to negotiate.

Offline stations are sometimes provided to serve as collection and distribution points (e.g., transit centers, intermodal centers, and/or parking facilities) that are located near the managed lanes. The stations can be incorporated into other land uses as part of parking facility design. Access to and from the managed lanes is either along local street connections or via direct ramps. The station may be somewhat removed from the freeway corridor, or the station may be adjacent to the freeway right-of-way. Offline transit stations often provide connections to a parking facility and rely on the local street network.

Some examples of median on-line HOV transit stations exist and many concepts have been developed for such facilities but in the Ontario context it must be considered an unlikely scenario for actual application except possibly for local-express passenger transfer in a non-retrofit situation. **Figure 12.11.4** illustrates a typical median on line HOV transit station.

The provision of bus bays on right side HOV lanes exhibits significantly greater potential for utility, reasonable cost, and attractiveness (and indeed the potential for good local transit interface is a significant portion of the rationale for right side lane application. See **Figure 12.11.5**

Right side HOV lane bus bays are suited to locations between interchanges, at simple crossing structures, or at major employment of residential focal points for simplicity of access and operation; if an interface is needed at an interchange, the operational and physical requirements alter so significantly as to require special consideration, and a simple bus bay is generally not feasible.

There may be some situations where it is desirable to link the busway with a crossing or adjacent high-standard roadway or controlled access highway. Conventional one-way or two-way ramps are used. Single-lane ramps should have a minimum width of 4.2 m (14 feet) with 1.2 m (4-foot) shoulders to allow for passing of disabled buses or maintenance vehicles. For radii of 120 m (500 feet) or less, off-tracking of a bus becomes significant and should be determined to verify the minimum width needed for passing. Multiple lane ramps should have lane widths consistent with the adjacent sections of the busway.

The median busway should be designed with at least a 0.6 m (2-foot) paved shy distance between the edge of the median barrier and the edge of the bus lane. The bus lane should be at least 3.2 m (10.5 feet) wide, with a preferred width of 3.6 m (12 feet). The median busway does not require a horizontal separation between the bus lane and the adjacent general-purpose traffic lane, although 0.6 m (2 feet) of painted marking separation is considered desirable unless speed differential regulation applies in which case greater separation may be required.

The unobstructed vertical clearance over the busway should desirably be a minimum of 5.0 m (16.5 feet). The minimum recommended clearance is 4.7 m (15.5 feet). This will allow other vehicles, such as maintenance and emergency vehicles, to utilize the busway, as well as allow for possible future conversion to light-rail transit.

12.11. 2 Off-Line / Interchange Interfaces

Most of the users of a freeway HOV facility will access the freeway corridor from the crossing arterial road system, and most major arterials have interchanges with the freeway. The need to transfer passengers to the HOV express services, for local buses to access the HOV lane, and for mixed flow traffic to use the interchange ramps efficiently and safely all conflict at the typical Ontario Parclo "A" type interchange. Significant constraints are placed on the median interface concept and bus bays for right side HOV lanes are most appropriately located in mid-interchange positions.

The most common alternative, and one which is essentially impossible to use by median HOV lane express buses, is the provision of bus interface opportunities at the ramps of Parclo "A" interchanges. At Parclo "A" type interchanges, the stopping of local buses on the cross road within the interchange area poses unacceptable safety and operational impacts.

Configurations for three interface types are shown in **Figures 12.11.6, 12.11.7 and 12.11.8** Standards have yet to be developed for "B" type interchanges or other variations found on the Ontario freeway system. It should be noted that such interfaces are well suited to interchanges with ramp metering and accompanying HOV Bypass Lanes, although there are some implications as to the location of the bypass lane (e.g. on the left side of a metered entry ramp for a Parclo "A" layout) and for property requirements. The design standards are already applied on new Ontario freeways in urban areas with respect to property acquisition needs. An interchange type which is well suited to off-line transit interface is the full diamond layout, however, such configurations are rare in Ontario. If a new freeway is being planned with HOV priority in mind, traffic patterns at each interchange should be examined closely to determine the need for a "Parclo A" type interchange and the traffic signal impact if one or both of the inner loops were to be replaced by left turns or other substitutes. If less than 100 vehicles in the peak hour are projected to use the loop ramp, it may be possible to accommodate those vehicles by a left turn at the off-ramp terminal signal, thereby freeing up significant flexibility for HOV interface options, as well as property which could be used for a Park and Ride lot or transit facility. There may be retrofit opportunities at some interchanges in proposed HOV corridors

Rather than attempting to accommodate all of these conflicting demands at a Parclo "A" interchange (which is a complex enough operating entity as it is), it may be more appropriate to group Park and Ride, Park and Pool, local-express transit interface, and walk-in transit facilities all in a single dedicated off-line station linked with the HOV lane, either by direct ramp to the adjacent freeway median or by slip ramp to / from a right-side facility. The provision of a direct ramp requires cost-effectiveness justification in the form of significant demand levels (provided by the large multi-purpose HOV lot). It may be considered that a transit interface facility as shown in **Figure 12.11.7** is capable only of accommodating walk-in and transfer passengers from the arterial route; the Park and Ride market and Park and Pool HOV formation would still have to be addressed in other ways. Under these circumstances, the provision of a dedicated multi-purpose HOV centre at key points in an HOV lane corridor should be seriously considered as significant ancillary features to the HOV lanes themselves.

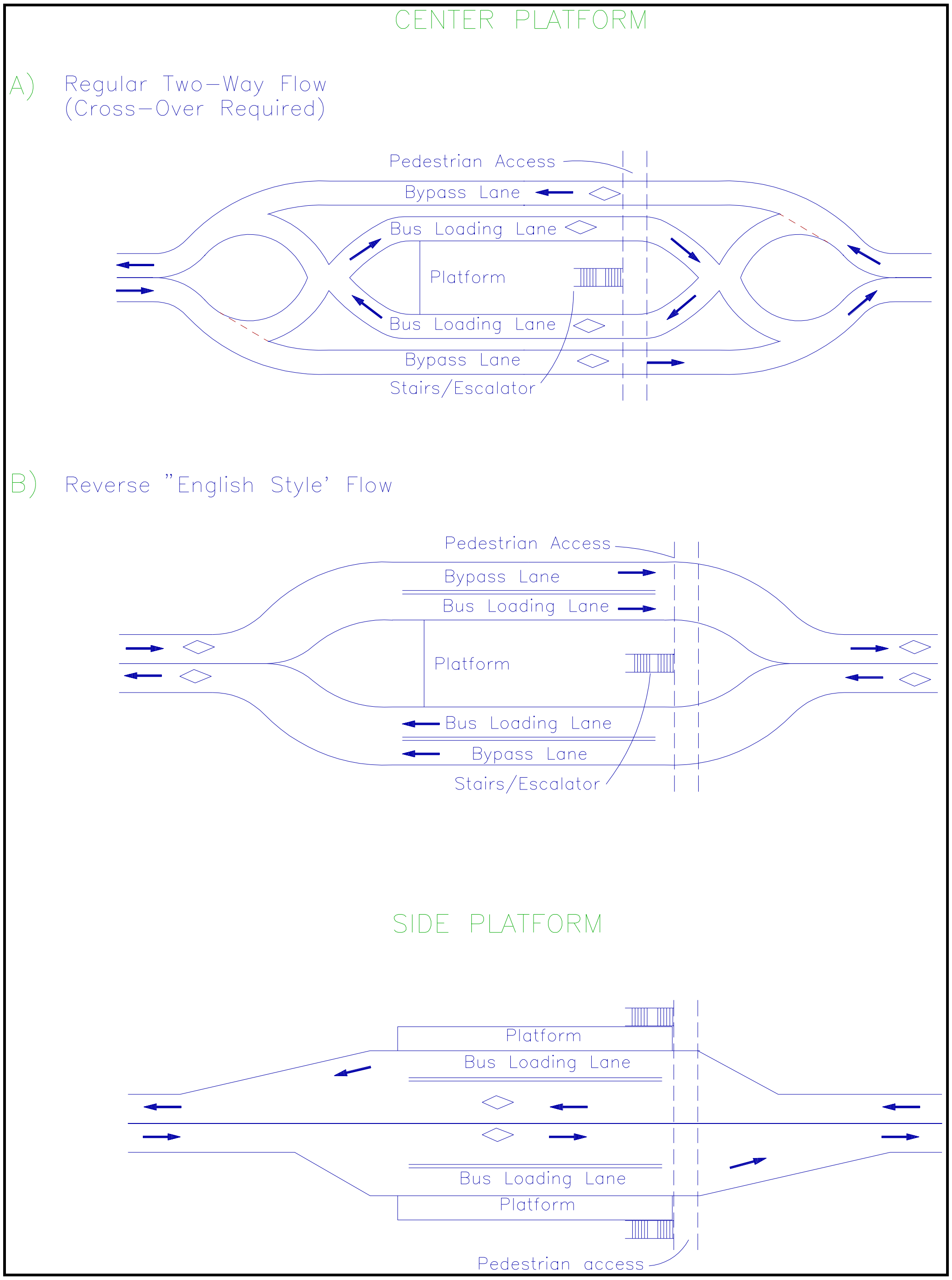


Figure 12.11.4 Median On-Line Transit Station

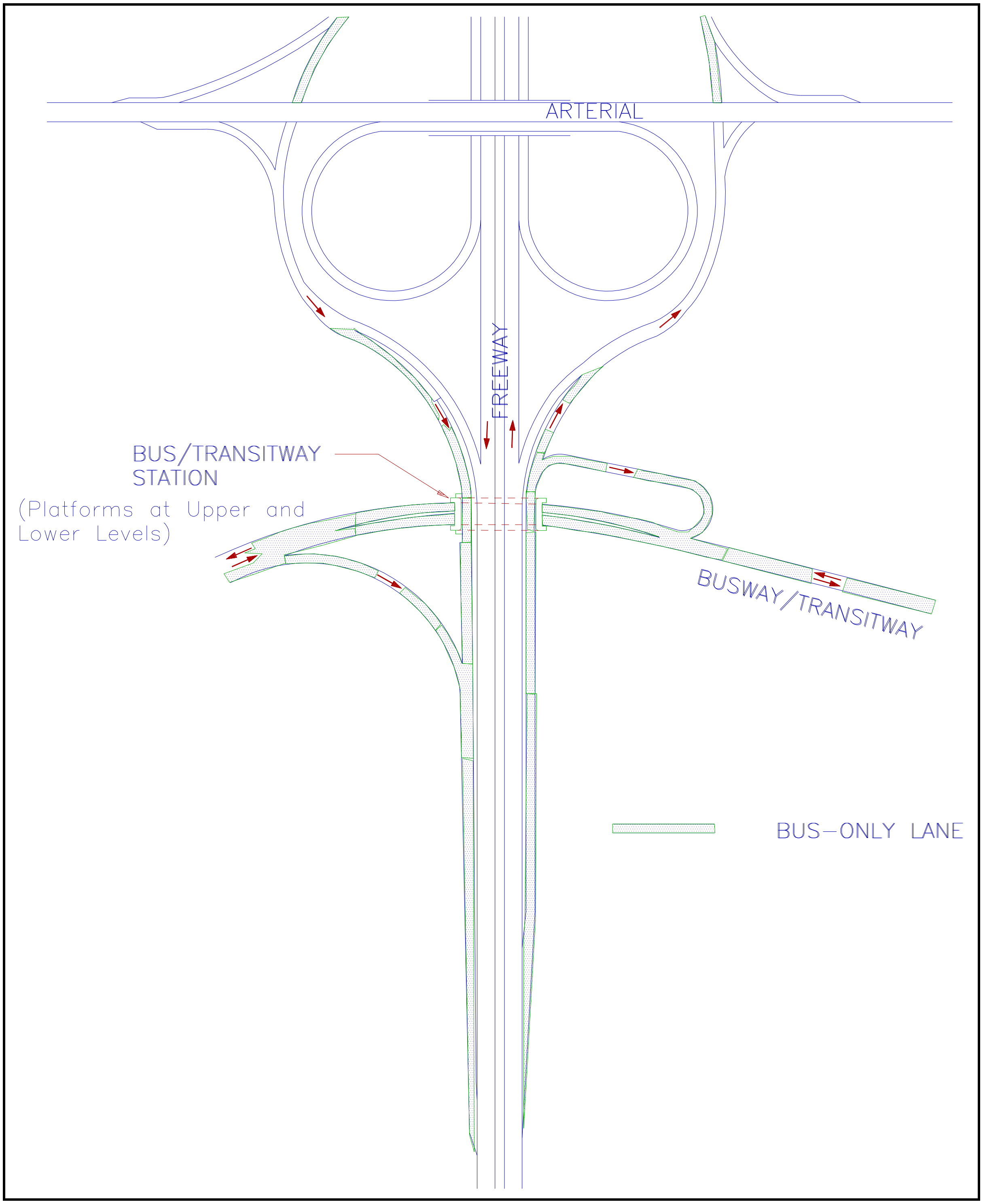


Figure 12.11.5 On-Line Transit Stop for Right Side RBL

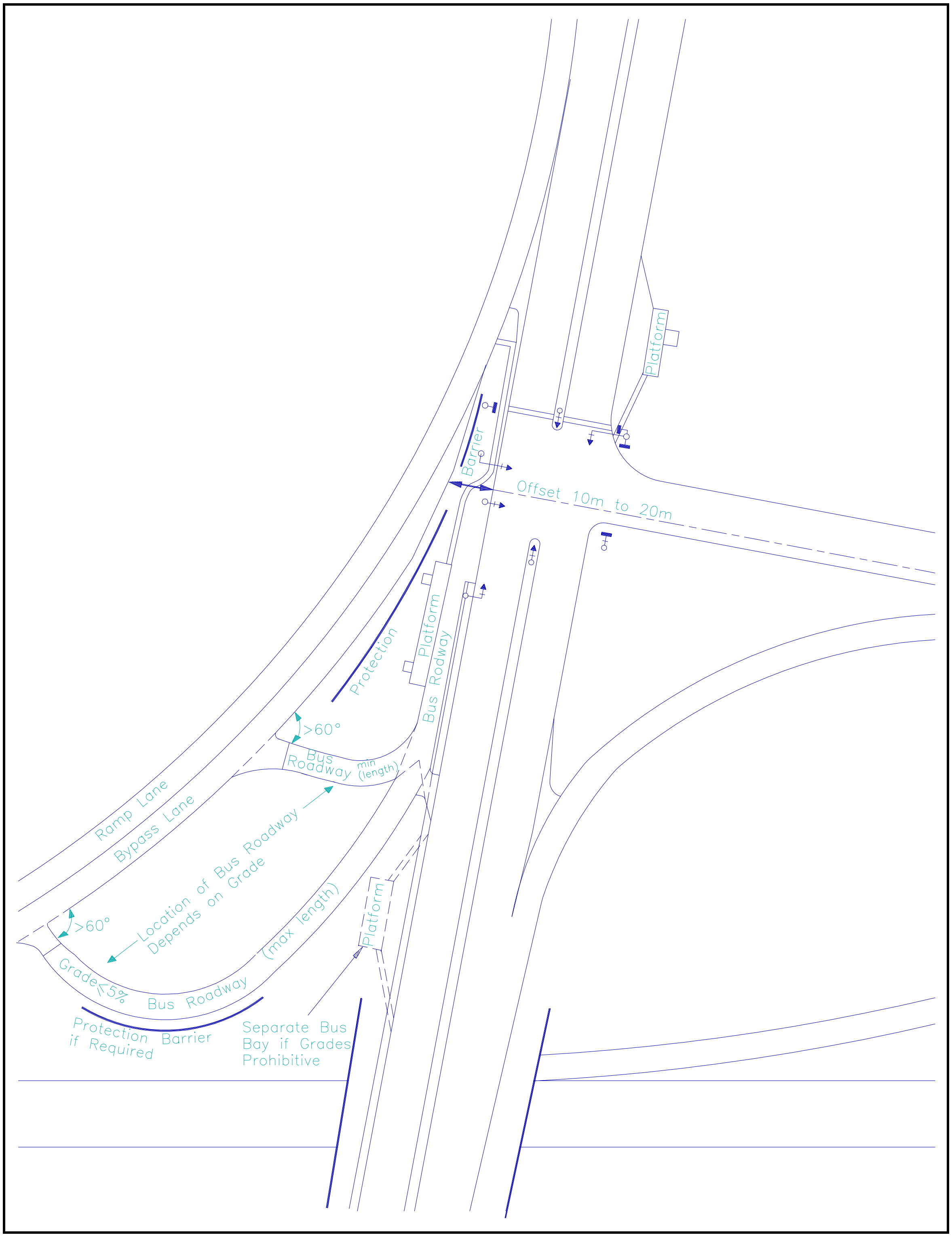


Figure 12.11.6 Freeway Interchange Bus Interface TYPE I

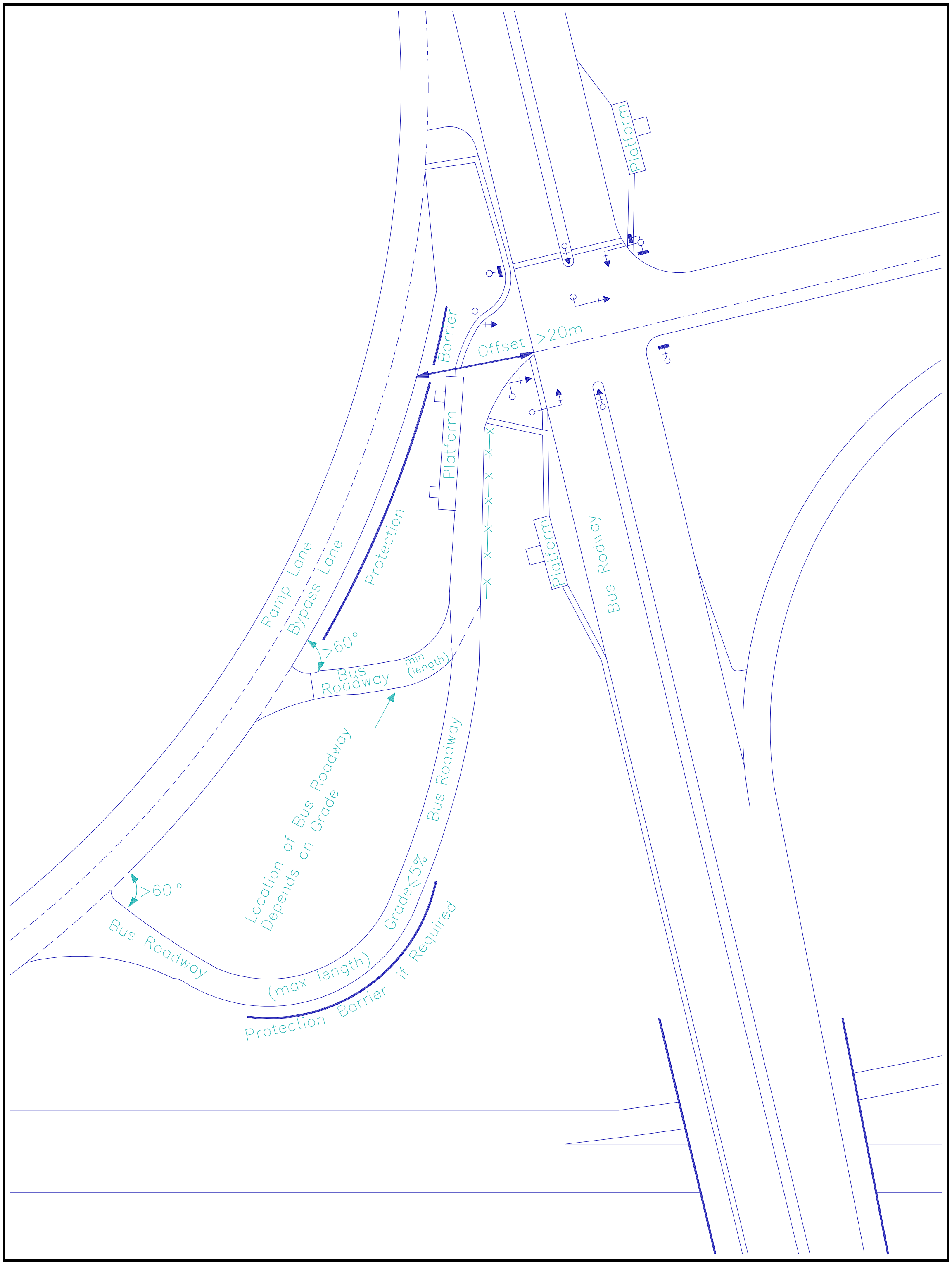


Figure 12.11.7 Freeway Interchange Bus Interface TYPE II

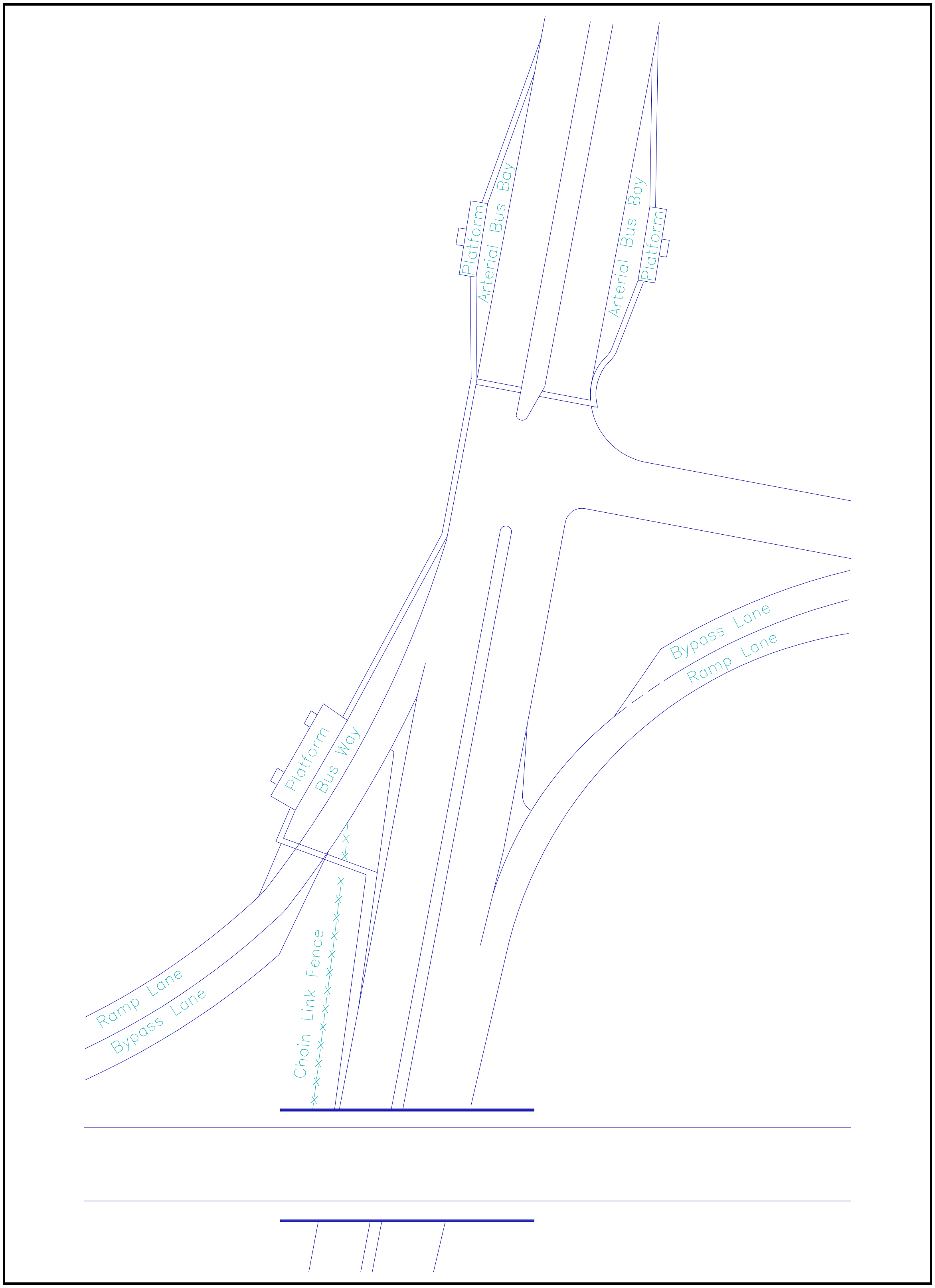


Figure 12.11.8 Freeway Interchange Bus Interface TYPE III

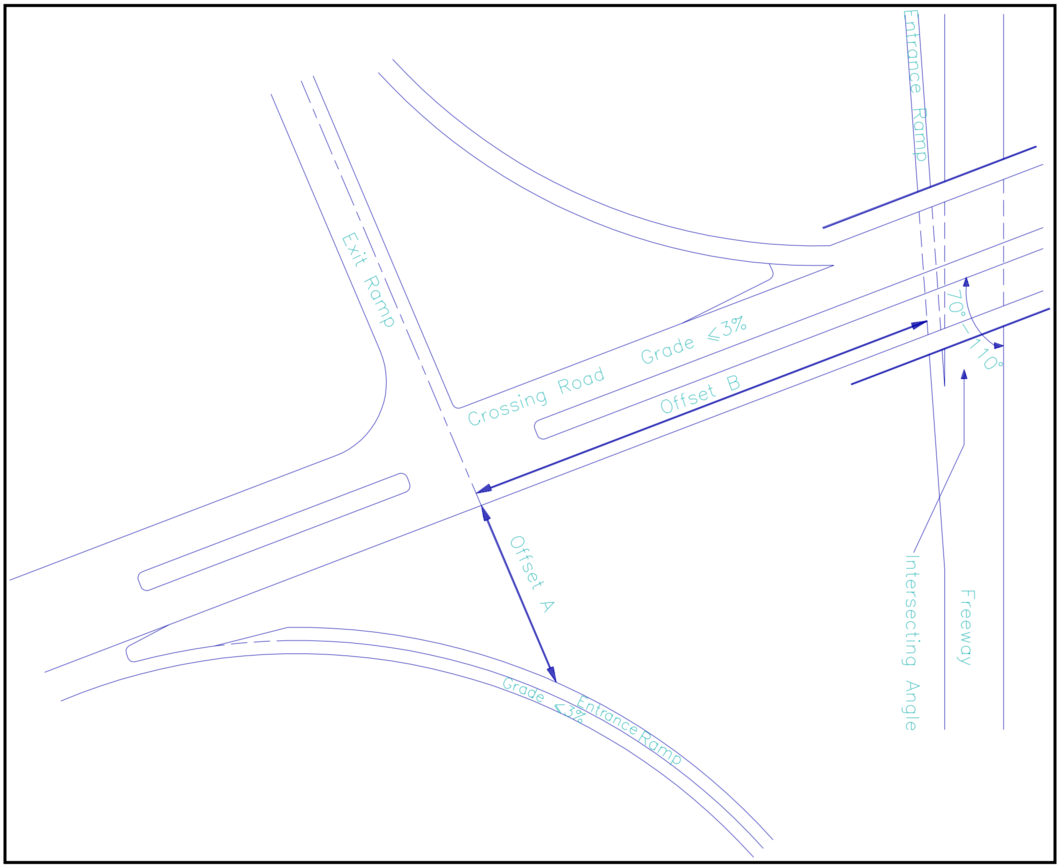


Figure 12.11.9 Interface of Freeway and Local Bus Services at "Parclo A" Interchanges (TYPE I & II)

Guidelines

Step 1

- If intersecting angle is 70°-110° then proceed to step 2
- If angle is beyond this range then proceed with layout of bus interface

Step 2

- If "OFFSET A" is >20 m then "OFFSET B" must be ³ 100 m to provide TYPE II interface
- If "OFFSET A" is 10-20 m and intersecting angle is ³ 90° then "OFFSET B" must be ³ 140 m to provide TYPE I interface with or without local bus exit
- If "OFFSET A" is 10-20 m and intersecting angle is < 90° then proceed with layout of bus interface
- If "OFFSET A" is < 10 m then proceed with layout of bus interface

Step 3

- Provide crossing road grade of 3% for TYPE I interface with or without local bus exit

- Provide entrance ramp grade of 3% for TYPE I or TYPE II interface
- If grades are > 3% then proceed with layout of bus interface

Note: These guidelines are intended for use in conceptual, functional and preliminary design of interchanges only. Design standards should be followed in pre-design and detail design.

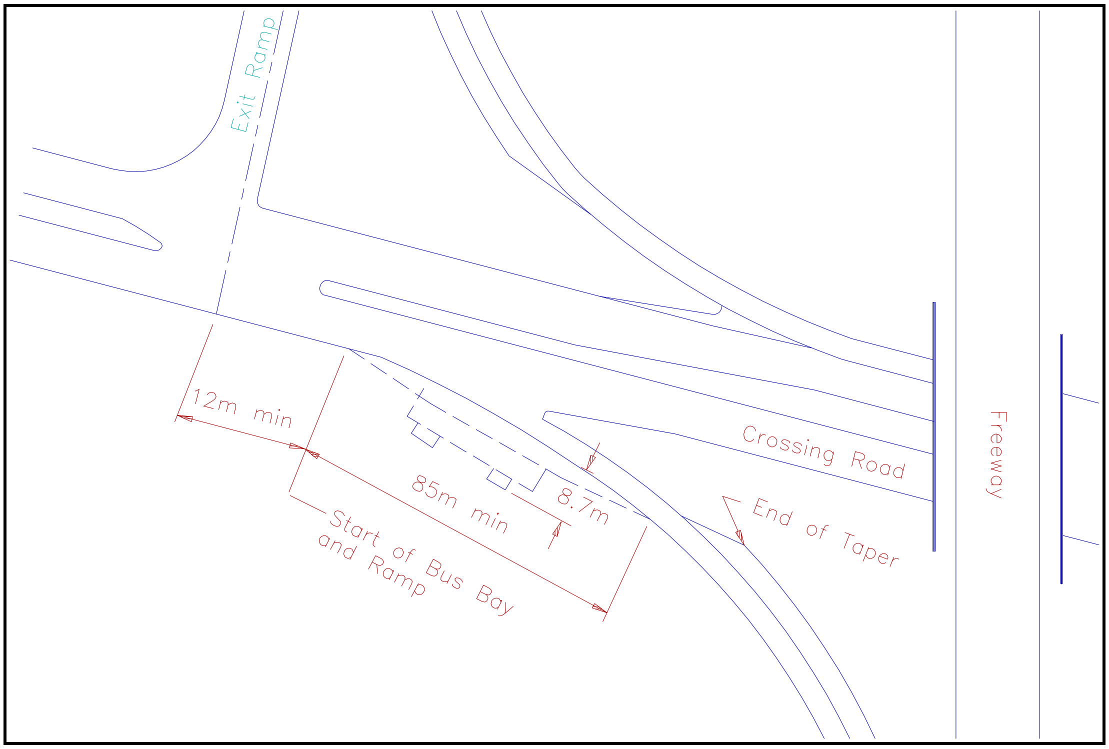


Figure 12.11.10 Interface of Freeway and Local Bus Services at "Parclo A" Interchanges (TYPE III)

Guidelines

Step 1

- If bypass ramp lanes are being considered for eventual construction then proceed to STEP 2
- If not, then ensure that an envelope of land is available adjacent to the freeway ramp such that the bus bay can be constructed and will not interfere with arterial operations
- Length of bus bay measured along the ramp should be 35 m and width from the outside edge of ramp to back edge of bus shelter, along the platforms should be 8.7 m
- Ensure that buses turning left from the freeway exit ramp can manoeuvre into the bus bay at an appropriate approach angle. (A minimum distance of 12 m from bus turning lane to start of bus bay)

Step 2

- Locate the downstream end of the bus bay 85.0 m along the ramp from the start of the curve on the arterial.
- Ensure that the downstream end of the bus bay is adjacent to or upstream of end of taper/start of the bypass lane (the point at which 2 vehicles can travel side-by-side)
- Ensure that buses turning left from the freeway exit ramp can manoeuvre into the bus bay at an appropriate approach angle. (A minimum distance of 12 m from bus turning lane to start of bus bay)
- For the length of the platform provide an offset from edge of ramp of 8.7 m.

Note: These guidelines are intended for use in conceptual, functional and preliminary design of interchanges only. Design standards should be followed in pre-design and detail design.

12.11.3 Bus Interface at Parclo "A" Interchanges

Five parameters are used to define the Type I and II bus interface space requirements:

- Offset from crossing road at exit ramp to direct entrance ramp with by-pass lane (if required)
- Offset from exit ramp along crossing road to edge of pavement at freeway or inner loop entrance ramp
- Intersection angle of the roadways
- Grade of the crossing road
- Grade of the direct entrance ramp.

Two parameters are used to define the Type III bus interface space requirements:

- Length along the direct entrance ramp, between the start of the bypass lane (the point at which 2 vehicles can travel side-by-side) and the upstream end of the bus bay.
- Offset from the edge of the entrance ramp which will accommodate the bus bay and the platform area and a bus shelter.

These guidelines should be appropriate for most applications, however, if conditions are restricting then a layout of the interface should be undertaken using the Design Standards.

12.11.3. 1 Selection of Interface Type

1. **Interface Type I**

In cases where an offset between the Freeway exit terminal and entrance ramp of 10 - 20 m is provided, develop crossing road profile and entrance ramp profile to permit possible implementation of Type I Freeway Interchange Bus Interface (**Figure 12.11.6**) with:

- A bus platform length of 35 m;
- A bus roadway at a 0.5% longitudinal grade between the crossing road and the downstream end of the platform;
- A bus roadway at a grade of no more than 5% with appropriate vertical transition curves between the platform and the freeway entrance ramp;
- iIncases where the climbing grade of the crossing road permits it, a bus roadway at a grade of not more than 5% with appropriate vertical transition curves between the platform and the re-entry point at the crossing road; or,
- In cases where the climbing grade of the crossing road does not permit local bus re-entry onto the crossing road, a separate local bus bay to be located along the crossing road before the crossing road structure.

2. **Interface Type II**

In cases where an offset between the Freeway exit terminal and entrance ramp of at least 20 metres is available, develop crossing road profile and entrance ramp profile to permit possible implementation of Type II Freeway Interchange Bus Interface (**Figure 12.11.7**) with:

(i) a bus platform length of 35 metres;
(ii) a bus roadway at a 0.5% longitudinal grade between the crossing road and the downstream end of the platform; and
(iii) a bus roadway at a grade of no more than 5% with appropriate vertical transition curves between the platform and the freeway entrance ramp.

3. In cases where an offset of less than 10 m is provided between the Freeway exit terminal and entrance ramp, develop a Type I Freeway Interchange Bus Interface as per #2 above at a point downstream of the Freeway exit terminal where necessary offset is available.

4. In cases where the crossing road exit terminal is downstream of the Freeway exit terminal. These guidelines suggest that in circumstances of new design, an offset of at

least 20 m is sufficient to provide a Type II Bus Interface and possibly a Type I Bus Interface. If property limitations or the skew of the crossing road to the freeway is such that an offset of 10 - 20 m results, then a Type I Bus Interface is appropriate with or without a separate local bus bay depending on local conditions. If the offset is less than 10 metres, then a Type I Bus Interface is still appropriate, but it must be located downstream of its normal position where sufficient offset is available. If the Freeway entrance ramp is accessed downstream of the Freeway exit ramp, then a new design is required which is not yet developed.

3. **Interface Type III**

This additional geometric design standard provides guidance in providing for an interface at Parclo "A" Interchanges which are configured such that the freeway direct entrance ramp is located downstream along the crossing road from the exit ramp terminal. This Type III bus interface which is most suitable to this interchange configuration is indicated in **Figure 12.11.8**.

12.11.3.2 Operational Considerations

(i) Interface Type I and II

Bus access to the bus interface will be from the exit ramp left-turn lane in situations where the exit ramp terminal at the crossing road is 2 lanes.

Bus access to the bus interface will be from the center freeway exit ramp either/or turn lane in situations where the freeway exit ramp terminal at the crossing road is 3 lanes. Location and alignment of the bus interface entrance shall be designed such that conflicts between turning traffic in adjacent lanes is avoided.

Buses will access the bus roadway and stop at one of two possible bus platforms at the interface.

Buses can proceed through the interface platform area at speeds not exceeding 35 km/h which has been established as reasonable from the point of view of manoeuvrability, safety and costs.

During unmetered times of the day, buses will likely enter directly into the main traffic flow from the bus roadway.

Passengers will access the bus interface by either transferring from local transit or walking in

from the crossing road.
Access will be directly to the platform since fares will likely be collected on-board the buses. Platform access can be at either end or along its length.

(ii) Interface Type III

As with all freeway bus operations, bus access to the Type III interface will be from the exit ramp left turn lane in situations where the exit ramp terminal at the crossing road is only 2 lanes.

Bus access to the Type III bus interface will be from the centre freeway exit ramp either/or turn lane in situations where the freeway exit ramp terminal at the crossing road is 3 lanes. Location and alignment of the Type III bus interface entrance shall be designed such that conflicts between turning traffic in adjacent lanes is avoided.

Buses will access the Type III interface at the freeway entrance ramp terminal and stop at one of two possible bus platforms.

Buses will exit from the platforms directly onto the ramp when there is a suitable break in traffic flow. If there is a bypass lane and a metered lane on the ramp and if metering is in operation, then the bus may move left into the bypass lane without undue weaving difficulties. At such time that metering is not in operation then the bus may stay in the main flow of traffic.

Passengers will access the Type III bus interface by walking from local bus bays on either side of the arterial or by crossing the freeway entrance ramp from the other side of the interchange.

Passenger access to buses will be uncomplicated since fares will likely be collected on-board the buses and not at turnstiles at the ends of the platforms. This allows platforms to be accessed from the ends or along its length. If the access is along its length, then additional offset from the ramp will be required.

12.11.3.3 Staging Considerations

Integration of the bus system with the ultimate rail system has been considered and it is anticipated that bus interfaces will be operational during the integration process.

Transitway sections between interchanges will ultimately be linked together with grade-separated structures, however at an interim measure, at-grade bus crossings could possibly be developed. This condition may have traffic operational improvements or geometric design provisions then it may be possible to utilize the initial bus interfaces to facilitate transfers between local buses and freeway buses. The Type I Bus Interface however does not permit left turns into the bus roadway from the crossing road due to its inherent design characteristics.

Full development of transit service staging should be undertaken during preliminary design activities for the transitway.
If at-grade bus crossing impacts are minimized through traffic operational improvements or geometric design provisions, then it may be possible to utilize the initial Type III bus interfaces to facilitate transfers between local buses and freeway buses during the interim time frame.

12.11.3. 4 Design Standards

The design should consider desirable alignment elements which improve passenger ride, such as reducing sags, crests and directional changes while moderating costs.

Design of Bus Interfaces should consider:

- safety
- capital costs
- alignment
- intended operation
- impact on crossing road and bus roadway access/egress locations

Design speeds shall be 35 km/h on bus roadways and platform areas.

12.11.3. 4.1 Horizontal Alignment

Sufficient sight distance shall be provided for buses on the bus roadway such that drivers can maintain safe and efficient operation of the vehicles. Minimum stopping sight distance must be provided at egress to the freeway entrance ramp.

Passing sight distance does not apply since no passing will occur on the bus roadway except the passing of stalled or immobile vehicles.

The bus roadway shall be on tangent through the platform area.

Minimum edge of pavement radii for the B-12 design vehicle are as follows:

Stop Condition (0 - 15 km/h)	Radii: 18 m

Yield Condition (15 - 25 km/h) Radii: 20 m

Note that on a four-lane roadway with a 15 m radius, buses use both lanes when making a right turn.

12.11.3. 4.2 Vertical Alignment

The maximum gradient on the bus roadway shall not exceed 5%, as depicted on **Figures 12.11.11**.

The minimum gradient on the bus roadway should be no less than 0.5% at platforms to permit positive drainage.

The design parameter for crest curves and sag curves on the bus roadway shall remain above a minimum K = 4 m for crest and K = 8 m for sag curves (at 40 km/h).

12.11.3. 4.3 Turning Vehicle Paths

The **Design Vehicle** dimensions shall be used to ensure that highway buses can manoeuvre easily on bus interface sites. The highway bus type B-12 shall be the design vehicle for all bus interface layouts. This design vehicle will accommodate standard Buses.

A clearance of at least 1.0 m should be provided between the line given by the Design Vehicle Turning Radius and any fixed object that a bus could collide with.

There are two paths for the design vehicle, as follows:

Stop Condition

The vehicle commences a turn from a stationary position (e.g. from bus platform on bus roadway). Stop condition reflects the treatment for stop sign control where the access road joins a two-lane roadway, using the 15 m turning radius design vehicle template.

Yield Condition

The vehicle commences a turn at speeds between 15 and 25 km/h (e.g. downstream of platform along bus roadway). Yield condition reflects the treatment for signal control where an access road joins a two-lane roadway, using the 20 m turning design vehicle template.

12.11.3.4.4 Safety and Security Measures

Chain link security fencing shall be provided as required to encourage safety and pedestrian control in the bus interface area.

Fencing may be replaced by longitudinal traffic barrier with aluminium pedestrian barrier affixed to the top or fencing affixed to the top of a retaining wall if so required.

Longitudinal traffic barrier shall be installed along Freeway traffic entrance ramps where safety is at risk due to vehicles accidentally veering towards pedestrian areas of the interface.

Longitudinal barrier shall be installed if the unprotected clearance between the bus roadway and the freeway edge of pavement is within 10 m.

Such barrier shall be located in accordance with the latest edition of ministry's "**Roadside Design Manual"**

Provisions are to be made for access by emergency vehicles, including fire trucks and ambulances. Designated fire routes, no parking zones, etc., shall meet municipal approval, although emergency vehicles will generally use bus roadways.

12.11.3.5 Interface Location

Interfaces at interchanges shall be located as closely as practicable to crossing roads of suitable geometrics and ridership potential.

Pedestrian walk distances shall be minimized between local and freeway buses.

12.11.3.6 Platform Facilities

Standardized bus interface designs shall be provided if practical.

Geometric design provisions at bus interfaces should allow for platforms to be 35 m long, 4 m wide and the bus platform level should be 150 mm above the bus pavement level.

Satellite shelter pads should be provided for along the platform such that a 1.2 m by 3.65 m shelter (approximate dimensions) could be constructed.

Lighting of the bus roadway, and the platforms, and of sidewalks and shelters should be integrated with that of the ramp and crossing road. Under pavement crossings should be provided accordingly.

12.11.3.7 Local Bus Facilities

Where freeway bus interfaces are located adjacent to crossing roads, the municipality may request that bus bays for local service be provided, particularly if the interface cannot accommodate local bus facilities. Bus bays will assist the through traffic movement and reduce the accident-prone weaving movement on four and six-lane roads.

The location and dimensions of the bus bay must be reviewed with the transit authority to ensure that the location suits their operations. It will also require a careful site review to ensure that conflicts with driveways or other topographic features are minimized, and that the location is approved by the municipality. Typical configurations are provided on **Figure 12.11.13.**

Care must be taken in the bus bay design allowing appropriate entrance and exit lengths to discourage serious disruption of traffic movement in the adjacent lanes. Both Standard and some models of Articulated Buses (B-12) should be accommodated in bus bay design.

Local buses travelling in one direction on the crossing road may be provided with bus stopping privileges at freeway bus platforms for Type I interfaces where the offset between the crossing road and the freeway entrance ramp permits it and where the grade differential is small. This arrangement provides optimum passenger transfer potential between buses. Under favourable circumstances local buses then re-enter the crossing road upon leaving the interface.

Buses which may wish to turn left from the crossing road into the bus interface will be able to do so only at Type II interfaces. Type I interfaces do not provide sufficient area in which to turn a bus from that position.

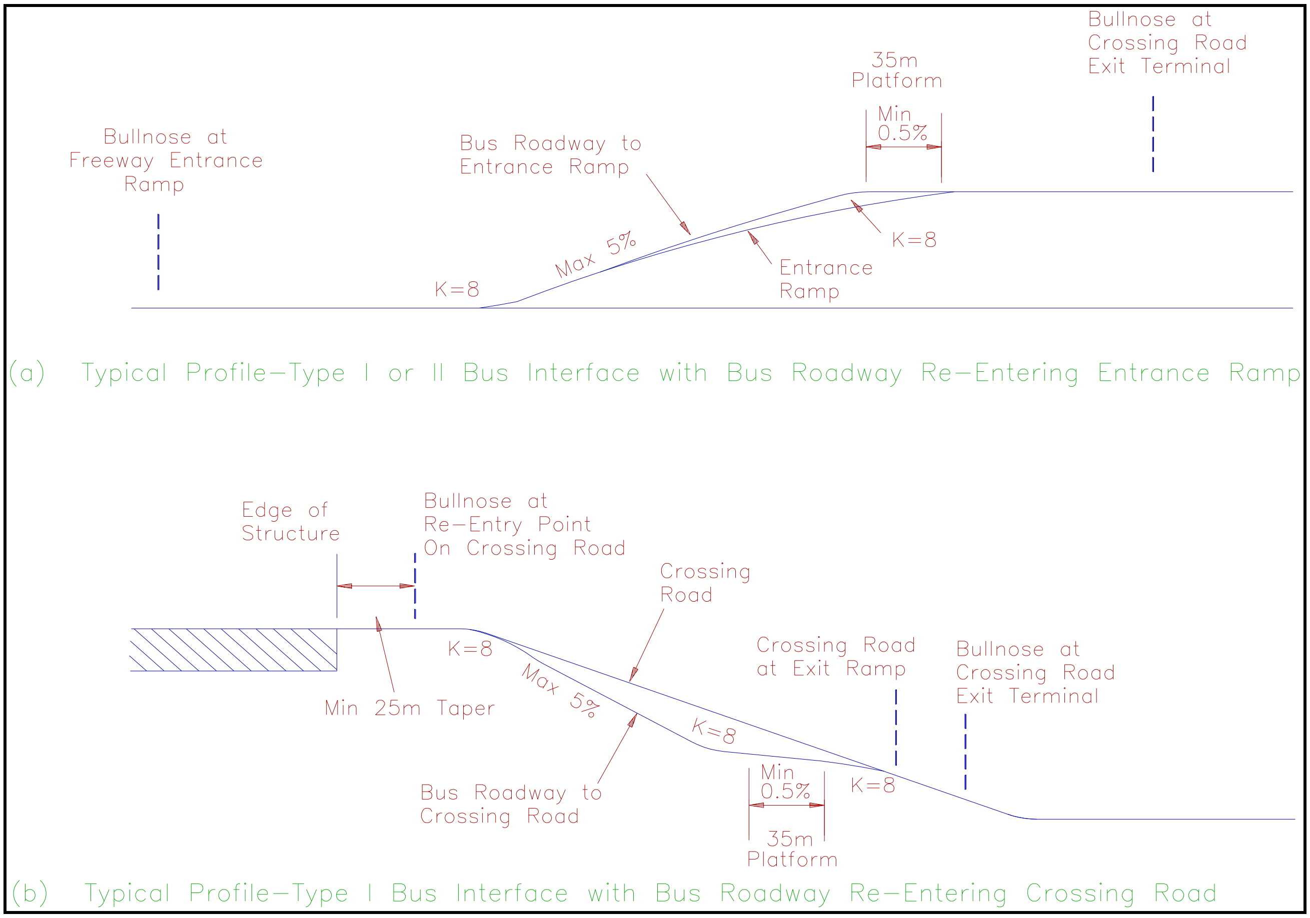


Figure 12.11.11 Typical Profile of Interchange with Bus Interface TYPES I, II &III

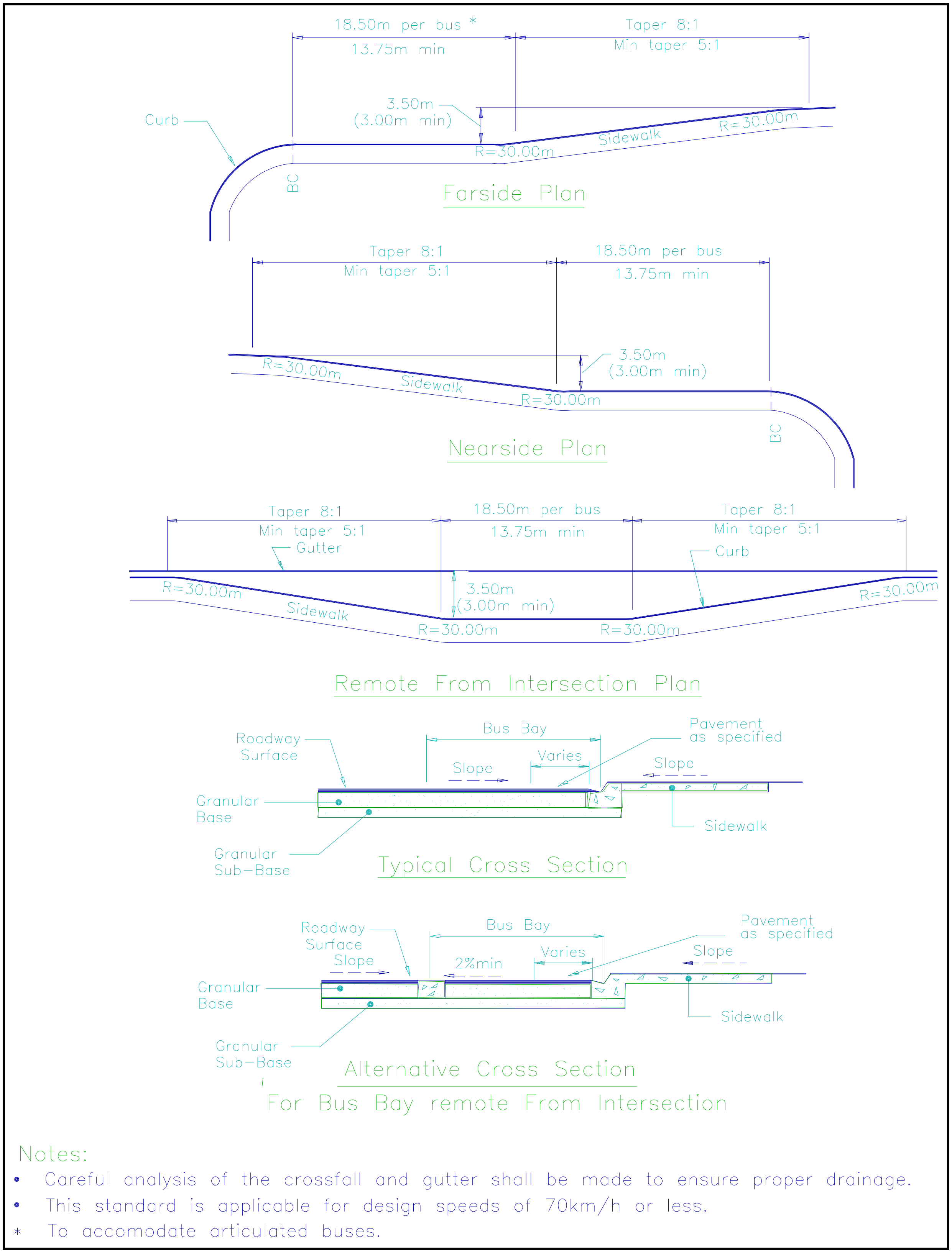


Figure 12.11.12 Arterial Bus Bays

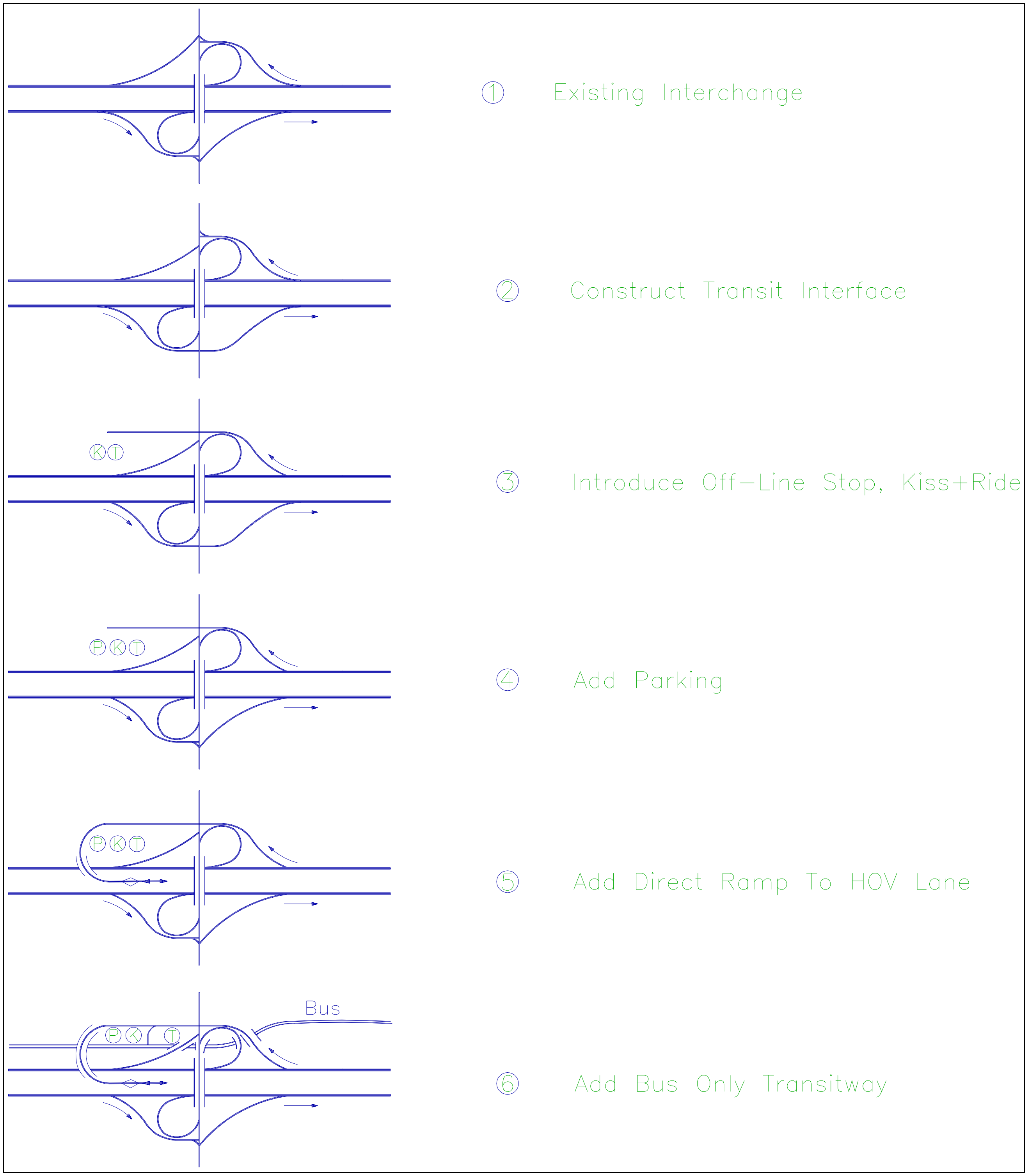


Figure 12.11.13 Staged Development Transit Station

12.11.4 Other Design Considerations: Pavement Structure

Guidelines for the design of busway pavements stem from direct experience with the design of flexible and rigid roadway pavement systems. These guidelines are proposed for use in the planning stage only and do not preclude the need for detailed pavement structure design.

Subsequent detailed investigation, necessary before final design, will almost certainly indicate the need for modifications to the typical pavement thickness given in this document. Factors such as design traffic, subgrade conditions, environmental effects, availability of acceptable construction materials, construction traffic, performance of similarly loaded pavements in the area and economics all need to be considered as part of detailed design to arrive at an optimum pavement structure.

Pavement design is directly influenced by the expected number of heavy axle loadings, as opposed to the gross vehicle weight, as multiple axles help spread the load on the pavement and reduce the impact. However, loading is not even across axles, and typically the rear axle on a two-axle vehicle will carry 70 to 75 percent of the gross vehicle weight. Note that even small increases in weight on an axle can cause disproportionately large amounts of damage to the pavement structure.

Typical pavement section depths for a rigid pavement are in the range of 175 to 250 millimeters of Portland cement concrete on a 150 millimeter deep crushed granular base course. For a flexible pavement, the typical depths are 125 to 175 millimeters of asphaltic concrete pavement over 300 to 375 millimeters of crushed granular base course. The life cycle of asphalt would include an overlay of 2 inches at approximately 12 to 15 years.

12.11.5 Bus Bypass Shoulder (BBS)

Bus-on-shoulder operations, also known internationally as **"bus bypass shoulder" (BBS)** operations, are a low-cost strategy allowing buses to travel at or near free-flow speeds through congested freeway routes. BBS describes the routing of a bus onto the shoulder of a road, usually a highway, in lieu of the standard general-purpose lanes. BBS is a policy-based alternative to constructing dedicated rights-of-way or restricting lane use to high-occupancy vehicles (HOV). The primary goal is to prioritize the reliable performance of public transit over capacity for single-occupant vehicles (SOV). Bus-on-shoulder is typically used only where roadway congestion is severe enough that traveling on the shoulder improves on-time reliability and even decreases overall trip time (**Figure**

12.11.14).

Safety

Shoulders are generally reserved for emergency vehicle access and to provide a safe haven for disabled vehicles. From a highway operations and safety viewpoint the BBS use operations raise several important concerns. These concerns encompass the loss of basic functions that shoulders are intended to provide (removal and storage of disabled vehicles, emergency vehicle access, and highway maintenance staging), traffic safety risks, and the added costs for maintenance and enforcement.

The traffic safety concerns include:

- Conflicts at on- and off-ramps;
- Sight distance adequacy, particularly at on-ramps;
- Conflicts for motorists pulling onto the shoulder;
- Loss of safe evasive movement shelter area;
- Need for bus driver training;
- Speed differential;
- Impact on adjacent lane motorists;
- Return merge distance adequacy;
- Shoulder area debris hazards;
- Reduced clearance for buses at bridge abutments; and
- Highway drainage.

Visibility around access ramps can be a challenge. Older facilities may have very narrow exits or on-ramps making a challenge both for the bus traveling at high speed and other vehicles entering the highway. Conflicts with merging traffic on the right shoulder can be averted through ramp metering technology (as done in Vancouver) or by permitting use of the right shoulder only where the bus makes frequent exits and/or on-or-off ramps occur infrequently. In cold climates, the shoulder may be essential for snow storage if it cannot be cleared beyond the paved surface, diminishing the practicality of the bus-on-shoulder service

Figure 12.11.14 Bus ByPass Shoulders
Source: The Big Move – Metrolinx

Figure 12.11.15 Mississauga Transit including Bus ByPass Shoulders on Highway 403

12.11.5.1 Choosing Corridors for Bus on Shoulders

The concept of bus usage of shoulders is a low-cost solution for relieving buses from the pressures of traffic congestion. Because cost is a constraint, BOS cannot be implemented just anywhere. Only corridors with high levels of bus usage and significant peak period congestion would result in enough benefits to bus riders to warrant costs. Minor improvements to shoulders can be made to accommodate buses, but most of the elements required for bus usage must be in place at the start to make projects non-cost-prohibitive. In the ideal case, a corridor would only need appropriate signage to implement BOS. Many cities that have implemented BOS developed a list of criteria for choosing potential BOS corridors.

A suggested list is as follows:

- There must be predictable congestion delays, meaning the traffic running speed must be less than 55 km/hr during the peak period and/or approaches to intersections have continuous backups.
- Congestion delays must occur one or more days per week.
- A minimum of six transit buses per day must use the proposed bus shoulder.
- The expected time savings of using the shoulder must be greater than 5 minutes per kilometer per week.
- The proposed shoulder must have a continuous shoulder width of at least 3.3 m.

O. Reg. 618/05: DESIGNATION OF BUS BY-PASS SHOULDERS ON KING'S HIGHWAY, includes the sections of Highways 403, 417, 8 and 401 that are designated as having paved shoulders for use by a bus operated in accordance with a license issued under the *Public Vehicles Act* and an authorization provided by the Ministry. Refer to O.Reg 618/05 for the signage required on shoulders.

12.11.5.2 Bus Shoulder Lanes

Bus shoulder lanes are authorized bus-only lanes that run along selected freeways. They are a low-cost solution that fully use the capacity of existing corridors and provide immediate benefits to fixed route buses operated by local transit agencies. Most bus shoulder lanes are on the right shoulder, which allow buses to enter the freeway from the right-side during peak congestion hours and avoid having to weave into either general purpose or HOV traffic. Bus shoulder lanes are not designed to carry a large amount of traffic and are only used during specific times so buses can maintain a reliable schedule during periods of peak congestion.

Bus shoulder lanes look and operate like any other shoulder and have a minimal effect on traffic in the general purpose or HOV lanes. The shoulder will still be available first for disabled vehicles, incident response and emergency or enforcement situations. The lanes are designed for adequate stopping sight distance with the reduced operating speeds.

Buses using the specified bus shoulder lanes cannot exceed all other traffic by more than 15 mph to ensure safe travel for all corridor users. The maximum speed allowed is 55 Km/hr.

All bus drivers traveling in bus shoulder lanes have to yield to all other traffic, including any vehicles entering the shoulder and all motorists in the general purpose or HOV lanes when exiting the shoulder.

Signs alerting non-transit drivers of the potential for buses traveling along the shoulder during designated hours are posted along freeway corridors with bus shoulder lanes. Supplemental "Emergency Stopping Only" signs are located throughout the corridor.

12.11.5.3 Bus Use of Shoulders in HOV Lane Corridors

High-occupancy vehicle (HOV) lanes can be used transit vehicles on freeways and expressways. The HOV lane can be located on either the median side or the outer side of the general-purpose traffic lanes. The operational challenge with use of a median HOV lane is getting buses out of the lane and across the general-purpose traffic lanes to exit.

A possible configuration for longer-distance transit routes is to use existing shoulders on expressways or freeways. This configuration is often referred to as a reserved bus lane (RBL) or bus on shoulders (BOS). BOS typically uses the right-hand shoulder, though left-hand shoulders can also be used for BOS if it is an express-type service.

There are **advantages to placing the Transitway on the shoulders,** including the following:

- Transit vehicles have the ability to enter and exit the shoulder whenever necessary to leave or enter the general-purpose outer traffic lane to maintain operating speed.
- The investment costs to convert a conventional shoulder to a BRT guideway are relatively low, typically limited to upgrading the pavement structure on the

shoulder to accommodate the heavier and more constant use by BRT vehicles and the adjustment of storm water inlets for ride quality.

- Transit vehicles have the ability to exit the freeway without weaving if they are making connections at interchanges.
- Freeway design standards usually permit high BRT vehicle operating speeds.

The disadvantages of having the Transitway on a freeway shoulder include the following:

- Disabled vehicles on the shoulder require that all transit vehicles re-enter the adjacent general-purpose traffic lane to pass the disabled vehicle.
- Upgrading of the shoulder pavement structure to accommodate the loadings from Transit vehicles may create delays to freeway traffic during construction work, unless there is sufficient room in the median to permit the lanes to be shifted during construction.
- Extra signage and motorist information is required to explain the use of the shoulders by buses.
- Transit vehicles may have to merge into the general-purpose lanes in advance of interchange exits if the bus does not exit at that location.
- Consideration needs to be given in operating policies to possible major speed differentials between buses and other traffic on the adjacent congested general-travel lanes.

It is desired that a Transit vehicle have an 3.5 m (10.5 Feet) wide travel lane with an additional 0.6 m (2 feet) wide paved shy distance between the edge of the running way and any obstructions, piers, sign supports, walls, ditch edges or guiderails, as well as a 0.6 m buffer between the Transit Lane and the adjacent general-purpose lanes. However, in retrofit situations, the dimensions are typically limited by existing adjacent obstructions. Widening of the existing shoulder width to the desired 4.5 m (15 feet) section is not always attainable.

High-occupancy vehicle (HOV) lanes can be used for BRT and other transit vehicles on freeways and expressways. The HOV lane can be located on either the median side or the outer side of the general-purpose traffic lanes. The operational challenge with use of a median HOV lane is getting buses out of the lane and across the general-purpose traffic lanes in order to exit.

The pavement structure of the existing median or shoulder should be reviewed carefully to ensure that it can accommodate the additional loads from the BRT.

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MTO Design Supplement

Appendix 13

Work Zones

June 2023

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Appendix 13

Work Zones

This chapter is being developed by the ministry and currently under review. It will be either added to this MTO Design Supplement or will be implemented as a standalone chapter.

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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads, June 2017

Appendix A

Glossary

June 2023

MTO Design Supplement
Appendix A
Glossary

This glossary is applicable for all chapters of TAC Geometric Design Guide for Canadian Roads – June 2017 and MTO Design Supplement:

TERM	DEFINITION / DESCRIPTION
85th-percentile Speed[b]	The speed at or below which 85 percent of all observed traffic is traveling at a particular point or segment.
Acceleration Lane	An auxiliary lane to enable a vehicle entering a roadway to increase speed to merge with through traffic as applied at channelized intersections, or as speed-change lane at interchanges.
Access Control	See “Controlled Access”
Access Management	The management of the location and basic dimensions of access to property, from a roadway.
Accident	Not used. (See “Collision”)
Adverse Crown[a]	A section with the cross-slope removed to a zero slope. This change in cross-slope is accomplished over the tangent runout.
Advisory Speed[b]	The speed displayed on an advisory speed plaque and determined on the basis of an engineering analysis.
Alternating One-way Operation[b]	A construction work zone mitigation strategy used on two-way roadways wherein opposing directions of travel take turns using a single travel lane. Flaggers, with or without pilot vehicles; STOP signs; or signals are normally used to coordinate the two directions of traffic. This strategy compensates for the removal of permanent travel lanes from service and is sometimes referred to as one-lane, two-way operation.
Ancillary Space	The part of the roadway, between the travel lanes and the curb or pavement edge.
Annual Average Daily Traffic[b] (AADT)	The total volume of traffic passing a point or segment of a highway in both directions for 1 year divided by the number of days in the year.

Approach Nose	The end of a median or island that faces approaching traffic.
Approach Taper	The taper required in advance of an intersection to shift the through lanes laterally to the right to provide the width for a left-turn auxiliary lane.
Area of Concern[b]	An area within the roadside environment and within the desirable clear zone that has a higher severity index than a barrier system.
Area of Contents	An object or roadside condition that may warrant safety treatment.
Arterial Road	A road primarily for through traffic.
Assumed Speed[b]	The assumed speed for calculating minimum stopping sight distance is based on the 85^{th} percentile wet weather speeds as derived from a traffic study.
Assured Passing Opportunity[b]	A condition in which a vehicle can safely pass another without restriction either by visibility or opposing traffic.
Auxiliary Lane[a]	A lane in addition to, and placed adjacent to, a through lane intended for a specific maneuver such as turning, merging, diverging, weaving, and for slow vehicles, but not parking.
Average Annual Daily Traffic (AADT)	The total volume of traffic passing a point or segment of a roadway, in both directions for one year, divided by the number of days in the year.
Average Daily Traffic[b] (ADT)	The total volume of traffic during a given time period (in whole days) greater than one day and less than one year divided by the number of days in that time period.
Back Slope[b]	Where the roadway is in cut, the slope between the drainage channel and the natural ground is referred to as a back slope.
Barrier[b]	A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect an errant vehicle of a particular size range, at a given speed and angle of impact.
Barrier System[b]	A system which provides a physical limitation through which an errant vehicle would not normally penetrate or vault over. It is intended to contain or redirect an errant design vehicle of a particular size range, at a given speed and angle of impact.
Barrier Transition	A method by which a change in longitudinal barrier type provides continuous protection to adjacent traffic.
Barrier Warrant	A criterion that identifies a potential need for a traffic barrier.
Bifurcation Point[b]	The point or area at which a roadway divides into two branches or parts.

Bike Lane	A lane intended for the exclusive use of bicycles, within a roadway used by motorized vehicles.
Bike Path	A bicycle facility physically separated from roadways, where motor vehicle traffic, except maintenance vehicles, is excluded.
Bike Route	Any roadway signed specifically to encourage bicycle use.
Bikeway	A roadway, or part of a roadway, intended for the use of bicycles, either exclusively or shared with other vehicular traffic or pedestrians.
Border	The area adjoining the outer edge of the sidewalk.
Boulevard[a]	A reserve which separates the roadway and sidewalk. It provides some protection to the pedestrian and can accommodate street accessories such as traffic signs the fire hydrants. It is a suitable location for underground utilities and may be used for illumination poles. It also provides an area for snow storage.
Brake Reaction Time[b]	The time that elapses from the instant the driver decides to take remedial action, to the instant that remedial action begins (contacts brake pedal).
Braking Distance	The distance travelled from the instant that braking begins to the instant the vehicle comes to a stop.
Break Point	The outer extremity of the shoulder where the side slope begins.
Breakaway	A design feature that allows a device such as a sign, luminaire or traffic signal support to yield or separate upon impact.
Bridge Railing	A longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.
Broken Back Curve	An arrangement of curves in which a short tangent separates two curves in the same direction.
Building Line	A line prescribing the nearest limits for the erection of buildings in relation to a roadway.
Bulbing	A widened portion of the median or outer separation, usually at an intersection.
Bullnose[b]	Location where edge of highway and edge of ramp meet each other. Bullnose may include or exclude curb and gutter.
Bus Only lane (BOL), busway, or transitway[b]	Managed lane dedicated primarily to buses
Channelization	The separation and direction of traffic movements and pedestrians into

	defined paths at an at-grade intersection through the use of geometric features, pavement markings and traffic control devices.
Choker (Curb Bulb)	A narrowing of a roadway, either at an intersection or mid-block, in order to reduce the width of the roadway surface.
Clear Zone[a]	The unobstructed, traversable area provided beyond the edge of the through travelled way available for use by errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes. The clear zone also includes recoverable slopes, and non-recoverable slopes with a clear run-out area. The selected clear zone width is dependent upon traffic volumes and design speed, and roadside geometry.
Climbing Lane	A lane added on the right side of a roadway on an upgrade intended for use by trucks and other slow vehicles to discourage these vehicle types from using the through lanes.
Collector Lanes[a]	Those lanes of an express/collector system separated from express lanes by an outer separation.
Collector Road	A road on which traffic movement and access have similar importance.
Collision	An event in which travel by a vehicle results in the vehicle being in an inappropriate location, or in an appropriate location at an inappropriate time, culminating in unwanted contact with a fixed object, vehicle, other roadway user or other obstacle.
Collision-Free	Circumstances under which a collision will never occur, i.e. "absolute" safety.
Commercial Motor Vehicle (CMV)[b]	A motor vehicle having a permanently attached truck or delivery body, including fire apparatus, busses, and truck tractors and trailers (combination units) used for hauling purposes on the highways, and requiring a Commercial Vehicle Operating Registration (CVOR).
Construction Work Zone[b]	An area occupied for three or more days for the purpose of constructing, reconstructing, rehabilitating, or performing preventive maintenance. A construction work zone extends from the first Temporary Traffic Control (TTC) device to the last TTC device.
Continuous Right-Turn Auxiliary Lane	A right-turn lane that is continuous for a significant distance serving a number of driveways.
Controlled Access	The condition where the opportunity for access to a roadway is controlled by public authority.
Corner Clearance	The distance between the near curb of a street intersection and the

	near edge of a driveway throat or public lane.
Crash	Not used. (See "Collision")
Crash Cushion[a]	An energy attenuating system which provides a physical limitation through which an errant vehicle would not normally penetrate. It is intended to contain or redirect or stop an errant design vehicle of a particular size range, at a given speed and angle of impact.
Crest Vertical Curve	A vertical curve having a convex shape in profile viewed from above.
Criterion	A value, determined either by mathematical relationships or by experience, that represents the degree of excellence required for a particular application, acknowledged as appropriate for that application where prevailing conditions are normal and typical, recognizing that in atypical circumstances some variation may be appropriate. It may be regarded as a basis for assessing existing designs and formulating opinion on their quality, but is not treated as a rigid value to which there is any obligation for designs to conform.
Cross Fall (Cross Slope)	The average grade between edges of a cross section element.
Crossover[b]	Any portion of a roadway distinctly indicated for pedestrian crossing by signs on the highway and lines or other markings on the surface of the roadway as prescribed by the regulations and the Highway Traffic Act, with associated signs Ra-4, Ra-4t, Ra-5L, Ra-5R, Ra-10, and Ra-11.
Cross Section	The transverse profile of a road.
Cross Street	A street of lower classification that crosses a roadway of higher classification, either at grade or passing over or beneath.
Crosswalk[a]	Any portion of a roadway, at an intersection or elsewhere, distinctly indicated for pedestrian crossing by appropriate pavement markings and/or signs, or by the projections of the lateral lines of the sidewalk on opposite sides of the road.
Crown	The highest break point of the surface of a roadway in cross section.
Cul-De-Sac	A road opens at one end only.
Curb	A structure with a vertical or sloping face along the edge of a lane or shoulder strengthening or protecting the edge or clearly defining the edge.
Curb Drop	The transition length required to decrease the curb height to accommodate a driveway or sidewalk ramp.

Curb and Gutter[b]	Curb and gutter is placed adjacent to an outside lane or shoulder and is intended to control and conduct storm-water and also provides delineation for traffic. In some instances, curb is introduced without a gutter.
Curb Return	The curved section of curb used at intersections or driveways in joining straight sections of curb.
Curve to Spiral (CS)	The point of alignment changes from circular curve to spiral curve, in the direction of stationing.
Curvilinear Alignment	An alignment in which the majority of its length is circular and spiral curve.
Cut[b]	A roadway located below natural ground elevation is said to be in cut.
Cut Side Slope[b]	Where the roadway is in cut, the slope between the road-way and drainage channel is referred to as a cut side slope.
Deceleration Lane[a]	An auxiliary lane to enable a vehicle exiting from a roadway to reduce speed after it has left the through traffic lanes as applied at channelized intersections, or as speed-change lane at interchanges.
Decision Sight Distance	The distance required for a driver to detect an information source or hazard which is difficult to perceive in a roadway environment that might be visually cluttered, recognize the hazard or its potential threat, select appropriate action, and complete the manoeuvre safety and efficiently.
Deflection Angle	The angle between a line and the projection of the preceding line.
Departure Taper	The taper required beyond a flared intersection to laterally shift the through lanes to the left, back to a normal alignment or cross section.
Design Consistency	An indication of the quality of design offered by a roadway.
Design Controls[b]	Factors outside the designer's discretion that may affect the design process and designed solution. Examples include traffic volumes, vehicle size and weight, atmospheric conditions, driver, and other human characteristics.
Design Criteria[b]	Characteristics by which the sufficiency of a design feature may be assessed.
Design Exception	A "Design Exception" is a documented decision to design elements of highway for criteria that do not meet minimum values or ranges established in the highway standards, policies or specifications.
Design Features[b]	Geometric and dimensional characteristics of the roadway and

	roadside, including horizontal and vertical alignment and cross-sectional elements.
Design Speed[a]	A speed selected for purposes of design and correlation of the geometric features of a road and is a measure of the quality of design offered by the road. It is the highest continuous speed at which individual vehicles can travel with safety on a road when weather conditions are favourable and traffic density is so low that the safe speed is determined by the geometric features of the road.
Design Hour Volume (DHV)	An hourly traffic volume selected for use in geometric design.
Desirable Value[b]	The value at the top of a range of values in a design standard, or the discreet value when a range is not given in a design standard.
Desired Speed	The Operating Speed that drivers will adopt on the less constrained alignment elements of a reasonably uniform section of road (e.g., the longer straights and large radius horizontal curves) when other vehicles or users do not affect their speed choice.
Detour[b]	A construction work zone mitigation strategy wherein traffic in one or both directions is rerouted onto an existing highway to avoid a construction work zone. Detoured vehicles may travel on permanent roads only or on a combination of permanent and temporary roads. This strategy compensates for the removal of permanent travel lanes from service.
Development Roadway	A roadway whose primary purpose is to provide access to undeveloped areas.
Diversion[b]	A construction work zone mitigation strategy wherein traffic in one or both directions on a designated route is carried by a temporary roadway around a work area and reconnected with the permanent infrastructure of the designated route. This strategy compensates for the removal of permanent travel lanes from service.
Double Left-Turn Lanes	A pair of adjacent lanes intended for the exclusive use of vehicles about to turn left. Interchangeable with dual left-turn lane.
Drainage Channel[a]	A drainage channel is placed adjacent to an outside lane or shoulder and is intended to control and conduct storm-water runoff. A shallow drainage channel is sometimes referred to as a swale.
Earth Roadway	A roadway that has a driving surface consisting of subgrade material.

Easement	A right acquired by public authority to use or control property for a designated purpose.
Effective Wheelbase (EWB)	The distance from the centroid of the front axle group to the centroid of the rearmost axle group, which significantly influences the turning envelope. For two-axle vehicles, total and effective wheelbase are the same.
Emergency Turnouts[b]	Segments of wider-than-typical shoulder. May be provided as disabled vehicle refuge at regular intervals or where conditions permit on roadways (perhaps temporary) where it is not practical to provide a continuous full-width shoulder. May also be referred to as intermittent shoulders.
End Treatment	The method by which the end of a barrier facing on-coming traffic is treated to minimize its hazard.
Energy Attenuator	See “Crash Cushion”.
Entrance	The general area where turning roadway traffic enters the main roadway.
Entrance Terminal	The part of an entrance comprised of acceleration lanes or speed change lanes, including the ramp proper up to the ramp controlling curve.
Exit	The general area where turning roadway traffic departs from the main roadway.
Exit Terminal	The part of an exit comprised of deceleration lanes or speed change lanes, including the ramp proper up to the ramp controlling curve.
Express Lanes[a]	Managed lane that restricts access or a ML that employs electronic tolling in a freeway right-of-way with or without access restrictions. Express lanes can be located within tolled or non-tolled facilities and may be operated as reversible flow or bi-directional facilities to best meet peak demands.
Express-Collector System	A freeway in which the through or express lanes are physically separated from the collector lanes.
Express toll lane (ETL) [b]	ETL is a limited access managed lane employing electronic tolling that charges users’ toll, and they do not exempt high occupancy vehicles.
Expressway	A divided arterial road for through traffic with full or partial control of access and with some interchanges.
False Grading	The practice of distorting the profile of a roadway, relative to the top of

	curb, so as to avoid flat grades in order to effect drainage.
Fill[b]	A roadway located above the natural ground elevation is said to be in fill.
Fill Side Slope[b]	Where the roadway is in fill, the slope between the roadway and the natural ground is referred to as the fill side slope or sometimes the fill slope.
Flare	The variable offset distance of a barrier to place it further from the travelled way.
Flexible Barrier	A form of the longitudinal barrier that is intended to redirect an errant vehicle by rail tension, usually through a system of cables installed in tension.
Four-Lane Divided Highway[b]	A highway consisting of four (4) through lanes total, with two (2) through lanes in each direction which are separated by an unpaved area or physical barrier, including but not limited to a curbed island.
Four-Lane Road[b]	A road that provides two through lanes of traffic in each direction.
Frangible	Readily or easily broken upon impact.
Freeway[a] (Multi-Lane Freeway)	A multi-lane, divided highway with more than four (4) through lanes total (two (2) through lanes in each direction) with a continuous dividing median. This highway is a fully controlled access road limited to through traffic, with access through interchanges and a posted speed of greater than 90km/h. See also “Staged Freeway”
Friction Factor	The coefficient of friction between tire and roadway, measured either longitudinally or laterally.
Front Overhang (FOH)	The distance from the front bumper of a vehicle to the centroid of its front axle group.
Frontage Roadway	A road contiguous to a through road so designed as to intercept, collect and distribute traffic desiring to cross, enter or leave the through road and to furnish access to property.
Full Road Closure[b]	A construction work zone mitigation strategy wherein traffic operations are removed or suspended in either one or two directions on a segment of roadway or ramp.
Geometric Design	The selection of the visible dimensions of the elements of a road.
Gore Area[a]	Area between edge of highway, edge of ramp and bullnose.
Grade Separation	Vertical separation of two intersecting roadways or a roadway and a

	railway.
Gradient (Grade)[a]	The rate of rise or fall with respect to the horizontal distance; usually expressed as a percentage.
Gravel Road	A road that has a driving surface consisting of granular material.
Guiderail (Guardrail)	See “Barrier”.
Guidelines	Outlines of acceptable practice.
Gutter	A paved shallow waterway provided for carrying surface drainage.
Gutter Line	The bottom of the curb face where it meets the concrete gutter, or the paved surface where a gutter is not employed.
Gutter Lip	The edge of a concrete gutter opposite the curb where it meets the paved roadway.
Hazard	Any obstacle or other feature such as an embankment, or a body of water of depth greater than 1 m which, without protection, is likely to cause significant injury to the occupants of a vehicle encountering it.
Heuristic	An aid to design based on experience - a "rule of thumb".
High-Occupancy-Toll (HOT) Lane, also referred to as Value-Priced lanes [b]	HOV lane that is electronically tolled for single- or lower occupancy vehicles and free to higher-occupancy vehicles
High-Occupancy-Vehicle (HOV) Lane[a]	Managed lane restricted primarily to high-occupancy vehicles (no tolling applied)
High-Speed Highway[b]	A road or highway on which traffic operates with an 85th-percentile free-flow speed of 80 km/h or greater.
Highway	Synonymous with roadway but generally limited to higher-speed roadways in rural areas.
Horizontal Alignment[a]	The configuration of a road or as seen in plan, consisting of tangents, lengths of circular curve, and lengths of spiral or transition curves.
Horizontal Curve	A circular curve to plan to provide for change of direction.
Independent Alignment	A divided highway in which each roadway is designed independently both in horizontal and vertical alignment, to take advantage of topographical features.
Inside Lane	The left lane in one direction of a roadway with two or more lanes in that direction also referred to as an inner lane.
Interchange	A grade-separated intersection with one or more turning roadways for travel between the through roads.

Intermittent Closure[b]	A construction work zone mitigation strategy wherein all traffic in one or both directions is stopped for a relatively short period to allow for construction operations.
Intersection (At-Grade)	The general area where two or more roads join or cross, within which are included the roadway and roadside facilities for traffic movements.
Intersection Approach	That part of an intersection leg used by traffic approaching the intersection.
Intersection Sight Distance (ISD)	The sight distance to left and right available to a driver intending to execute a maneuver onto a through roadway from an intersecting roadway.
Island	A defined area between traffic lanes for control of vehicle movements or for pedestrian refuge and the location of traffic control devices.
King's Highway[b]	An administrative classification referring to all Provincial numbered lower than 500, and including the Queen Elizabeth Way (Q.E.W.). While "Freeways" fall under the administrative classification of a King's Highway, they have their own functional classification that differs from other King's Highways.
Lane (Traffic Lane)	A part of the travelled way intended for the movement of a single line of vehicles.
Lane Closure[b]	A construction work zone mitigation strategy wherein one or more travel lanes and any adjacent shoulders are closed to traffic. As defined here, this term is not limited to closing one lane of a multilane highway. Lane closures are inherent to median crossovers.
Lane Constriction[b]	A construction work zone mitigation strategy wherein the width of one or more travel lanes is reduced. The number of travel lanes may be retained (possibly through median or shoulder use) or reduced.
Left-Turn Lane	A lane added on the approach to an intersection for the exclusive use of left-turning vehicles.
Length of Need	Total length of a longitudinal barrier needed to shield an area of concern.
Local Roadway	A road intended to provide access to development only.
Long Combination Vehicle (LCV)	A combination of a tractor and trailer(s) used for special purposes, with an overall length greater than 25 m. Examples are 'triples' and 'turnpike doubles'.
Longitudinal Barrier[a]	A barrier placed adjacent to a roadway, intended to contain a vehicle leaving the normal travel path, by re-directing it.

Low Volume Roadway[a]	A road with average daily traffic of 200 vehicles per day of less, and whose service functions are oriented toward rural road systems, roads to or within isolated communities, recreation roads and resource development roads.
LRT	Light rail transit.
Mainline	The principal route.
Median[a]	The area that laterally separates traffic lanes carrying traffic in opposite directions. A median is described as flush, raised or depressed, referring to the general elevation of the median in relation to the adjacent edges of traffic lanes. The terms wide and narrow are often used to distinguish different types of median. A wide median generally refers to depressed medians sufficiently wide to drain the base and subbase into a median drainage channel. Flush and raised medians are usually narrow medians.
Median Barrier[a]	A longitudinal barrier placed in the median to prevent a vehicle from crossing the median and encountering oncoming traffic or to protect a vehicle form a fixed object in the median.
Median Crossover[b]	A construction work zone mitigation strategy used on freeways and multilane divided highways to establish two-way traffic. In this strategy: • The number of lanes in both directions is reduced; • At both ends, traffic in one direction is routed across the median to the opposite-direction roadway on a temporary roadway constructed for that purpose; and • Two-way traffic is maintained on one roadway while the opposite direction roadway is closed. This strategy involves the inherent use of median crossovers, and this strategy may be employed in combination with use of shoulder.
Merging-End	The physical end of an entrance terminal between the outer travel lane and the ramp, beyond which traffic merges. Also known as the painted wedge.
Minimum Passing Sight Distance	The least visible distance required by a driver in order to make a passing manoeuvre safely, based on a given set of circumstances.
Minimum Stopping Sight Distance	The least stopping sight distance required by a driver to come to a stop under prevailing vehicle, pavement and climatic conditions.
Minimum Turning	The radius of the path of the outside of the outer front wheel for the

Radius (TR)	minimum radius turning condition. In former TAC Design Guides, this dimension was used to denote the minimum design turning radius.
Minimum Value[b]	The value at the bottom of a range of values in a design standard.
Multi-Lane Roads[b]	Roads having more than two through lanes of traffic in each direction. In the Traffic and Capacity chapter Multilane refers to four lanes or more.
Multi-Use Path (MUP)	A path with multiple users of different types (e.g., pedestrians, bicycles, and similar user types); a MUP may be shared (all users share the same pathway space, with or without a marked centre line) or may be separated (i.e., the pathway is separated into parallel travelled ways, e.g. one exclusively for pedestrians and one exclusively for bicycles).
Multi-Use Trail (MUT)	See “Multi-Use Path”.
Narrow Median[b]	A median without an unpaved area or physical barrier between opposing through lanes.
Noise Berm/Barrier	A physical barrier, consisting of compacted earth in a trapezoidal shape, used as a means of minimizing the transmission of traffic sounds.
Normal Crown	A cross section in which adjacent surfaces slope in opposite directions from the centre line or a lane edge to effect drainage to the sides.
Nominal Safety	Nominal safety is a consideration of whether the highway design elements meet minimum design criteria. For example, if design features such as lane width, shoulder width, lateral clearance, etc. meet the minimum values or ranges, the highway proposed design is considered to have nominal safety.
Obstacle[a]	Any fixed object which is likely to cause significant injury to occupants of a vehicle encountering it. Or Any non-breakaway and non-traversable feature within the roadside environment greater than 100mm in height that can increase the potential for personal injury and vehicle damage when struck by an errant vehicle leaving the roadway.
Offset Mid-Block Crossing	A pedestrian crossing on a divided roadway in which the alignment of the crossing is staggered at the median.
One-lane One-way Road	A road with one lane that carries one-directional traffic.

One-lane Two-way Road	A road that provides sufficient roadway width for the safe passing of opposing vehicles.
Operating Speed	The 85th percentile speed of vehicles at a time when traffic volumes are low and drivers are free to choose the speed at which they travel.
Outer Separation[a]	A reserve on freeways (including shoulders) between lanes carrying traffic in the same direction.
Outside Lane	The right lane in one direction on a roadway with two or more lanes in that direction (also referred to as an outer lane).
Overall Length	The distance between the front bumper of the power vehicle and the rear bumper on the rear unit of a vehicle or trailer combination. It equals the sum of its effective wheelbases, front overhand and rear overhang.
Overpass (vehicle)	A grade separation in which the subject road passes over an intersecting road or railway.
Painted Wedge	See “Merging-End”.
Parameter	A quantity that is a variable in the general case and is constant in the specific case under consideration. (Radius of circular curve is an example, in which radius varies from one curve to another but for one particular circular curve is the same at any point on the curve~~.~~).
Parclo	An abbreviation for the PARtial CLOverleaf interchange, a grade separation having loop ramps in fewer than all four quadrants.
Parking Lane	A supplementary lane intended for parking.
Passing Lane	A supplementary lane intended for passing.
Passing Opportunity	The distance ahead required to be visible to a driver to initiate a passing maneuver safely.
Passing Sight Distance	The distance ahead visible to the driver available to complete a passing maneuver.
Perception Time[b]	The time that elapses from the instant that a driver observes an object for which it is necessary to stop, until the instant that he decides to take remedial action.
Platform Intersection	An intersection in which the area common to the two roadways is at the same elevation as the top of curb or sidewalk.
Policy	Principle, course of action, or strategy adopted by government, government agency or technical organization that reflects prevailing community values, intended to provide direction and guidance in the

	selection of technical and non-technical criteria for general application, and specific dimensions in the planning and design process. Policy necessarily incorporates some element of political or other non-technical community viewpoints.
Posted Speed	A speed limitation introduced for reason of safety, economy, traffic control and government regulatory policy aimed at encouraging drivers to travel at an appropriate speed for surrounding conditions.
Public Lane (Alley)	A narrow minor street, usually without sidewalks, located at the rear of lots for vehicle access to garages or other parking spaces and which also serves as a utility right of way.
Raised Crosswalk	A crosswalk on a curbed street whose elevation is the same as the top of curb or sidewalk.
Ramp	A turning roadway to permit the movement of traffic from one highway to another.
Reaction Time	The time that elapses from the instant a visual stimulus is perceived by a driver to the instant the driver takes remedial action.
Rear Overhang (ROH)	The distance from the rear bumper of a vehicle to the centroid of its rearmost axle group.
Recovery Area	Generally synonymous with clear zone.
Retrofit	The reconstruction of an existing roadway with geometric improvements.
Reverse Crown	A typical surface cross section in which adjacent surfaces slope in the same direction at the normal crown.
Reverse Curve	Two curves, curving in opposite directions from a common point.
Right-Of-Way (ROW)	The area of land acquired for or devoted to the provision of a road.
Right-Turn Lane	A lane added on the approach to an intersection for the exclusive use of right-turning vehicles.
Right-Turn Taper	The taper from the edge of the through lane to the beginning of a right-turning roadway at an intersection, where an auxiliary lane is not used.
Rigid Barrier	A form of longitudinal barrier that is intended to redirect an errant vehicle with minimum deflection in the barrier system and usually consist of a continuous concrete mass.
Road	The entire right-of-way comprising a common or public thoroughfare, including a highway, street, bridge and any other structure incidental thereto.

Roadside	The area adjoining the outer edge of the roadway.
Roadside Barrier	A longitudinal barrier used to shield roadside obstacles or non-traversable terrain features. It may occasionally be used to protect pedestrians from vehicle traffic.
Roadside Environment[b]	The portion of the ROW beyond the roadway, including medians, not designed for vehicular use. The roadside environment may include a variety of surfaces and slopes, fixed Obstacles (such as signs, poles, bridges piers, abutments, culverts, ditches, sideslopes, backslopes, barrier systems, crash cushions, etc) and natural features (such as water bodies, trees and other vegetation, boulders and rock outcrops, etc).
Roadway	That part of the road that is improved, designed or ordinarily used for the passage of vehicular traffic, inclusive of the shoulder.
Roadway Hump	A speed control device in which the roadway surface is raised over a length of about 3.5 to 4.0 m to a maximum height of 80 mm.
Roundabout	A channelized intersection in which traffic moves counterclockwise around a centre island of sufficient size to induce weaving movements in place of direct crossings. It is sometimes referred to as a rotary or traffic circle.
Rounding[a]	Width between edge of shoulder and cut or fill slope.
Rumble Strips	Indentations in the surface of a paved shoulder that provide an audible or tactile warning to a driver that the vehicle has left the travelled lane.
Runout Length[b]	The distance parallel to the roadway, measured from the object to the point of vehicle encroachment. This distance varies with design speed and traffic volume.
Rural Area	An area characterized by low density development on large parcels.
Safety Zone[a]	An area officially established within a roadway for the exclusive use of pedestrians, protected or so indicated as to be plainly visible.
Sag Vertical Curve	A vertical curve having a concave shape in profile viewed from above.
Secondary Highway[b]	An administrative classification referring to all 500, 600, and 700-Series Provincial Highways.
Semi-rigid Barrier[a]	A form of longitudinal barrier that is intended to direct an errant vehicle by a system of steel beam action to adjacent posts.
Service Road	Same as frontage road but not necessarily contiguous with the through road.

Severity Index[b]	A number from zero to ten used to categorize the potential severity of an encroachment or impact by an errant vehicle for a range of design speeds over a variety of surfaces and slopes, fixed objects and natural features within the roadside environment. The number is used for evaluating alternative safety treatments.
Shared Street	A street designed to be shared by pedestrians, cyclists, and slow-moving motorists, with no physical separation of modes and typically an emphasis on use as a livable public space.
Shielding	The introduction of a barrier or crash cushion between a vehicle and an obstacle or area of concern to reduce the severity of impacts of errant vehicles.
Shoulder[a]	Areas of pavement, gravel or hard surface placed adjacent to through or auxiliary lanes. They are intended for emergency stopping and travel by emergency vehicles only. They also provide structural support for the pavement.
Shoulder Closure[b]	A construction work zone mitigation strategy wherein a shoulder is closed to traffic.
Shy-Line Offset	A distance beyond which a roadside object will not be perceived by a driver to be a threat, to the extent of changing lane position or speed.
Sidewalk	A travelled way intended for pedestrian use, following an alignment generally parallel to that of the adjacent roadway.
Sight Distance	From any given point, the unobstructed distance a driver can see, usually along the roadway ahead.
Sight Distance at Intersection[b]	See "Intersection Sight Distance".
Sight Triangle	The triangle formed by the line of sight and the two sight distances of drivers, cyclists or pedestrians approaching an intersection on two intersecting streets.
Simple Open Throat Intersection[a]	A simple or un-channelized intersection where additional area of pavement may be provided for turning of large vehicles.
Slot Left-Turn Lane	On a divided roadway, a left-turn lane which is angled and situated entirely within a wide median to accommodate a divisional island between the left- turn lane and the adjacent through lane.
Speed Hump	See "Roadway Hump".
Speed Change Lane	A deceleration or acceleration lane.

Spiral Parameter (A)[a]	"A" designates the sharpness of the spiral. It is a measure of the flatness of the spiral, the larger the parameter, the flatter the spiral.
Spiral to Curve (SC)	The point of change form spiral curve to circular curve, in the direction of stationing.
Spiral to Tangent (ST)	The point of change from spiral curve to tangent, in the direction of stationing.
Spline	A flexible drafting tool used to draw curved lines of varying radii.
Staged Freeway[b]	A freeway (typically rural) that is planned to be a multi-lane dived freeway that is built using staged construction. In the plans for each stage of development, provisions should be made to adapt each stage to the next or the ultimate stage (completion). The transition should be made with minimum waste of the exiting plant and minimum interference to traffic. Typically, this might include treatments such as interim at-grade intersections in lieu of interchanges.
Standard	A value for a specific design feature, which practice or theory has shown to be appropriate for a specific set of circumstances, where no unusual constraints influence the design.
Steering Angle	The angle between the longitudinal axis of the vehicle and the direction of the steering wheels, limited by the dimensions of parts of the steering mechanism.
Stop Block[b]	Pavement marking to indicate where vehicles are required to stop for a traffic control device.
Stopping Distance	The distance travelled by a vehicle from the instant the driver decides to stop, to coming to a stop.
Stopping Sight Distance	The distance between a vehicle and an object, for which the driver decides to stop, to the instant the vehicle begins to come into view.
Street	Synonymous with road, but generally limited to lower speed roads in urban areas.
Street Furniture	Practical and decorative features introduced into the streetscaping, intended to enhance the comfort, convenience and aesthetic quality of the roadway environment.
Streetscaping	The practice of applying aesthetic treatments to the street and its facilities, intended to enhance the quality of the roadway environment.
Suburban Area	An area characterized by larger scale developments. Building coverage and development density can vary, but typically are less than in Urban Areas.

Substantive Safety	Substantive Safety is the expected or estimated long-term average, safety performance of a roadway. The concept of substantive encompasses methods for estimating the following expected quantitative measures: • Collision Frequency • Collision types • Collision severity
Summer Average Daily Traffic (SADT)[b]	The average 24-hour, two-way traffic for the period July 1st to August 31st including weekends.
Superelevation	The gradient measured at right angles to the centre line across the roadway on a curve, from the inside to the outside edge.
Superelevation Runoff	The transition between a typical section of normal crown and a fully superelevated section. (See also Tangent Runout.)
Surfaced Roadway	A roadway in which the travelled lanes have been hard surfaced, usually by some form of bituminous or concrete surface.
Swale	A shallow drainage channel.
Tangent Runout	The length of road needed to accomplish the change in cross slope from a normal cross-section to a section with the adverse crown removed.
Tangent to spiral (TS)	The point of alignment change from tangent to spiral curve, in the direction of stationing.
Taper	Where an auxiliary lane is being developed or terminated, the straight-line transition from the edge of the through lane to the beginning of the full width auxiliary left- or right-turn lane.
Target Speed	The speed at which the designer intends for traffic to operate.
Temporary Construction Barrier[b]	A temporary construction traffic barrier is a portable construction safety shape barrier.
Temporary Roadway[b]	A roadway constructed to carry highway traffic exclusively during construction. Temporary roadways are used in conjunction with diversion and median crossover work zone strategies and may be used with a detour work zone mitigation strategy.
Temporary Traffic Control[b]	A construction work zone mitigation strategy wherein devices and measures are used to facilitate road users through work zones.
Terminal[b]	A crashworthy end treatment or crashworthy anchor used at the end of

	a barrier system.
Tertiary Highway[b]	An administrative classification referring to all 800-Series Provincial Highways.
Throat Length	The provision of sufficient unobstructed on-site driveway length to prevent stopped vehicles from blocking the path of entering vehicles or vehicles travelling along the circulation roadways on site.
Through Lane	A lane intended for through traffic movement.
Toll Lane (Toll Road) [a]	A road open to traffic only upon payment of a direct toll or fee; sometimes called tollway, throughway, turnpike or auto-route. (may not be a managed lane if travel benefits are not assured)
Total Wheelbase (TWB)	The centre-to centre distance from the front axle to the rearmost axle of a tractor-trailer combination. (The nomenclature used for design vehicles is based on total wheelbase, for example "WB-19" refers to a tractor-semitrailer having a total wheelbase of approximately 19 m.)
Traffic Barrier/Barrier[b]	Traffic barriers are placed adjacent to a roadway to protect traffic from hazardous objects either fixed or moving (other traffic). Barriers placed in a median are referred to as median barriers and may be placed in flush. Raised or depressed medians.
Traffic Management Plan[b] (TMP)	A strategy to manage the work zone impacts of a project. Each TMP will include a Traffic Staging Plan.
Traffic Staging Plan[b] (TSP)	Drawings showing the plan, profile, cross section, signage and pavement markings of a specific stage of the work zone.
Trail	A beaten or maintained path or track often for a specified type of traffic (e.g. ski trail).
Transit Lane	A lane intended primarily for public transit vehicles.
Transition	A method by which a change in longitudinal barrier type provides continuous protection to errant vehicles.
Transition (spiral) curve	A curve whose radius continuously changes.
Travelled Way[a]	That part of a roadway intended for vehicular travel. This includes through lanes, turn lanes, and other auxiliary lanes. This does not include shoulders or ancillary space. It may have a variety of surfaces but is most commonly hard surfaced with asphalt or concrete or gravel surfaced.
Truck Escape Ramp	A ramp provided on the right side of a long downhill section of roadway

(TER)	to allow vehicles (usually trucks) to escape in the event of brake failure.
Turning Roadway	A separate roadway or ramp to accommodate turning traffic at the intersection or interchange of two roads.
Turnout	A widened section of roadway provided for passing of vehicles travelling in opposite directions on a one-lane roadway, or in the same direction on a two-lane roadway.
Two-Lane Road	A road that provides for one lane of through traffic in each direction.
Two-Way Left-Turn Lane (TWLTL)	The middle lane on a two-way undivided street intended for the exclusive use of vehicles about to turn left from either direction into property accesses.
Underpass	A grade separation in which the subject roadway passes under a roadway or railway.
Use of Shoulder[b]	A construction work zone mitigation strategy involving the use of a right-side or median shoulder as all or part of a temporary traffic lane. This strategy compensates for the removal of permanent travel lanes from service. Employing this strategy may require constructing or upgrading shoulder pavement structures to adequately support traffic loads.
Urban Area	An area characterized by extensive development and building coverage.
Vertical Alignment[a]	The configuration of a road or roadway as seen in longitudinal section, consisting of tangents and parabolic curves.
Vertical Curvature (K)	The horizontal distance along a parabolic curve required to effect a one percent change in gradient.
Vertical Curve[a]	A parabolic curve on the longitudinal profile or in a vertical plane of a road to provide for change of gradient.
Warrant[a]	A criterion that identifies a potential need or the justification for an addition to the highway such as traffic signals, traffic barrier, truck climbing lanes, passing lanes, left turn lanes etc.
Waterbody[b]	Any natural or constructed body of water.
Watercourse[b]	Any stream, river, or channel in which flow of water occurs either continuously or intermittently.
Weaving	The condition in which vehicles move obliquely from one lane to another, and cross the paths of other vehicles moving in the same direction.
Weaving Lane	A lane added to provide additional capacity and operational

	improvement in sections of roadway experiencing weaving.
Weaving Section	A section of roadway between an entrance and an exit, such that the frequency of lane changing exceeds that for open highway condition.
Wide Median[b]	A median on a divided roadway and/or freeway consisting of an unpaved area or physical barrier between opposing through lanes.
Work Zone Design Speed[b]	A selected speed used to determine specific work zone geometric design features.

NOTES:

a These definitions are modified from the Glossary of TAC Geometric Design Guide for Canadian Roads - June 2017.

b These definitions are in addition to the Glossary of TAC Geometric Design Guide for Canadian Roads - June 2017.

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MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix B

Geometric Design Standards Summary Tables

June 2023

Overview

The summary tables presented in this document are to act as a tool utilized during the creation of Design Criteria(s) (DC). The information presented in these tables are extracted from the *Transportation Association of Canada (TAC) Geometric Design Guide for Canadian Roads,* the *MTO Design Supplement for TAC Geometric Design Guide for Canadian Roads* and the *Roadside Design Manual.*

The values presented in the summary tables are the standard minimum values of attributes, for a 6% superelevation. It is MTO common practice to use a maximum superelevation of 6%, however, if a differing superelevation is to be used, the standard values presented in these tables will be incorrect, and the designer must refer to the source documents (the *Transportation Association of Canada (TAC) Geometric Design Guide for Canadian Roads,* the *MTO Design Supplement for TAC Geometric Design Guide for Canadian Roads* and the *Roadside Design Manual*) to determine the proper values.

Notes and terminology included in this document have been taken directly from the above-mentioned source documents where possible, which may result in minor terminology discrepancies. However, in a few cases minor modifications have been made for clarity purposes.

The use of these tables does not remove the obligation from designers to base their designs on the source documents. This document should be considered more of a tool for checking design parameters obtained. In the event of a discrepancy between this document and the source documents, the source documents shall take precedence.

GEOMETRIC DESIGN STANDARDS FOR RURAL KING'S HIGHWAYS (6% SUPERELEVATION)

Design Speed	Design Year Traffic Volume		Max Grade	Width (meters)			Minimum Curves			Min. Stopping Sight Distance
							Horiz.	Vertical		
km/h	AADT	DHV	%	Lane	Shoulder	Rounding	Radius (m)	K-Crest	K-Sag	m
130	>4000	>600	3	3.75	3.00	1.00	950	130	80	285
120	>4000	>600	6 - 7	3.75	3.00	1.00 (I)	750	100	70	250
	3000-4000	450-600	-	-	-					
	2000-3000	300-450	-	-	-					
	1000-2000	150-300	-	-	-					
	400-1000	60-150	-	-	-					
	<400	<60	-	-	-					
110	>4000	>600	6 - 7	3.75	2.50 (E)	1.00 (I)	600	80	60	220
	3000-4000	450-600	6 - 7	3.75	2.50 (E)					
	2000-3000	300-450	6 - 7	3.75	2.50					
	1000-2000	150-300	6 - 7	3.50 (C)	2.50					
	400-1000	60-150	-	-	-					
	<400	<60	-	-	-					
100	>4000	>600	6 - 8	3.75	2.50 (E)	1.00 (I)	450	60	45	185
	3000-4000	450-600	6 - 8	3.50 (A)	2.50					
	2000-3000	300-450	6 - 8	3.50 (B)	2.50					
	1000-2000	150-300	6 - 8	3.50	2.00 (G)					
	400-1000	60-150	6 - 8	3.50	1.00					
	<400	<60	-	-	-					
90	>4000	>600	6 - 8	3.50 (A)	2.50	0.50 (I)	340	40	40	160
	3000-4000	450-600	6 - 8	3.50 (A)	2.50					
	2000-3000	300-450	6 - 8	3.50	2.00 (F)					
	1000-2000	150-300	6 - 8	3.25	2.00					
	400-1000	60-150	6 - 8	3.25	1.00					
	<400	<60	-	-	-					
80	>4000	>600	6 - 8	3.50	2.50	0.50 (I)	250	30	30	130
	3000-4000	450-600	6 - 8	3.50	2.50					
	2000-3000	300-450	6 - 8	3.25	2.00					
	1000-2000	150-300	6 - 8	3.25	2.00					
	400-1000	60-150	6 - 8	3.25	1.00					
	<400	<60	8	3.25 (D)	1.00 (H)					
70	>4000	>600	-	-	-	0.50 (I)	190	18	25	105
	3000-4000	450-600	6 - 12	3.25	2.00					
	2000-3000	300-450	6 - 12	3.25	2.00					
	1000-2000	150-300	6 - 12	3.00	1.00					
	400-1000	60-150	6 - 12	3.00	1.00					

	<400	<60	12	3.00	1.00 (H)					
60	>4000	>600	-	-	-	0.50 (I)	130	12	18	85
	3000-4000	450-600	-	-	-					
	2000-3000	300-450	-	-	-					
	1000-2000	150-300	6 - 12	3.00	1.00					
	400-1000	60-150	6 - 12	3.00	1.00					
	<400	<60	12	3.00	1.00 (H)					
50	>4000	>600	-	-	-	0.50 (I)	90	8	15	65
	3000-4000	450-600	-	-	-					
	2000-3000	300-450	-	-	-					
	1000-2000	150-300	-	-	-					
	400-1000	60-150	-	-	-					
	<400	<60	12	2.75	1.00 (H)					

NOTES:

A. If commercial motor vehicle percentage exceeds 10% of AADT, increase lane width by 0.25 m.
B. If commercial motor vehicle percentage exceeds 15% of AADT, increase lane width by 0.25 m.
C. If commercial motor vehicle percentage exceeds 25% of AADT, increase lane width by 0.25 m.
D. 3.00m lane width may be acceptable where the type, size, and volume of commercial vehicles are not significant.
E. If commercial motor vehicle percentage exceeds 10% of AADT, increase shoulder width by 0.50 m.
F. If commercial motor vehicle percentage exceeds 15% of AADT, increase shoulder width by 0.50 m.
G. If commercial motor vehicle percentage exceeds 25% of AADT, increase shoulder width by 0.50 m.
H. Shoulder width of 0.50 m is acceptable on King's Highways where there is no foreseeable possibility of the road being paved within a 20-year period. Where guide rail is installed, shoulder width must be 1.00 m.
I. On Major Capital Expansion Projects, desirable rounding width should be as detailed in Table 2-8 of the Roadside Design Manual.

- Minimum lane width for all paved 2-lane King's Highways is 3.50 m.
- For design use DHV if available.
- Minimum usable shoulder width for disabled vehicle: 2.00 m.
- Highway 11:3.50 m minimum lane width, 2.00 m minimum shoulder width.
- Highway 17: 3.75 m minimum lane width, 2.50 m minimum shoulder width.
- Standard lane width increments of 0.25 m.
- Standard shoulder width increments of 0.50 m.
- Lane widths of 3.33m or 3.66m may be encountered on existing highways do to previously used imperial measurements. These lane widths can be maintained if no operational and/or safety concerns are present
- Minimum shoulder width for pavement support: 0.50 m paved, 1.00 m granular surfaced.
- Minimum stopping sight distance is for level terrain only

GEOMETRIC DESIGN STANDARDS FOR SECONDARY HIGHWAYS (6% SUPERELEVATION)

Design Speed	Design Year Traffic Volume		Max Grade	Width (metres)			Minimum Curves			Minimum Stopping Sight Distance
							Horiz.	Vertical		
km/h	AADT	DHV	%	Lane	Shoulder	Rounding	Radius (m)	K-Crest	K-Sag	m
100	>1000	>150	6 - 8	3.50	2.00 (B)	0.50	450	60	45	185
	400-1000	60-150	6 - 8	3.50	1.00					
	<400	<60	-	-	-					
90	>1000	>150	6 - 8	3.25	2.00	0.50	340	40	40	160
	400-1000	60-150	6 - 8	3.25	1.00					
	<400	<60	-	-	-					
80	>1000	>150	6 - 8	3.25	2.00	0.50	250	30	30	130
	400-1000	60-150	6 - 8	3.25 (A)	1.00					
	<400	<60	8	3.25 (A)	1.00 (C)					
70	>1000	>150	6 - 12	3.00	1.00	0.50	190	18	25	105
	400-1000	60-150	6 - 12	3.00	1.00					
	<400	<60	12	3.00	1.00 (C)					
60	>1000	>150	6 - 12	3.00	1.00	0.50	130	12	18	85
	400-1000	60-150	6 - 12	3.00	1.00					
	<400	<60	12	3.00	1.00 (C)					
50	>1000	>150	-	-	-	0.50	90	8	15	65
	400-1000	60-150	-	-	-					
	<400	<60	12	2.75	1.00 (C)					

NOTES:

A. 3.00m lane width may be acceptable where the type, size, and volume of trucks are not significant.

B. If commercial motor vehicle percentage exceeds 25% of AADT (or AADT > 2000) shoulder width to increase by 0.50 m.

C. Shoulder width of 0.50 m is acceptable on where there is no foreseeable possibility of the road being paved within a 20-year period. Where guide rail is installed, shoulder width must be 1.00 m.

- Major secondary highways shall have a minimum lane width of 3.50 m.
- For design use DHV if available.
- Lane width may be increased by 0.25 m to a maximum of 3.50 m if warranted by type, size and volume of commercial motor vehicles.
- Minimum shoulder width for pavement support: 0.50 m paved, 1.00 m granular surfaced.
- Minimum usable shoulder width for disabled vehicle: 2.00 m.
- Minimum stopping sight distance is for level terrain only

GEOMETRIC DESIGN STANDARDS FOR UNDIVIDED URBAN ROADS (6% SUPERELEVATION)

Design Speed	Design Year Traffic Volume		Max Grade	No. of Lanes	Width (metres)	
km/h	AADT	DHV	%		Lane	Parking Lane
80	>6000	>600	6 - 8	4	3.50 - 3.75 (B)	3.00
	3000-6000	300-600	6 - 8	2 - 4 (A)	3.50 - 3.75 (B)	3.00
	2000-3000	200-300	6 - 8	2	3.50	3.00
	1000-2000	100-200	-	-	-	-
	<1000	<100	-	-	-	-
60 - 70	>6000	>600	6 - 12	4	3.50	2.50
	3000-6000	300-600	6 - 12	2 - 4 (A)	3.50	2.50
	2000-3000	200-300	6 - 12	2	3.25	2.50
	1000-2000	100-200	6 - 12	2	3.25	2.50
	<1000	<100	-	-	-	-
50	>6000	>600	-	-	-	-
	3000-6000	300-600	-	-	-	-
	2000-3000	200-300	8 - 12	2	3.00	2.50
	1000-2000	100-200	8 - 12	2	3.00	2.50
	<1000	<100	8 - 12	2	3.00	2.50
40 - 50	>6000	>600	-	-	-	-
	3000-6000	300-600	-	-	-	-
	2000-3000	200-300	-	-	-	-
	1000-2000	100-200	-	-	-	-
	<1000	<100	8 - 12	2	2.75 - 3.00 (B)	2.50

NOTES:

A. Four lanes are appropriate in the upper part of this traffic volume range where there is a measurable capacity deficiency with only two lanes.

B. Upper value is desirable, lower value is acceptable.

- Minimum lane width for all paved 2-lane King's Highways is 3.50 m.
- For design use DHV if available.

GEOMETRIC DESIGN STANDARDS FOR FREEWAYS & DIVIDED HIGHWAYS (6% SUPERELEVATION)

<table>
<tr><th rowspan="2">Design Speed</th><th rowspan="2">Max Grade</th><th colspan="8" rowspan="2">Width (m)</th><th colspan="3">Minimum Curves</th><th rowspan="2">Minimum Stopping Sight Distance</th></tr>
<tr><th>Horiz.</th><th colspan="2">Vertical</th></tr>
<tr><th rowspan="4">km/h</th><th rowspan="4">%</th><th colspan="3" rowspan="2">Lane</th><th colspan="4">Shoulder</th><th rowspan="4">Round</th><th rowspan="4">Radius (m)</th><th rowspan="4">K-Crest</th><th rowspan="4">K-Sag</th><th rowspan="4">m</th></tr>
<tr><th colspan="2">4-Lane Divided</th><th colspan="2">Multi-Lane Freeway</th></tr>
<tr><th colspan="2">4-Lane Divided</th><th rowspan="2">Multi-Lane Freeway</th><th rowspan="2">Left Side</th><th rowspan="2">Right Side</th><th rowspan="2">Left Side</th><th rowspan="2">Right Side</th></tr>
<tr><th>Urban</th><th>Rural</th></tr>
<tr><td>130</td><td>3</td><td>3.75</td><td>3.75</td><td>3.75 (A)</td><td rowspan="5">1.00</td><td>3.00</td><td rowspan="5">2.50 (C)</td><td rowspan="5">3.00</td><td>1.00</td><td>950</td><td>150</td><td>80</td><td>305</td></tr>
<tr><td>120</td><td>3</td><td>3.75</td><td>3.75</td><td>3.75 (A)</td><td>3.00</td><td>1.00</td><td>750</td><td>100</td><td>70</td><td>265</td></tr>
<tr><td>110</td><td>3 - 4</td><td>3.75</td><td>3.75</td><td>3.75 (A)</td><td rowspan="3">(B)</td><td>1.00</td><td>600</td><td>80</td><td>60</td><td>235</td></tr>
<tr><td>100</td><td>3 - 4</td><td>3.75</td><td>3.75</td><td>3.75 (A)</td><td>0.5</td><td>450</td><td>60</td><td>45</td><td>200</td></tr>
<tr><td>90</td><td>4 - 5</td><td>3.75</td><td>3.50</td><td>3.75 (A)</td><td>0.5</td><td>340</td><td>40</td><td>40</td><td>170</td></tr>
</table>

NOTE:

A. For multi-lane freeways, the width of the median lane is be 3.50 m, and all other lanes are to be 3.75 m to minimize overall pavement width. The pavement may be striped to equal lane width.

B. Right side shoulder width for 4-lane divided highways is to be same as for undivided King's Highways. Please refer to ***GEOMETRIC DESIGN STANDARDS FOR RURAL KING'S HIGHWAYS (6% SUPERELEVATION)*** or ***Exhibit 4-J*** in ***MTO Design Supplement for the TAC Geometric Design Guide for Canadian Roads.***

C. Left or median shoulder is 2.50 m. Where a median barrier system is placed, the left median shoulder width varies according to the type of barrier used

D. Multi-Lane Freeway is defined as any divided roadway with greater than two (2) through lanes of traffic in each direction