Roundabout Design Guide

4/27/2023

Revision 2.3

Atlanta, GA 30308

GDOT
Georgia Department of Transportation

This document was developed as part of the continuing effort to provide guidance within the Georgia Department of Transportation in fulfilling its mission to provide a safe, efficient, and sustainable transportation system through dedicated teamwork and responsible leadership supporting economic development, environmental sensitivity and improved quality of life. This document is not intended to establish policy within the Department, but to provide guidance in adhering to the policies of the Department.

Your comments, suggestions, and ideas for improvements are welcomed.

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DISCLAIMER

The Georgia Department of Transportation maintains this printable document and is solely responsible for ensuring that it is equivalent to the approved Department guidelines.

Revision Summary

Revision Number	Revision Date	Revision Summary
1.0	December 2019	N/A

2.0	11/15/2021	The revision of this document dated November 2021 incorporates:
		• The preference to include turbo roundabout features on multilane applications
		• Revision and restructuring of the entire document
		• Portions of the appendices moved into the body of the document and the addition of sections related to:
		    • Acronyms and Definitions
		    • Roundabout types (1.1)
		    • Expandable design (2.1.1)
		    • Design vehicles (3.5)
		    • Roundabout shapes (3.9)
		    • Metering (5.3.3)
		    • Roundabout railroad crossings (6)
		    • Spiral design (Appendix E)

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List of Effective Chapters

Document	Revision Number	Revision Date
List of Effective Chapters	2.3	4/27/23
Table of Contents	2.0	11/15/21
Definitions	2.0	11/15/21
Chapter 1. Introduction	2.1	9/30/22
Chapter 2. Capacity and Operations	2.0	11/15/21
Chapter 3. Geometric Design	2.1	9/30/22
Chapter 4. Designing for Pedestrians and Bicyclists	2.1	9/30/22
Chapter 5. Traffic Control Devices	2.2	4/27/23
Chapter 6. Roundabout Railroad Crossing and Preemption	2.0	11/15/21
Chapter 7. Lighting	2.0	11/15/21
Chapter 8. Landscaping	2.1	11/9/22
Chapter 9. Pavement Design	2.0	11/15/21
Chapter 10. Alternative Concepts for Staging Roundabout Construction	2.0	11/15/21
Appendix A. Practical Design	2.0	11/15/21
Appendix B. OSOW	2.0	11/15/21
Appendix C. High Speed Approach Design	2.0	11/15/21
Appendix D. Roundabout Performance Checks	2.0	11/15/21
Appendix E. Spiral Design	2.0	11/15/21
Appendix F. Vertical Design Best Practice	2.0	11/15/21

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Table of Contents

Revision Summary i
List of Effective Chapters iii
Table of Contents v
Acronyms and Definitions ix
Acronyms ix
Definitions x
Chapter 1. Introduction - Contents 1-i
1.1 Roundabout Types 1-3
1.1.1 Single Lane Roundabouts 1-3
1.1.2 Multilane Roundabouts 1-5
Chapter 2. Capacity and Operations - Contents 2-i
2.1 Roundabout Operational Analysis Process 2-1
2.1.1 Expandable Design 2-3
2.1.2. Common Pitfalls 2-4
2.2 Operational Analysis Software 2-5
2.2.1. SIDRA Intersection 2-5
2.2.2. GDOT'S Roundabout Analysis Tool 2-6
Chapter 3. Geometric Design - Contents 3-i
3.1 Design Process and Workflow 3-1
3.2 Practical Design Considerations 3-2
3.3 Design Criteria 3-3
3.4 Roundabout Functional Area 3-4
3.4.1 Driveway Access/Median Opening 3-4
3.5 Design Vehicle 3-5
3.6 Check Vehicle 3-6
3.6.1 OSOW Permit Types 3-6
3.6.2 OSOW Template Library 3-7
3.7 Circle Location and Alignment of Approaches 3-8
3.8 Circle Size 3-11
3.9 Roundabout Shapes 3-13
3.10 Design of Approaches 3-14
3.10.1 High Speed 3-15
3.11 Entry Curves 3-19
3.12 Fastest Path 3-20
3.13 Stopping Sight Distance 3-25

3.14 Intersection Sight Distance 3-28
3.15 Truck Considerations 3-29
3.15.1 Truck Aprons 3-29
3.15.2 Multilane Roundabout Cases 3-30
3.15.3 Check Vehicle Accommodation 3-33
3.16 Path Alignment 3-34
3.16.1 Entry Path Alignment 3-34
3.16.2 Circulatory Path Alignment 3-39
3.17 Horizontal Alignments & Vertical Design 3-40
3.17.1 Horizontal Alignments 3-40
3.17.2 Profiles 3-40
3.17.3 Grading and Drainage 3-41
3.18 Typical Sections and Curb Types 3-42
3.18.1 Raised Multilane Features 3-47
3.18.2 Mini-Roundabouts 3-49
Chapter 4. Designing for Pedestrians and Bicyclist - Contents 4-i
4.1 Pedestrian Accommodations 4-1
4.2 Bicycle Accommodations 4-4
Chapter 5. Traffic Control Devices - Contents 5-i
5.1 Signing 5-1
5.2 Marking 5-2
5.2.1 Rumble Strips 5-10
5.3 Active Devices 5-10
5.3.1 Rectangular Rapid-Flashing Beacons (RRFB) 5-10
5.3.2 Pedestrian Hybrid Beacons (PHB) 5-10
5.3.3 Metering Signals 5-11
Chapter 6. Roundabout Railroad Crossing and Preemption - Contents 6-i
6.1 Gating 6-3
6.1.1 Gating at the Railroad Crossing Only 6-3
6.1.2 Gated Closures at Railroad Crossing and On Circulating Lanes 6-4
6.1.3 Gated Closures at Railroad Crossing and Roundabout Entries 6-6
6.1.4 Railroad through the Roundabout 6-8
6.2 Signalizing Approaches 6-9
6.3 Blank Out Sign 6-10
Chapter 7. Lighting - Contents 7-i
7.1 Principles 7-1
7.2 Pole Placement Recommendations 7-2

Chapter 8. Landscaping - Contents 8-i
8.1 Central Island Grading 8-1
8.2 Landscaping 8-2
8.3 Color and Texture Treatments for Truck Aprons 8-5
Chapter 9. Pavement Design - Contents 9-i
9.1 Pavement Type Selection 9-1
9.2 Axle Loading Analysis 9-2
Chapter 10. Alternative Concepts for Staging Roundabout Construction - Contents 10-i
10.1 Short-Term Closure 10-2
10.1.1 Night Closure(s) 10-2
10.1.2 Weekend Closure(s) 10-2
10.1.3 Multiple Week Closure with Detour 10-3
10.2 Long-Term Closure with a Traffic Detour 10-4
10.3 Partial Detour (Close the Cross Road) 10-5
10.4 Construction of a Roundabout Off Alignment 10-6
10.5 Construction of the Roundabout Under Traffic 10-7
10.5.1 Undivided 2-Lane Roadway 10-7
10.5.2 Divided 4-Lane Roadway 10-8
Appendix A. Practical Design A-1
A.1 Principles A-1
A.2 Left-Offset Approach Alignment A-3
A.3 Practical Design Alternatives A-5
Appendix B. OSOW B-1
B.1 Review of OSOW Permits B-1
B.2 OSOW Template Library B-5
Appendix C. High Speed Approach Design C-1
Appendix D. Roundabout Performance Checks D-1
D.1 Entry Path Deflection – Permits D-1
D.1.1 Drawing Fastest Paths D-1
D.1.2 Measuring the Critical RADII of the Spline and their Associated Speeds D-2
D.2 Sight Distance Envelopes D-5
D.2.1 Stopping Sight Distance (SSD) D-5
D.2.2 Intersection Sight Distance D-10
D.3 Vehicle Analysis D-13
D.3.1 2D Analysis D-13
D.3.2 3D Analysis D-14
Appendix E. Spiral Design E-1

Appendix F. Vertical Design Best Practice F-1
F.1 Alignments and Profiles F-1
F.2 Example Profile Creation F-3
F.3 Grading Design F-5

Acronyms and Definitions

Acronyms

AASHTO – American Association of State Highway and Transportation Officials

ADA – Americans with Disabilities Act

DPM – Design Policy Manual (GDOT document)

FHWA – Federal Highway Administration

GDOT – Georgia Department of Transportation

HCM – Highway Capacity Manual

ICD – Inscribed Circle Diameter

ICE – Intersection Control Evaluation

ISD – Intersection Sight Distance

LOS – Level of Service

MUTCD – Manual on Uniform Traffic Control Devices (FHWA)

NCHRP – National Cooperative Highway Research Program

OMAT – Office of Materials and Testing

OSOW – Oversized/overweight vehicle

PDP - Plan Development Process

PHB – Pedestrian Hybrid Beacon

PHF – Peak Hour Factor

RRFB – Rectangular Rapid-Flashing Beacons

ROW – Right-of-Way

SSD – Stopping Sight Distance

TMC – Transportation Management Center

Definitions

Accessible Pedestrian Crossings – Pedestrian crossings provided at roundabouts must be accessible to and usable by all pedestrians; including the visually impaired, wheelchairs, strollers and pedestrians walking bicycles.

Bicycle Path Diversion – Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either by riding in the travel lane as a vehicle, or by exiting the roadway and, if available, using a shared-use path, depending on the bicyclist's level of comfort.

Capacity – The maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or uniform segment of a lane or roadway during a given period under prevailing roadway, traffic, and control conditions.

Central Island – The raised area in the center of a roundabout, around which traffic circulates. The central island is typically circular in shape but can be modified to accommodate truck turning movements.

Circulatory Roadway –The travel way portion of the roundabout used by vehicles to travel in a counterclockwise fashion around the central island.

Cross Slope – The rate of elevation change across a lane or a shoulder.

Design Exception – A design condition that does not meet AASHTO guidelines and requires specific approval from the GDOT Chief Engineer and FHWA.

Design Speed – A selected speed used to determine the various geometric design features of a roadway. The maximum safe speed that can be maintained over a specified section of the road when conditions are so favorable that the design features of the road govern.

Design Variance – A design condition that does not meet GDOT policy. A design variance requires specific approval from the GDOT Chief Engineer.

Design Vehicle – A selected motor vehicle, the weight, dimensions, and operating characteristics of which are used as a control in road design. As defined by FHWA: the longest vehicle permitted by statute of the road authority (state or other) on that roadway (MUTCD).

Design Year – The anticipated future traffic, typically 20 years from the base year/open year for all GDOT projects.

Edge Line Extension (Entry Line) – A pavement marking line of demarcation separating traffic approaching the roundabout from the traffic already in the circulating roadway. The point which a vehicle typically yields to circulating traffic is usually defined by a wide dotted edge line extension. By practitioners, it is commonly referred to as a yield line.

Entry Radius – The minimum radius of curvature measured along the right curb at entry of a roundabout. Smaller radii may decrease capacity, while larger radii may cause inadequate entry deflection.

Entry Width – The perpendicular distance from the right curb line of the entry to the intersection of the left edge line and the inscribed circle of a roundabout.

Exit Radius – The minimum radius of curvature measured along the right curb at the exit of a roundabout. Exit radii should then be larger than entering radii.

Exit Width – The perpendicular distance from the right curb line of the exit to the intersection of the left edge line and the inscribed circle.

ICE – Intersection Control Evaluation is a transparent and traceable engineering study process for intersection alternative selection to address operational and safety problems at intersections and major access points. Intersection control selection relies on quantitative and qualitative measures of capacity, safety and cost. The process is codified, and guidance is provided in GDOT policy.

Landscape Buffer – Placed between the curb and sidewalk to separate vehicular and pedestrian traffic and to help direct pedestrians to cross only at the designated crossing locations and to provide space for sign placement. Landscaping can also significantly improve intersection aesthetics and contribute to traffic calming provided it is placed outside the required sight limits. The buffer must be detectable by people of all abilities.

Level of Service – A qualitative rating of a road's effectiveness relative to the service it renders to its users (from A-best to F-worst). LOS is measured in terms of a number of factors, such as operating speed, travel time, traffic interruptions, freedom to maneuver and pass, driving safety, comfort, and convenience.

Path Efficiency – The balancing of paths in and through the roundabout so that each movement has approximately the same path length. It promotes balanced speed control from opposing approaches. See Section 3.16.

Practical Design – Designers should optimize circle size, location, and alignment of legs that promotes balanced speed control from opposing approaches and ensure efficient movements for a practical design.

Practical Geometry – Utilizing existing features or geometry to reduce costs at an intersection; or coming up with new geometry that will help save costs (minimal footprint).

Right turn Bypass Lane – A lane added, that bypasses the circulatory roadway, when there is a high right turn traffic demand, or geometry requires the bypass to accommodate an acute right turn.

Sidewalk / Shared-Use Path – It is common to provide a shared-use path at the perimeter of the roundabout to provide both pedestrians and bicyclists off-road accommodation. Standard sidewalks are provided in lieu of a shared-use path when bicycle traffic is expected to use the roadway through the roundabout.

Spiral (spiral lane transition) – A spiral is a geometric feature of the truck apron needed for some multilane roundabout configurations with exclusive left-turn lanes. The spiral transitions left-turning vehicles from the inside to the outside circulating lane to allow vehicles to exit without changing lanes within the circulatory roadway (not to be confused with a highway curve spiral).

Splitter Island – Typically a raised median on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and provide median refuge for pedestrians crossing the road in two stages.

Truck Apron – The mountable portion of the central island adjacent to the circulatory roadway. It is required to accommodate the wheel tracking of long or oversized vehicles Oversize/Overweight vehicles (OSOW). It is usually concrete with a contrasting color to delineate the apron from the normal vehicle path.

Truck Aprons (Outside) – A truck apron placed on the outside of the travel way, usually on corner radii that are too tight for large trucks and OSOW trucks to track in the travel way. They can also be incorporated into splitter islands for OSOW truck accommodation.

Chapter 1. Introduction - Contents

Chapter 1. Introduction - Contents 1-i
1.1 Roundabout Types 1-3
1.1.1 Single Lane Roundabouts 1-3
1.1.2 Multilane Roundabouts 1-5

Chapter 1. Introduction

The modern roundabout is characterized by the following basic principles:

- Generally circular shape with counterclockwise traffic flow
- Yield-at-Entry – Vehicles approaching the roundabout must wait for a gap in the circulating flow before entering the circle.
- Slow speed environment – Through geometric curvature and entry path deflection, the traffic is directed or channeled to the right of the central island with a curved entry path into the circulatory roadway.

Roundabout design is a **principles-based**, **performance-driven design process** where the critical elements of circle size, circle location and alignment of approaches are guided by safety and operational performance criteria. Operational analysis (2.1) determines the required lane configuration which is then followed by geometric design. Safety performance can be achieved through a geometric design (3) that provides speed control, minimizes potential for entry-circulating crashes and establishes priority to circulating traffic. Approach geometry and a visibility package of signs, markings and landscaping should build driver expectation of speed reduction and yield on entry.

This design guide presents the principles and methods of achieving practical design and optimal roundabout operations through performance-based design. Appendix A provides examples of practical design implementation. Appendix B provides a step-by-step on reading oversized/overweight (OSOW) records and determining a check vehicle. Appendix C shows an example of how to do high speed approach design. Appendix D provides instructions to undertake design performance checks and an example of a performance checks package. Appendix E shows examples of how to develop spiral approach design. Appendix F explains best-practice vertical design methods in more detail.

This document is intended to supplement the GDOT Design Policy Manual (DPM) Chapter 8 and is underpinned by NCHRP 672, ***Roundabouts: An Informational Guide – 2nd Edition (2010)***. Where stated values and figures differ from NCHRP 672, the GDOT Roundabout Design Guide should take precedent for GDOT roundabout design practice. This document is a guide for designers; it is intended to answer frequently asked questions about roundabout designs. This document is not intended as policy or design standards.

Increasingly over the last decade, roundabouts are being implemented in Georgia, partially due to the implementation of the Intersection Control Evaluation (ICE) process/policy. The ICE tool offers single lane and multilane roundabout alternatives as configurations to be considered when evaluating an intersection.

The revision of this document dated **November 2021** incorporates:

- the preference to include turbo roundabout features on multilane applications
- revision and restructuring of the entire document
- portions of the appendices moved into the body of the document

and the addition of sections related to:

- Acronyms and Definitions

- Roundabout types (1.1)
- Expandable design (2.1.1)
- Design vehicles (3.5)
- Roundabout shapes (3.9)
- Metering (5.3.3)
- Roundabout railroad crossings (6)
- Spiral design (Appendix E)

1.1 Roundabout Types

Depending on the entering and circulating volumes, a roundabout can be designed as a single lane or a multilane roundabout. Single lane roundabouts typically have a smaller Inscribed Circle Diameter (ICD) than a multilane roundabout. To provide more capacity, bypasses can be added to a roundabout. Right turn bypasses allow right turning traffic to pass the roundabout without using the circulatory lane.

1.1.1 Single Lane Roundabouts

A single lane roundabout is composed of three or more legs. It contains a single lane circulatory roadway with single lane exits and entries. Three different types of single lane roundabouts can be distinguished:

- **Conventional single lane roundabout:** This is the most common roundabout layout, as defined above. The central island is not fully traversable (mountable).
- **Compact roundabout:** A single lane roundabout with a smaller ICD (see Section 3.8) to minimize property impacts. Compact roundabouts provide many similar features to conventional single-lane roundabouts, including non-traversable (landscaped) portions to their central islands. A compact roundabout may be used when there are construction cost and right-of-way constraints. Compact design needs to be consistent with the site context and lane configuration needs, while still meeting the design performance checks (space for trucks and speed control).
- **Mini-roundabout:** A single lane roundabout with a fully traversable (mountable) central island. As described in NCHRP 672, Section 6.6, it has limitations due to reduced ability to control speeds and lower visibility to approaching vehicles due to the lack of central island landscaping. Therefore, design considerations will need to be utilized to address these limitations, see Section 3.18.2.

The key features of roundabouts are illustrated on Figure 1-1.

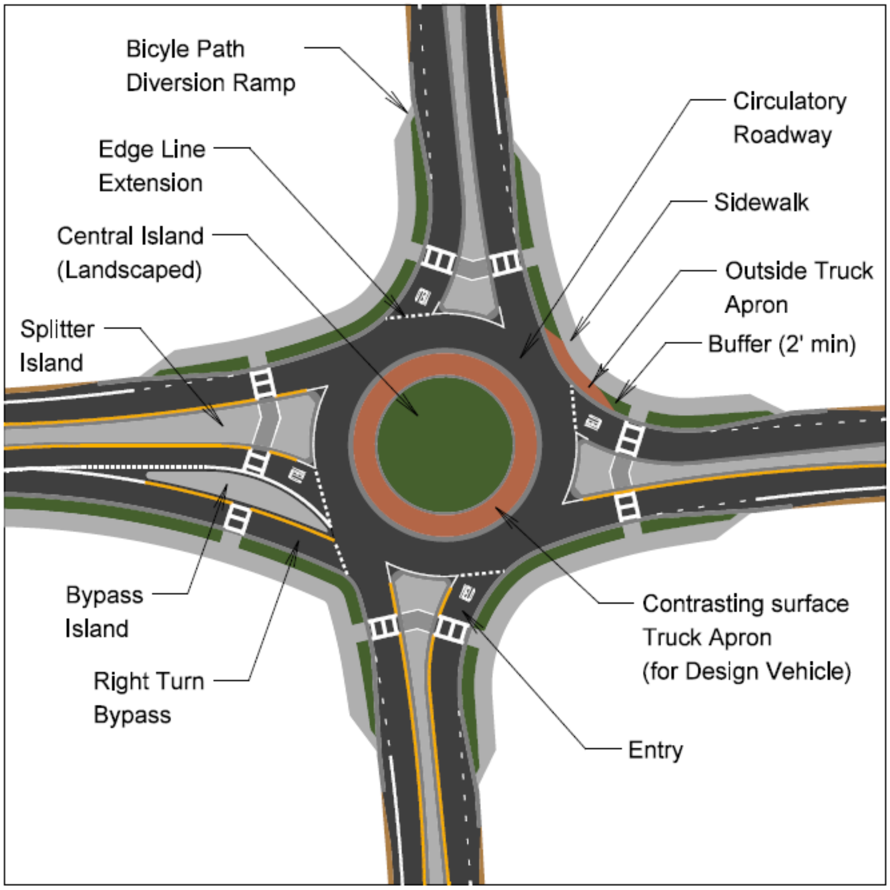

Figure 1-1. Key Roundabout Features

1.1.2 Multilane Roundabouts

A multilane roundabout contains more than one lane on one or more sections of the circulatory roadway.

Roundabout designs have evolved to include geometric features to improve safety performance. The most predominant evolution is the practice of using left offset. A newer development has been Turbo Roundabouts, following the Dutch-style Turbo design. There are several features of this type of roundabout that add potential safety value. One of the most valuable features of this Turbo design are the raised lane dividers.

Prior to the release of this version of the Roundabout Design Guide, multilane roundabouts have not been largely implemented in Georgia and did not include any turbo features.

For design considerations, **all multilane roundabouts will incorporate some turbo features**, like lane dividers, while not sacrificing our core principles, like left offset.

Physical elements, typically lane dividers, help to improve the channelization and guidance of traffic through the roundabout, potentially increasing traffic safety and capacity. In some cases, other physical elements such as rumble strips are used in lieu of raised lane dividers for the physical separation, see Section 3.15.2 (Multilane Roundabout Cases). Figure 1-2 includes examples of lane divider alternatives.

- **Full multilane roundabout** (typically 2x2): A roundabout with two lanes for the entire circulatory roadway and two-lane entries and exits, to increase capacity for higher volumes.
- **Hybrid roundabout** (typically 2x1): A roundabout with a blend of one and two circulating lanes dependent on capacity needs [e.g. a minor roadway intersecting a major roadway].

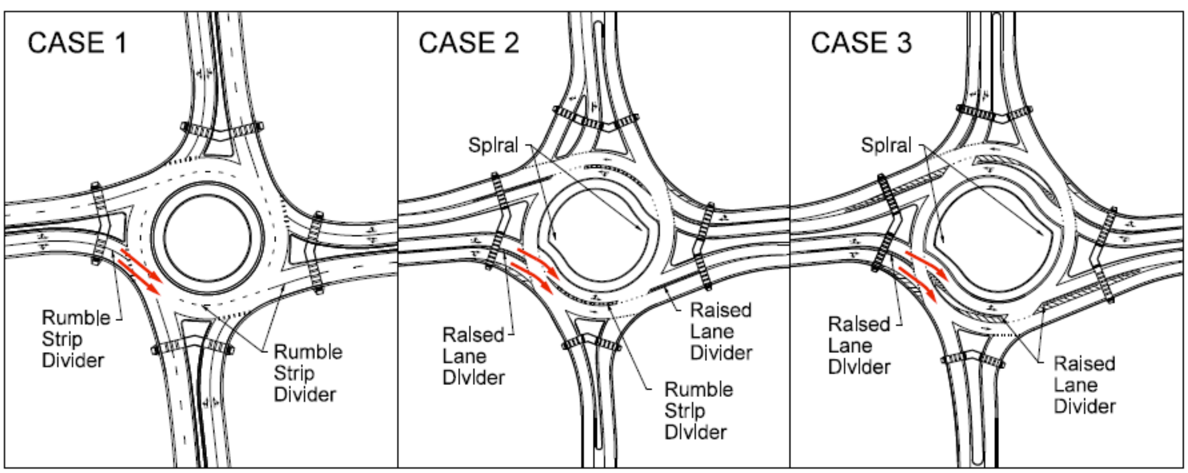

Figure 1-2. Multilane Roundabout Key Features

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Chapter 2. Capacity and Operations - Contents

Chapter 2. Capacity and Operations - Contents 2-i
2.1 Roundabout Operational Analysis Process 2-1
2.1.1 Expandable Design 2-3
2.1.2. Common Pitfalls 2-4
2.2 Operational Analysis Software 2-5
2.2.1. SIDRA Intersection 2-5
2.2.2. GDOT'S Roundabout Analysis Tool 2-6

Chapter 2. Capacity and Operations

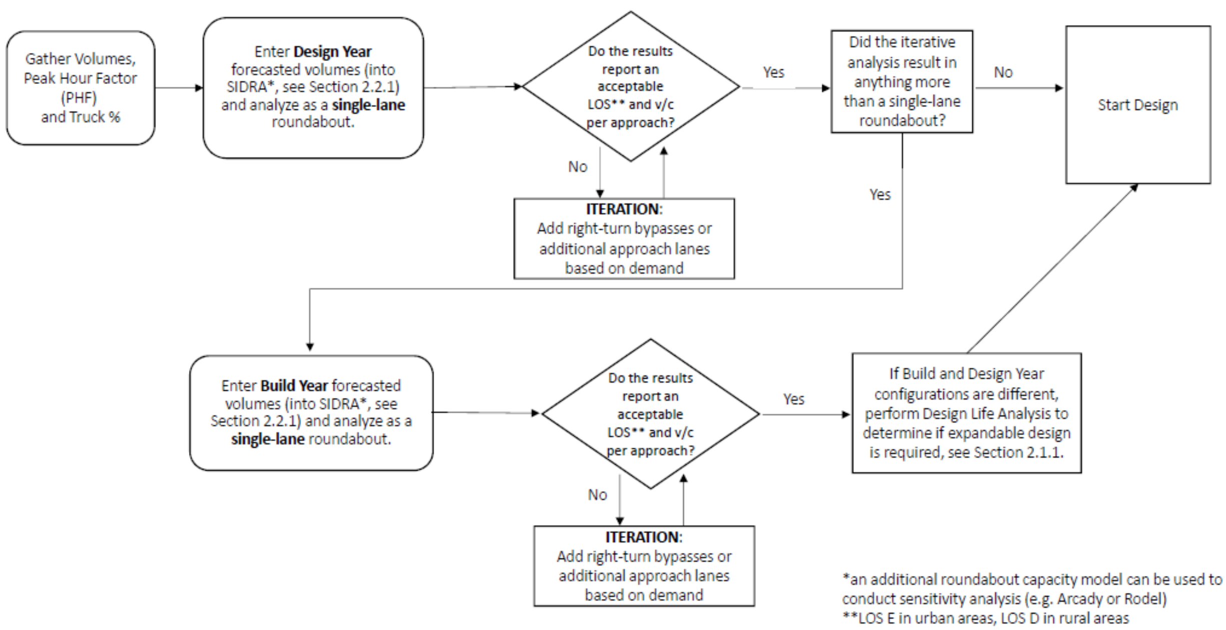
The sizing of a roundabout depends on traffic, geometric and environmental factors, as well as budgetary constraints. The designers process should be to perform operational analysis first and then draw the roundabout layout. The preliminary stages of potential project development are shown below.

Traffic Flow Data	Operational Analysis	Lane Configuration	Initial Geometric Parameters

2.1 Roundabout Operational Analysis Process

Choosing the number and configuration of entering and circulating lanes is an iterative process. Each approach leg of the roundabout is evaluated individually to determine the number of entering lanes. The capacity of a roundabout entry is driven by the amount of entering and conflicting traffic (vehicles traveling in the circulatory roadway). High conflicting volumes reduce opportunities for vehicles to enter the roundabout and therefore reduce the capacity of an approach leg; whereas low conflicting traffic volumes allow the approach leg to have a higher capacity.

A basic workflow for performing roundabout operational analyses is shown below. Analyze both AM and PM peak hours and perform the analysis for the Build Year and Design Year forecasted traffic.



Typically, four operational performance measures are used to estimate the operational performance of a roundabout entry: volume-to-capacity ratio, control delay, LOS, and queue length. These measures are checked to be within the desirable ranges for each lane configuration throughout the iterative process.

It can be beneficial to determine the approximate lane requirements before undertaking a more detailed software analysis. NCHRP 672 Section 3.5.1 provides guidance on estimating lane requirements. For instance, if the sum of the entering and circulating volumes for each approach is less than 1,100 veh/h, then a single-lane roundabout is likely to operate acceptably.

Starting with the Design Year traffic turning movements, begin the analysis with a single-lane roundabout (unless a multilane is needed to maintain lane continuity) and consider adding the following before creating a multilane roundabout, see Figure 2-1:

- Right turn bypasses
  - **Right turn Partial (Yielding) Bypass Lane** – A right turn yielding bypass lane with either a curbed or a painted channelization requires approaching vehicles to yield to traffic leaving circulatory roadway at the adjacent exit. This alternative should prevent the right turner from making a through movement while preserving good sight lines to the left for conflicting circulating/exiting traffic. Generally, an angle of 70 degrees or higher is desirable.
  - **Right turn (Free-flow) Bypass Lane** – Right turn free-flow bypass lanes allow vehicles to bypass the roundabout and then continue in a dedicated lane or merge into an adjacent lane. A high right turn demand when coupled with other approaching traffic may indicate the need for a full bypass lane in order to avoid a wider, faster entry. Right turn full bypass lanes create an additional conflict for pedestrians and bicyclists and should only be used when needed for additional capacity.
- Hybrid layouts (including exclusive left turn lanes)

In certain situations, metering may be appropriate for a single or multilane roundabout to mitigate delays, see Section 5.3.3.

To account for the functional area of the roundabout, the analyst should be aware of driveways near the roundabout (see Section 3.4). Ideally, the approach roadway should have adequate storage capacity so that the queue does not obstruct driveway access or another intersection.

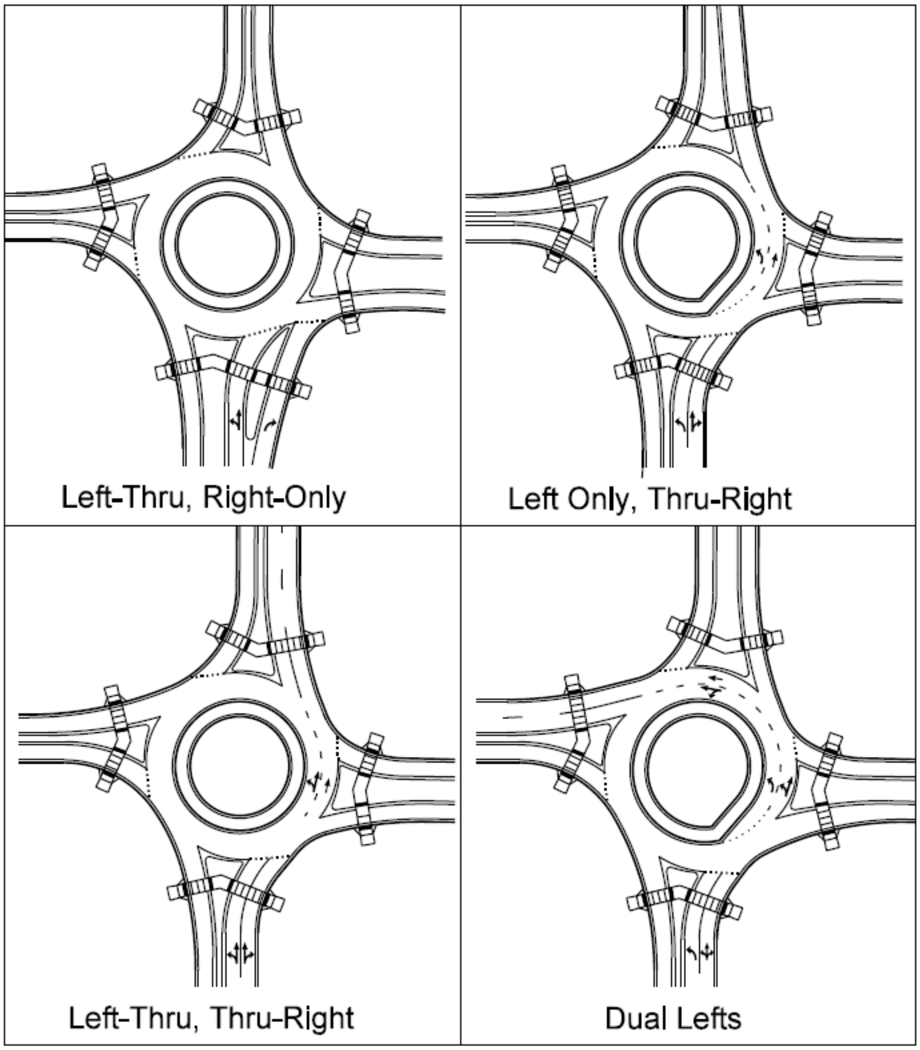


Figure 2-1. Lane Configuration Options for Two-lane Entry

2.1.1 Expandable Design

In some situations, the requirements for acceptable Design Year operations require a larger footprint than the Build Year. If this is the case, the roundabout should be constructed and operated in the Build Year lane configuration until traffic volumes dictate the need for conversion/expansion. A Design Life analysis should be run to determine how long the reduced lane configuration is projected to operate acceptably. We recommend 10 years for physical footprint changes, whereas 5 years might be acceptable for a striping change. When considering an expandable design, the designer should also evaluate the right-of-way and geometric needs for both the Build and Design Year lane configurations.

If considering a single lane roundabout and if capacity analysis indicates that conversion to a multilane roundabout is needed prior to the Design Year, then a conventional single lane ICD is likely more desirable than a compact or mini-roundabout for expandability.

2.1.2. Common Pitfalls

The following are four common pitfalls stemming from the initial roundabout analysis that can lead to impractical and more expensive designs:

- Traffic forecasts that overestimate traffic growth and indicate more lanes will be needed too soon.
- Capacity models that are very “conservative” and indicate failure of a single-lane design sooner than actual Design Life.
- Design horizons that are inappropriately long for the project or site context.
- Operational analysis based solely on Peak Hour traffic.

Being overly “conservative” in some or all these areas can lead to a roundabout that is more complex and expensive. To ensure a practical design, do a thorough operational analysis, as described in Section 2.1, to streamline the design process, prior to beginning the geometric design.

2.2 Operational Analysis Software

The SIDRA Intersection Software and the GDOT Roundabout Analysis Tool are both acceptable for use as a design and evaluation aid for roundabouts. SIDRA, however, is the preferred tool for operational analysis at roundabouts due to its superior layouts and ease of use. Within SIDRA, it is recommended to run both the SIDRA formulas and HCM formulas (which can be done simultaneously). If no SIDRA license is available, use the GDOT Roundabout Analysis Tool.

The analyst should run each capacity model with sensitivity testing (Design Life Analysis) and/or by varying the geometry, e.g. number of lanes. By doing so, the analysis will account for weaknesses in the traffic forecasts, models and/or geometry.

If there are concerns with the completed analysis in SIDRA, the analyst can use an additional roundabout capacity model to conduct sensitivity analysis (e.g. Arcady or Rodel).

On GDOT projects, it is recommended to consult with the Office of Traffic Operations if conducting sensitivity and/or Design Life Analysis for expandable design. Send an email to: roundabouts@dot.ga.gov.

2.2.1. SIDRA Intersection

SIDRA Intersection is a software tool that can run multiple different roundabout capacity models including the HCM models, as well as a proprietary SIDRA Standard model. The SIDRA Standard roundabout capacity model is a gap-acceptance theory, lane-based, “micro-analytical” model originating from Australian roundabout research. See Figure 2-2 for typical SIDRA software inputs. Information in the Options tab should follow guidelines from the DPM. Information in the Roundabout Data tab should be adjusted for site-specific conditions to refine your analysis after geometric design is confirmed (if needed). **Use Environmental Factor of 1.1 for Build Year and 1.05 for Design Year analysis**. In areas where roundabouts are more prevalent, more aggressive numbers can be used.

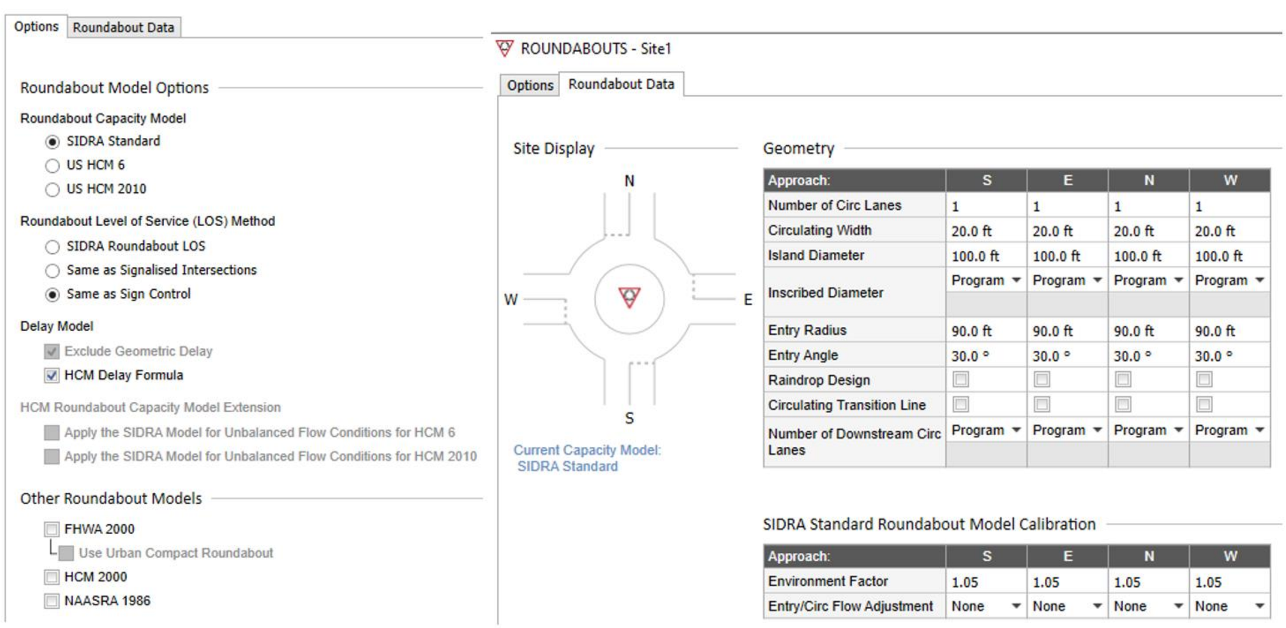


Figure 2-2. Typical SIDRA Software Inputs

2.2.2. GDOT'S Roundabout Analysis Tool

GDOT's Roundabout Analysis Tool is an Excel workbook containing an analysis spreadsheet for mini, single-lane, and multilane roundabout configurations.

The tool applies methodologies from the Highway Capacity Manual (HCM) 2010 Edition for mini-roundabout analysis. HCM 6th Edition methodologies are applied for single-lane and multilane/turbo roundabout analysis. Detailed instructions are located in the workbook.

Inputs include volumes (entered as origin-destination pairs), PHF, and truck percentages. There is also an option to analyze right turn bypass lanes.

Results include entry capacity, approach V/C ratio, approach delay, approach level of service (LOS), and 95th percentile queue.

Chapter 3. Geometric Design - Contents

Chapter 3. Geometric Design - Contents 3-i

3.1 Design Process and Workflow 3-1
3.2 Practical Design Considerations 3-2
3.3 Design Criteria 3-3
3.4 Roundabout Functional Area 3-4
3.4.1 Driveway Access/Median Opening 3-4
3.5 Design Vehicle 3-5
3.6 Check Vehicle 3-6
3.6.1 OSOW Permit Types 3-6
3.6.2 OSOW Template Library 3-7
3.7 Circle Location and Alignment of Approaches 3-8
3.8 Circle Size 3-11
3.9 Roundabout Shapes 3-13
3.10 Design of Approaches 3-14
3.10.1 High Speed 3-15
3.11 Entry Curves 3-19
3.12 Fastest Path 3-20
3.13 Stopping Sight Distance 3-25
3.14 Intersection Sight Distance 3-28
3.15 Truck Considerations 3-29
3.15.1 Truck Aprons 3-29
3.15.2 Multilane Roundabout Cases 3-30
3.15.3 Check Vehicle Accommodation 3-33
3.16 Path Alignment 3-34
3.16.1 Entry Path Alignment 3-34
3.16.2 Circulatory Path Alignment 3-39
3.17 Horizontal Alignments & Vertical Design 3-40
3.17.1 Horizontal Alignments 3-40
3.17.2 Profiles 3-40
3.17.3 Grading and Drainage 3-41
3.18 Typical Sections and Curb Types 3-42
3.18.1 Raised Multilane Features 3-47
3.18.2 Mini-Roundabouts 3-49

Chapter 3. Geometric Design

3.1 Design Process and Workflow

Achieving an optimal roundabout geometry requires a thorough exploration of the 'design space': location context, geometric requirements, and potential trade-offs of safety with capacity and/or cost. Concept sketching allows initial exploration of feasibility and potential impacts before investing significant effort in detail design elements. When sketching conceptual layouts, it is important to produce the most cost-effective layout, with minimal tradeoffs, for a given set of constraints and location context.

To limit the number of iterations of design, the operational analysis should be completed before the general footprint of a roundabout is designed. Figure 3-1 summarizes this process to align with the stages of project development for GDOT PDP Projects including roundabouts. Roundabouts constructed using non-PDP delivery mechanisms such as: Quick Response projects, special encroachment & driveway permits, a non-GDOT roadway, etc. may use an abbreviated project development process.

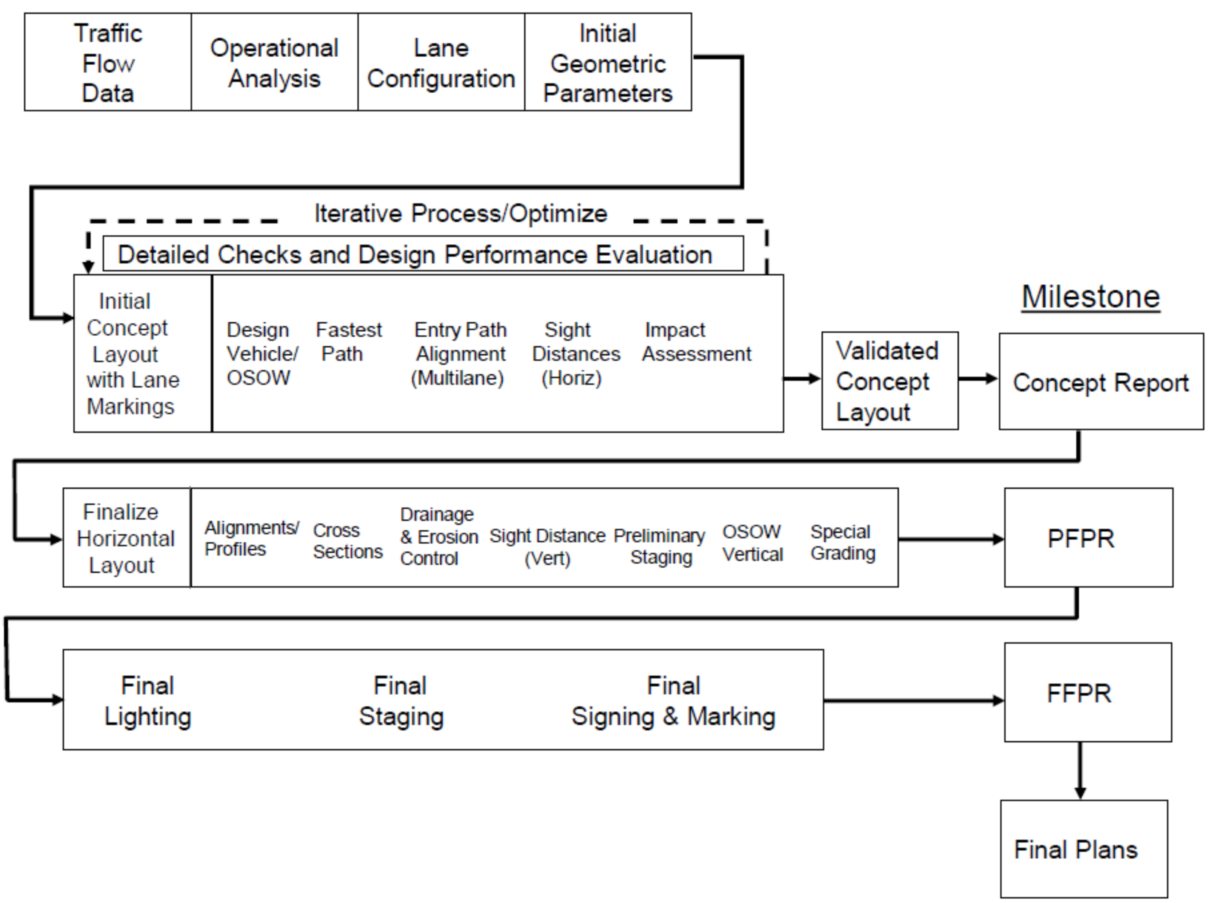


Figure 3-1. Design Process and Workflow for GDOT PDP Roundabouts

3.2 Practical Design Considerations

All roundabout designs should address the capacity and safety needs of an intersection, but designers should take a practical approach to reduce project costs. **Practical design** does not compromise safety nor eliminate standards and good practice. It does focus on context, need and purpose, and emphasizes engineering judgement.

Designers should optimize circle size, location, and alignment of legs that promotes balanced speed control from opposing approaches and ensure efficient movements for a practical design.

Practical design is essentially design optimization with a greater emphasis on balancing cost with capacity and safety benefits. This requires careful consideration of design trade-offs. Designers should consult with the Office of Design Policy and the Office of Traffic Operations when considering possible design variances implied by the list of cost saving ideas below.

Eliminating lower priority project design elements can result in lower cost and improved value without adverse effects on safety and capacity benefits. Depending on site context, designers should consider the following examples for a practical design:

- Remove excess curb – use curb to only confine trucks and to reduce speeds near the entries and exits rather than along the entire project length
- Reduce splitter island length – use shorter medians (splitter islands) with added visibility elements on the approach
- Reduce excess lighting – use pavement marking reflectors and illuminated bollards instead, see Section 7)
- Remove excess drainage structures – construct rural shoulders and ditches instead
- Avoid multiple construction stages and temporary pavement – employ road closures and off-site detours
- Pavement preservation – reduce the amount of pavement reconstruction by using milling & inlay or overlay instead of full depth construction

Practical design doesn't change the requirements to meet basic design criteria and the variances/exceptions needed for not meeting them. However, designers can achieve cost savings by utilizing flexibility that exists in current design guidance and standards. Practical design considerations include but are not limited to:

- Minimizing required Right-Of-Way (ROW) by:
    - using a smaller circle size
    - employing ellipses to mitigate intersection skew angle or avoiding adding right turn bypass channelization
    - shifting roundabouts to avoid parking, storage tanks or other property impacts that might cause full displacements and increase ROW costs.
- Rightsizing for traffic demands – staged expandability from single lane to multilane.
- Utilize context sensitivity by encompassing existing features such as: important trees and landscaping
- Setting the roadway and circle to blend with the existing roadway profiles

Appendix A provides a diagram of this list (Figure A-1) and an expanded discussion of practical design and examples of how it can be applied.

3.3 Design Criteria

The mindset of the designer should be that **performance, not geometric conformance, guides the geometric design**. Designers must strategically keep the performance objectives of safety and operations in mind and let them guide the selection of the applicable design details. The overall design composition and the resulting performance matters more than the individual dimensional elements.

The initial selection of roundabout size (Section Chapter 3) as well as position and approach alignments (Section 3.8) play a large role in achieving the following **high-level core principles**:

- Speed control
- Entry and exit path alignment
- Capacity (lane configuration)
- Space for trucks
- Stopping Sight Distance
- Entry and exit channelization
- Safety for vulnerable users (pedestrians and cyclists)

The following focus on fine-tuning the design while still supporting the principles above:

- Lane widths and transitions (including spirals, see Appendix E)
- Intersection Sight Distance (Section 3.14)
- Grading (Section 3.17.3)
- Traffic Control Devices (Chapter 5)
- Lighting (Chapter 7)
- Landscaping (Chapter 8)

3.4 Roundabout Functional Area

The roundabout's functional area begins where vehicles are expected to decelerate from the roadway's posted speed (transition/deceleration zone), see Figure 3-2. This is a reduced speed environment where low speed design criteria are applied. Standard design criteria are applied in the area preceding the roundabout's functional area; if these criteria cannot be met, approval of a design variance or design exception may be required.

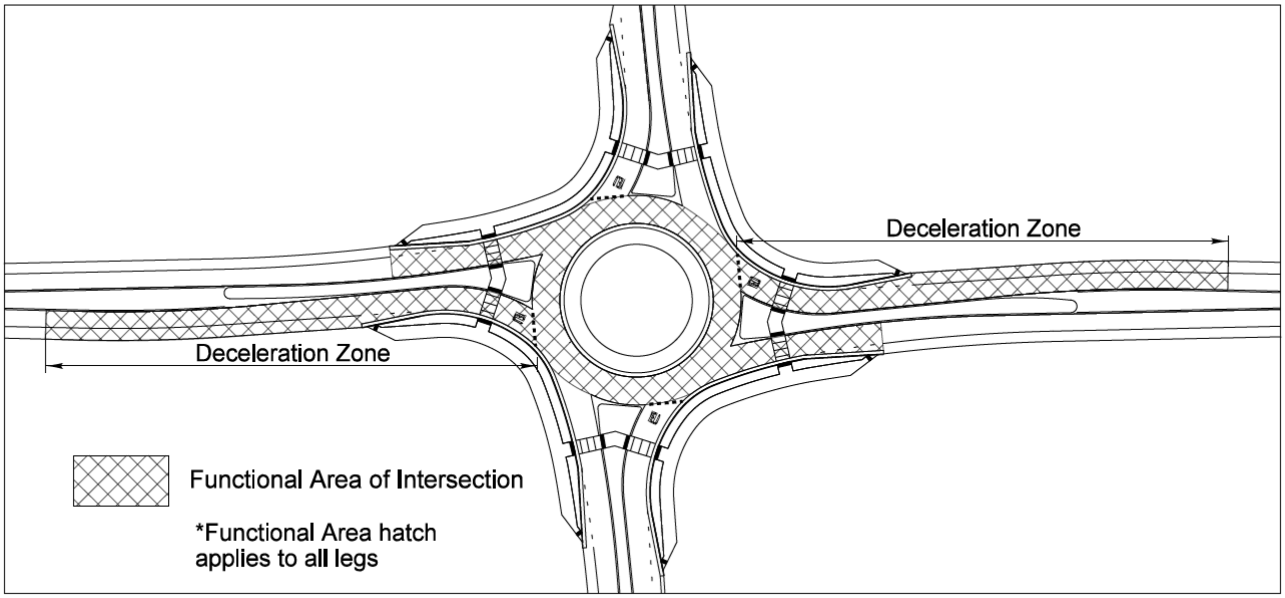


Figure 3-2. Roundabout Functional Area

3.4.1 Driveway Access/Median Opening

Full access driveways and median openings are typically not desirable in the areas of splitter islands and raised lane separations, except where it is feasible and practical to restrict access. Depending on site context, these are treatment options for consideration for pre-existing access/driveways:

- Connect a driveway to the circulatory roadway:
    - For low volume driveways (e.g. residential) a simple concrete dustpan drive (GDOT Construction Detail A-1) is typically preferred
    - For higher volume driveways (e.g. commercial) a driveway is typically treated as an additional leg to the roundabout
- Make a driveway right-in/right-out (especially if the property has additional or alternative full access point or U-Turn availability elsewhere)
- If a median opening is needed within the splitter island, provide sufficient median width for left-turn refuge to clear left turning traffic on approach or entry
- Shift the access point/driveway further from the roundabout

When considering new driveways in close proximity to roundabouts, the above context considerations should still be considered, especially dependent on driveway volume and sight distance.

See GDOT Regulations for Driveway & Encroachment Control for more information.

3.5 Design Vehicle

Before beginning geometric design, it is important to determine the appropriate design vehicle for all movements. **All design vehicle selections should account for engineering judgement and take into consideration: field observations, classification counts, local land use, site context, known future developments, and roadway functional classification**.

Table 3-1 should be used as a default/starting point for design vehicle considerations at roundabouts to reduce impacts, based on intersection type.

Table 3-1. Design Vehicle Considerations

Major	Minor	Design Vehicle Considerations[1,2,3]
Interstate / Interchange		WB-67 is a common truck configuration for freeways/expressways
State Route	State Route	WB-67 is a common truck configuration for state route movements
State Route	Non-State Route	WB-67 for thru movements on the mainline Minor road thru and turning movements typically use a smaller design vehicle (see below).
Non-State Route	Non-State Route	Minimum Design Vehicle (excerpt from DPM Table 3-1) Principal Arterial: WB-40 Minor Arterial: SU (rural), WB-40 or BUS-40 Collector: SU (rural) / BUS-40 or SU (urban) Residential/Local Road: S BUS 36 (rural) / SU or P (urban)

[1] Practical design may allow for a smaller design vehicle, reach out to Roundabouts@dot.ga.gov with design vehicle questions. Design vehicle will be checked during concept, turning movements will have to be collected and provided to ensure the design vehicle is selected properly.

[2] See Design Policy Manual Chapter 3.2 for further information.

[3] A U-turning vehicle should be accommodated based on the determined design vehicle for that route.

If an intersection must accommodate a large design vehicle for all turning movements, a compact roundabout may not be practical. For sites where WB-62/WB-67 size tractor trailers are only accommodated for mainline through movements and smaller design vehicles are used for the side streets (e.g. access to a residential subdivision), then a compact design may be more practical.

In addition, the following should be able to navigate the roundabout without mounting any curbs (truck aprons or blisters): emergency vehicles, single unit trucks (SU), School Bus (S BUS-36) (rural), buses (BUS-40) (urban); see Section 3.15 of this guide for accommodating design vehicles.

3.6 Check Vehicle

Unlike the design vehicle, a check vehicle is an infrequent vehicle that may utilize the intersection or corridor on multiple occasions, but not necessarily on a regular basis, such as a **WB-67 or oversized / overweight (OSOW)**.

A WB-67 is frequently used as a check vehicle for off system (non-state route) intersections or for state route intersection movements with low truck volumes. The check vehicle is not bound by having to drive with the cab being confined by the roadway; it can drive on the truck apron, outside truck apron, etc. (see Section 3.15.3).

OSOWs are oversized trucks that travel on the highway network on a permit basis. These vehicles typically transport oversized or overweight loads, which need special accommodations and/or escorts. OSOW status is given to vehicles when they are over-length (100 ft), overweight (80,000 lb), over-width (102 in), over-height (13.5 ft), or any combination of these. **If OSOWs identified as over-length/over-width are documented traveling through an intersection (either on or off system) the OSOW would be used as the check vehicle**.

Therefore, single-trip permit records and the annual permit route map should be checked for all intersections. OSOW single-trip permit records should be requested from OSOW@dot.ga.gov. The annual permit route map can be found here. See Appendix B for more OSOW information.

3.6.1 OSOW Permit Types

The following are definitions of permit types, more information can be found here on the GDOT webpage.

Single trip permit: May only be used once for movement during the times specified on permit; includes a description of the load; origin and destination, and routes of travel. The permit records are tabulated to help evaluate the size and direction of oversize vehicles and how many times they have traveled through the intersection. GDOT Office of Traffic Operations recommends accommodation of a vehicle if it has more than 3 occurrences over a three-year period. See Appendix B for a step-by-step on how to review single trip permit records and determine appropriate representative vehicles from the OSOW template library.

Multi-trip permit: A multi-trip permit authorizes the permitted load to return to its original destination on the same permit, if done so within ten days, with the same vehicle configuration, and following the same route, unless otherwise specified by the Department. These permits are typically treated as single trip permits with specific dimensions and routes, which are included in the single trip permit record information when obtained.

Annual Permit: Standard Annual permits are for specific types of loads with a maximum width of 12', height up to 14'6", length of 100 ft, and GVW of 100,000 pounds on a 5-axle tractor-trailer combination. Permit allows for unlimited use of this vehicle on the routes designated on the OSOW annual permit map. If the intersection lies on a designated route, an annual permit vehicle should also be used as a check vehicle.

3.6.2 OSOW Template Library

Since there are commonalities between various OSOW vehicles, the development of a truck library with representative check vehicles was created for the purpose of design. The following templates were developed with data from OSOW carriers' equipment list, permit record information, and AutoTURN's base vehicle library (see illustrations in Appendix B.2):

- Simple Lowboy (85 ft, 100 ft and 125 ft OL)
- DST Lowboy (125 ft OL)
- Mobile Home (100 ft and 110 ft OL)
- Booster Trailer (125 ft, 140 ft, and 150 ft OL)
- 13-Axle Trailer (150 ft, 165 ft, and 195 ft OL)
- Steerable Trailerless Load (150 ft and 180 ft OL)
- 19-Axle Trailer 125 Ton (250 ft OL)

Custom OSOW vehicles may need to be created for a specific intersection for the following reasons:

- If it **cannot be categorized** into one of the vehicles in the standard library
- If **review of the surrounding area** shows need for a custom vehicle type, i.e. flatbed log truck with an overhang.
  - These vehicles should still receive special attention even though they may not show up in the OSOW single-vehicle permits due to it being a multi-trip permit or the tractor-trailer themselves don't meet OSOW requirements (e.g. the overhang from a log or pole truck may require special attention to where light poles and/or signs are placed).

3.7 Circle Location and Alignment of Approaches

Once the design vehicle has been determined, the first step is to consider where the circle should be and to determine alignments of the approaches.

Circles should be located to optimize intersection visibility and entry speed reduction balanced from opposing directions. Where there are skewed intersections and space constraints, the circle location and approach alignments may need to be shifted, and the circle shape may also need to be modified, e.g. elliptical shape; see Section 3.9 for Roundabout Shape considerations.

It is desirable to arrange the legs of a roundabout to form equal angles between adjacent legs to minimize overtracking for large trucks and balance the entry path speed reduction for both approaches.

Practical Geometry – Utilizing existing features or geometry to reduce costs at an intersection; or coming up with new geometry that will help save costs (minimal footprint). The following can be considered:

- Existing features, such as: existing asphalt, utilities, existing grading, shoulders, curb line, etc.
- Effectively utilize existing asphalt to avoid overdesign of extra pavement/space
- Limit using new pavement (Will the new roundabout fit in the existing space?)
- Keep in mind special cases, e.g. elliptical roundabouts

Figure 3-3 to 3-6 illustrate common intersection approach alignment conditions designers may encounter and the practical alternative circle shape and approach alignment solutions that should be considered. Left offset of approach alignment should be achieved in each case.

These Figures depict centerlines not true alignments and are to be used as a reference.

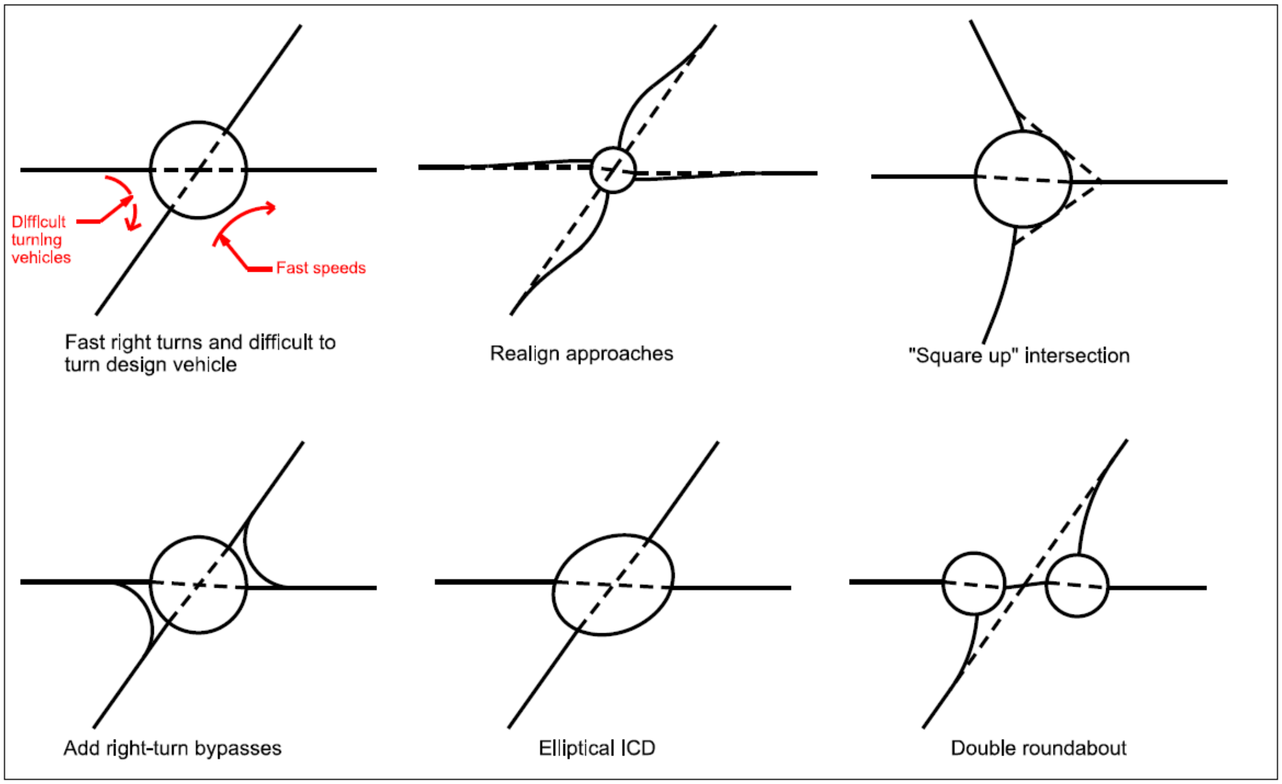


Figure 3-3. Skew Intersections

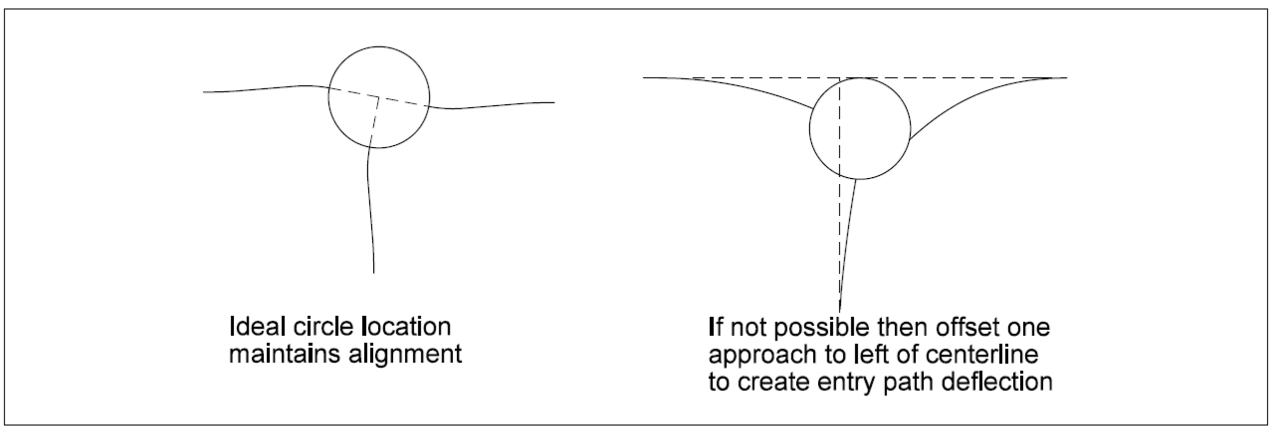


Figure 3-4. T Intersections

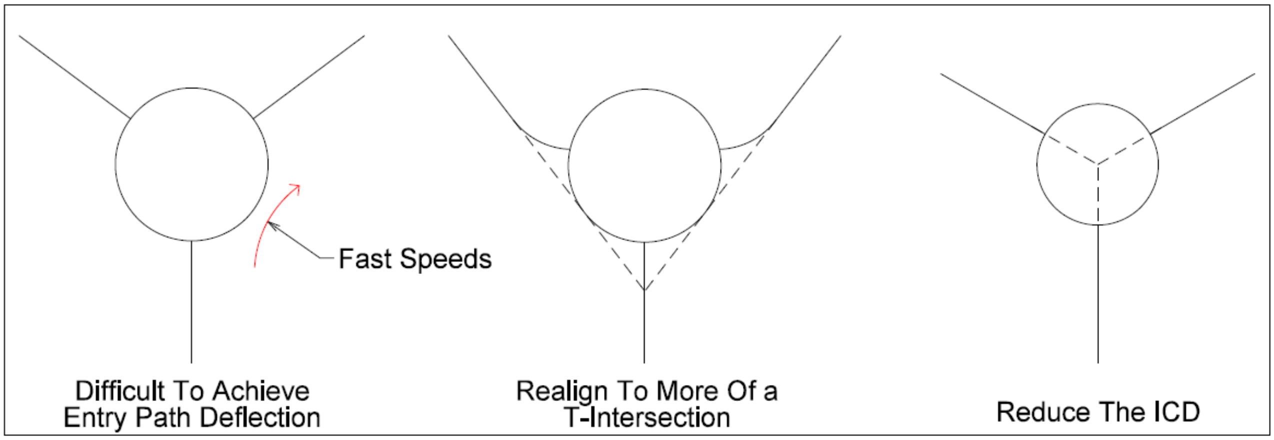


Figure 3-5. Y Intersections

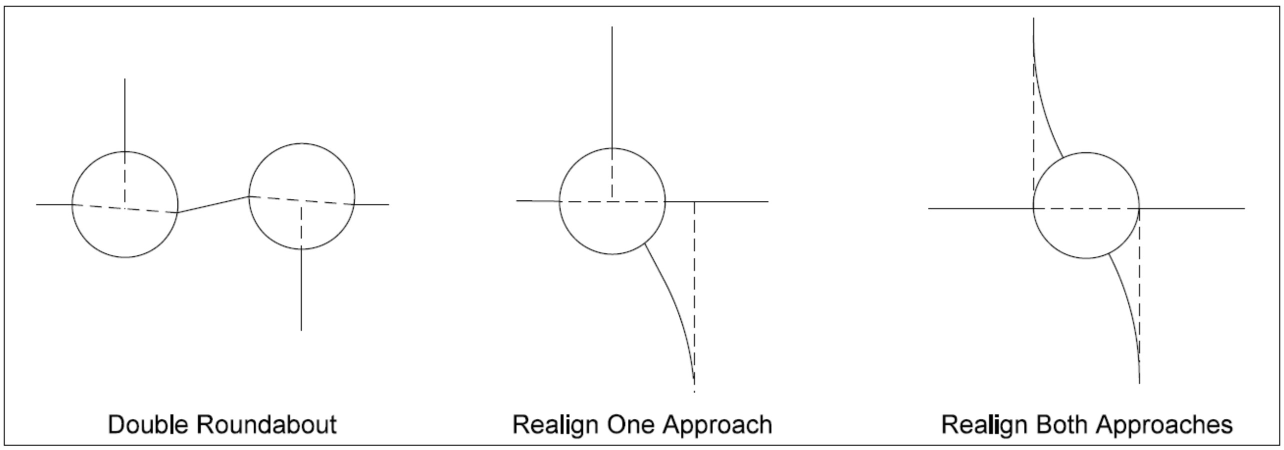


Figure 3-6. Offset Intersections

3.8 Circle Size

Once the circle location and alignment of approaches has been determined, the next step is to consider circle size.

Selection of a circle size, or Inscribed Circle Diameter (ICD), is dependent on traffic, space available and a combination of other factors; some examples are: environmental impacts, utility conflicts, existing roadway configuration, ROW limitations, roadway classification, design vehicle swept path, and design speed. Table 3-2 provides a range of **typical** ICDs associated with single and multilane roundabouts.

While the designer has flexibility in tailoring a layout to space constraints, the performance objective of speed control, specifically geometric entry speed, equally governs circle size. In a high-speed context, the combination of circle size and approach alignment, e.g. left offset, influences roundabout safety performance. Attaining speed control with smaller ICD's can be improved with left offset design of approach alignment; see Section 3.10 for left offset information.

For truck tracking considerations, three cases are identified to accommodate trucks in the multilane roundabout, these will affect circle size:

- Case 1 – Truck does not stay in-lane on entry or circulating
- Case 2 – Truck stays in-lane on entry, but uses both lanes for circulating
- Case 3 – Trucks in-lane on both entry and circulating

See Section 3.15.2 for more information on Multilane Roundabout Cases.

Circle size can vary slightly with the use of an elliptical shape, see Section 3.9, or the use of a spiral, see Section 3.16.2 (with hybrid and multilane roundabouts).

Table 3-2. Roundabout Categories (90° intersections with 4 legs)

Design Element	Single Lane Roundabout			Multilane Roundabout		
	Mini	Compact	Conventional	Case 1	Case 2	Case 3
Typical ICD	*70 to 90 ft	85 to 120 ft	120 to 160 ft	150 to 170 ft	160 to 190 ft	180 to 210 ft
Desirable range of theoretical fastest entry speed	15 to 20 mph	20 to 25 mph	20 to 25 mph	20 to 25 mph	20 to 28 mph	20 to 30 mph
Typical Truck Apron Width**	Traversable central island	12 to 14 ft	8 to 12 ft	8 to 12 ft	12 to 14 ft	14 to 16 ft

*ICD of less than 70 ft can be used on non-state routes (pay special attention to speed control).
**Truck apron should be determined based on design vehicles.

A reduced ICD may need to be considered to accommodate multiple features (pedestrian features need to be added & limited ROW, etc.).

Mini-Roundabout

Mini-roundabouts are single lane roundabouts defined by their smaller ICD with a diameter typically less than 90 ft. They accommodate large vehicles by allowing them to drive over the fully mountable central island, see Section 3.18.2 for typical sections on mini-roundabouts. The small footprint of a mini-roundabout offers flexibility when working within constrained sites.

Compact Roundabout

The choice of a compact or conventional single-lane roundabout is dependent on factors such as space available at an intersection, intersection angle (skew), class/speed of roadways and design vehicle.

A smaller ICD has tradeoffs related to accommodation of larger design vehicles. Typically, a compact roundabout will not accommodate a larger tractor trailer, e.g. a WB-62/WB-67, without overtracking outside edges of pavement/curbs. But often in these cases overtrack raised truck blisters may be used to compensate for the smaller ICD.

Single Lane Roundabout (Conventional)

A good starting point for a single-lane roundabout is an ICD of 130 feet. The ICD may be increased or slightly decreased to accommodate right-of-way, the design vehicle and to control speeds to meet fastest path requirements. At a 90-degree intersection that needs to accommodate a larger design vehicle for all movements, e.g. WB-67, a good range for the ICD is 130 to 150 ft. In situations with more than four legs or skewed intersection angles, larger ICDs or different circle shapes may be necessary; see Section 3.9 for Roundabout Shapes.

Hybrid Roundabout

Since a hybrid roundabout is a blend of one and two circulating lanes; it has a variable circle size.

Multilane Roundabout (Case 1-3)

At multilane roundabouts, the ICD is usually determined by balancing the need to achieve entry path deflection and provide smooth entry path alignment; see Section 3.12 and 3.16 for more information. Typically, the addition of lanes and satisfying both design objectives requires a slightly larger diameter than used for single-lane roundabouts. Lane configuration requirements and choice of case design for tractor trailers (see Section 3.15.2) also influence ICD.

3.9 Roundabout Shapes

The choice of roundabout shape is influenced by design performance requirements and context, e.g. closely spaced circles or skewed intersections. Below are the most common roundabout shapes.

Circle - The most common roundabout shape is a circle, with a consistent radius.

Ellipse - An ellipse is typically beneficial where a major road intersects a minor road at a skew angle where it is difficult to place a regular circular shape within the constraints of the project. An ellipse design is practical for separating the approaches to facilitate truck turning and to control entry speeds. The smaller radius of the ellipse should be placed into the quadrant of the acute angle of the two approaches, as shown in Figure 3-7. The range of diameters for each axes of the ellipse would be close to the range of the typical inscribed circle size. For single lane conventional roundabouts, the smaller radius is typically in the range of 120 to 150 ft with the larger radius being approximately 20 to 40 ft larger.

Peanut - A peanut roundabout is essentially two closely spaced circles where each circle does not permit a 360-degree movement. They are typically applicable at two closely spaced intersections that cannot have regular circles without overlapping. They can also be used at an extremely skewed intersection and/or when ROW is constrained (i.e. there is no miter).

Barbell/Dog Bone – A barbell or dog bone are other names for a peanut that is spaced further apart than a peanut shaped roundabout. They are used when two intersections are in close proximity but there is a benefit to having a tangent connecting the two individual circles.

Teardrop - A teardrop roundabout does not allow for continuous 360-degree travel within the circulatory roadway. The tear-drop is used to eliminate a portion of circulatory roadway not used at locations like ramp terminal intersections where there is no traffic volume due to the one-way ramp configuration. GDOT's preference is to use a teardrop only when needed for operational reasons.

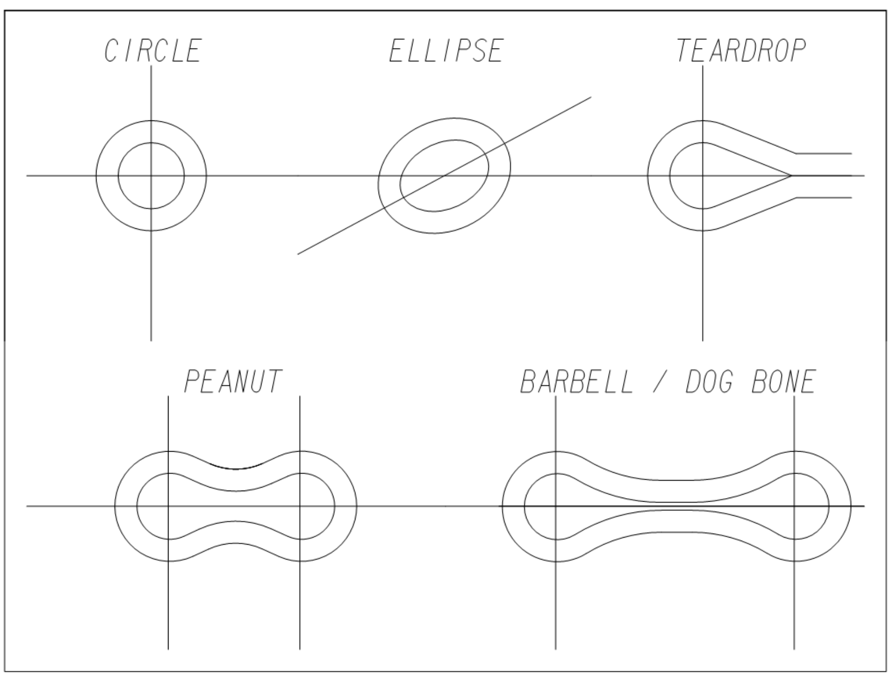


Figure 3-7. Roundabout Shapes

3.10 Design of Approaches

A primary goal of roundabout design is to make drivers aware of the roundabout with enough distance to gradually decelerate to a slow entry speed. This is especially necessary in rural areas where driver expectancy is free flow. Approach geometry should build driver expectation to reduce speed and yield at entry, a fundamental operating condition to maintain priority to circulating traffic. Geometric design of approaches that is safe and practical generally exhibits these principles:

- **Approach Alignment**
  - **Left Offset (preferred):** An approach alignment offset left of the circle center (see Figure 3-8) is most beneficial (and therefore recommended) to promote gradual speed reduction and yield at entry. This approach alignment typically generates the necessary entry path deflection to achieve geometrically slow entry speeds. For additional information, see NCHRP 672, Sections 6.2.1 & 6.7.1. Additional advantages to an offset left design are:
    - Increased deflection – best for speed control with rural design
    - Maintains clear sight of the central island
    - Beneficial for accommodating large trucks (allows for larger entry radius while maintaining deflection and speed control)
    - Helps to minimize circle size
    - May increase exit radius which reduces control of exit speeds/acceleration, but improves SSD of exit crosswalk
  - **Radial Approach:** Although not preferred, it can be used when there are ROW constraints, alignment concerns, low speed environment, and/or low volume approaches.
- **Forward Sight Distance/Stopping Sight Distance:** Desirable forward visibility of the roundabout entry, based on approach design speed.
- **Central Island Visibility:** Approaches should be aligned horizontally and vertically to make the central island and yield point as conspicuous as possible.

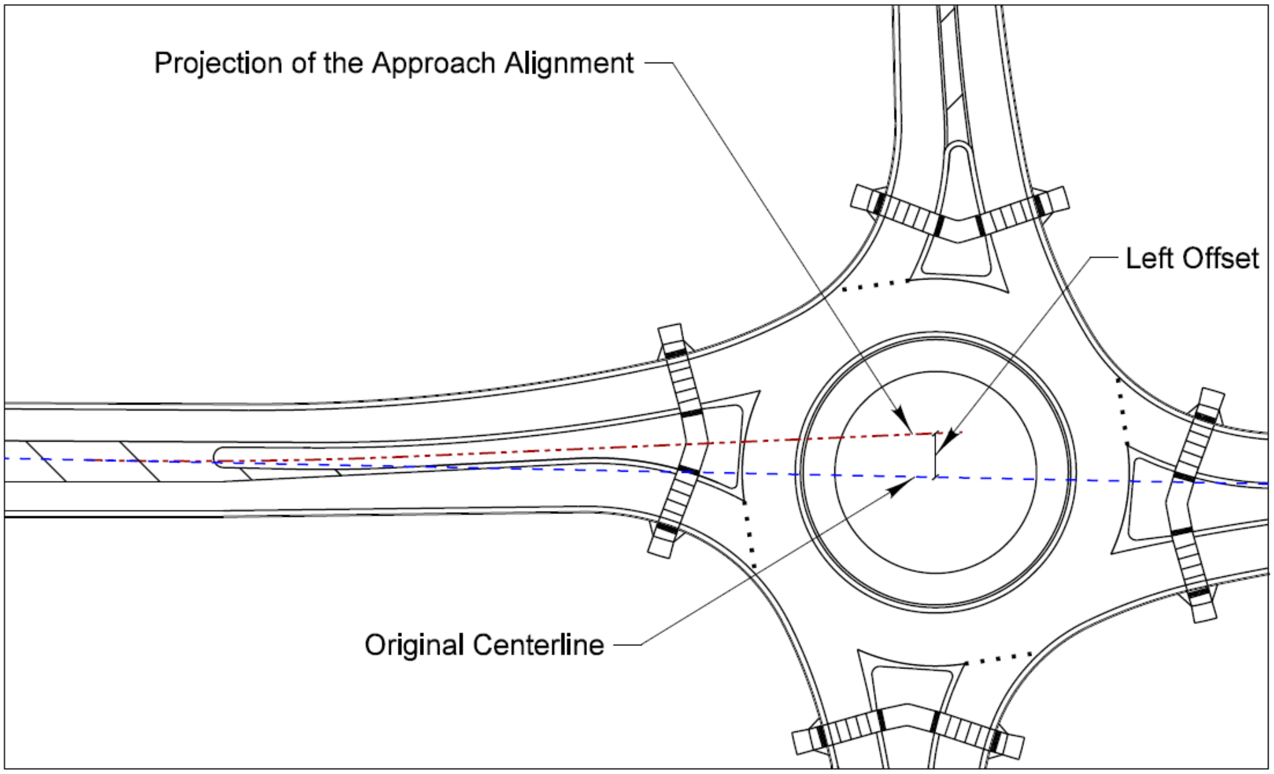


Figure 3-8. Left Offset Design for Entry Deflection

3.10.1 High Speed

In addition to principles stated above, the following should be explored for rural and higher-speed suburban design (see Figure 3-9a and Appendix C):

- **Approach curves (chicanes):** Chicanes use successively smaller curve radii to gradually reduce approach speeds. Within the transition/deceleration zone of a roundabout approach, selection of a horizontal curve radius, and vertical curve K value should be based on the speed contour closest to the center of the curve; see Figure 3-10. Speed contours assume comfortable braking to a potential stop at the crosswalk (or yield point in the absence of a crosswalk), as derived from Figure 2-34 in the AASHTO Green Book. Superelevation for curves within the deceleration zone should be selected from the AASHTO Green Book Table 3-13 *Minimum Radii and Super-elevation for Low-Speed Streets in Urban Areas* and should be based on the speed contour and curve radius per above.
  For approaches with existing superelevation before the start of the deceleration zone, apply GDOT DPM Section 4.5.4 (Table 4-10 and Table 4-11) to calculate the runoff length, L. See Appendix C for examples.
  - **Tangents between successive reverse curves:** Tangents, preferably the length of the design vehicle, minimize swaying of large truck loads and loss of control roadway departure crashes.
  - **Forward Sight Distance:** Stopping sight distance should be preserved when adding reverse curvature; this is necessary both horizontally and vertically. Avoid excessive approach curves that cause drivers to lose sight of the intersection.

- **Splitter islands:** Splitter islands extend upstream of the yield line to the point at which entering drivers are already decelerating. Practical design may dictate otherwise, but as a general guideline: 200 ft for speeds above 45 mph, 100 ft for speeds between 35 mph to 45 mph; and, 50 ft is acceptable for speeds below 35 mph.
  - The nose of the approach splitter island should incorporate a 2 to 4 ft offset from the face of curb to the paint line on high-speed approaches.
  - Pedestrian access through the splitter island should have ADA ramps and should be either ramped up or semi-depressed.
- **"Visibility package":** Ensure sufficient use of items such as: signs, pavement marking, raised pavement markers/delineators, landscaping and, in some cases, flashers and/or illumination on the approach to the roundabout (see Chapter 5, 7 and 8 for more information). This can compensate for shorter length splitter islands.
- **Curb and gutter:** Curb and gutter help vehicles to maintain lane and reduces speeds; therefore, introduce it in the transitional and low speed segments of the approach. Graduation from paved shoulder to mountable curb to vertical face curb provides an ideal transition from rural to urban cross-section.
- **Exit Taper:** Exit tapers are used to consolidate a two-lane exit to one lane. Exit taper lengths from roundabouts are based on the calculated in-lane exiting speed; therefore, the taper rate can be significantly shorter than the design speed of the roadway. Merging taper rates should be typically 20:1 to 30:1. The length of parallel full-width lanes beyond the circulating roadway to beginning the merging taper varies depending on volume and other factors. See Figure 3-9b.

  Since in-lane exiting speeds are typically less than 40mph, the taper can be calculated using MUTCD Table 6C-4's equation:

$$\text{40mph or less: } L = WS^2/60$$

  Where:

  - L = taper length in feet
  - W = width of offset in feet
  - S = posted speed limit, or off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed in mph

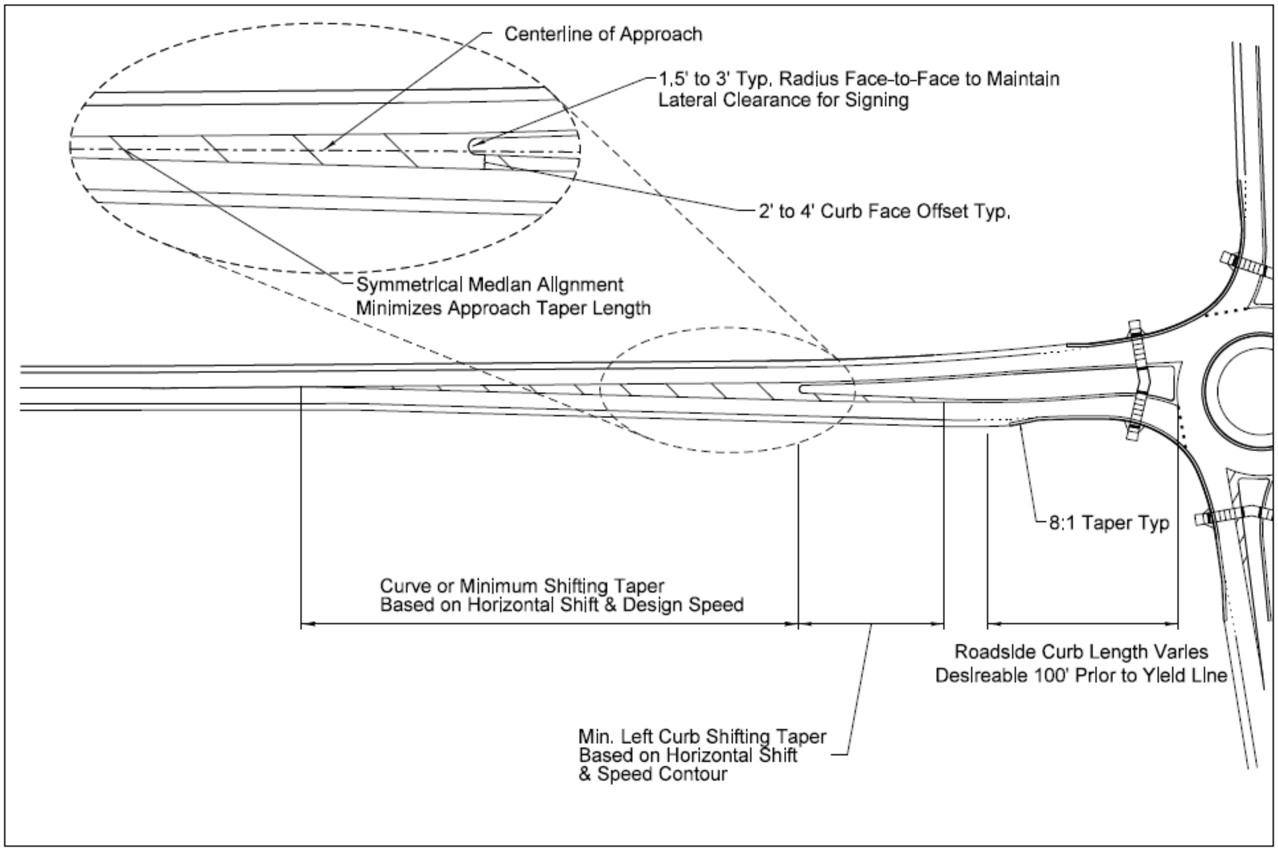


Figure 3-9a. High-Speed Approach Design

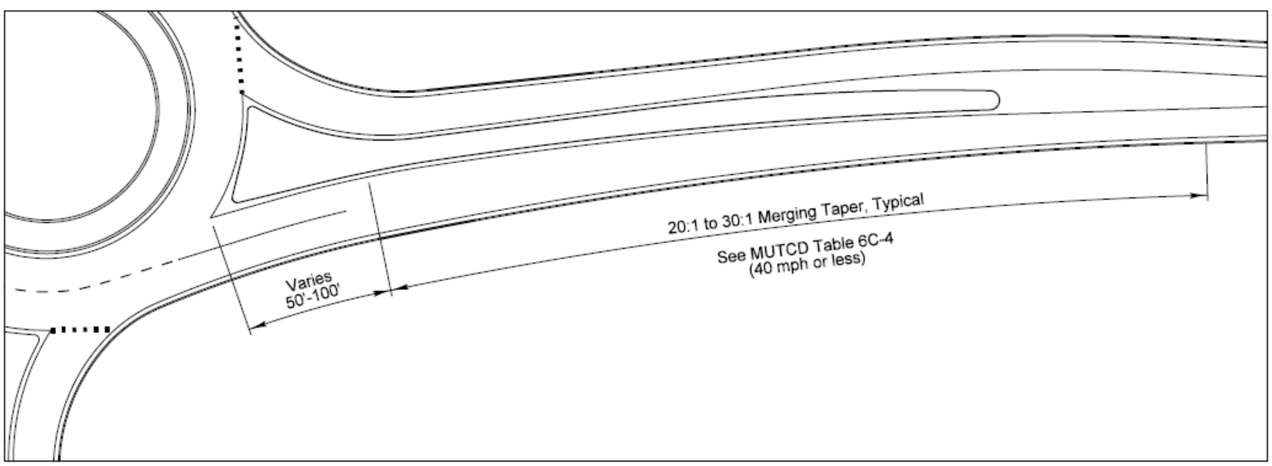
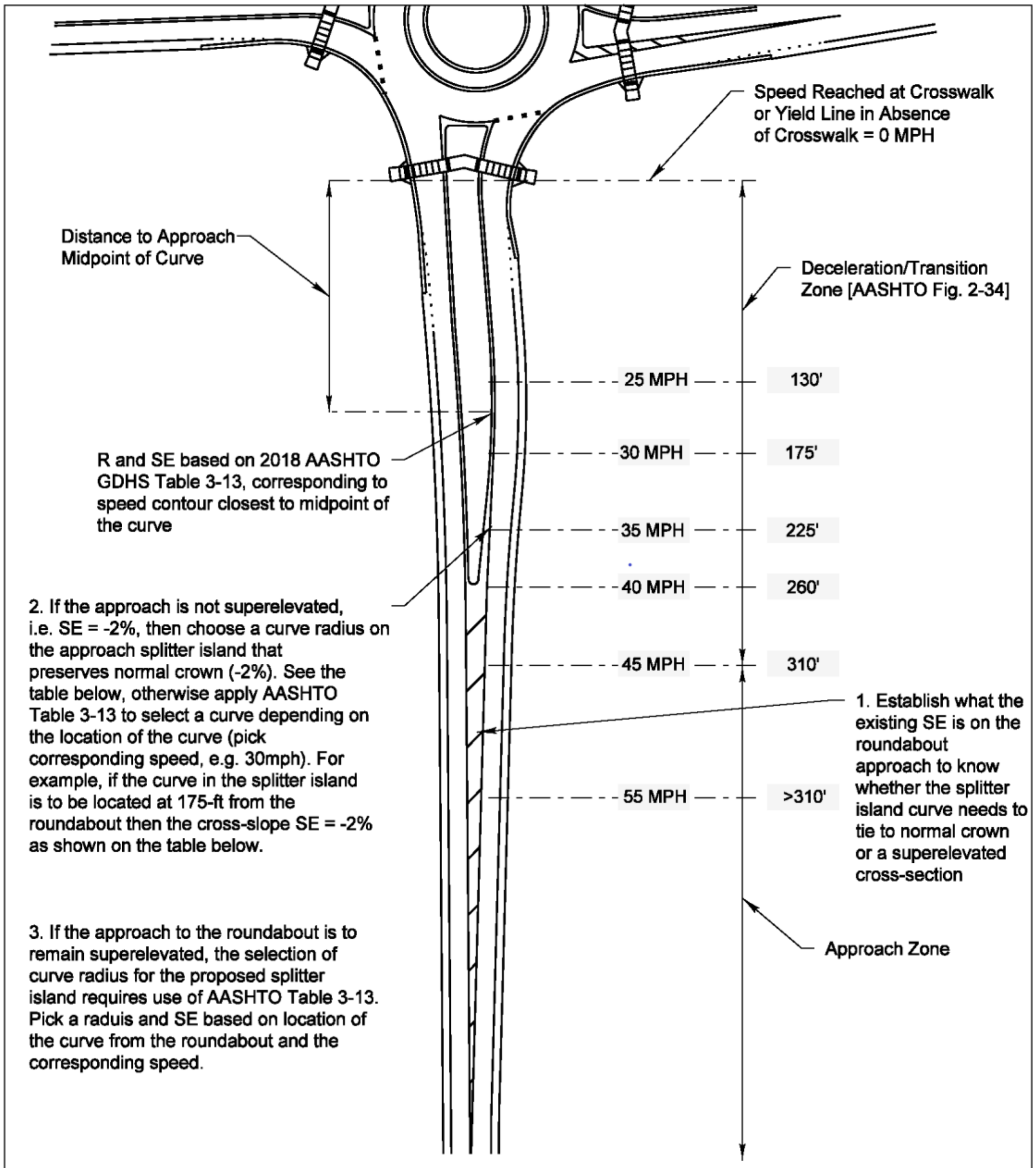


Figure 3-9b. High-Speed Multilane Exit Design



SPEED CONTOUR	55 MPH	45 MPH	40 MPH	35 MPH	30 MPH	25 MPH
DECELERATION DISTANCE FROM CROSS-WALK OR YIELD LINE	>310'	310'	260'	225'	175'	130'
CORRESPONDING RADIUS	*Standard Superelevation Tables*	*Green Book Table 3-13 Minimum Radii and Superelevation fo Low-Speed Streets in Urban Areas*				
		R 1039'	R 762'	R 510'	R 333'	R 198'
		Minimum Radii for Normal Crown (-2%)				

Figure 3-10. Superelevation on Approach

3.11 Entry Curves

The right-side curve near the roundabout entry, also called the entry radius, helps to control entry speeds and is typically in the range of 65 to 100-ft. A starting point for entry radius estimation is half of the ICD. The left side radius can be larger since it has no effect on entry speed control but does influence truck swept paths. Narrowing of the splitter island at the entry may be required to accommodate large trucks while maintaining speed control (minimizing the entry radius and entry width); see Figure 3-11 and Section 3.15 for truck considerations.

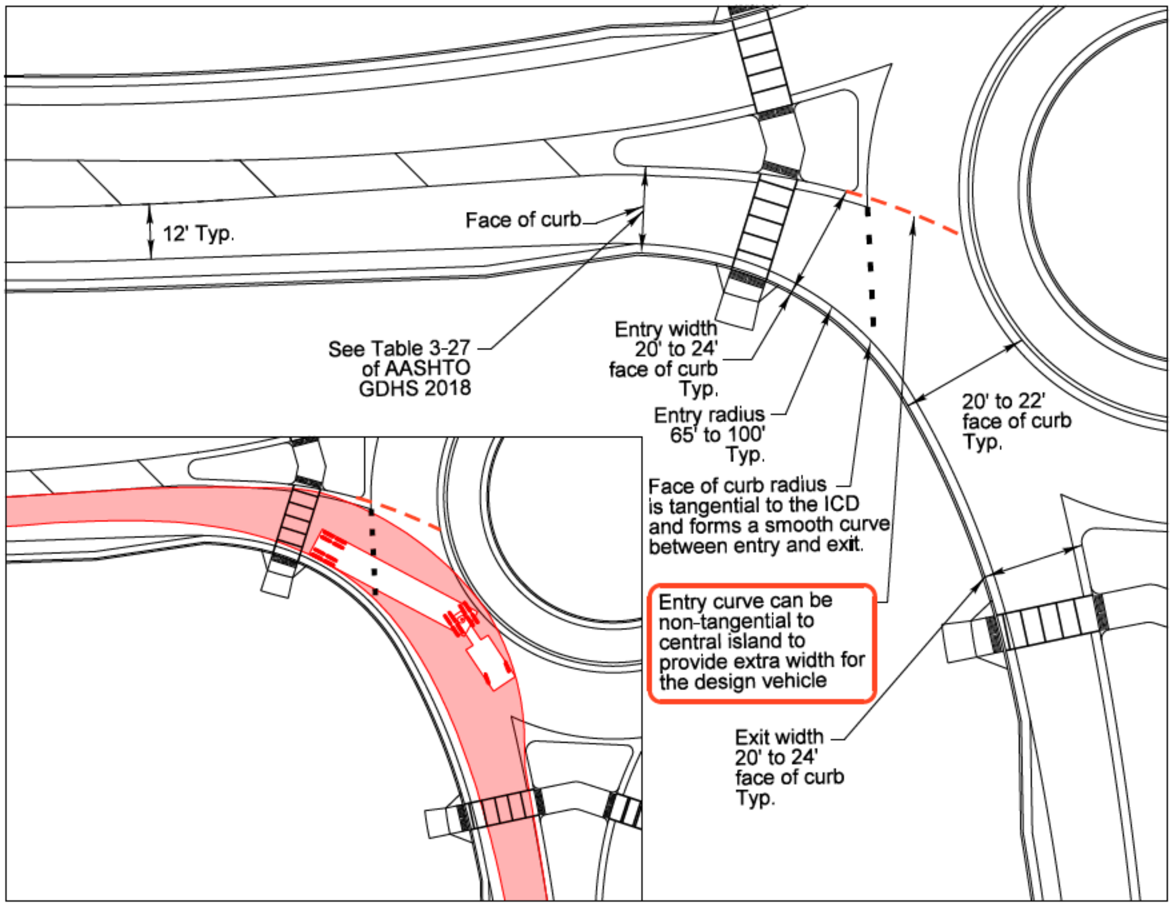


Figure 3-11. Example of Typical Entry to Exit Curves

Figure 3-11 illustrates a typical layout showing roadway width for approaches and exits. Along with this guidance, the following should be considered:

- Design width for entries, exits and right turn bypass lanes is 16 ft desirable [20 ft face of curb to face of curb] to 20 ft [24 ft face of curb to face of curb].
    - Approach width of pavement that accommodate the design vehicle and allow for passing a stalled vehicle at single-lane entries and exits are as follows per AASHTO *Green Book* 2018 Table 3-27

Place curb and gutter to define the roundabout entry and exit. Curb and gutter can be placed on both sides, if needed, for drainage reasons.

3.12 Fastest Path

The geometric design speed through the roundabout, often referred to as the "fastest path", is a critical safety performance measure in the design. It correlates with the probability and severity of crashes between entering and circulating vehicles. The geometric design speed of each movement is determined by drawing the fastest path possible for a passenger car making movements through a roundabout ignoring all lane lines. Figure 3-12 to Figure 3-17 illustrate the three major movements through mini, single lane, 'Y' roundabouts, and multilane, respectively; the five corresponding critical path radii should be checked for each approach. The radii are for each movement: through (R1, R2, & R3), left-turn (R4), right turn (R5). See Appendix D.1 for the Fastest Path Detailed Process.

Geometric **entry path deflection** is best represented by a continuous spline (a curve with constantly changing radii) because this most closely approximates how a vehicle traces its fastest path through a roundabout. A spline also allows analysts to draw the smoothest, most natural vehicular path. It is drawn from a starting point approximately 165 ft in advance of the entry line, with an offset of 5 ft from curbs, 5 ft from a centerline and 3 ft from other pavement markings (such as a painted median or two-way left-turn lane). The critical entry path radius, referred to as R1, occurs over the spline for 65 ft to 80 ft, near the yield point, where the tightest radius exists. However, R1 is not necessarily the speed controlling radius (entry radius referred to in Section 3.11 and shown on Figure 3-11). The center of the curve should be near the crosswalk and upstream of the entry. Vehicle speed estimation is in accordance with NCHRP 672, Section 6.7.1.2 Equations 6-1 and 6-2. Equation 6-3 may be used to estimate actual entry speed, but it does not govern the fastest path performance check.

In most cases, speed control on entry is the most important fastest path criteria for all roundabout configurations. In addition, if a location has a significant pedestrian count, steps should be taken to facilitate lower vehicle speeds at all pedestrian conflict areas (including exit speeds from the roundabout). When checking exit speeds, both the predictive method (based on the R3 exit path radius) and NCHRP 672 Equation 6-4 (which accounts for acceleration from R2 to R3) should be checked.

Mini-Roundabouts - Due to the smaller circle size, geometric entry path deflection at mini-roundabouts is more challenging; therefore, approach curvature typically governs entry speed. Along with left offset, deflection can be achieved through approach curvature (chicanes) and/or longer splitter islands (Figure 3-12). These features also contribute to recognition of the roundabout ahead so that drivers may decelerate in advance of the entry point.

Single Lane and Compact Roundabouts – The design of a single lane roundabout should have enough entry path deflection to create balanced speeds through the roundabout. The use of left offset helps in reducing speeds in advance of the entry line; this is especially important for compact roundabouts.

Multilane Roundabouts - At multilane roundabouts, the fastest path should use the full width of pavement ignoring striping, such as lane lines, gore striping and rumble strips. The fastest path should be controlled by physical constraints, such as vertical elements like curbing. Raised lane dividers (with curbing) provide the physical constraints necessary to facilitate in-lane fastest paths on multilane roundabouts. **The raised lane dividers should extend far enough back on the approaches from the yield point, and far enough from the exit, so that the fastest path speeds are controlled**.

Figure 3-15 to 3-17 show the R1, R2 and R3 for a Case 1, 2 and 3 multilane roundabouts.

See Section 3.15.2 for more information about the truck case designs shown in Figure 3-15 to 3-17.

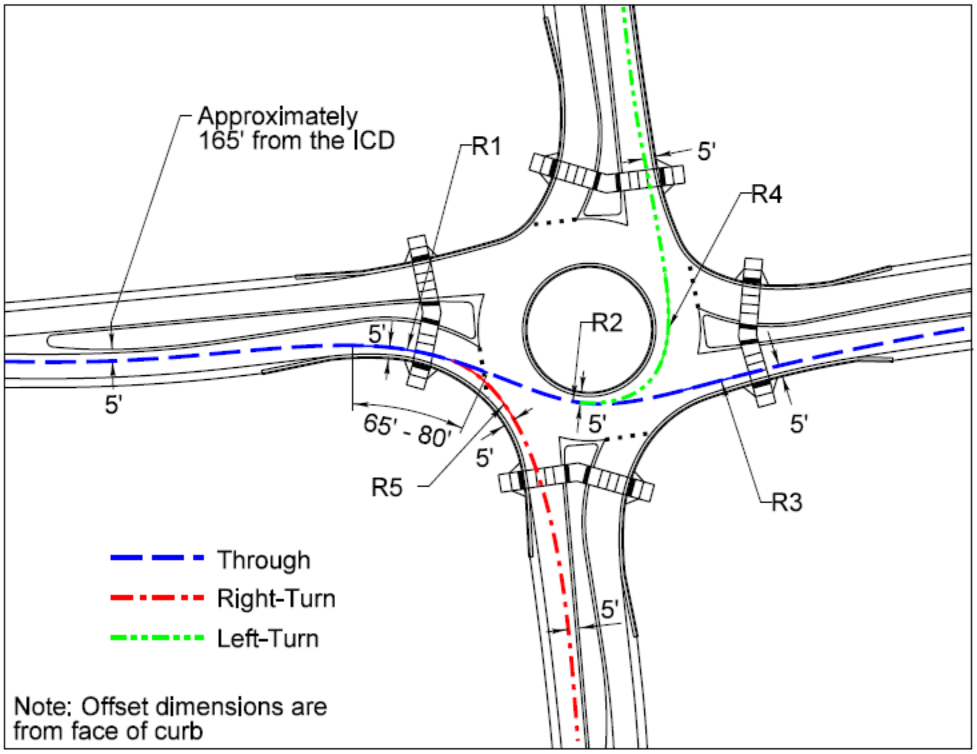


Figure 3-12. Determination of Entry Path Curvature – Mini-Roundabouts

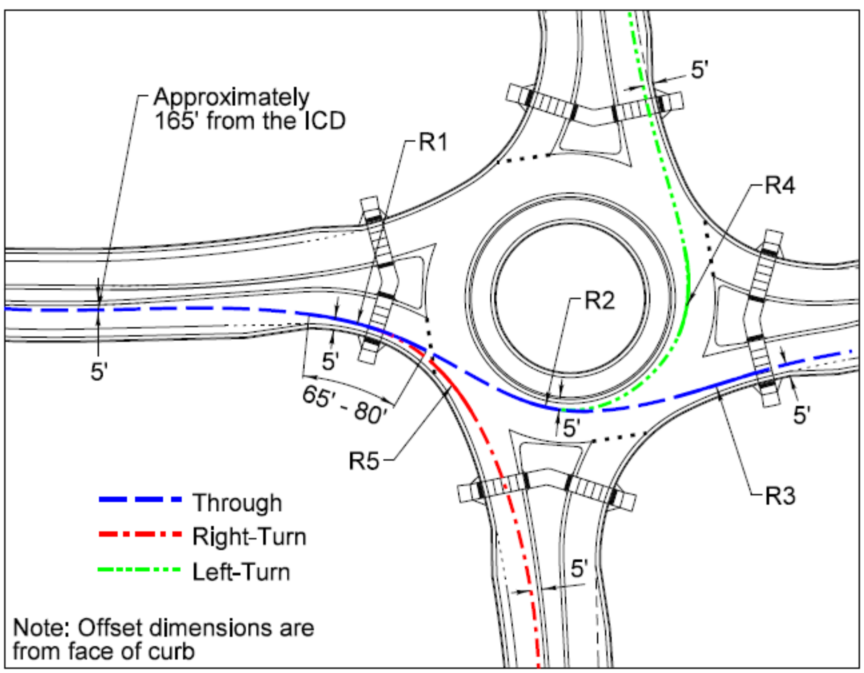


Figure 3 13. Determination of Entry Path Curvature – Single Lane Roundabouts

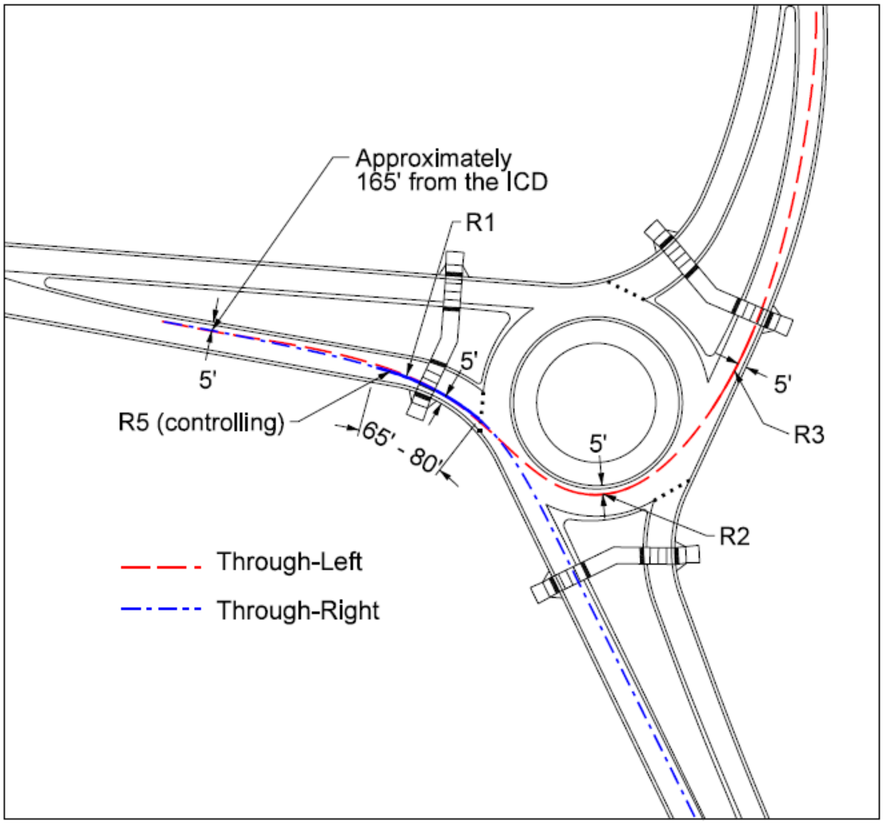


Figure 3-14. Determination of Entry Path Curvature – Y Roundabouts

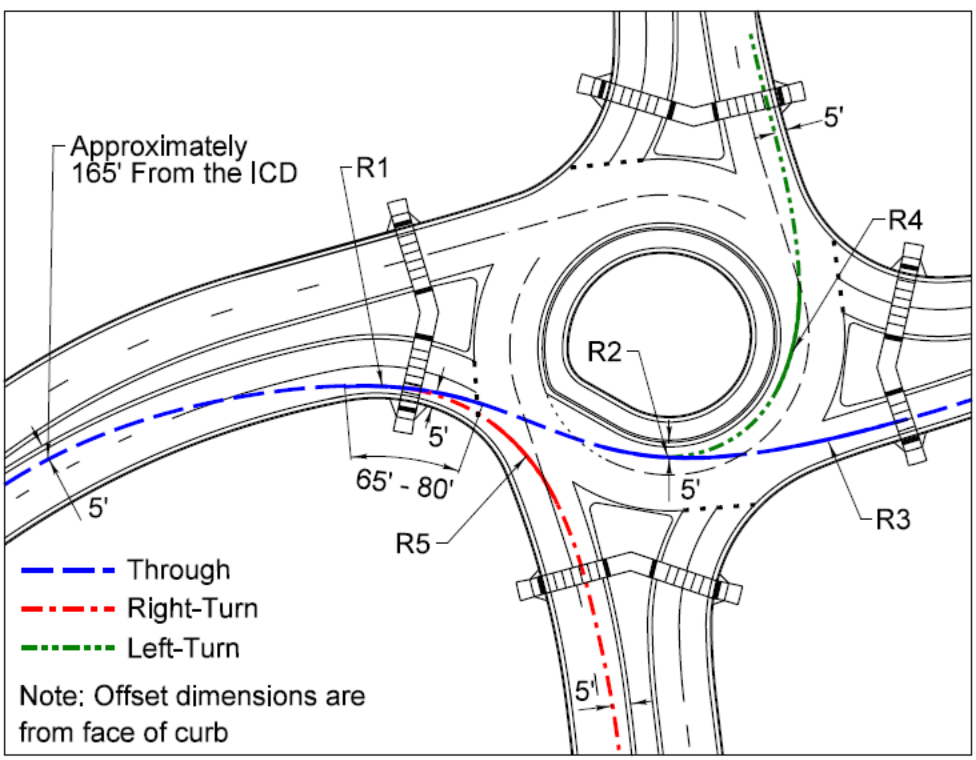


Figure 3-15. Determination of Entry Path Curvature – Multilane Roundabouts Case 1

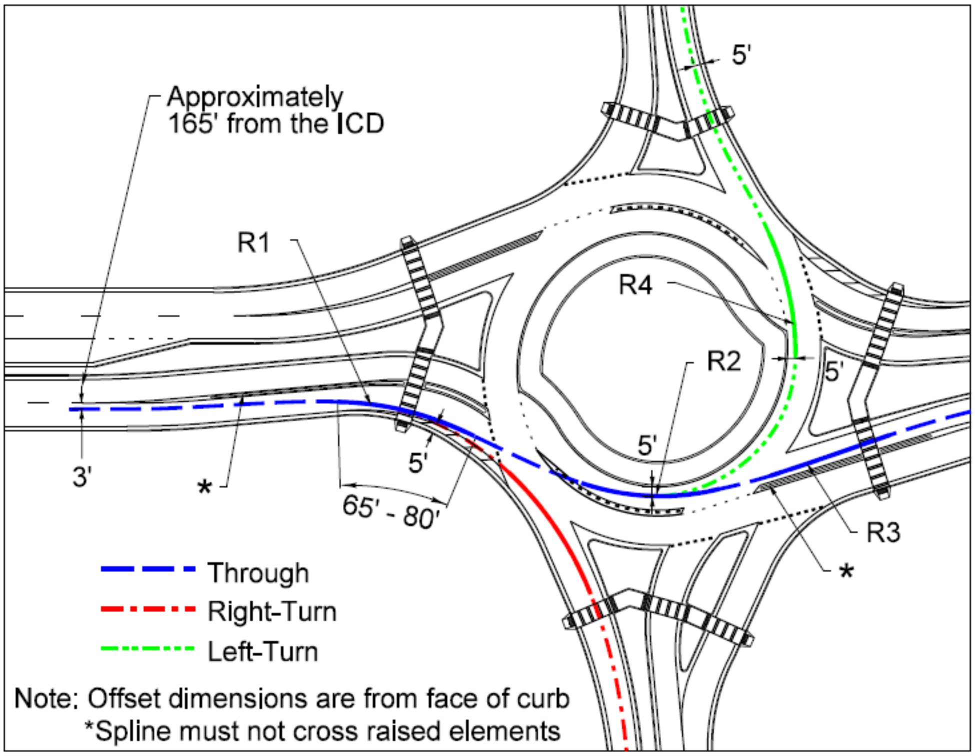


Figure 3-16. Determination of Entry Path Curvature – Multilane Roundabouts Case 2

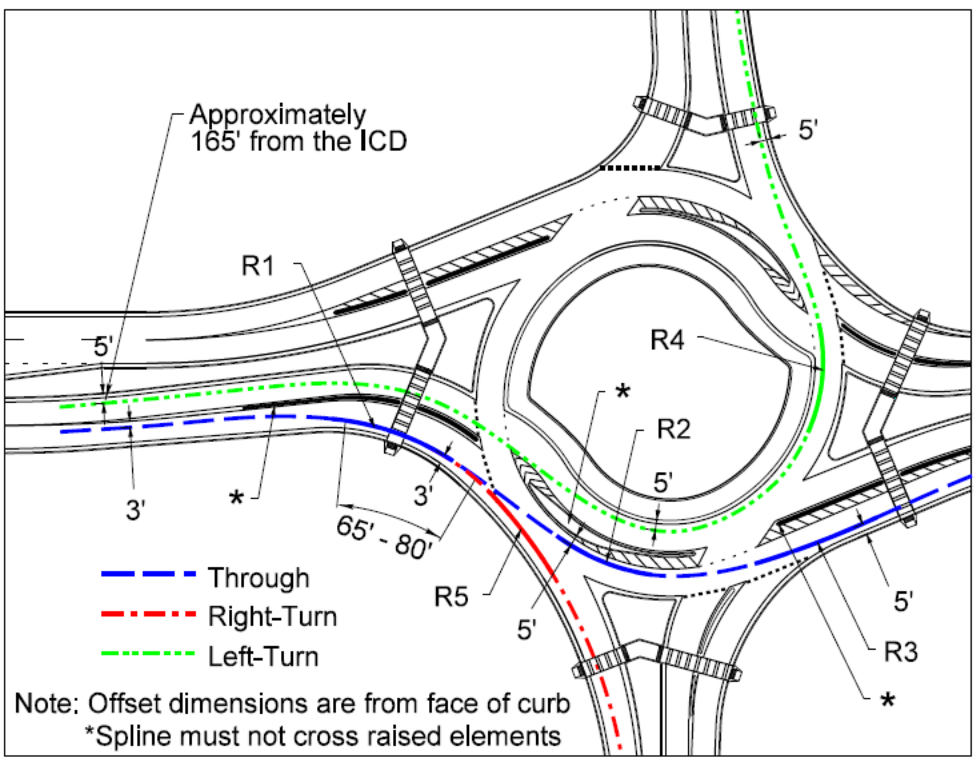


Figure 3-17. Determination of Entry Path Curvature – Multilane Roundabouts Case 3

Table 3-3 describes the critical radii that make up the fastest path and provides ranges of desirable speeds. The lower range of the table is preferred, especially where significant levels of pedestrians are present.

See Appendix D.1 on how to draw and measure Fastest Paths using Bentley MicroStation CAD software.

Table 3-3. Fastest Paths and Speed Tolerances

Critical Radius	Description	Desirable Range of Radii and Corresponding Speeds
Entry Path Radius, R1	The minimum radius on the fastest through path prior to the yield line. (This is not the same as Entry Radius.)	Single Lane and Multilane (Case 2&3) R1 ≤ 170’; V1 = 20 to 25 mph Multilane (Case 1) R1 ≤ 275’; V1 = 20 to 30 mph
Circulating Path Radius, R2	The minimum radius on the fastest through path around the central island.	R2 ≤ 170’; V2 = 15 to 25 mph
Exit Path Radius, R3	The minimum radius on the fastest through path into the exit*	**Pedestrians: R3 ≤ 25mph No Pedestrians: R3 ≤ 30-35mph
Left Turn Path Radius, R4	The minimum radius on the path of the left-turn movement.	R4 ≤ 95’; V4 = 10 to 20 mph
R1 – R4	The difference between entry and circulating speed	10 to 15 mph
Right Turn Path Radius, R5	The minimum radius on the fastest path of a right turning vehicle.	R5 ≤ 170’; V5 = 15 to 25 mph

*The exit speed is the minimum of the predicted speed based on the R3 radius or acceleration from the middle of R2 to the point of interest on the exit; see NCHRP 672 Section 6.7.1.2 Equation 6-4.

**If R>25mph, the SSD from the center of R2 to the crosswalk should ensure a car driving through the roundabout will have time to see a pedestrian and stop. (Supplemental treatments could also be considered such as RRFBs, PHBs, etc.)

3.13 Stopping Sight Distance

Sight distance envelopes should be provided for Stopping Sight Distance (SSD) to determine clear view zones using driver eye height of 3.5 ft and object height of 2 ft for the scenarios listed below, see Appendix D.2 for formulas and more information.

1. Approach SSD and Approach SSD (with reverse curves) (Figure 3-18 and Figure 3-19)
2. Approach SSD (with bypass lane) (Figure 3-20)
3. SSD to the downstream crosswalk (Figure 3-21)
4. SSD around the circulatory roadway (Figure 3-22)

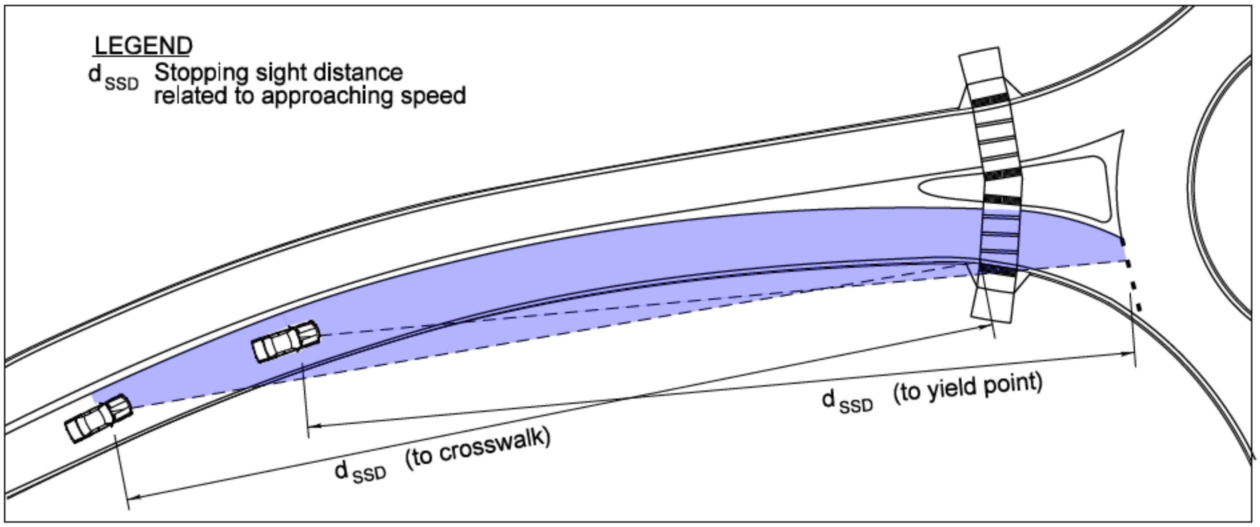


Figure 3-18. Approach Stopping Sight Distance (SSD)

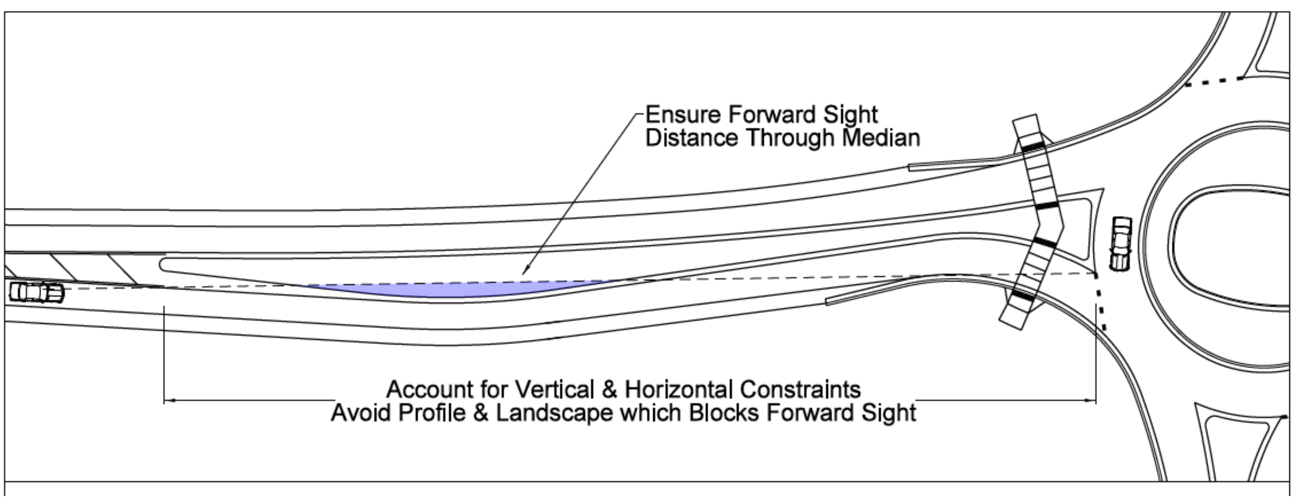


Figure 3-19. Approach SSD (with Reverse Curves)

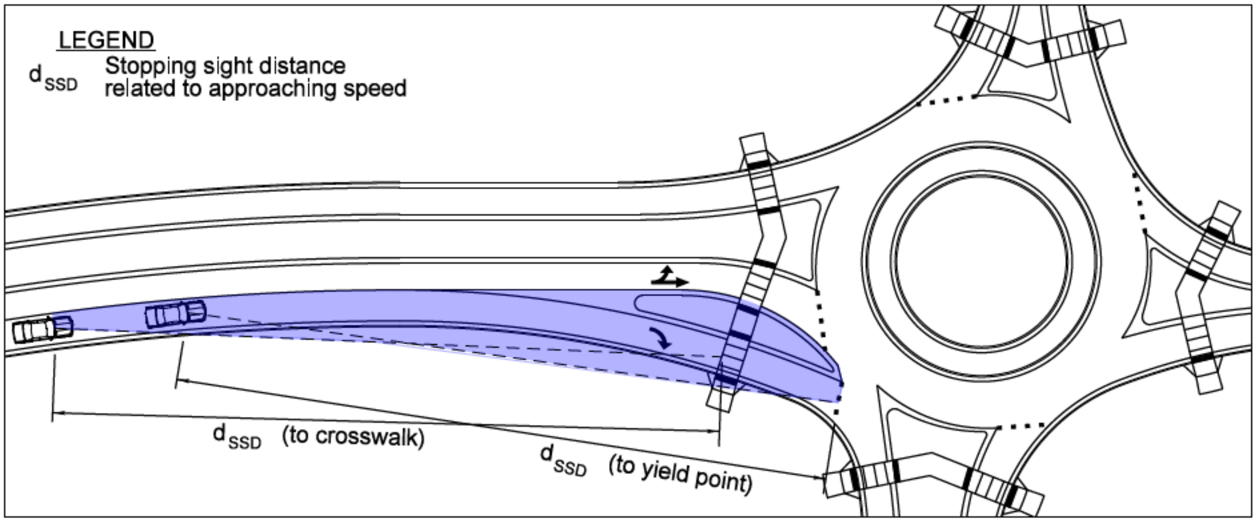


Figure 3-20. Approach SSD (with Bypass Lane)

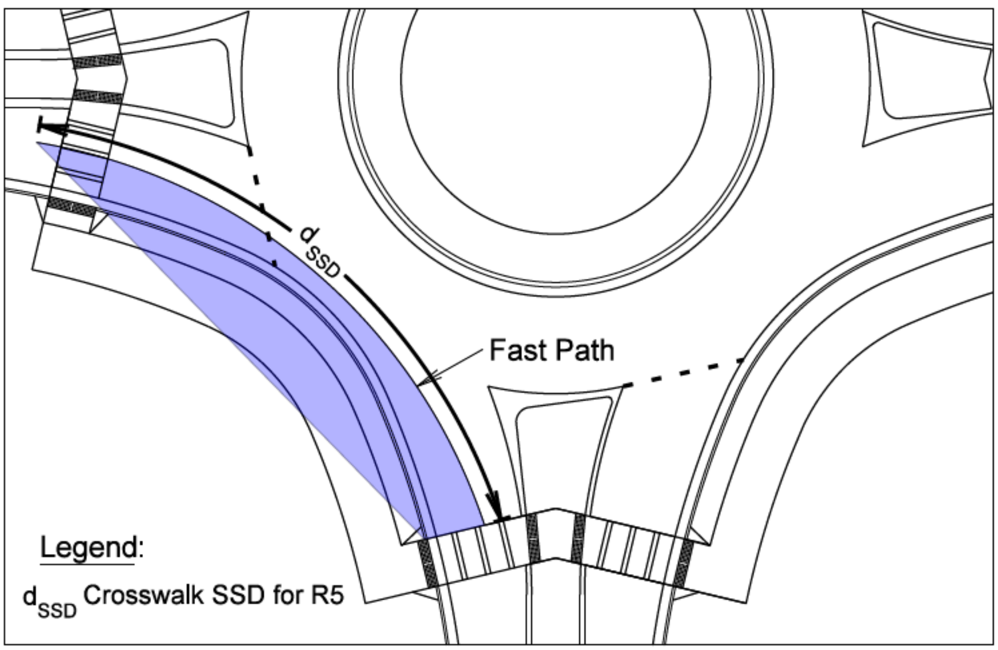


Figure 3-21. Stopping Sight Distance to the Downstream Crosswalk

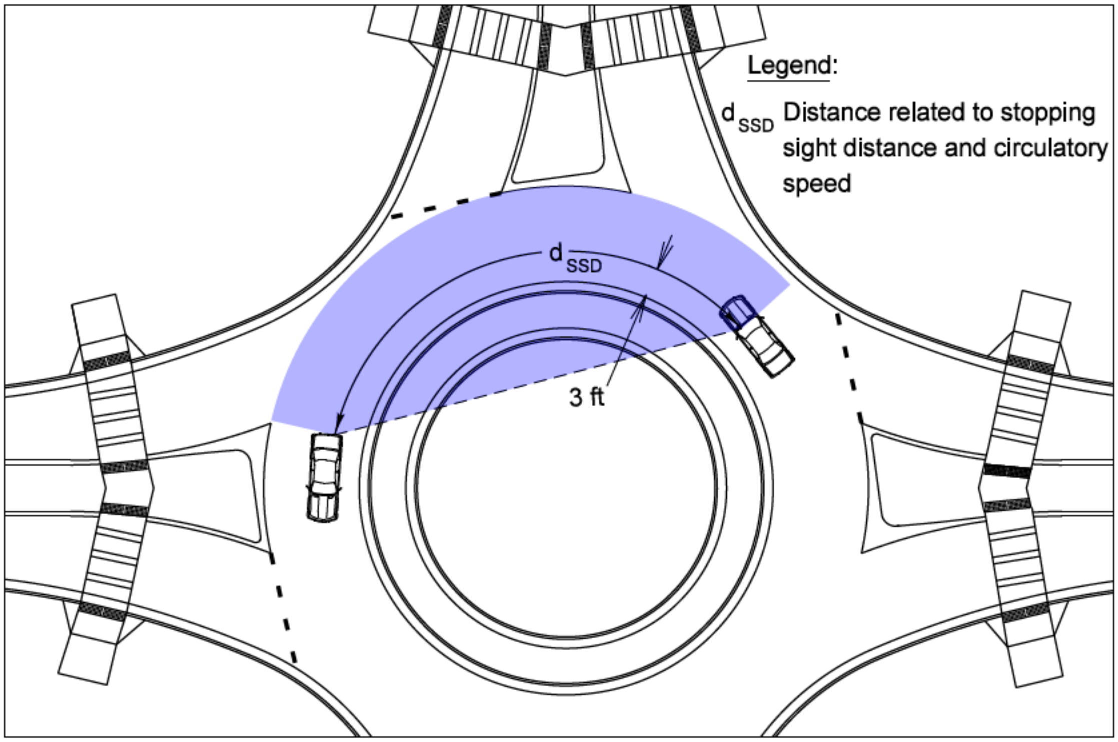


Figure 3-22. Stopping Sight Distance around the Circulatory Roadway

The approach stopping sight distance may be lost if a "table-top" profile is used at a roundabout entry, (e.g. for crosswalk transverse grade of 2% per US Access Board accessibility design criteria). Figure 3 23 illustrates the vertical sight distance problem created by flattening the approach profile versus a slightly steeper profile. ***Note, selection of K values based on the design speed approaching the roundabout does not guarantee approach stopping sight distance***.

Tipping the circle or raising the central island to improve central island visibility, are methods for improving substandard approach stopping sight distance. If it is infeasible to achieve approach SSD, it should be compensated for by adding additional approach visibility elements (e.g. signs).

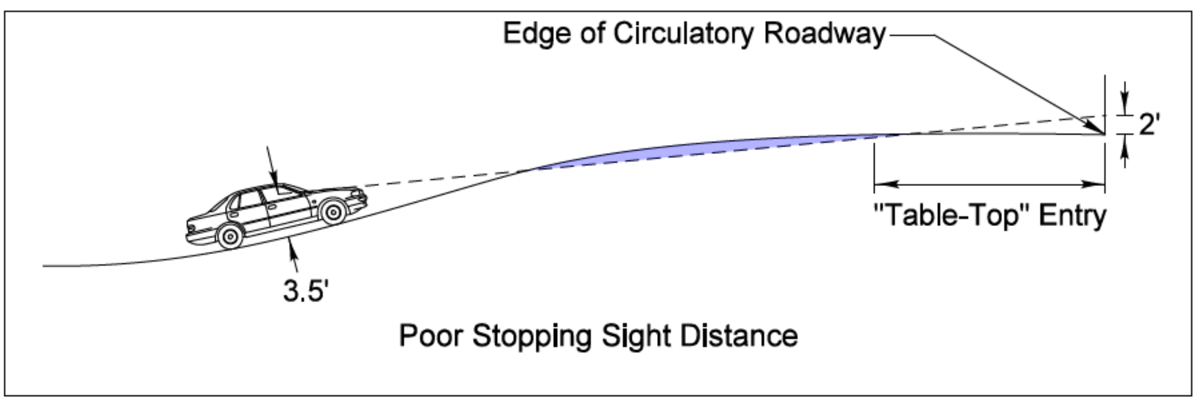


Figure 3-23. Vertical Considerations of Approach Stopping Sight Distance

3.14 Intersection Sight Distance

Intersection Sight Distance (ISD) is the distance required for a driver without the right-of-way to view and react to the presence of conflicting vehicles. ISD should be checked at entries for entering and circulating conditions; see Appendix D.2.2 for ISD envelope drawing tips.

ISD should be derived from the equations in the Appendix; however, at a minimum of 50 ft upstream of both approaches should be used. The department's preference is to be in between the minimum and maximum ISD, calculated from the NCHRP equations (involving the fastest path).

Figure 3-24 illustrates the entering ISD envelopes. The minimum applies where there are site constraints and the preferred is infeasible, e.g. guardrail or bridge walls near a roundabout approach. More than standard sight distance (defined here as the maximum) is undesirable because it can lead to drivers competing for gaps and failure to yield conflicts. For central island treatments to limit excessive circulating ISD, see Chapter 8 on Landscaping.

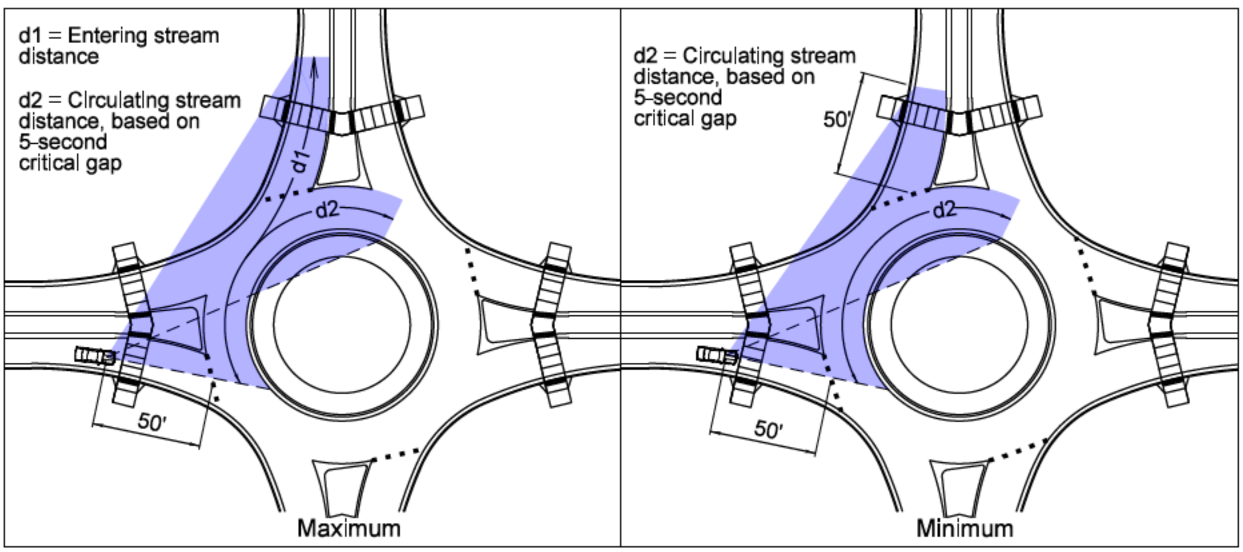


Figure 3-24. Maximum and Minimum Intersection Sight Distance

3.15 Truck Considerations

Roundabouts are designed with a raised and mountable truck apron where the design vehicle swept path may overtrack beyond the circulatory roadway into the central island. The wheels of the design vehicle should not overtrack onto sidewalks, or outside curbs (without the use of a truck blister). Accommodation of the design vehicle is verified through horizontal swept path analysis (AutoTURN, etc.) and, sometimes, vertical clearance analysis. When conducting a swept path analysis, typically provide 1 ft clearance from the tire of the cab to the curb face. However, the cab wheels should typically remain on the circulatory roadway and not need to track onto the truck apron to cross the roundabout. Additionally, all roundabouts should be designed to accommodate buses and emergency vehicles within the travel way without overtracking onto the truck apron. See Appendix D.3 on how to perform AutoTURN analysis of truck swept paths.

3.15.1 Truck Aprons

Truck aprons - The truck apron width, around the central island, may vary based upon the circle size and geometric composition of the roundabout. The truck apron should be wide enough to accommodate the swept path of the overtracking trailer plus 2-ft to face of curb at the back of the truck apron. **To maximize the landscaped area, the truck apron should have a variable width around the circle to accommodate design and check vehicles.** In urban conditions and/or low truck movements, the cab of right turning trucks can utilize the inside apron. This allows a smaller footprint and improves feasibility for lower cost in some situations.

4-inch curb face (type 9) is typical, see Section 3.18 for curb types.

3-inch curb face (type 9) can be used in locations with:

- higher truck volumes
- where vertical clearance for low-boy trucks is needed
- where truck cabs are expected to mount the apron

Outside Truck Aprons (Truck Blisters) – These may be necessary at outside curb radii to accommodate larger design vehicles, especially at skewed intersections or on compact roundabouts. In these cases, outside truck aprons can assist in maintaining a smaller footprint. Pedestrian safety can be impacted when trucks frequently overtrack a crosswalk landing within the outside truck apron; therefore, **avoid placing the outside truck aprons through crosswalks**, especially in areas with high pedestrian traffic. See Section 3.18 for an outside truck apron typical section.

3.15.2 Multilane Roundabout Cases

After determining your design vehicle from Section 3.5, the three cases for truck (design vehicle) tracking consideration are identified as follows:

- **Case 1 – Truck does not stay in-lane on entry or circulating (see Figure 3-25)**
    - Trucks will straddle the lane line on the approach of the roundabout and use both lanes for entry, circulating, and departure.
    - For new designs, rumble strips should be used on lane separation striping (to assist with passenger car lane discipline) for entry, circulating, and departure. Profiled striping or striping with RPMs can be used in lieu of rumble strips, if necessary (when concrete pavement is used, in some urban conditions, etc.)
    - When an approach is less than 120 trucks/hour, particularly in an urban context where smaller circles and lower entry speeds are desirable for pedestrian safety.

    * For Case 1 design, truck apron widths should be sized assuming the truck uses both lanes of the roadway.
- **Case 2 – Truck stays in-lane on entry, but uses both lanes for circulating (see Figure 3-26)**
    - For new designs, raised lane dividers should be used within lane separation striping for entry and departure.
    - For new designs, rumble strips should be used within lane separation striping (with or without gore striping and RPMS) for circulating.
    - Recommended when an approach exceeds 120 trucks/hour and physical constraints prohibit widening for case 3.
- **Case 3 – Trucks in-lane on both entry and circulating (see Figure 3-27)**
    - For new designs, raised lane dividers should be used within lane separation striping for entry, circulating, and departure.
    - Recommended when an approach exceeds 120 trucks/hour and physical constraints allow increased ICD.

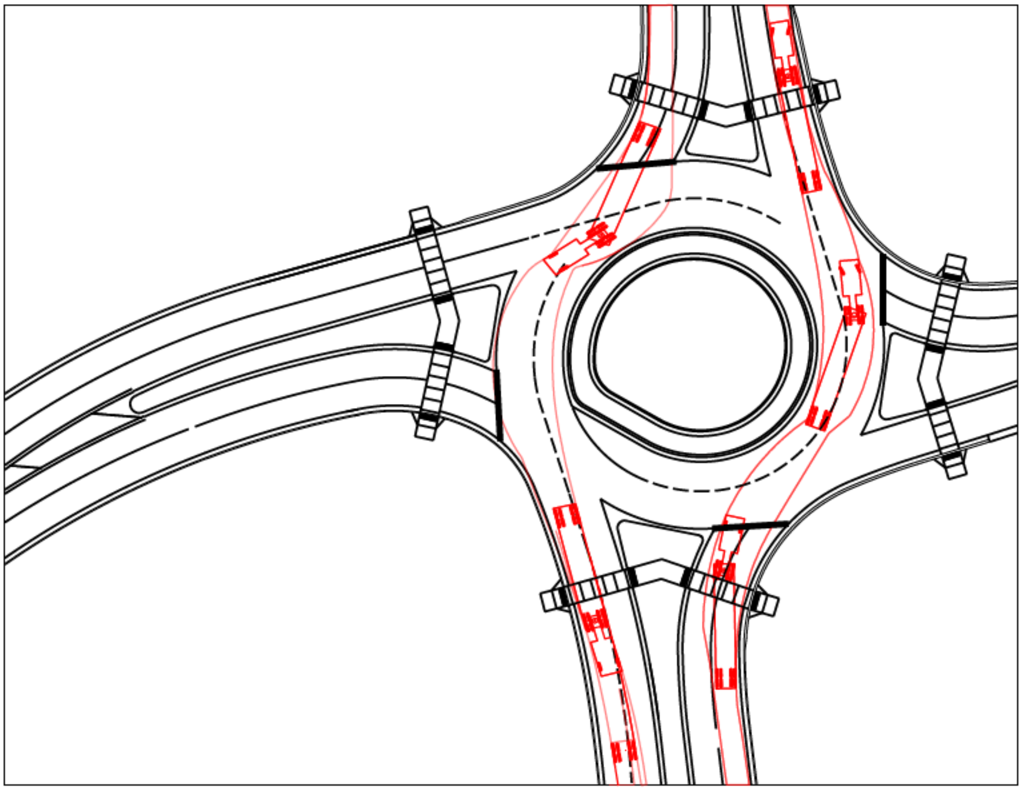


Figure 3-25. Truck Case 1

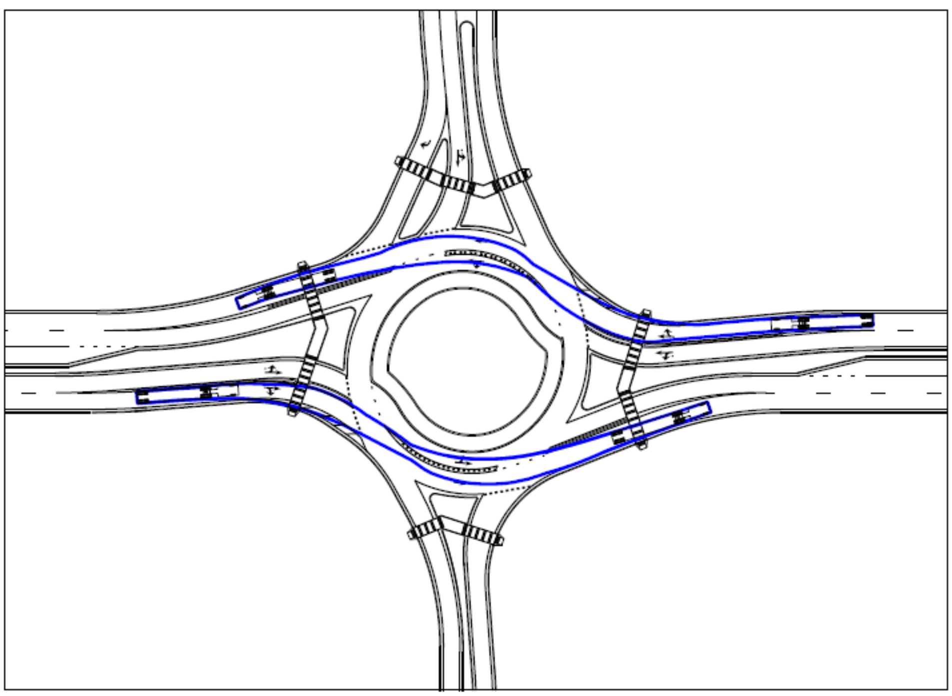


Figure 3-26. Truck Case 2

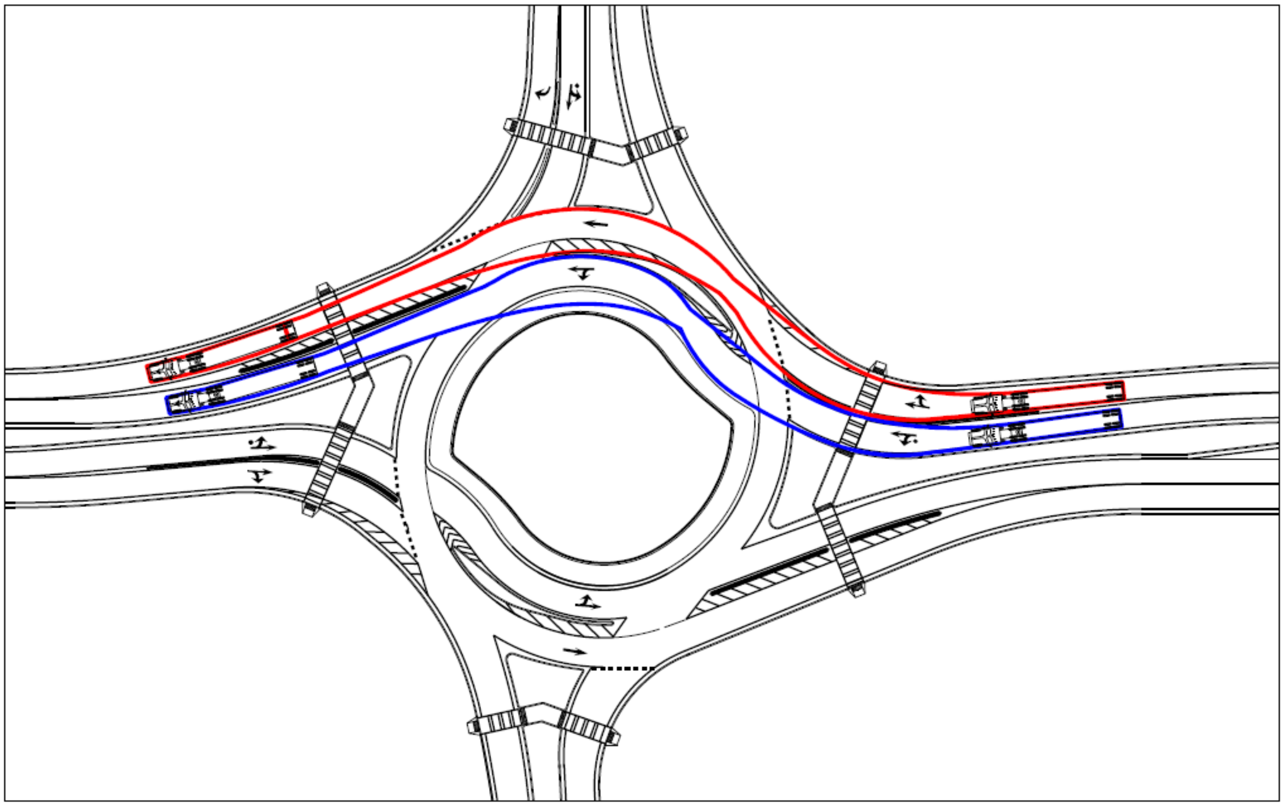


Figure 3-27. Truck Case 3

3.15.3 Check Vehicle Accommodation

It should be assumed that check vehicles can/will:

- overtrack all lanes and ignore lane lines
- cab will override mountable curbs (e.g. truck aprons, outside truck aprons, lane dividers, etc.) when necessary
- avoid fixed objects (signs, poles, etc.)
- try to avoid pedestrian features (sidewalks, etc.) when sufficient ROW is available to setback sidewalk

When conducting a swept path analysis for the check vehicle, provide 1-ft (desirable) clearance from the tire to the curb face. The design principles of the roundabout should not be compromised to accommodate the check vehicle; therefore, some of the special accommodations listed below can be used to address vehicle overtracking.

- Adjust pavement grades and cross slopes to prevent “hanging up” or scraping
- 4-in mountable curbs on splitter islands (e.g. Type 1 or Type 9, see 9032b)
- Wider truck aprons
- Flatter truck aprons (3”) when necessary
- Add outside truck apron
- Wider paved shoulders
- Relocation of signals, poles, signs, etc.
- Removable signs
- Gated bypass lane, in the central island, for OSOW vehicles only

Counter flow travel can be considered where the turning movements would require extremely wide truck aprons (i.e. the remaining central island would be significantly reduced). This does not compromise the size of the central island, which is important for increasing the visibility of the intersection, and for blocking sight across the intersection. If counter flow travel is used, flagging operation and/or law enforcement presence is needed.

See Figure 3-28 for an example of the central island modifications and the added tracking areas to accommodate an OSOW vehicle making through movements.

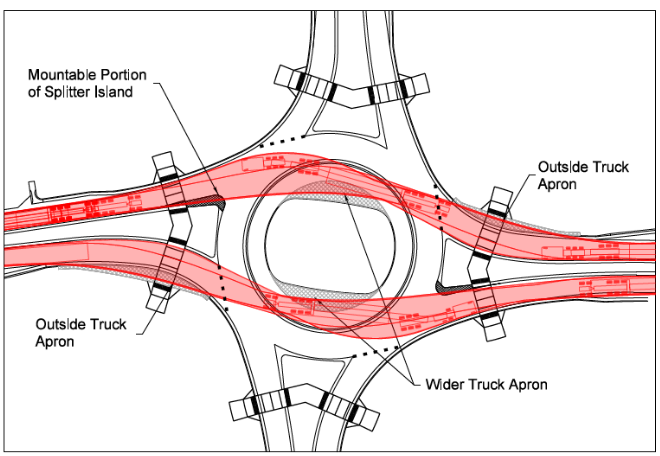


Figure 3-28. Overtracking Design Considerations for OSOW

3.16 Path Alignment

Path alignment ensures the vehicle is aligned at entry and exit with the appropriate receiving lane. At single-lane entries, reviewing path alignment considers where the driver is being aimed; additionally, path alignment at the entry curve slows down vehicles. For multilane roundabouts, path alignment of both entry and circulating path should be designed with additional care due to the characteristics of side-by-side vehicles.

Path efficiency is the balancing of paths in and through the roundabout so that each movement has approximately the same path length. The goal of path efficiency is to provide a balanced flow (speed control and path) for all movements. In some cases, designs might be able to have balanced paths and balanced speed control from opposing approaches. In non-uniform geometry, the attempt to form path efficiency may have unintended consequences due to the lack of speed reduction and increased costs. Fixating on path efficiency may result in a design that is not practical.

When determining circle size, shape, and alignment of legs, consider path alignment and path efficiency so that movements from every direction are balanced.

3.16.1 Entry Path Alignment

For multilane roundabout entry design, it is necessary to align the entry paths of side-by-side passenger cars to reduce the risk of sideswipe collisions and operational turbulence at entries and exits. **Path alignment problems occur when the natural paths of vehicles in adjacent lanes overlap or cross one another; this is called path overlap**. It occurs most commonly at entries where the geometry of the right-hand entry lane leads vehicles into the left-hand circulatory lane. However, vehicle path overlap can also occur at exits, where the exit geometry or striping of exit leads vehicles from the left-hand lane into the right-hand exit lane. Figure 3-29 illustrates an example of entry path overlap at a multilane roundabout. For additional information, see NCHRP 672, Sections 6.2.3 & 6.5.4.

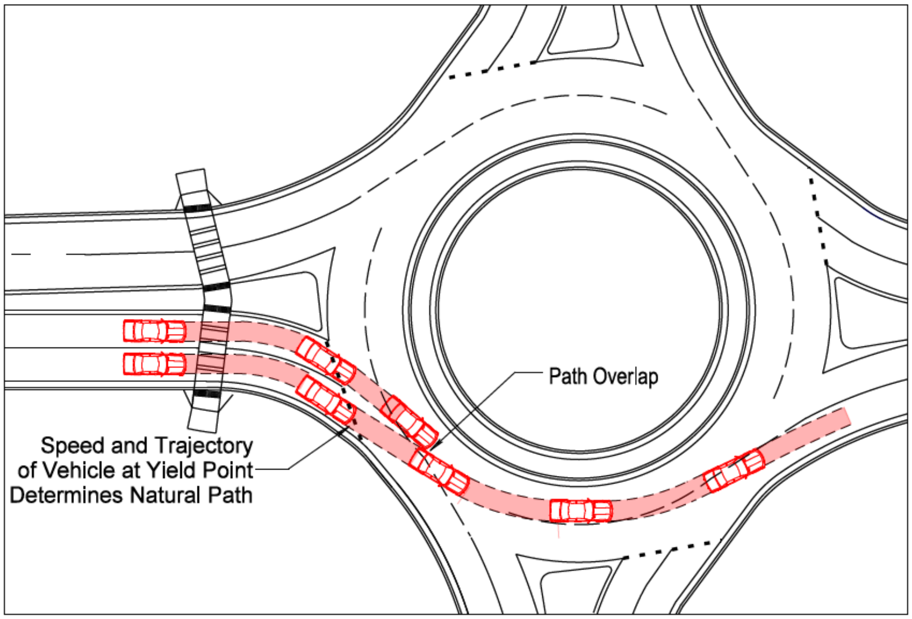


Figure 3-29. Entry Path Overlap (Avoid)

The combination of the approach alignment, entry radius, and location of the entry curve nearest to the yield point directly affects vehicle path alignment. If the speed controlling entry radius is located too close to the circulatory roadway, it can result in path overlap. However, if it is located too far away from the circulatory roadway, it can result in higher fastest path speeds or drivers accelerating into the entry. For additional information, see NCHRP 672, Section 6.4.3. Figure 3-30 illustrates geometric characteristics that are both smooth and slow. This minimizes entry and exit turbulence so that multilane design performs as expected.

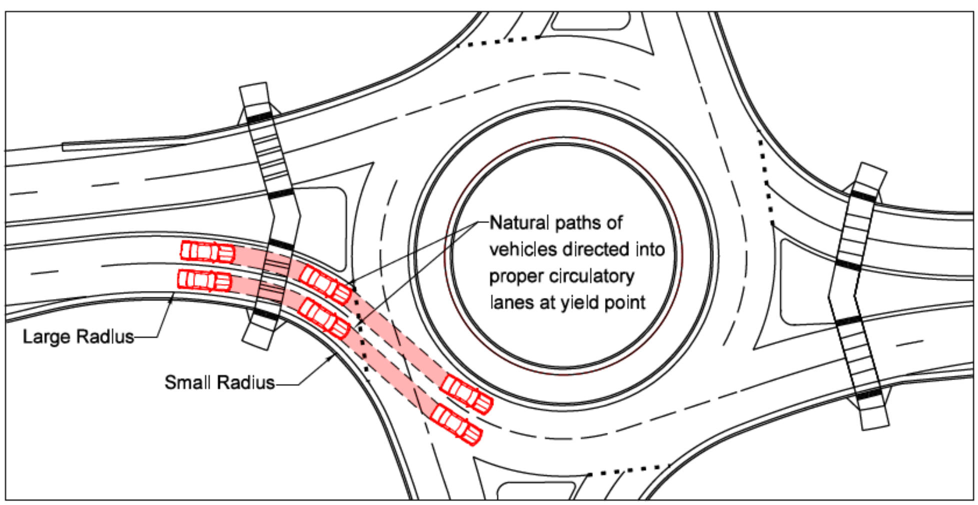


Figure 3-30. Multilane Entry Design to Minimize Path Overlap

Figure 3-31 provides a method for checking and avoiding path overlap (for Case 1). For the entry and exit path tangents, the tangent should extend from the circulating curve to the entry or exit. Path overlap can typically be avoided if there is approximately 5 ft between the central island curb and the extension of the splitter island curb, with the radius of that curve extension in the range of 75 to 100 ft. Another way to avoid path overlap is to add raised lane dividers to physically separate vehicles, such as shown for Case 2 and Case 3 multilane designs.

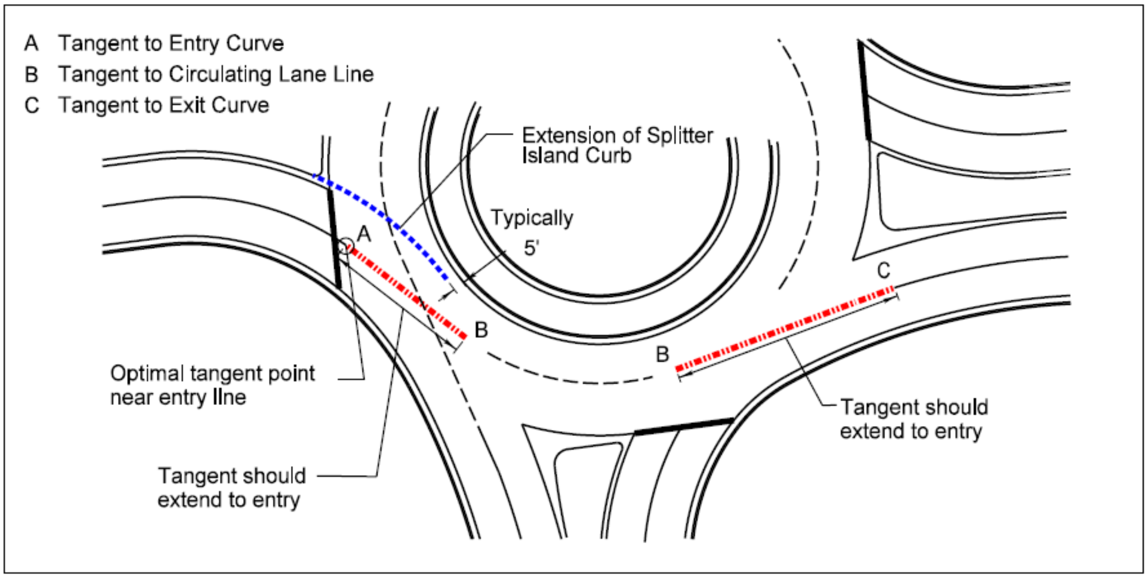


Figure 3-31. Method for Checking Path Overlap (Case 1)

Figure 3-32 shows path overlap in a Case 3 multilane roundabout; the raised lane separation within the circulatory roadway should start closer to the entry to avoid this path overlap. Figure 3-33 shows raised lane dividers on the entry that will guide traffic into the correct circulatory lane and prevent path overlap.

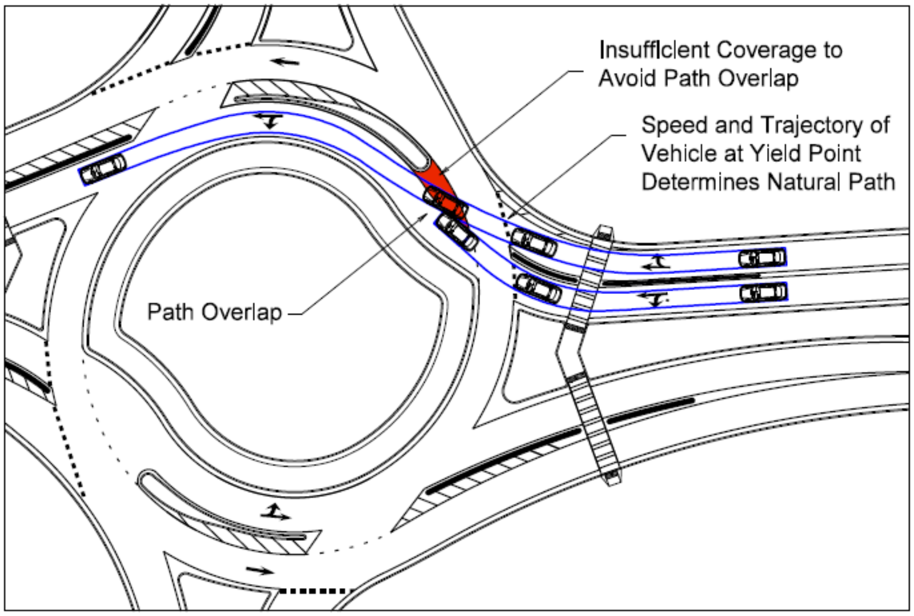


Figure 3-32. Case 3 Multilane Roundabout with Path Overlap (Avoid)

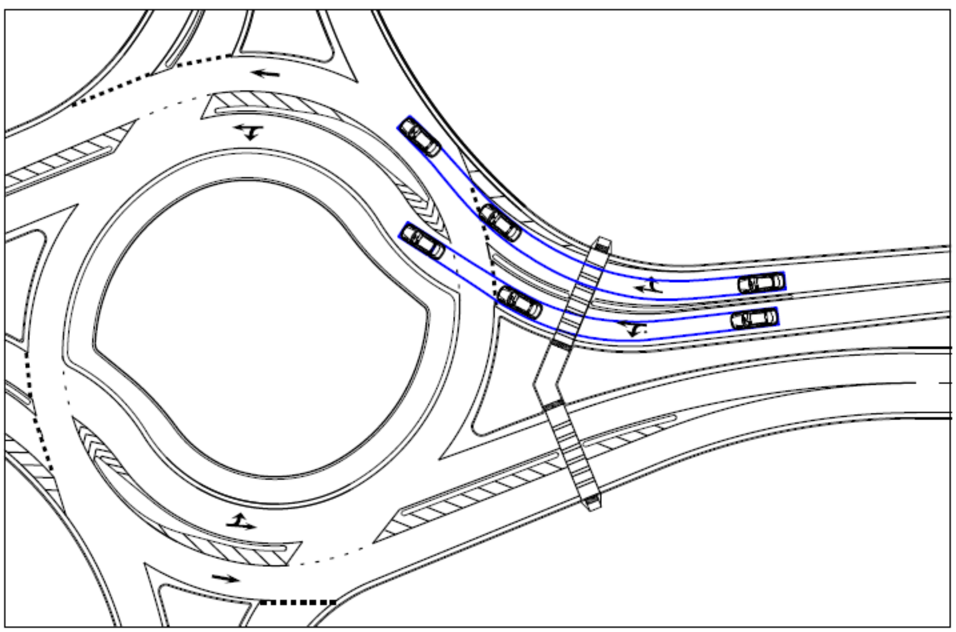


Figure 3-33. Case 3 Multilane Roundabout Entry Path Alignment

Case 3 roundabouts should implement a tapered nose (aka. frog), a mountable raised divider that will be used by large trucks, to transition the beginning of the raised lane divider and to assist in avoiding path overlap. See Section 3.18 for tapered nose detail.

The opening width is measured where the left lane entering crosses a portion of the circulatory roadway (see Figure 3-34). Keeping the opening width small helps to avoid path overlap; the striping on either side of the opening is critical to guide drivers into the correct circulatory lane of a multilane roundabout.

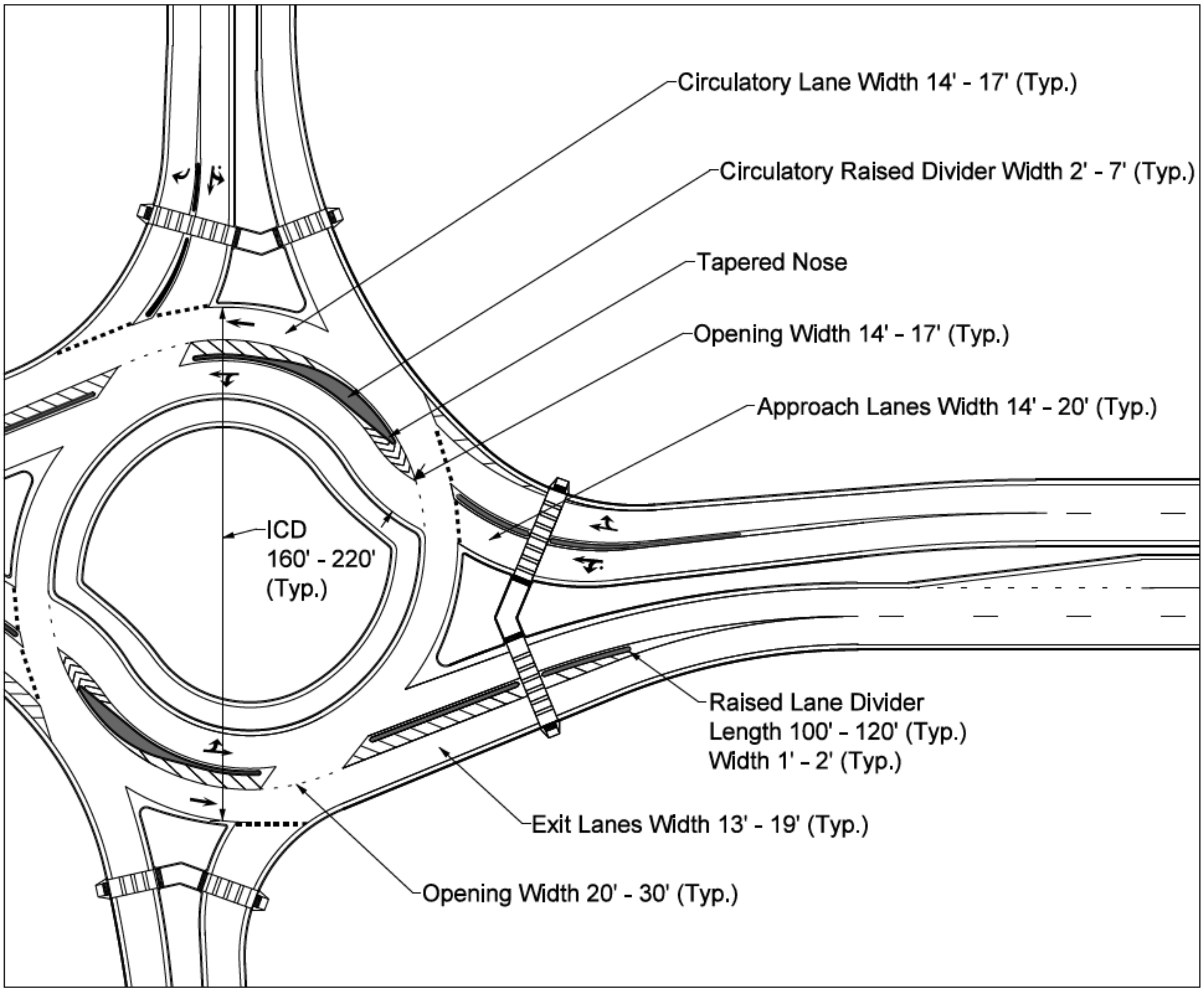


Figure 3-34. Case 3 Multilane Roundabout Opening Width and Path

3.16.2 Circulatory Path Alignment

For multilane roundabouts, there is striping with rumble strips and/or raised lane dividers between the two lanes in the circulatory roadway. This helps maintain lane discipline and helps avoid lane changes in the circulatory roadway.

Case 1 & 2 – Rumble strips in the circulatory roadway assist in circulatory path alignment by providing audible feedback to drivers when they are not maintaining their lane.

Case 3 – Raised lane dividers in the circulatory roadway assist in circulatory path alignment by keeping vehicles in their lane. They also protect circulating drivers from conflicting traffic.

A spiral is a geometric feature of the truck apron needed for some multilane roundabout configurations. They are used:

- Where one or more entries require exclusive left-turn lanes
- Where a combination of entering and exiting lanes requires a spiral to maintain lane continuity
- To push the circulating driver to the outside lane when transitioning from single to multilane portions of the circulatory roadway
- At a 2 x 1 hybrid multilane design (Figure 3-35) to ensure that the adjacent outside lane yields at entry

Spirals should not be used **where U-turns are frequent** because the spiraled driver ends up in the outside lane, unable to make a U-turn without changing lanes.

For Figure 3-35, Radius 1 is the original circle radius; Radius 2 provides the spiral.

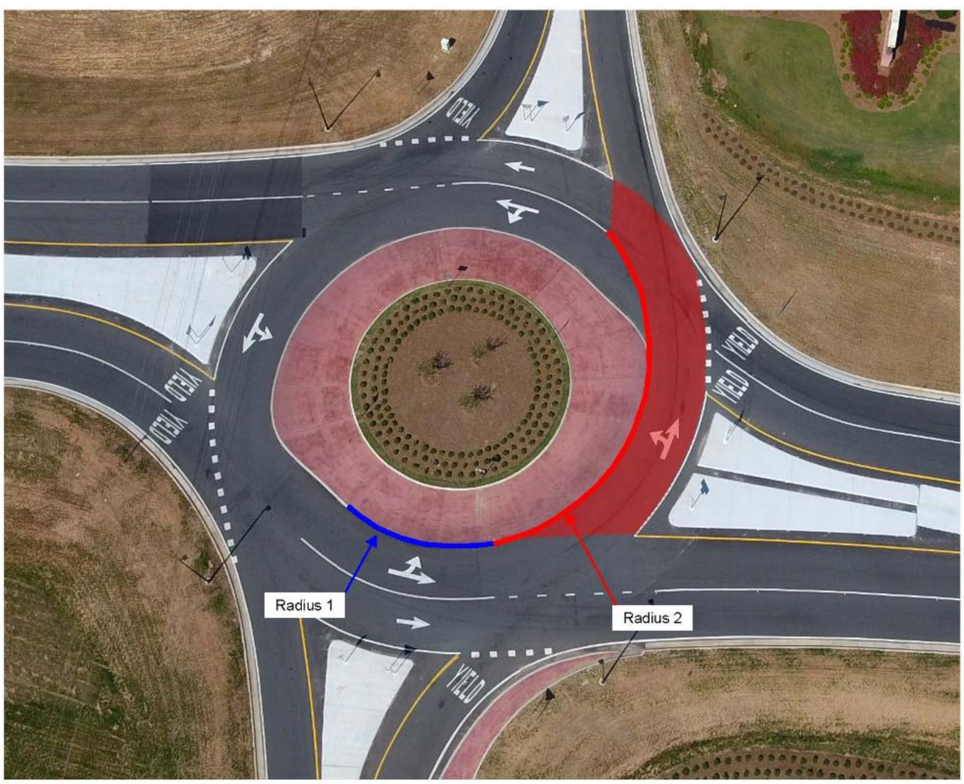


Figure 3-35. Example of Spiral

For more information on drawing spirals, see Appendix E.

3.17 Horizontal Alignments & Vertical Design

Since roundabout design is performance based, it is helpful to complete horizontal design and validate it through geometric performance checks before setting construction alignments. After horizontal alignments have been set, vertical design can start.

Vertical design is an iterative process and includes profiles, superelevation, approach grades and drainage. The fastest-path checks should be confirmed after vertical design is complete to determine whether the cross-slopes influence geometric entry speed predictions. For a detailed walk-through, see Appendix F.

3.17.1 Horizontal Alignments

When considering the location and number of horizontal alignments (stationed and profiled), the designer should consider their usefulness in generating cross-sections, profiles, layout details, and ease of use during construction layout.

At a minimum, there should be a mainline construction centerline per roundabout leg and a horizontal alignment around the outside of the truck apron. Horizontal alignments should also be considered along the outside gutter line edge of pavement and on splitter island curb lines/inside lane lines of each approach, exit and bypass island. These alignments are often useful for the designer to ensure a thorough and accurate grading design, particularly in the transition areas entering and exiting the circle and to avoid holes in the 3D surface. Providing stationed and profiled horizontal alignments along the outside gutter line provides a staking alignment of the contractor to set vital drainage profiles for catch basins.

It may also be beneficial to create alignments along the outside edges of pavement (usually from bike ramp to bike ramp) to help control grades around the circulatory roadway, see Appendix F.1 for Figures.

3.17.2 Profiles

When developing profiles, it is best to start by considering the general topography of the intersection before getting into detail design of individual profiles (e.g. would a tipped circle, or a circle with the circulatory roadway sloping inwards on the high side, be more practical in the given context?).

It is important to understand the existing terrain, roadway profiles and cross-slopes; keep general grading, drainage and sight distance considerations in mind when designing. Sometimes varying profiles are needed to accommodate adjacent properties, avoid ESAs, etc. Existing constraints and impacts should always be considered.

For the circulatory roadway profile, visualizing the roundabout as an upside-down dish tilting on a plane (tipped circle) is ideal. It would have one high point (HP) and one low point (LP) and a continuous profile that closes on itself. Figure 3-41A and 3-41B illustrate a cross-section of a tipped circle. The circulatory roadway profile should be designed from short vertical curves and tangents. To avoid potential sight line issues, consider limiting longitudinal grade to 4%. It is recommended to have short curves (K values for 20 to 25 mph) without flat grades for drainage purposes, especially near the sag. Begin the profile at a point approximately halfway between the LP and the HP so that the vertical curves will not be bisected on the profile plan sheet.

For the splitter island profiles, one option is to choose appropriate K values based on the deceleration zone speed contours. Splitter islands can also be designed using offsets and grade callouts. Construction cost can often be reduced by staying close to the existing surface and matching what the existing roadway is doing at the tie-ins. Keep low points out of crosswalks to avoid grate inlets or standing water within crossing areas. Additionally, check that the cross slope for the crosswalk is no steeper than 5% per ADA requirements for an uncontrolled crossing (PROWAG R302.6.1). A profile with a grade of 5% or less does not require a GDOT design variance. Break overs between splitter island profiles and circulatory roadway cross slopes in those locations should be no more than 4%.

If using outside curb line alignments, ensure that there are smooth transitions and that proper breakovers (< 4%) are maintained.

3.17.3 Grading and Drainage

When designing roundabout grading and grading transitions, it is important to consider truck stability, general sight distance needs, and drainage.

The circulatory roadway cross slope should be 1.0% to 2.0% whenever possible, preferably sloping outward so that drainage structures may be placed on the outer curbs instead of at the truck apron where trucks will be tracking over. However, the cross slope of the circulatory roadway may vary according to the intersecting roadways profiles and can slope inwards up to 4% on the high side if this would produce a more practical design (given existing topography and grades); see Figure 3-40A and 3-40B. The varying cross-slope(s) of the circulatory roadway will determine the tie-in elevations of the splitter island alignments to the outside edge of the circulatory roadway. It is recommended to maintain at least 0.5% profile along outside gutters to maintain appropriate drainage.

To prevent tipping of trucks and to ensure smooth transitions in to, out of, and around the circle, rate of change of cross slope should be between 0.02%/ft and 0.04%/ft to limit maximum relative gradients. It is calculated according to GDOT DPM Section 4.5.4, generally using 25mph design speed and circulating widths of 1 to 2 lanes. It is important to detail these transition areas, see Appendix F.3 for more information. In general, the truck apron cross-slope should be kept at a constant 1% to 2%. A crowned roadway could also be a workable approach, and even preferable in some cases.

Once vertical design is complete, a 'design surface' can be created to perform vertical clearance checks for OSOW low-boy trucks, if they were identified as a check vehicle. Appendix D.3.2 describes how to run a vertical clearance check.

Drainage structures should normally be placed on the outer curb line of the roundabout and upstream of crosswalks but should not be placed in the entry and exit radii of the approaches. Drainage structures located on the outer curb line of the circulatory roadway should be designed to withstand vehicle loading (e.g., Type E, Standard Drop Inlet with Hood shown on GDOT Standard Drawing 1019A). Maximum gutter spreads should match the requirements for the approach roadways, as outlined in the GDOT manual Drainage Design for Highways.

See Section 6.8.7 of NCHRP 672 for a discussion of vertical alignment considerations, which includes drainage.

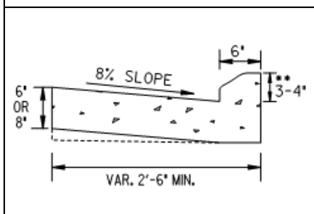
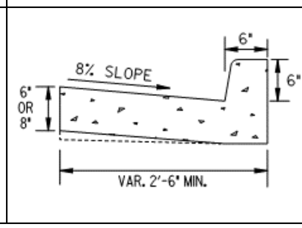
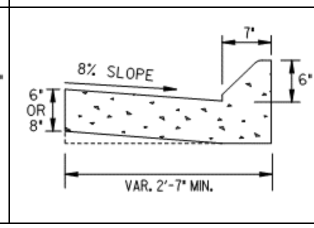
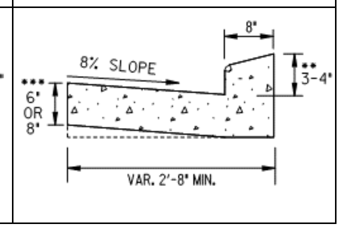
3.18 Typical Sections and Curb Types

Curb Types; see Figure 3-36 and GDOT Detail 9032b. Further information on the principles for using curbs is provided in Sections 6.8.7.4 and 6.8.8.1 of NCHRP 672.

- **Outside Edge of Pavement** - Type 2 Curb & Gutter
- **Front of truck apron** – Type 9 Curb* (3-inch or 4-inch)
- **Back of truck apron** - Type 1 Curb* (optional when not being used for drainage purposes)
- **Front of Outside Truck Apron** - Type 9 Curb & Gutter (3-inch or 4-inch)
- **Back of Outside Truck Apron** – Type 1 Curb (where there is sidewalk behind the curb)
- **Splitter** islands – Type 7 Curb*; for OSOW accommodation, use Type 1 Curb*
- **Raised Lane Dividers:** Type 1 or 9 (3-inch) Curb

*Depending on application, Curb & Gutter may be needed for drainage purposes (e.g. tipped circle).

In many cases, monolithic pours (with integral curb) are preferred, for staging reasons and to reduce costs. The above curb types should be shaped into the truck apron, outside truck aprons, and splitter islands (See Figure 3-41A).

Type 1	Type 2	Type 7	Type 9
			

****Curbs for truck aprons are typically 4" with a type 9 face; however, 3" can be used in locations with higher truck volumes.**

***8" should be used for Front of Truck Apron

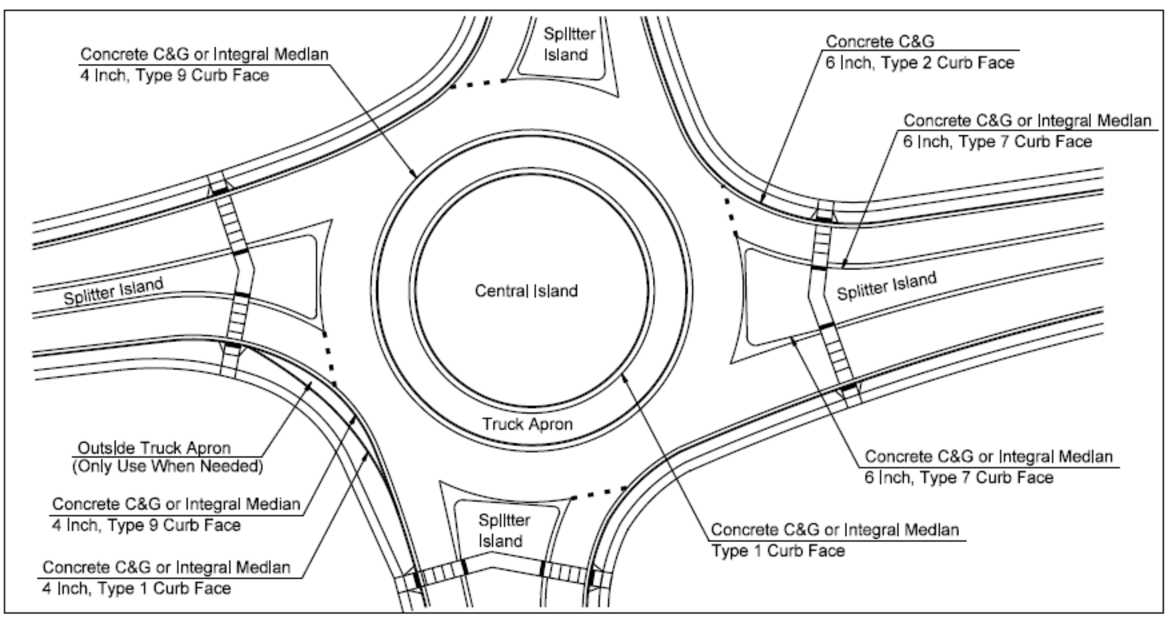


Figure 3-36. Curb Types Within the Roundabout

At a minimum, typical sections should be prepared for:

- Approaches and Exits beyond splitter island areas
- Splitter Islands
- Central Island
- Outside truck aprons

Splitter Island

Figure 3-37A shows a typical section for a monolithic splitter island. Figure 3-37B shows a typical section with curb and gutter which may be beneficial under some circumstances for drainage purposes. Pedestrian access through the splitter island should have ADA ramps and should be either ramped up or semi-depressed.

Central Island (including Truck Aprons)

Figure 3-38A shows the monolithic (with integral curb) slab type truck apron suitable for projects where the truck apron can be placed over existing asphalt, as compared to full-depth construction. This can be advantageous when construction staging prevents placement of curb and gutter. Figure 3-38B shows a curb and gutter truck apron which can be used in some circumstances. Header curb on the front of the truck apron is not preferred due to constructability and durability reasons. GDOT Detail RA-2 can be referenced for the sawing of construction joints in concrete truck aprons.

The circulatory roadway can be tipped in one direction so that water will drain to one quadrant (see Figures 3-39A and 3-39B). The central island should be mounded to block through sight across the circle and excessive sight distance around the circle. This can be done using cross slopes within the range of 10:1 to 6:1 and a maximum mounding height of 6ft above back of curb; see 8.1 and NCHRP 672 Section 9.3 for more information.

Figure 3-40A and 3-40B also shows a typical section of an outside truck apron.

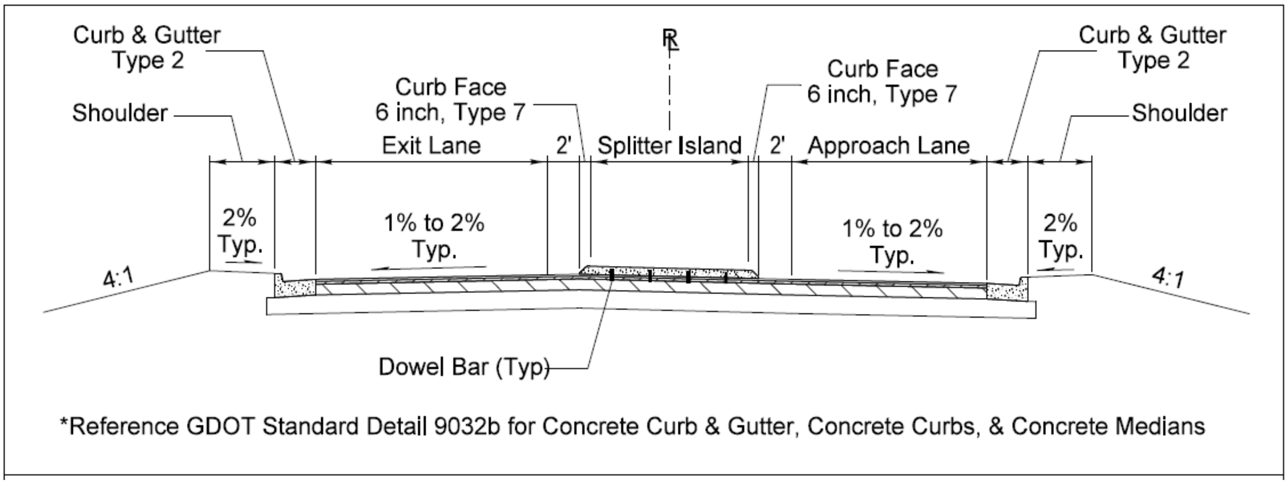


Figure 3-37A. Roundabout Approach Typical Section with Monolithic Splitter Island

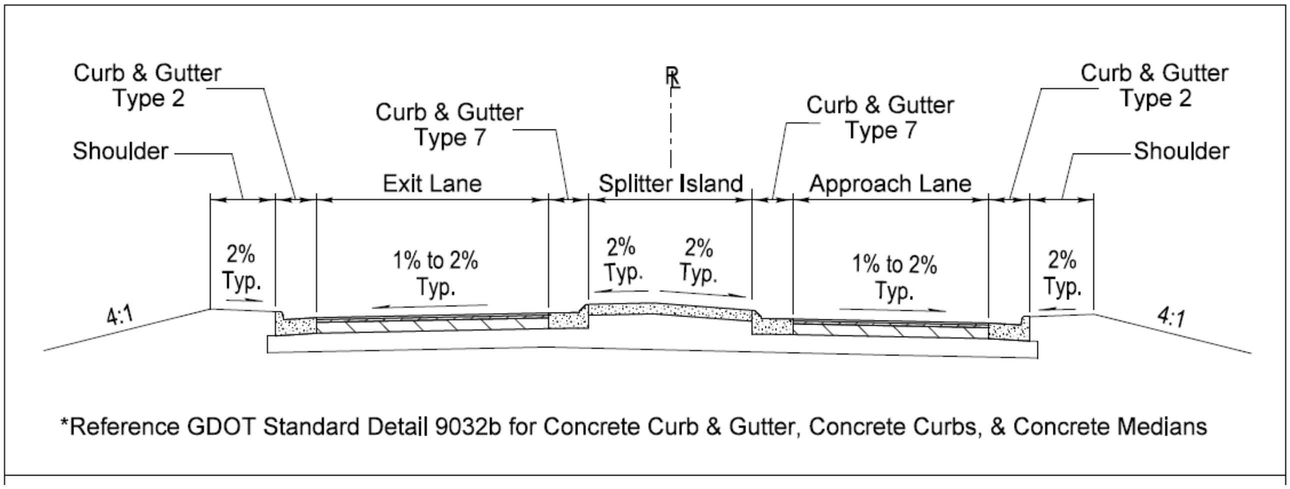


Figure 3-37B. Roundabout Approach Typical Section

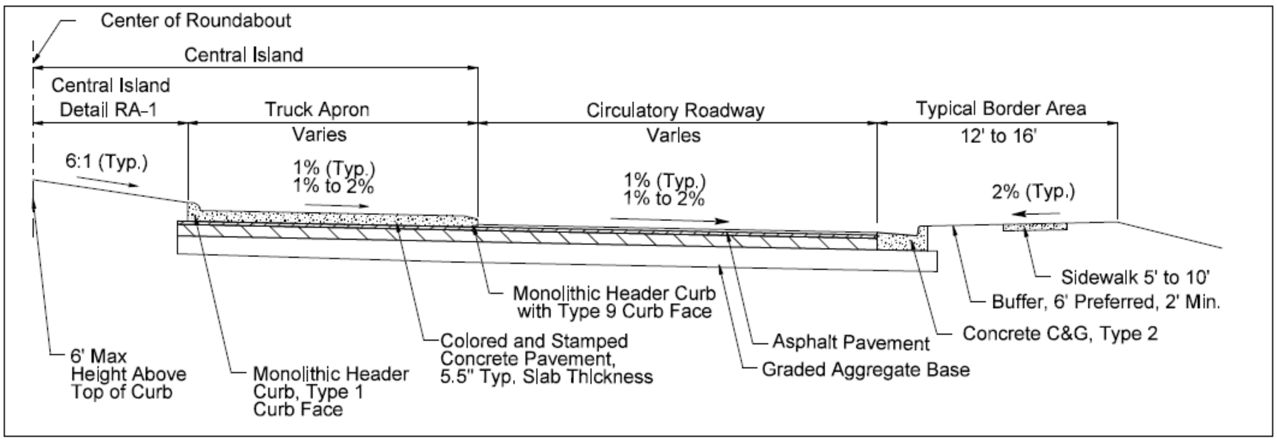


Figure 3-38A. Roundabout Detailed Section with Monolithic Truck Apron

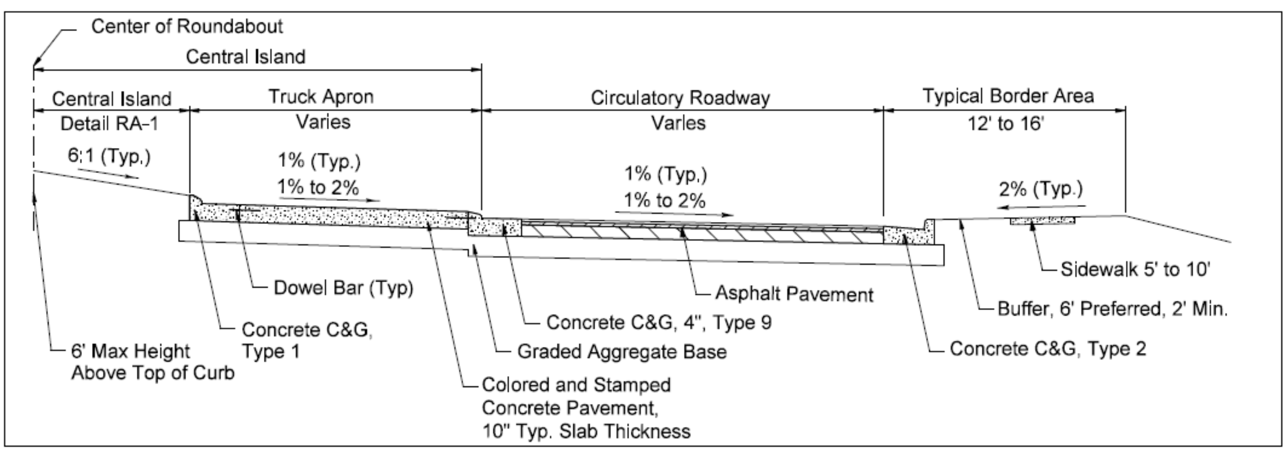


Figure 3-38B. Roundabout Detailed Section

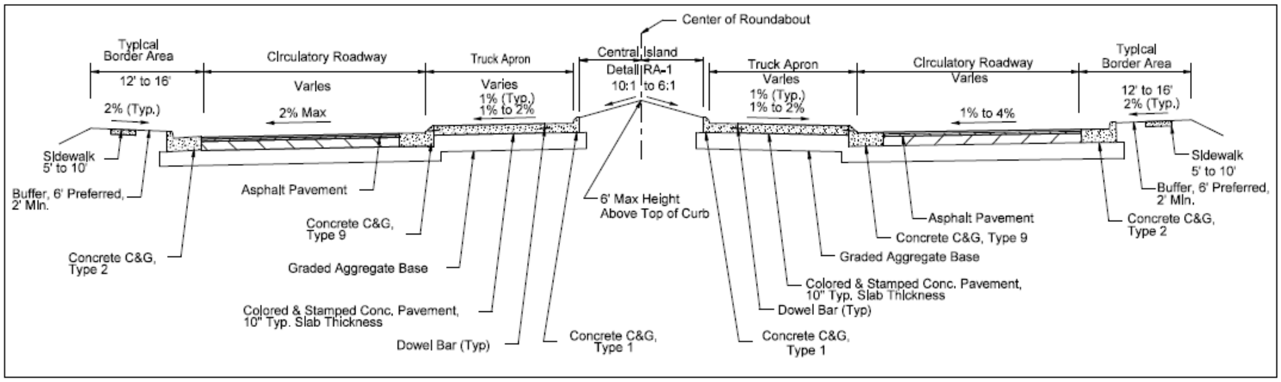


Figure 3-39A. Roundabout with Tipped Circle Section (Truck Apron Sloped Out)

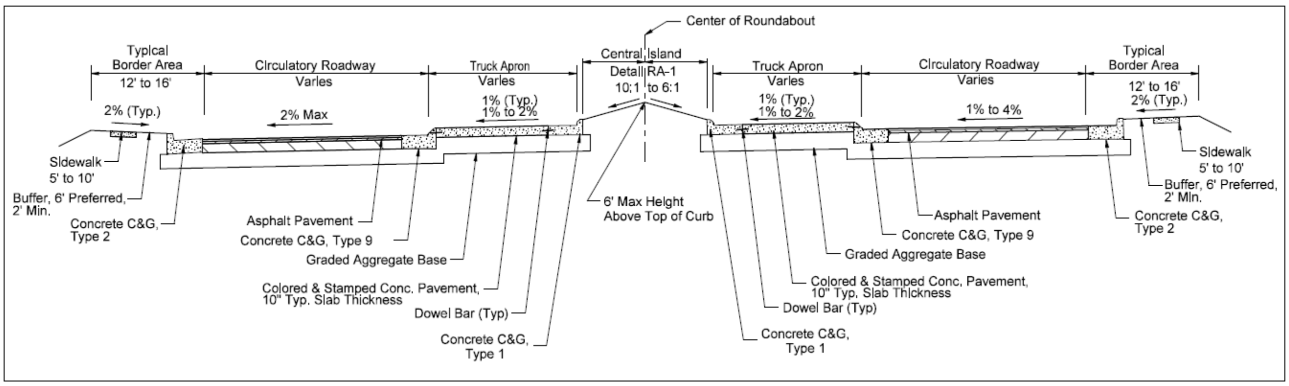


Figure 3-39B. Roundabout with Tipped Circle Section (Truck Apron Sloped In)

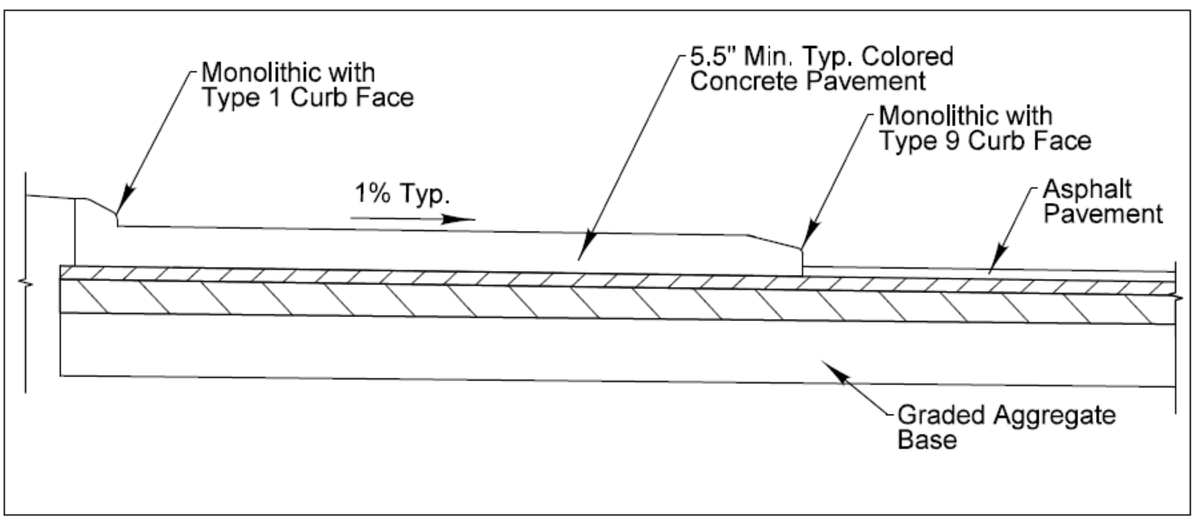


Figure 3-40A. Outside Truck Apron (Monolithic) Typical Section

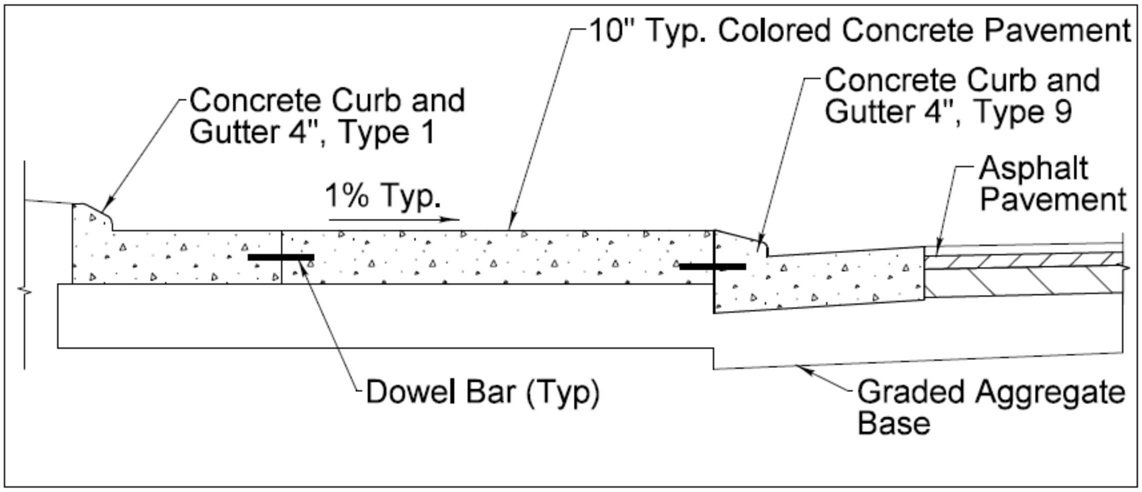


Figure 3-40B. Outside Truck Apron Typical Section

3.18.1 Raised Multilane Features

At multilane roundabouts, the approach, departure, and sometimes circulatory lanes are separated by raised elements with a white stripe on both sides, as seen in Figure 3-42. A typical section for a Case 3 Multilane Roundabout approach is shown in Figure 3-43 with 1 ft wide raised lane dividers. Figure 3-44 shows a typical section for a Case 3 Multilane Roundabout's circulatory roadway. Short gaps can be provided in the raised lane dividers to allow for drainage.

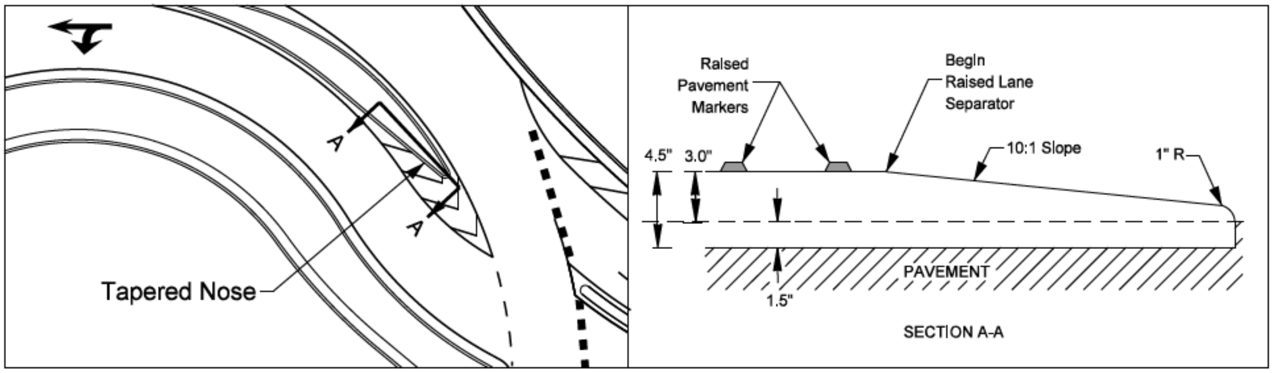
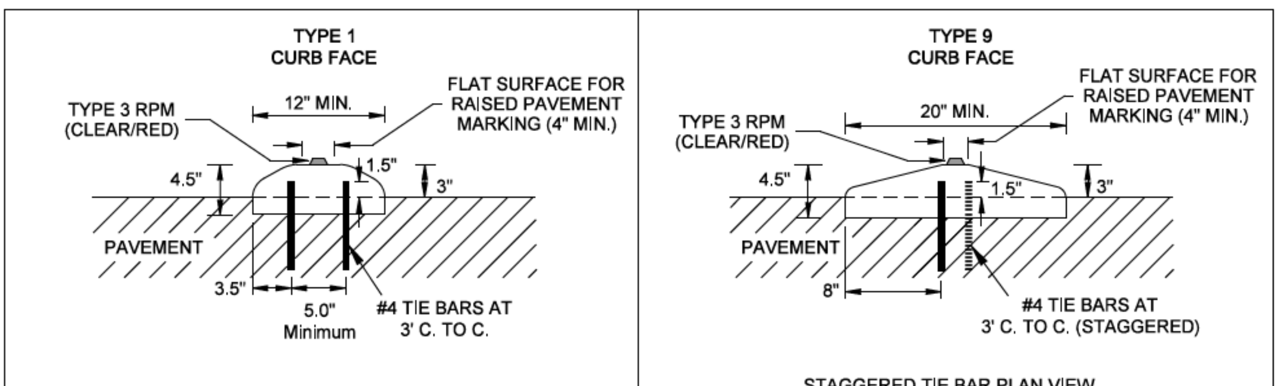


Figure 3-41. Tapered Nose Detail (Frog)



MINIMUM TIE BAR LENGTHS (FOR CONC. DOWELED CURBS OR CONC. MEDIAN)

CURB TYPE	P.C. CONC. PAV.	ASPHALT PAV.
1 OR 9	6"	8"

Figure 3-42. Raised Lane Dividers

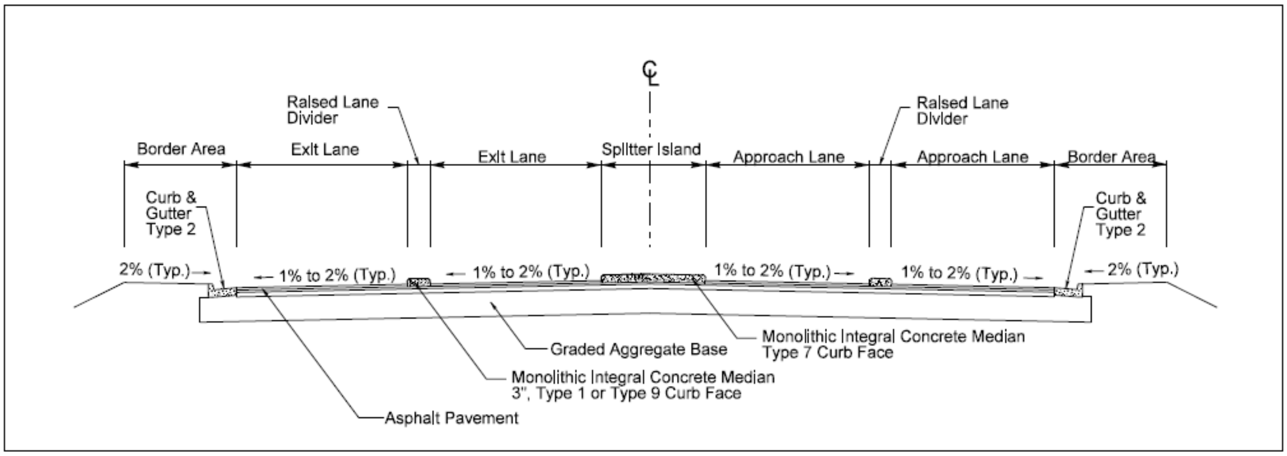


Figure 3-43. Case 3 Multilane Roundabout Approach/Departure Typical Section

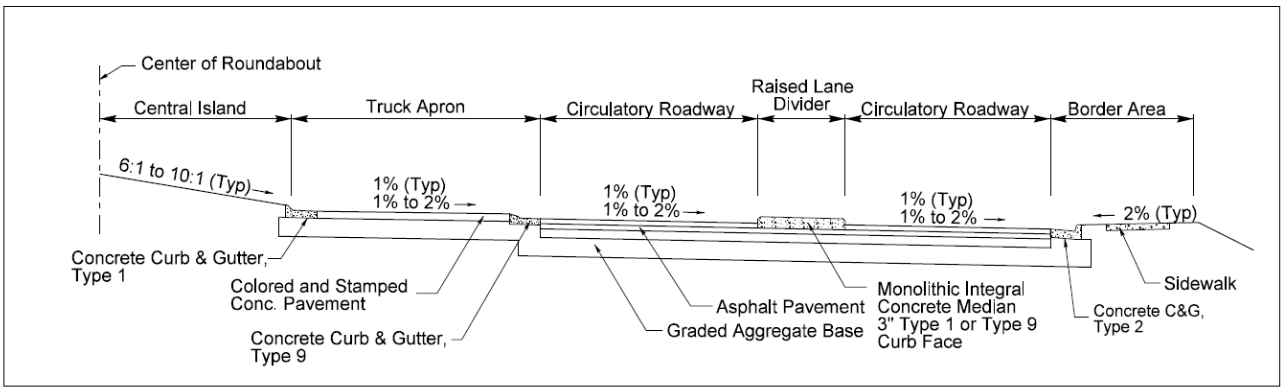


Figure 3-44. Case 3 Multilane Roundabout Circulatory Roadway Typical Section

3.18.2 Mini-Roundabouts

Due to their smaller circle size, mini-roundabouts require a fully mountable (traversable) central island to accommodate trucks. Special consideration should be applied to mini-roundabouts when:

- the posted speed limit is above 35mph (lack of deflection of the smaller circle)
- pedestrian generators are nearby (narrower splitter islands)
- there are more than four legs (lack of spacing between the approaches)

For a mini-roundabout to operate as intended, especially on a higher speed roadway, it is essential that the intersection type can be recognized and that drivers have adequate forward visibility of the intersection. For this reason, the central island at mini-roundabouts should be defined by not only paint, but also by including a fully mountable raised concrete center island (no more than 5 inches high). The island may have a 3" or 4" mountable curb face (monolithic or curb and gutter). See Figure 3-45.

Internally illuminated bollards with keep-right chevrons are recommended for illumination and visibility. These are designed to withstand vehicle overtracking and, therefore, may be installed on the mountable central island. See Figure 3-46.

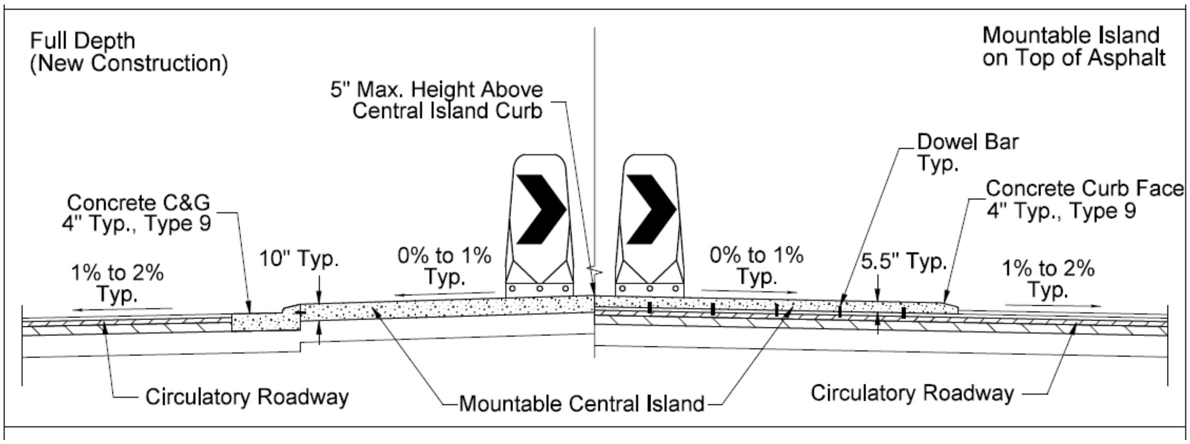


Figure 3-45. Mountable Apron at Mini-Roundabouts, shown with Bollards

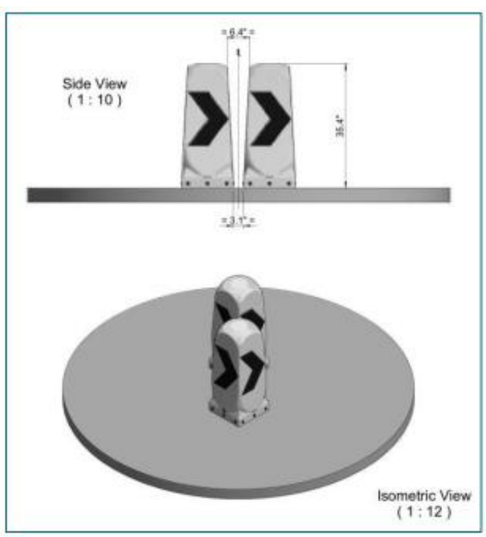


Figure 3-46. Additional Detail of Bollard Configuration

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Chapter 4. Designing for Pedestrians and Bicyclist - Contents

Chapter 4. Designing for Pedestrians and Bicyclist - Contents 4-i
4.1 Pedestrian Accommodations..4-1
4.2 Bicycle Accommodations..4-4

Chapter 4. Designing for Pedestrians and Bicyclist

Roundabouts are generally considered a safer intersection choice than conventional intersections for both pedestrians and cyclists due to their low speed environments. They also provide short crossing distances with raised islands so pedestrians only cross one direction at a time.

Projects should be evaluated to comply with GDOT's Complete Streets Policy, (DPM Chapter 9) which establishes standard warrants and guidelines for the design of features to serve pedestrians, bicyclists, and transit. Like any intersection, roundabouts should be designed to accommodate pedestrians and cyclists.

4.1 Pedestrian Accommodations

Pedestrian crosswalks should be used at all roundabouts due to the non-traditional paths of pedestrians through the intersection. Pedestrians should never be directed to the central island of a roundabout. Ideally, non-motorized users will be provided the opportunity to cross the street in a two-staged crossing with a refuge provided in the splitter island.

Pedestrian crossings at roundabouts must comply with the ADA accessibility standards. For additional guidance, see the GDOT Pedestrian & Streetscape Guide; NCHRP 672 Section 5.3.3; and NCHRP 834, *Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities: A Guidebook*.

General design considerations for pedestrian crossings should include:

1. Pedestrian crossing distance and location
2. Crossing alignment
3. Splitter island and pedestrian refuge design
4. Providing for visually impaired pedestrians as well as other disabilities
5. Discouraging pedestrian from crossing to the central island

In general, pedestrian crossings are placed approximately one car length (20-25 ft) upstream from the yield point (entry line), see Figure 4-1, For multilane entries, the pedestrian crossing can be placed up to two car lengths from the yield point. For roundabout exits, crosswalks can be placed further than the 20-25 ft to help with yielding rates and allow for more storage for exiting vehicles (see FHWA TOPR34 and NCHRP 834). By having the crosswalks close to the roundabout, the crosswalks are safer due to slower vehicular speeds. Detectable warnings must be applied at curb ramps and island cut-throughs, which should be elevated as detailed in GDOT Details A-3 and A-4.

Splitter islands should be designed to provide sufficient refuge (6' minimum) to separate the two-directional crossings into two isolated decisions for pedestrians. Pedestrian access through the splitter island should have ADA ramps and should be either ramped up or semi-depressed. Supplemental treatments can be provided at the pedestrian crossings to support enhanced pedestrian visibility, aid in driver yielding, and/or where more pedestrians may be present. Designers should consider the use of activated pedestrian crossing devices (e.g. RRFB, PHB, etc.) for pedestrian crossings across free-flow bypasses and at multilane roundabouts; see Section 5.3. It is GDOT current practice to install necessary conduit across all roundabout multilane pedestrian crossings, from shoulder to splitter island, in the location required for installation of a future pedestrian signal.

There are three general principles to optimize wayfinding for visually impaired people who rely on nonvisual information:

- Curb ramps should be oriented so that the running slope is in the same direction as the crosswalk and/or the edges of landscaping or ramps should be aligned in the direction of travel on the crosswalk.
- Alignment of pedestrian crossing should be perpendicular to the edge of the travel way and with the direction change in the refuge island to create the shortest crossing path.
- Landscaping, fences, or other features should restrict the ability of pedestrians to cross at locations other than crosswalks, or at least make it very clear where crossing is not intended and provide guidance to the crosswalk location.

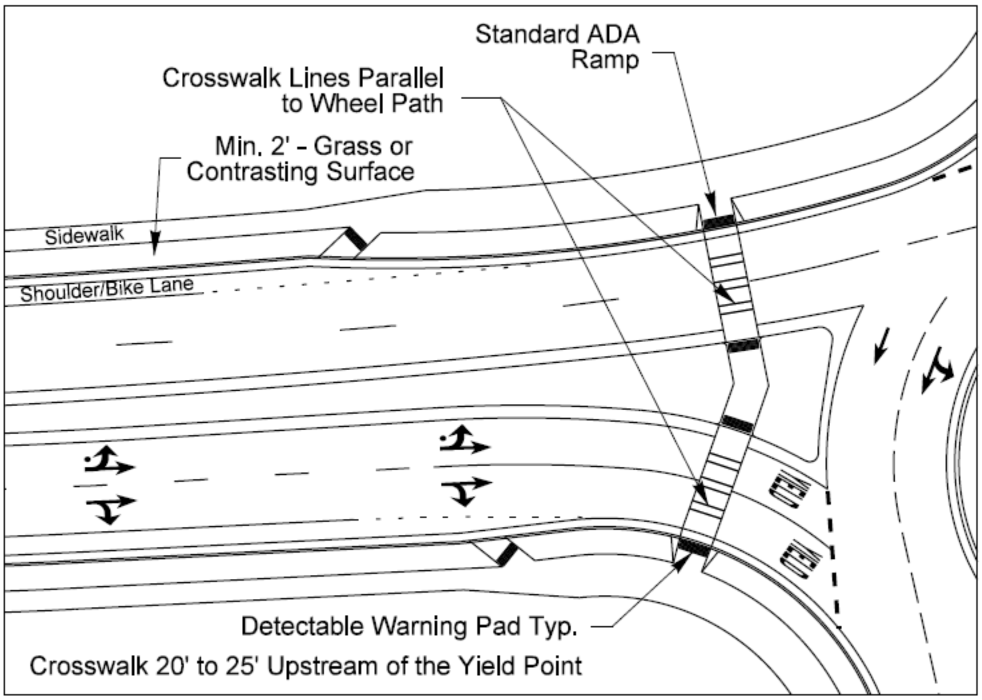

Figure 4-1. Pedestrian Crossing Treatment

Where outside truck aprons are required at a roundabout entry, designers should avoid the crosswalk and pedestrian ramp if possible (including relocating the crosswalk, if practical). If this cannot be avoided, the crosswalk striping should extend through the apron with a ramp. The ramp through should allow smooth overtracking of larger vehicles (see Figure 4-2). The pedestrian ramp and detectable warning strip should not be located within the outside truck apron, so there does not appear to be refuge within the apron.

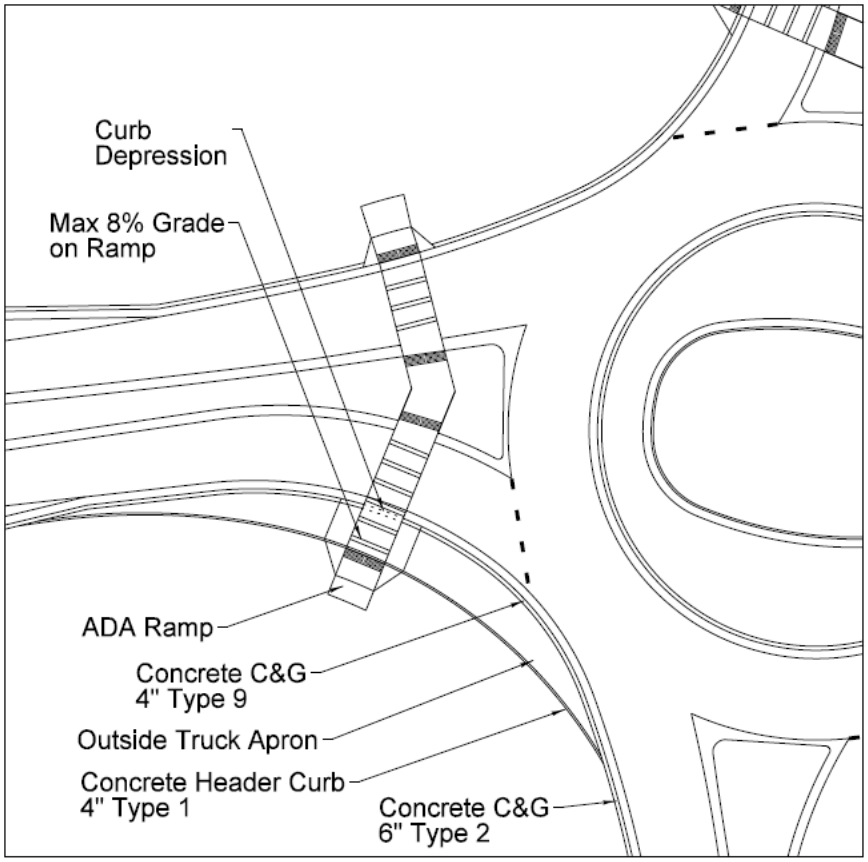

Figure 4-2. Crosswalk through Outside Truck Apron

4.2 Bicycle Accommodations

Due to low speed nature of roundabouts, most experienced cyclists simply share the road and ride through the roundabout using the circulatory roadway. At roundabouts, motorized vehicle speeds are typically lower, and the decisions are simpler.

To increase comfort for less experienced cyclists, designers should include bike ramps and shared-use paths in the roundabout design. Shared-use paths (8 ft min., 10 ft typ.) and bike ramps should be provided at multilane roundabouts and are optional at single-lane roundabouts.

Bike ramps should be 5 ft. wide and angled at 30 to 45 degrees (not perpendicular) so bicyclists do not have to slow significantly to enter (or exit) the shared-use path. Place bicycle ramps a maximum of 100 ft from the yield point (or 50 ft from the crosswalk). Refer to Figure 4-3 and Figure 4-4.

A shoulder or bike lane should not be provided within the circulatory roadway. Begin and end the paved shoulder or bike lane upstream of the yield point to allow the bicyclist an opportunity to transition either onto the travel lane (shared with motorized traffic), or where available, the shared-use path. It is recommended to begin and end paved shoulders or bike lanes using an 8:1 taper rate.

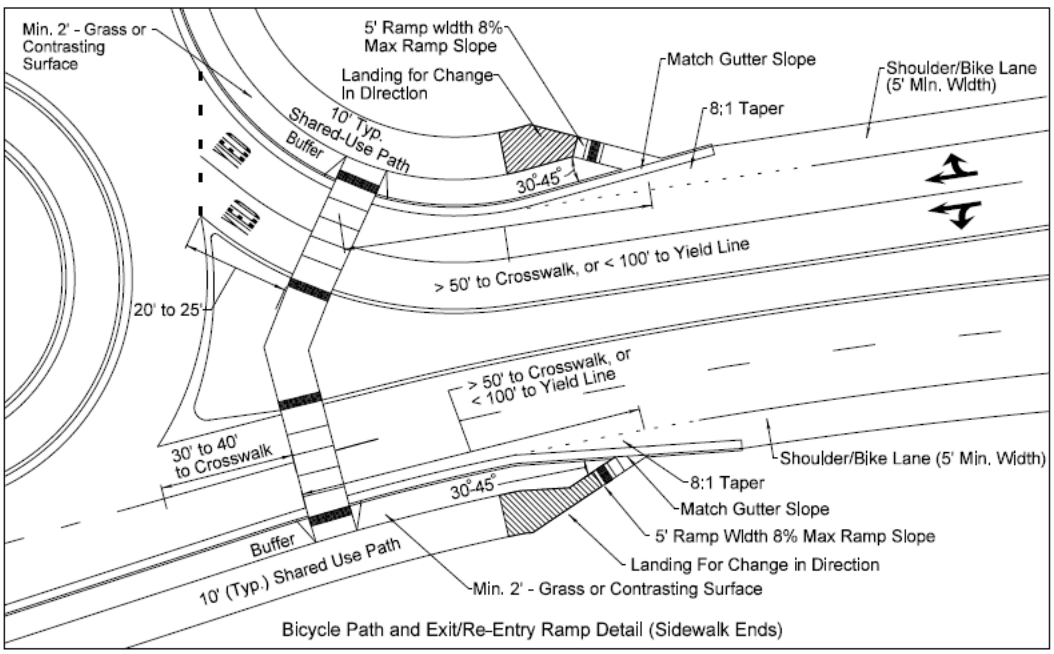

Figure 4-3. Bicycle Path Exit and Entry without Extended Sidewalk

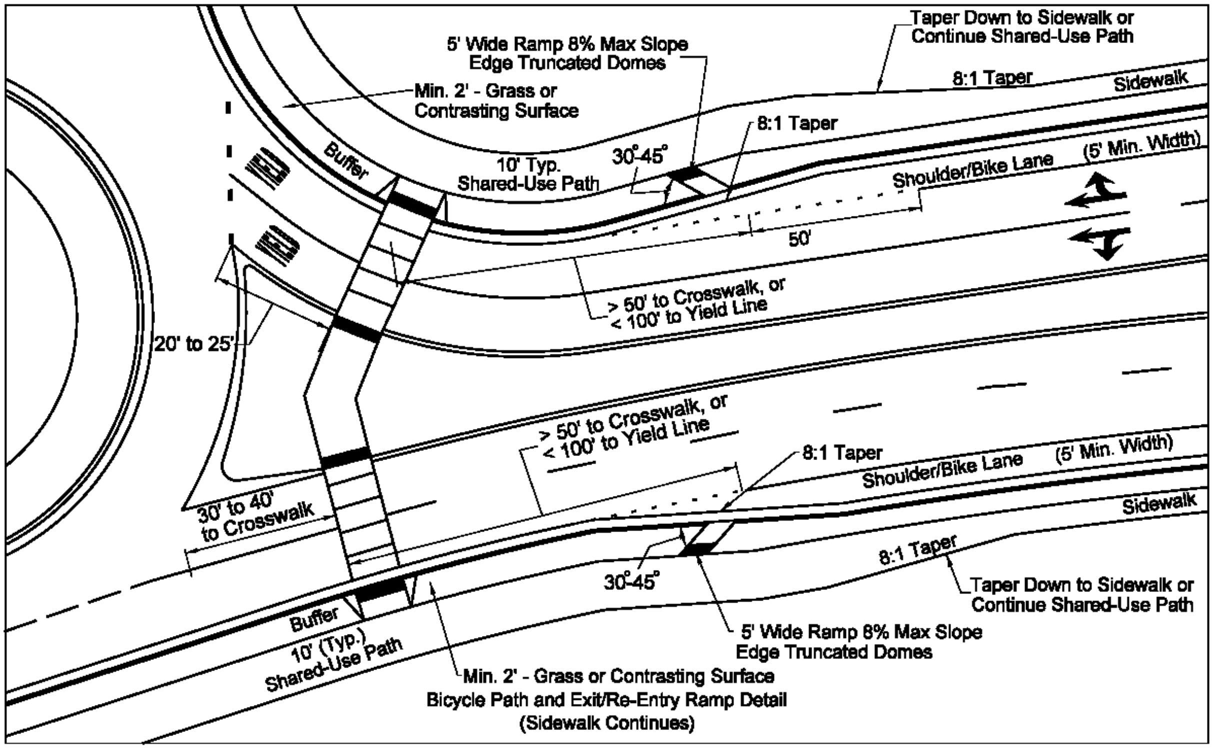

Figure 4-4. Bicycle Path Exit and Entry with Extended Sidewalk

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Chapter 5. Traffic Control Devices - Contents

Chapter 5. Traffic Control Devices - Contents 5-i
5.1 Signing 5-1
5.2 Marking 5-2
5.2.1 Rumble Strips 5-10
5.3 Active Devices 5-10
5.3.1 Rectangular Rapid-Flashing Beacons (RRFB) 5-10
5.3.2 Pedestrian Hybrid Beacons (PHB) 5-10
5.3.3 Metering Signals 5-11

Chapter 5. Traffic Control Devices

The traffic information system, consisting of regulatory, warning and navigation signing, and marking is an essential contributor to safe and efficient operation of roundabouts. This chapter illustrates application of the standards and guidelines presented in the GDOT Signing and Marking Design Guidelines (Chapter 13). This guide must be used for the design of roundabouts for GDOT projects, specifically signing and pavement markings. See Figure 5-1 through 5-5 for the sign sequence and marking patterns typically associated with single lane and multilane roundabouts.

5.1 Signing

Similar to conventional intersections, signing at roundabouts includes regulatory signs, warning signs and guide signs. Section 13.2 of the GDOT Signing and Marking Design Guidelines covers signing at roundabouts. The required signs are covered in the following sections of the Signing and Marking Guide:

- Advanced Warning Signs W2-6 and W13-1P 13.2.1
- Yield Signs R1-2 13.2.2
- Guide Signs D1-5 or D1-3d, M5 (State Route Shields) 13.2.3
- Lane Use Signs R3-8 series or R3-6 series 13.2.4
- Pedestrian Signs W11-2 and W16-7P 13.2.5

LED bordered yield signs can be considered to improve conspicuity (and are recommended at mini-roundabouts). Internally Illuminated Bollards with a chevron symbol should be installed in the central island at mini-roundabouts. They can also be used for nose point treatments on splitter islands with the R4-7 sign to improve visibility. Both LED bordered yield signs and internally illuminated bollards need to be permitted by the GDOT TMC Signal Permitting Section.

5.2 Marking

Section 13.3 of the GDOT Signing and Marking Design Guidelines covers pavement marking at roundabouts. The required pavement marking items are covered in the following sections of the Signing and Marking Guide:

• Edge Line Extension (Entry Line/'Yield Line')	13.3.1
• Yield word marking	13.3.2
• Arrows on multilane approaches	13.3.3
• Pedestrian crossing	13.3.4

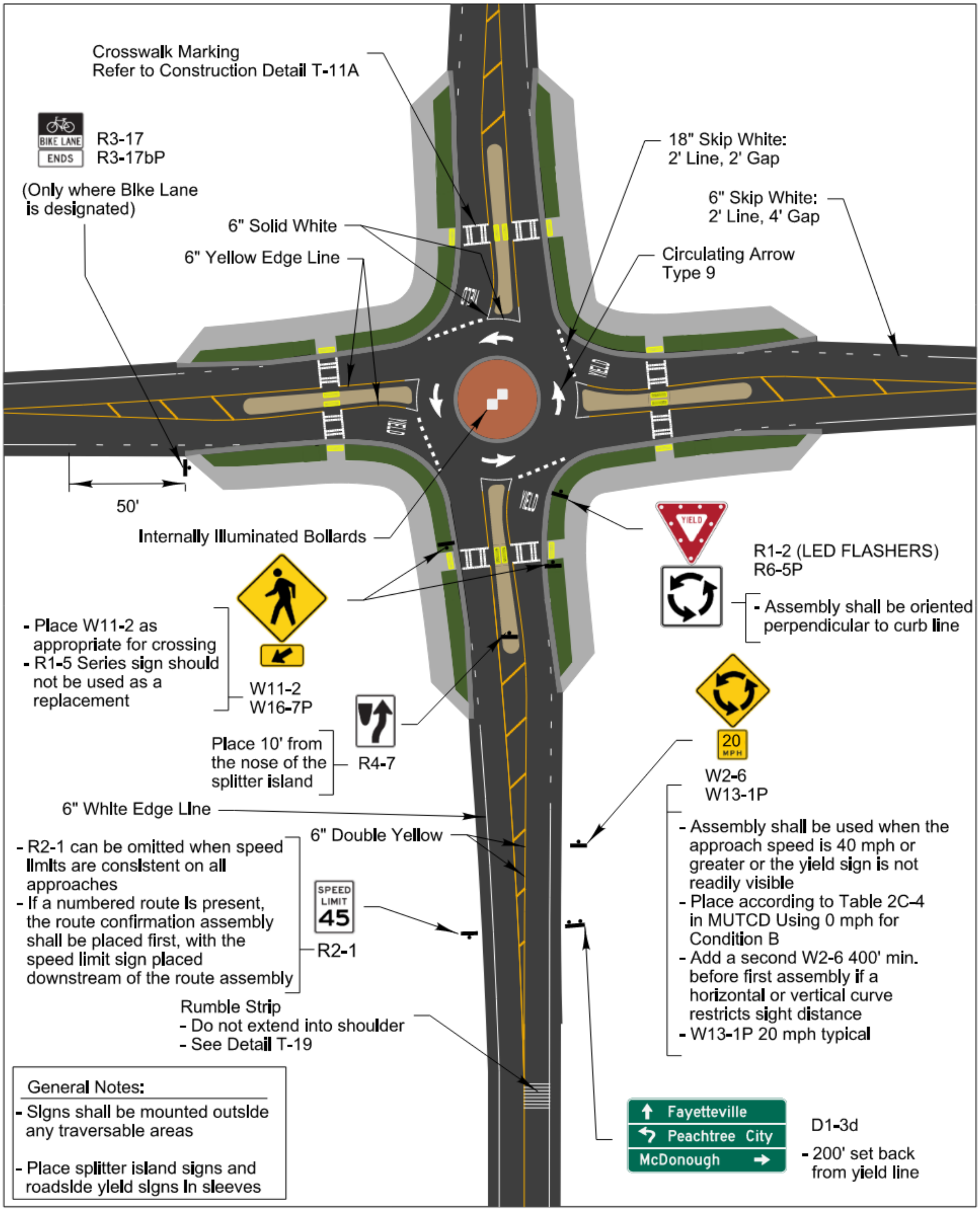


Figure 5-1. Mini-Roundabout Signing and Marking

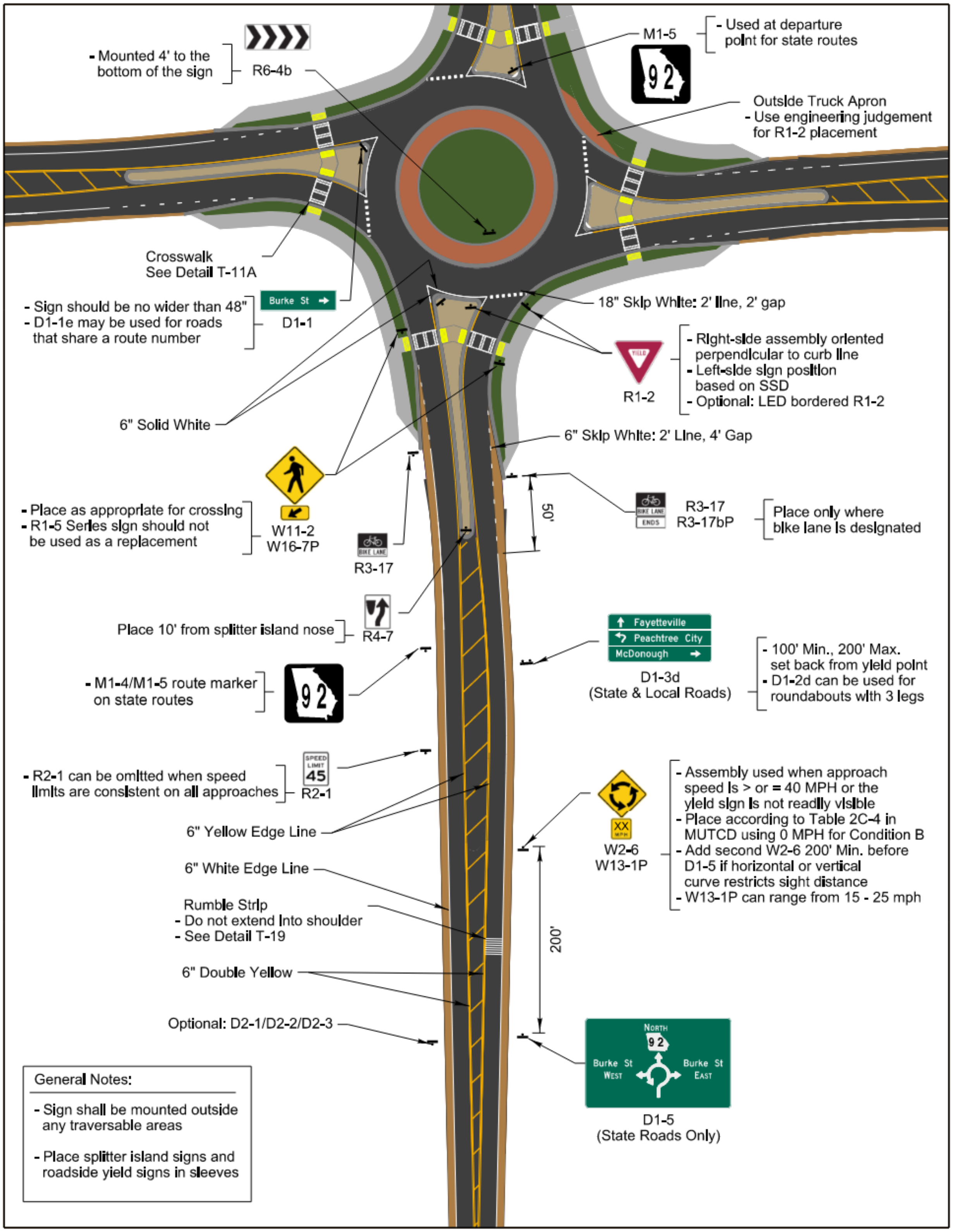


Figure 5-2. Single Lane Roundabout Signing and Marking

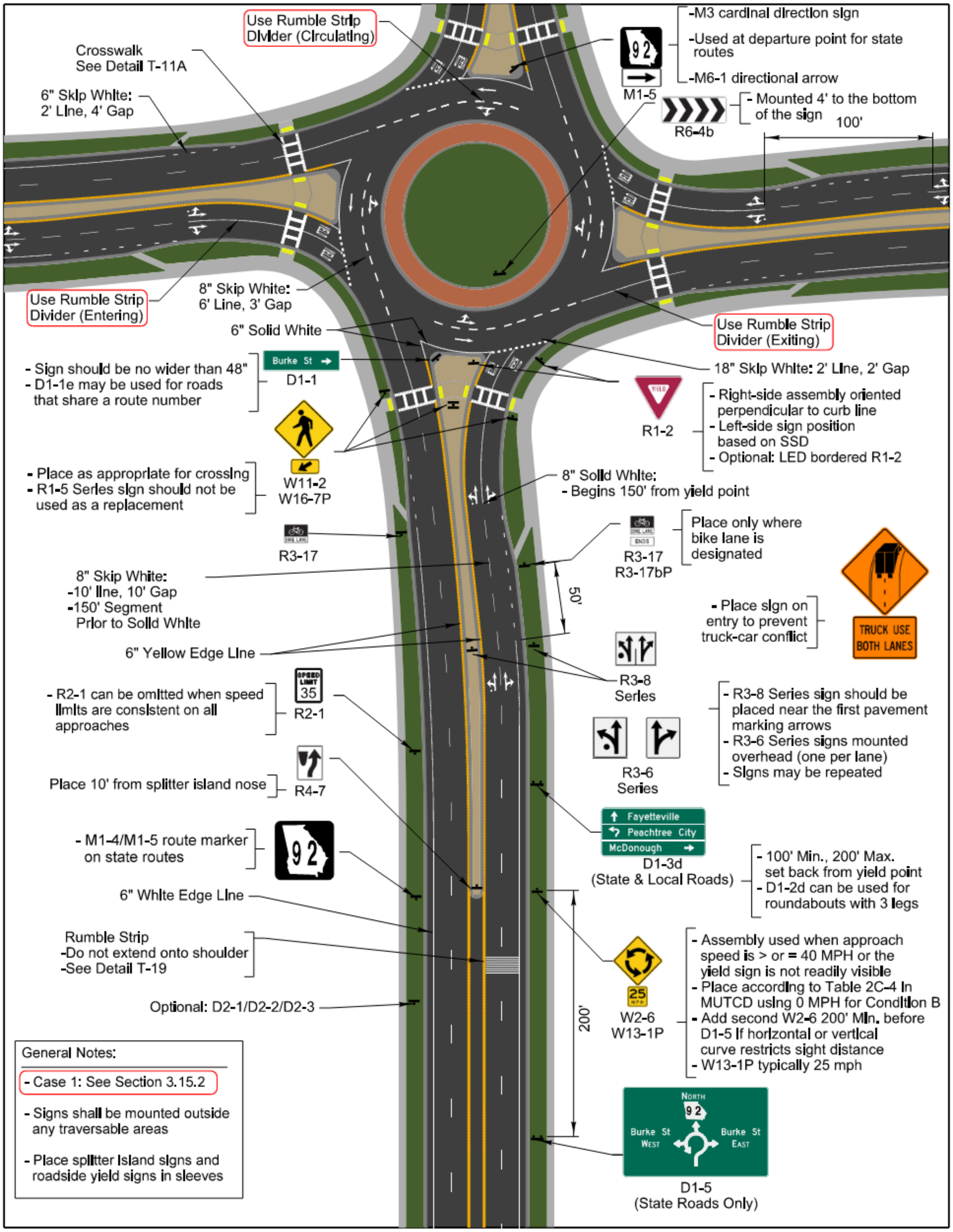


Figure 5-3. Case 1 Multilane Roundabout Signing and Marking

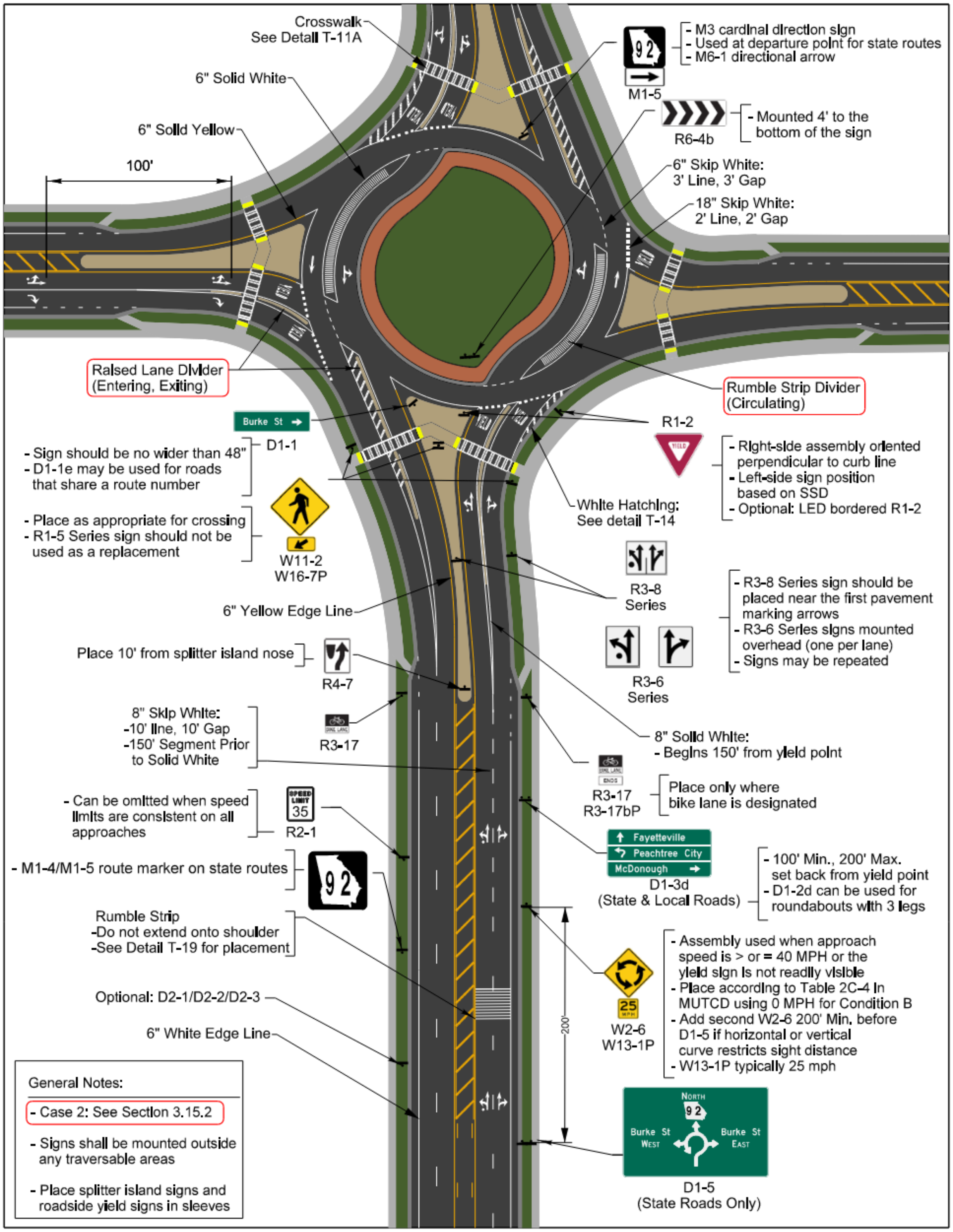


Figure 5-4. Case 2 Multilane Roundabout Signing and Marking

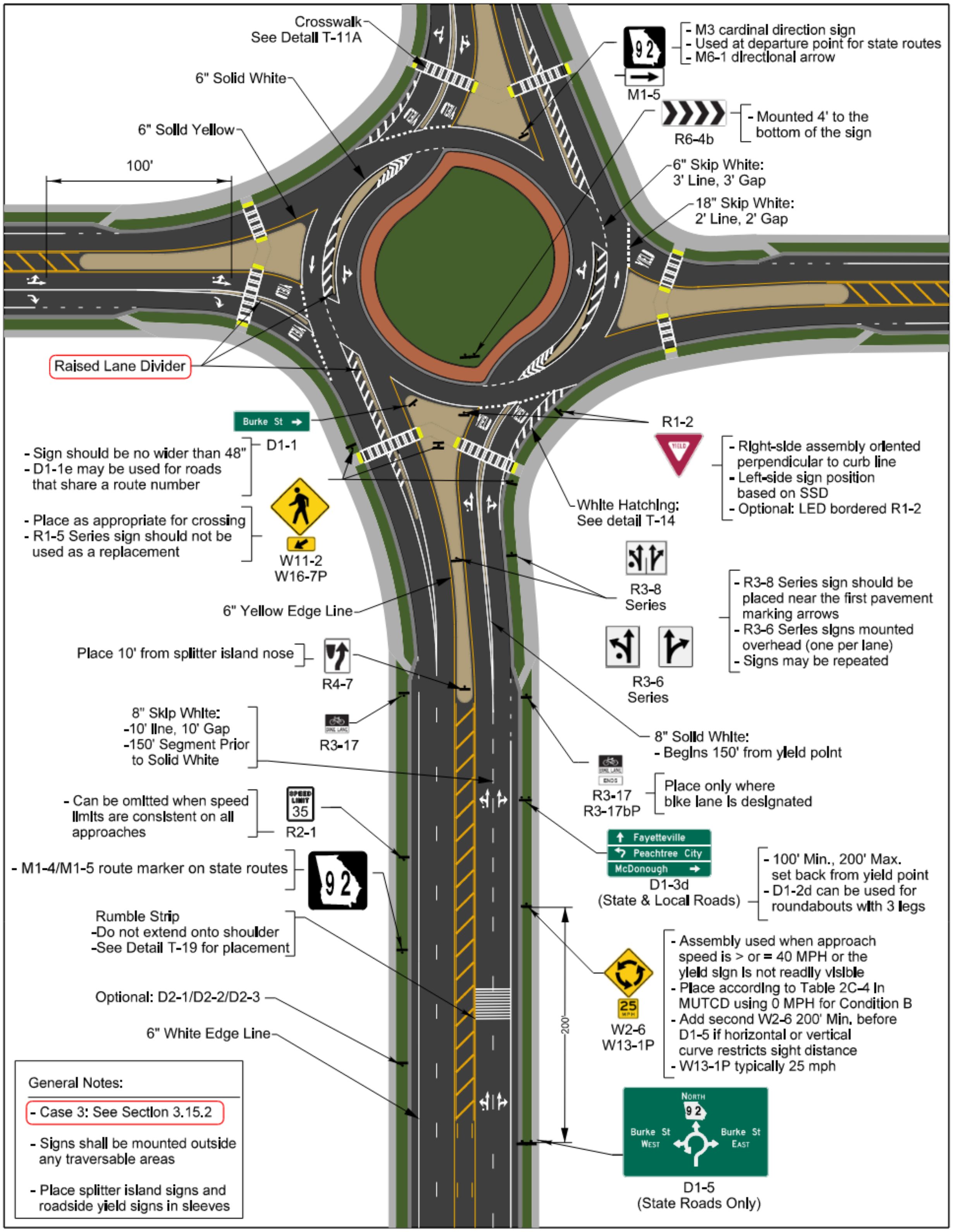


Figure 5-5. Case 3 Multilane Roundabout (1x2) Signing and Marking

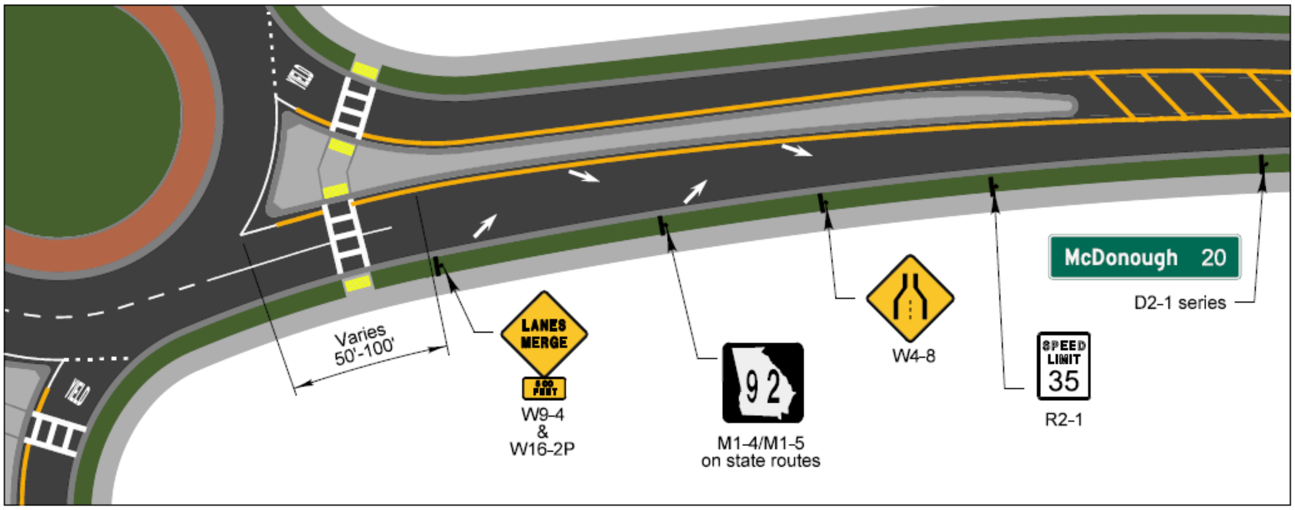
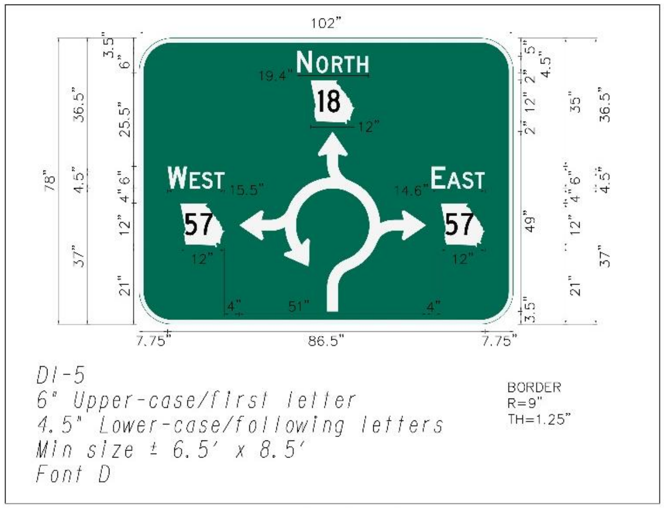
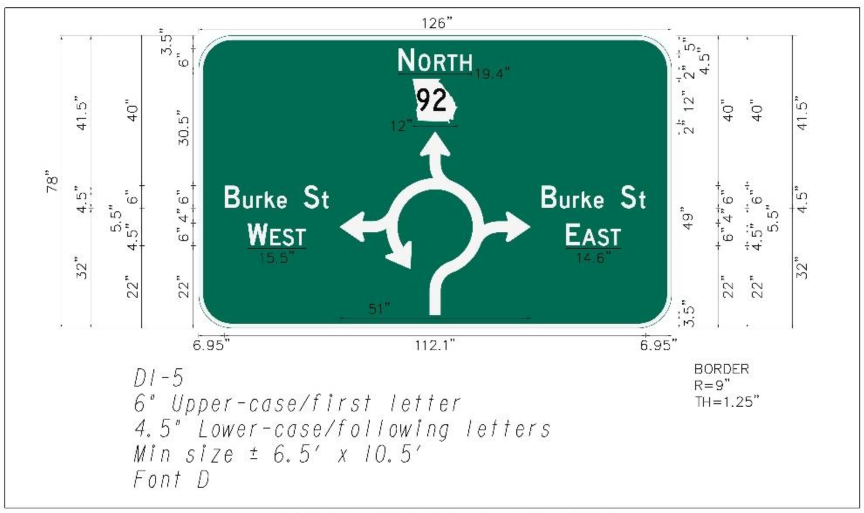


Figure 5-6. Lane Drop Multilane Roundabout Signing and Marking

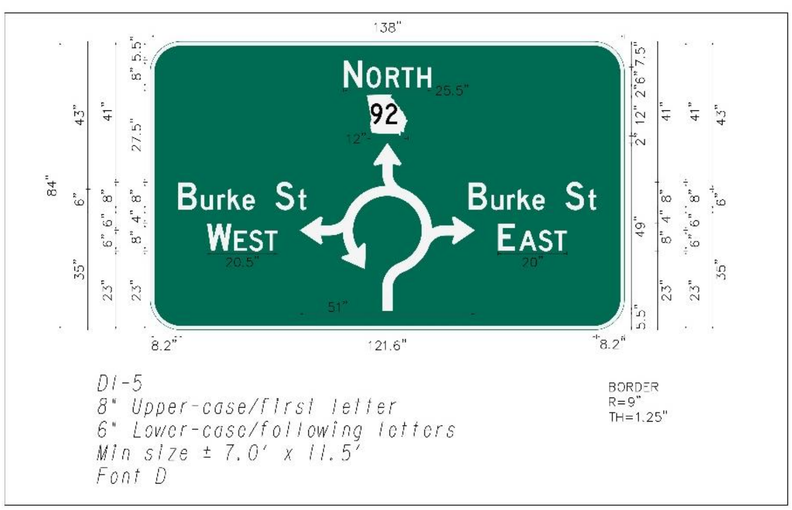
D1-5 signs should be used on all State Route approaches. Context sensitivity should be used to determine the need for installation on the local road approaches. Different text sizes should be utilized based on approach speed for all roadways, with larger text sizes to be used on roads with posted speeds greater than 45 MPH. Figure 5-7 shows typical dimensions and sizing for D1-5 signs as a guide for designers.



STATE ROUTES



LOCAL ROADS ≤ 40 MPH



LOCAL ROADS ≥ 45 MPH

Figure 5-7. D1-5 Marking Typical Dimensions

5.2.1 Rumble Strips

High build thermoplastic transverse rumble strips should be placed on rural roads, on short/steep approaches, and on high-speed approaches (50 mph or greater). Rumble strips are typically not used in residential areas, or across the shoulder or bike lanes where cyclists would be impacted. Refer to construction detail T-19 for installation. If transverse rumble strips are used, the Environmental Survey Boundary may have to be expanded.

Longitudinal rumble strips are used in conjunction with lane separation striping on Case 1 and Case 2 multilane roundabouts, as specified in Section 3.15.2. Longitudinal rumble strips may be present on roadway approaches to a roundabout. They are also sometimes used on a paved shoulder in rural applications to encourage better in-lane behavior.

5.3 Active Devices

RRFBs and PHBs are commonly considered for pedestrian crossings across free-flow bypasses and at multilane roundabouts, especially for intersections with high pedestrian volumes. Designers should consult with the Office of Traffic Operations for guidance on the use of RRFBs or PHBs. For roundabouts with significant traffic queuing, metering signals can be used as a mitigation. **RRFBs, PHBs, and metering signals are considered active devices and therefore must be permitted by the TMC**.

5.3.1 Rectangular Rapid-Flashing Beacons (RRFB)

RRFBs are typically located at the pedestrian crosswalks to help with identifying the presence of a pedestrian for drivers. An RRFB provides a flashing yellow warning indication, activated by pedestrian pushbuttons, to supplement the pedestrian crossing warning sign (W11-2).

5.3.2 Pedestrian Hybrid Beacons (PHB)

PHBs are also typically located at the pedestrian crosswalks to help with identifying the presence of a pedestrian for drivers. A PHB is a signal device that provides a solid red indication that requires drivers to stop for pedestrians. PHBs are installed overhead and are activated by pedestrian pushbuttons. **PHBs should meet the MUTCD volume warranting criteria**.

5.3.3 Metering Signals

Roundabout lane configuration should regulate capacity according to demands; but in future years metering may be necessary to improve operations. Metering a roundabout entry restricts vehicle flow into the roundabout and is considered when a dominant traffic flow impedes a downstream entry to the extent that an excessive queue spillback is generated, typically during peak periods or times of highly unbalanced flow.

Metering can be applied to either single-lane or multilane roundabouts. The metering signal is intended to function like a ramp meter, resting in dark when not in use. Design guidance for metering traffic signals can be found in Chapter 9 of the GDOT ITS manual with some adaptation to use in roundabouts.

Metering signals can be used to extend the life of a roundabout that may become congested before its Design Life or for a location with peak event traffic. One application is to use metering as a mitigation for excess congestion on a single approach in future years. For example, if a single lane roundabout (model) works for 15 years and then starts to experience undesirable queues, metering may be considered to mitigate delay rather than expanding to a multilane roundabout. However, use of geometric alterations, e.g. adding a right turn bypass on the congested entry, should be evaluated before metering is considered.

When a vehicle queue spills back to a detector on an approach, the metering signal is activated to restrict upstream vehicle flow into the roundabout. This decrease in vehicles entering the roundabout upstream causes a reduction in circulating flow and allows vehicles from the downstream leg to enter. Additional detection can be used to reduce the metering effect when an extended queue is detected on the metered approach. Vehicle detection location (distance from the yield line, etc.) is typically determined by an engineering study.

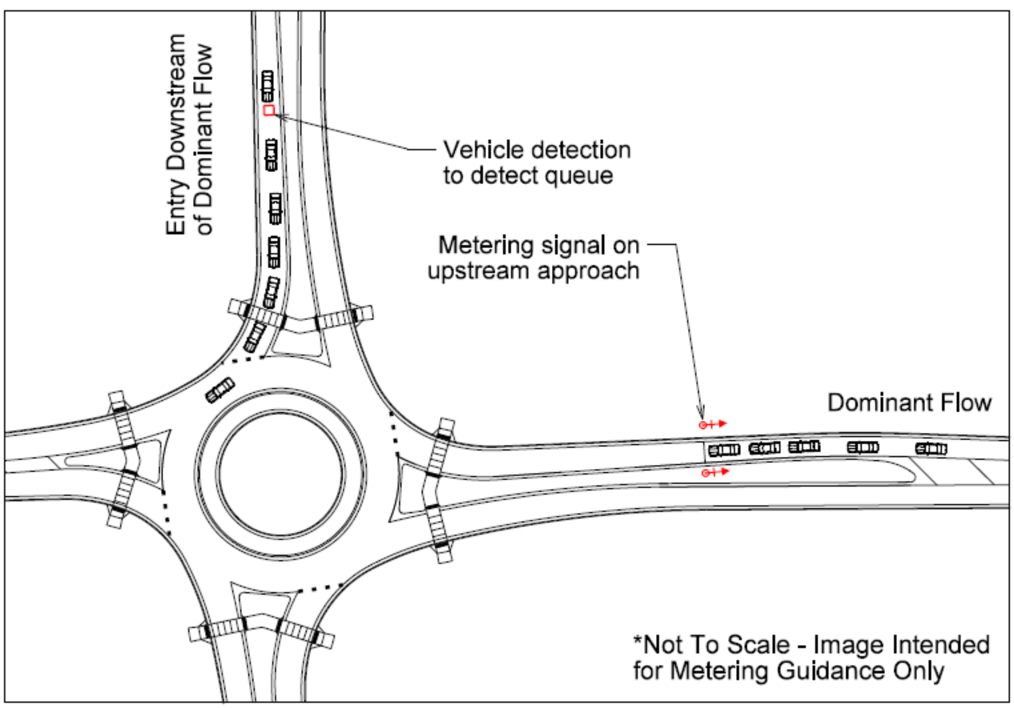


Figure 5-8. Roundabout with Signalized-Meter Approach

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Chapter 6. Roundabout Railroad Crossing and Preemption - Contents

Chapter 6. Roundabout Railroad Crossing and Preemption - Contents 6-i
6.1 Gating 6-3
6.1.1 Gating at the Railroad Crossing Only 6-3
6.1.2 Gated Closures at Railroad Crossing and On Circulating Lanes 6-4
6.1.3 Gated Closures at Railroad Crossing and Roundabout Entries 6-6
6.1.4 Railroad through the Roundabout 6-8
6.2 Signalizing Approaches 6-9
6.3 Blank Out Sign...6-10

Chapter 6. Roundabout Railroad Crossing and Preemption

Design of roundabouts near railroad crossings require consideration of railroad crossing proximity, speed & frequency of trains, as well as volume & class of roadways; and should be coordinated with the GDOT Railroad Crossing Manager, Railroad Crossing Improvement Unit, in conjunction with concept development.

The designer should also be familiar with most current versions of the following resources:

- GDOT DPM, Chapter 7.6
- AASHTO Green Book, Chapter 9
- FHWA MUTCD Chapter 8

The 2009 MUTCD Section 8C.12, requires an engineering study to be made for all proposed roundabouts within 200 ft of railroad crossing to determine the interaction of potential roundabout queues and the railroad crossing. When considering a railroad crossing near a roundabout, the following factors influence the choice of railroad crossing treatment:

- Distance between the roundabout and the Railroad crossing
  - Spacing and traffic characteristics of closely surrounding intersections and driveways
- Characteristics of railroad traffic, including
  - Number of tracks
  - Frequency and duration of trains at the crossing
  - Speed of trains through the crossing
- Volume of vehicular traffic
  - At the railroad crossing and number of travel lanes
  - Spilling back from the roundabout towards the railroad crossing (length of vehicle queue)
  - On other roadways near the railroad and opportunities to serve movements not crossing the railroad
- **Roundabouts have significant advantages when compared to traffic signals near a railroad crossing due to the recovery strengths of roundabouts after a crossing event**.

The following sections present the most common treatments to mitigate potential conflicts near a railroad crossing depending on the engineering study results. These treatments show the sequence of gating events to restrict traffic from crossing the railroad and/or to allow traffic to flow at the roundabout. The treatments are presented in order of general consideration; however, they do not address every scenario of railroad crossing location or setback. Engineering judgement is required to determine design details for basic gating treatment and timing for each specific location being evaluated. This guidance does not address gate timing or duration, just potential sequences.

Note: If a gate is considered for installation on a roundabout project, a conceptual layout should be developed and sent to the railroad group. They will forward it to the involved railroad company for their review to determine the feasibility of installing a gate at the crossing prior to moving into the preliminary design phase.

Table 6-1 compares the different queue management devices and techniques based on the clear storage distance (CSD) and minimum track clearance distance (MTCD). Per the MUTCD definition, (Part 1A.13),

> *"CSD is the distance available for vehicle storage measured between 6 ft from the rail nearest the intersection to the intersection stop line or the normal stopping point on the highway. The MTCD is the length along a roadway at one or more railroad tracks and is measured from either the gate arms or stop lines."*

Reference the *FHWA-FRA Highway-Rail Crossing Handbook (3rd Ed.)* "Figure 38 - Clear Storage and Minimum Track Clearance Distance" for a diagram showing the CSD and MTCD at a railroad crossing.

Table 6-1. Comparison of Queue Management Techniques

Clear Storage Distance	Application	Key Operational Characteristics
75 ft to 200-250 ft[a]	6.1.1	• Activation and timing plan designed to prevent vehicles from queuing in the MTCD, but vehicles may queue in CSD.
Less than 25-75 ft[a]	6.1.2	• Intersection gate timing should clear the Clear Storage Distance (CSD) as well as the Minimum Track Clearance Distance (MTCD).

[a]*Based upon length of vehicle used as the basis for design.*

Additional Considerations: Dynamic Envelope Pavement Marking can be used to discourage queuing on the tracks

6.1 Gating

Gating is a physical barrier preventing traffic from moving forward while in use. When gates are located outside the railroad right-of-way, the railway authority may not want to maintain the gate nor interconnect them to preempt the crossing.

Gating may be useful when an engineering study has concluded the roundabout queue is likely to spill back from the roundabout to the railroad crossing. Depending on the length/speed of the train and the duration the gate is down, the traffic exiting the roundabout that is stopped at the gate may spill back to the roundabout, effecting operations.

6.1.1 Gating at the Railroad Crossing Only

Gating exclusively at the railroad crossing, shown in Figure 6-1, is useful **when an engineering study has concluded that roundabout queues will not interact with the railroad crossing**. By blocking railroad crossing traffic with gated closures, roundabout movements (that do not interact with the railroad crossing) are unrestricted, preserving most of the roundabout's capacity.

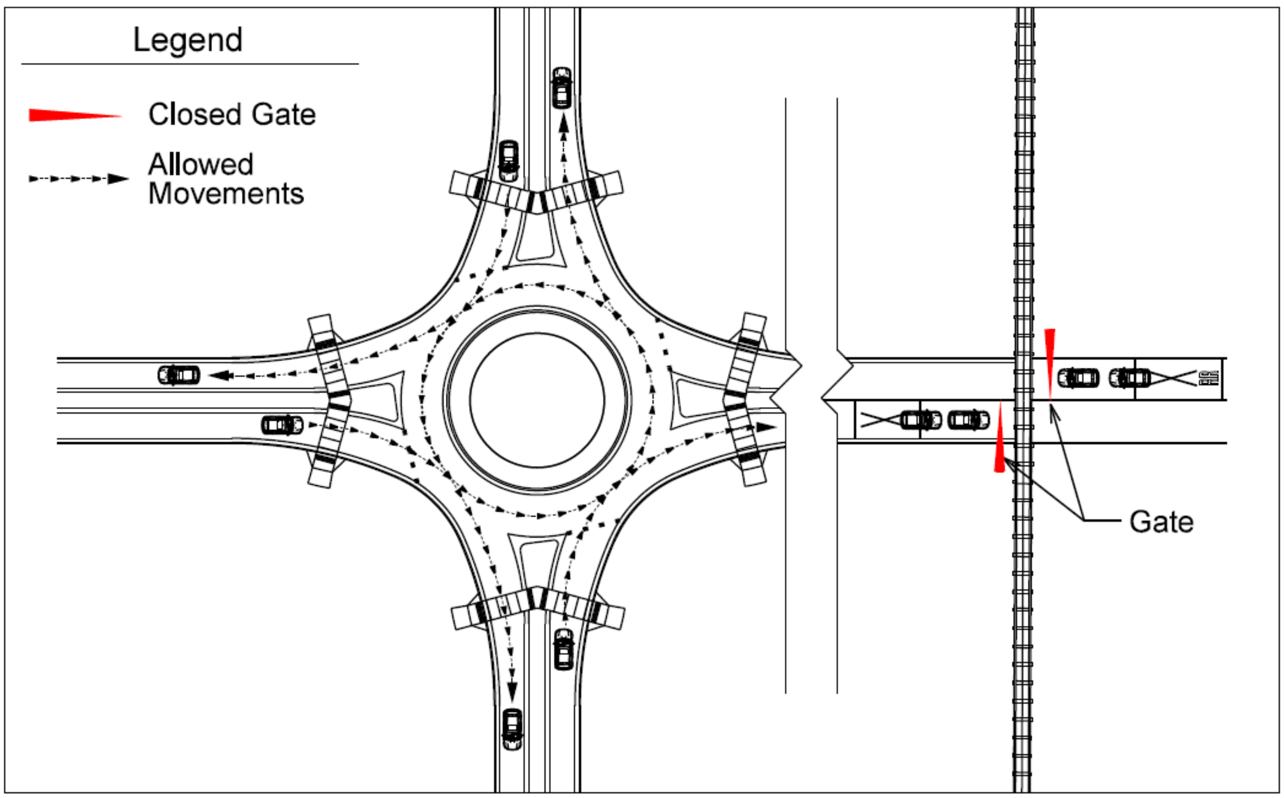

Figure 6-1. Gated closures exclusively at railroad crossing

6.1.2 Gated Closures at Railroad Crossing and On Circulating Lanes

When an engineering study concludes a queue of traffic entering the roundabout **is likely to spill back to the railroad crossing**, as shown in Figure 6-2A, gating the circulating lanes is an option. This sequence of gating and timing allows for a queue of vehicles to be "flushed" to ensure no vehicles are caught inside the railroad crossing gates.

As shown in Figure 6-2A, in the first sequence, the circulating gate is lowered to allow the queue of conflicting vehicles between the roundabout and the railroad to clear. During this sequence, the gates at the tracks are still raised. Once the queue of conflicting vehicles is cleared, queueing back to the railroad crossing is unlikely.

As shown in Figure 6-2B, the roadway gate remains down, and track gates are lowered to keep vehicles from approaching the roundabout and, eventually, queuing onto the tracks.

At that point, a third sequence may be used, as shown in Figure 6-2C, where movements through the roundabout not affected by the railroad crossing can be restored by raising the roadway gate.

The Design team should note that railroads may not want to install and maintain warning devices that are not on their ROW. If the gates and relative equipment are out of railroad ROW, they would need to be installed and maintained by the Department.

The use of a vehicle refuge area, accessible to vehicles in queued traffic at a railroad crossing, may be effective crash risk mitigation irrespective of the type or cause of queue. More information on refuge areas can be found in the AREMA standards and FRA regulations.

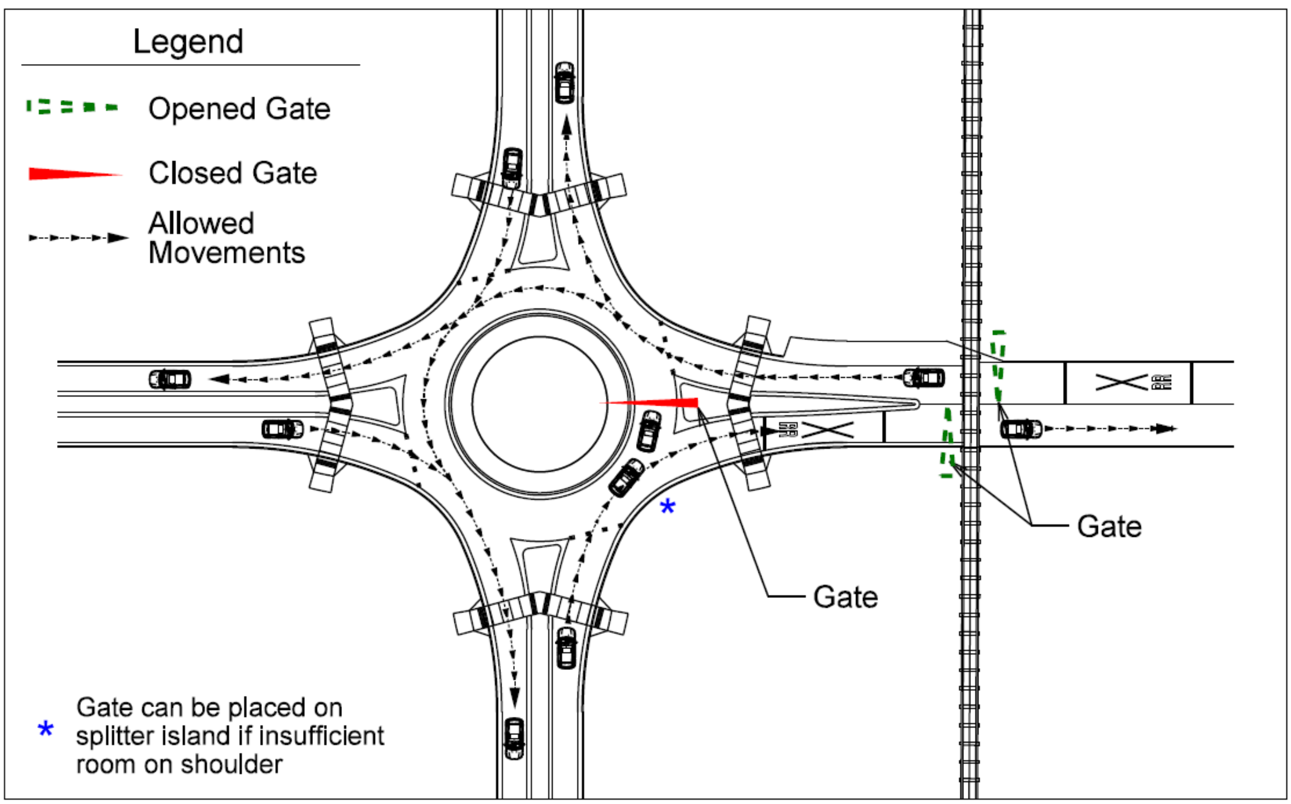

Figure 6-2A. Track clearance stage with gated closure for circulating flow

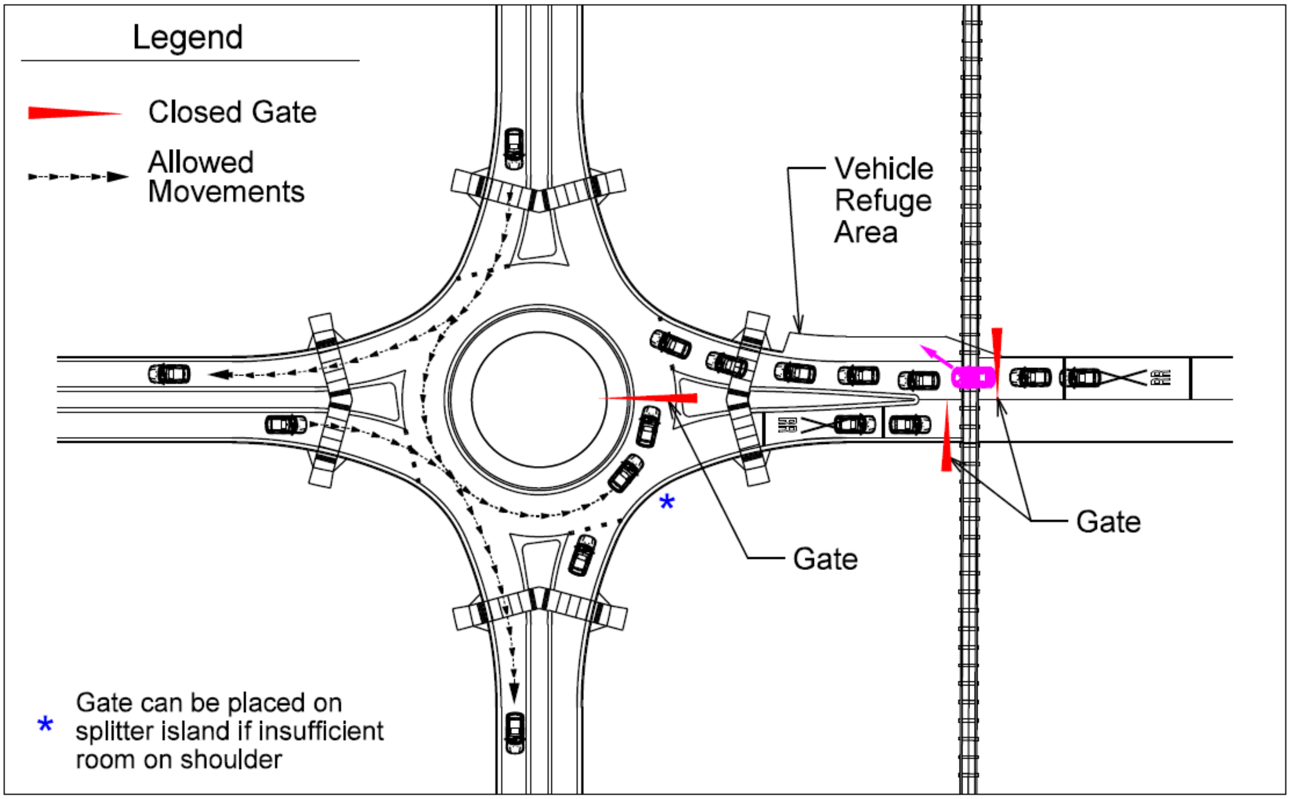

Figure 6-2B. Track clearance stage with gated closure for circulating flow and at track crossing

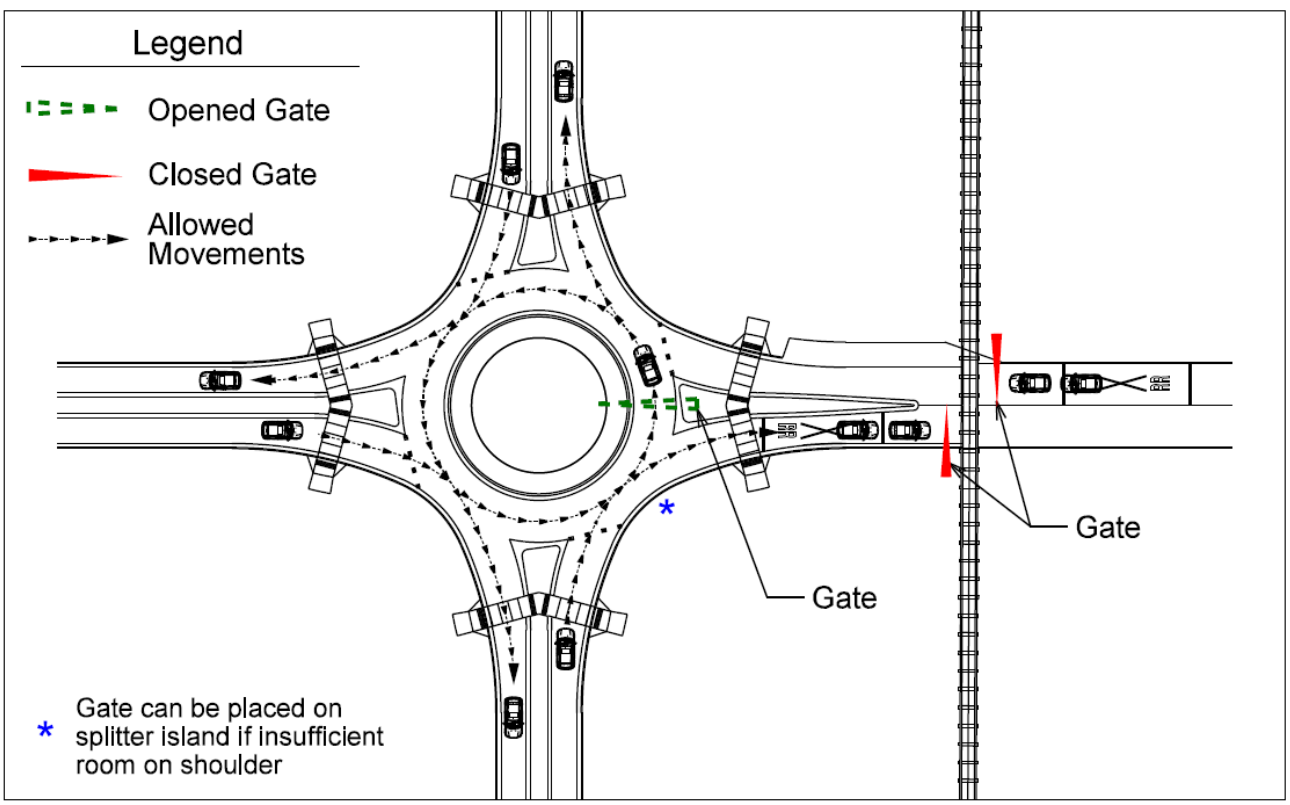

Figure 6-2C. Track hold stage with gated closure at railroad crossing only

6.1.3 Gated Closures at Railroad Crossing and Roundabout Entries

Gated closures at railroad crossing and roundabout entries prevents vehicles from progressing through the roundabout and into the railroad crossing by lowering the approach gates for all roundabout entries prior to the railroad crossing gate. Similar to Treatment 6.1.2, it allows any queues of vehicles blocking the railroad crossing to 'flush' through the roundabout exits as shown in Figure 6-3A to complete the track clearance stage. The railroad crossing gates are subsequently lowered, as shown in Figure 6-3B, to prevent any traffic flow from entering the roundabout and from crossing the railroad tracks, and to complete the pre-empt hold stage.

Note: The time required to effectively clear out the roundabout should be evaluated. The total railroad flashing operation is typically 30 seconds, at a minimum. See AREMA standards and FRA regulations for more information.

After the railroad tracks are cleared and gates are lowered, the roundabout approach gates can then be lifted for traffic to enter the roundabout, as shown in Figure 6-3C. This relieves any queues that may have formed during the pre-empt hold stage. Treatment 6.1.3 is not practical if the roundabout carries a high volume of traffic and/or the rail traffic consists of long or slow trains (in this case, use Treatment 6.1.2).

The design team should note that railroads may not want to install and maintain warning devices that are not on their ROW. If the gates and relative equipment are out of railroad ROW, they would need to be installed and maintained by the Department.

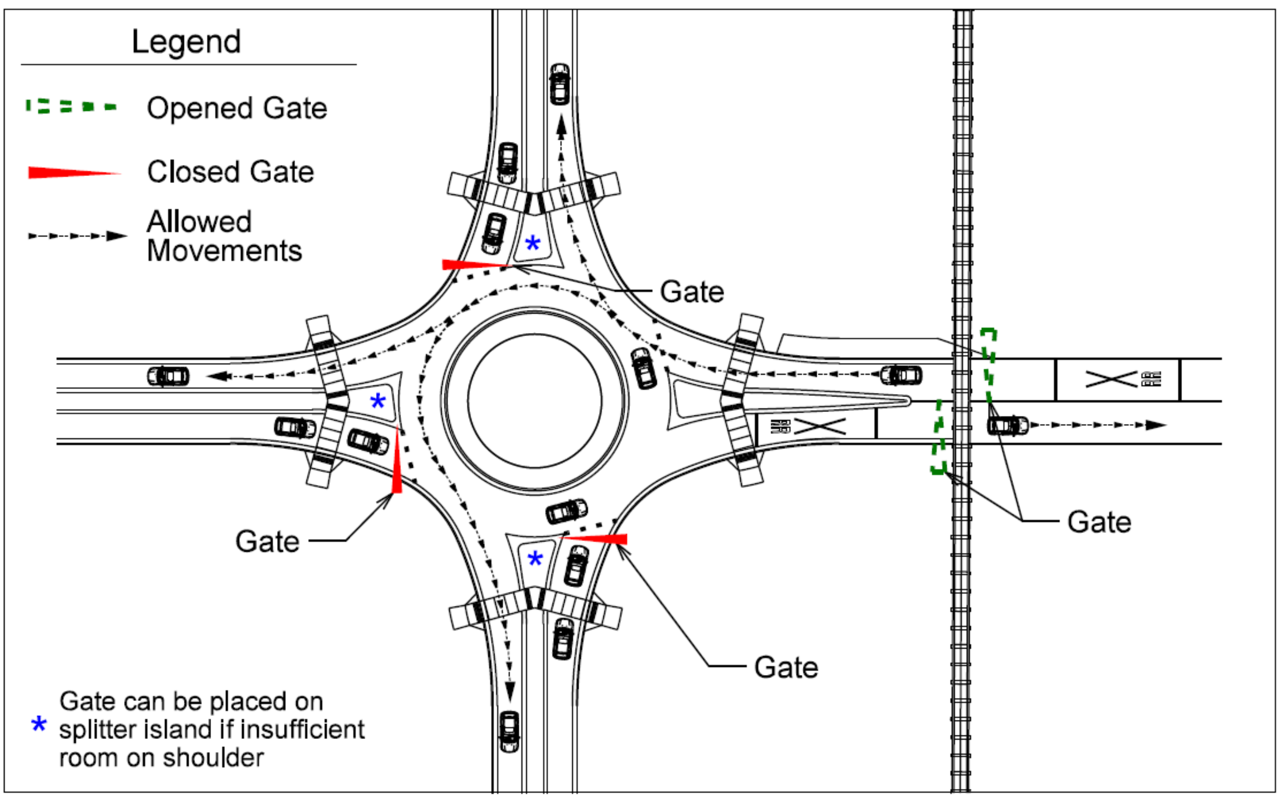

Figure 6-3A. Track clearance stage with gated closures at roundabout approach entries

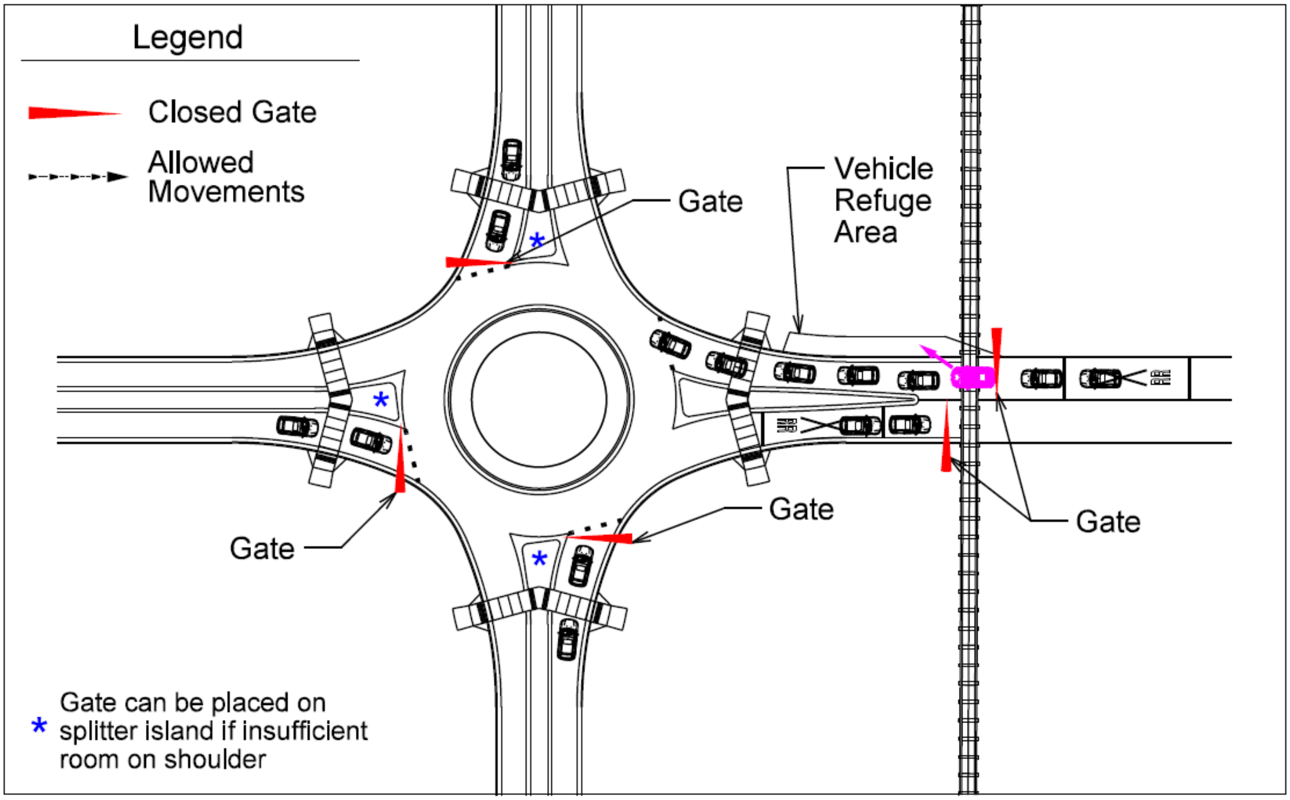

Figure 6-3B. Pre-empt hold stage with gated closures at approach entries and railroad crossing

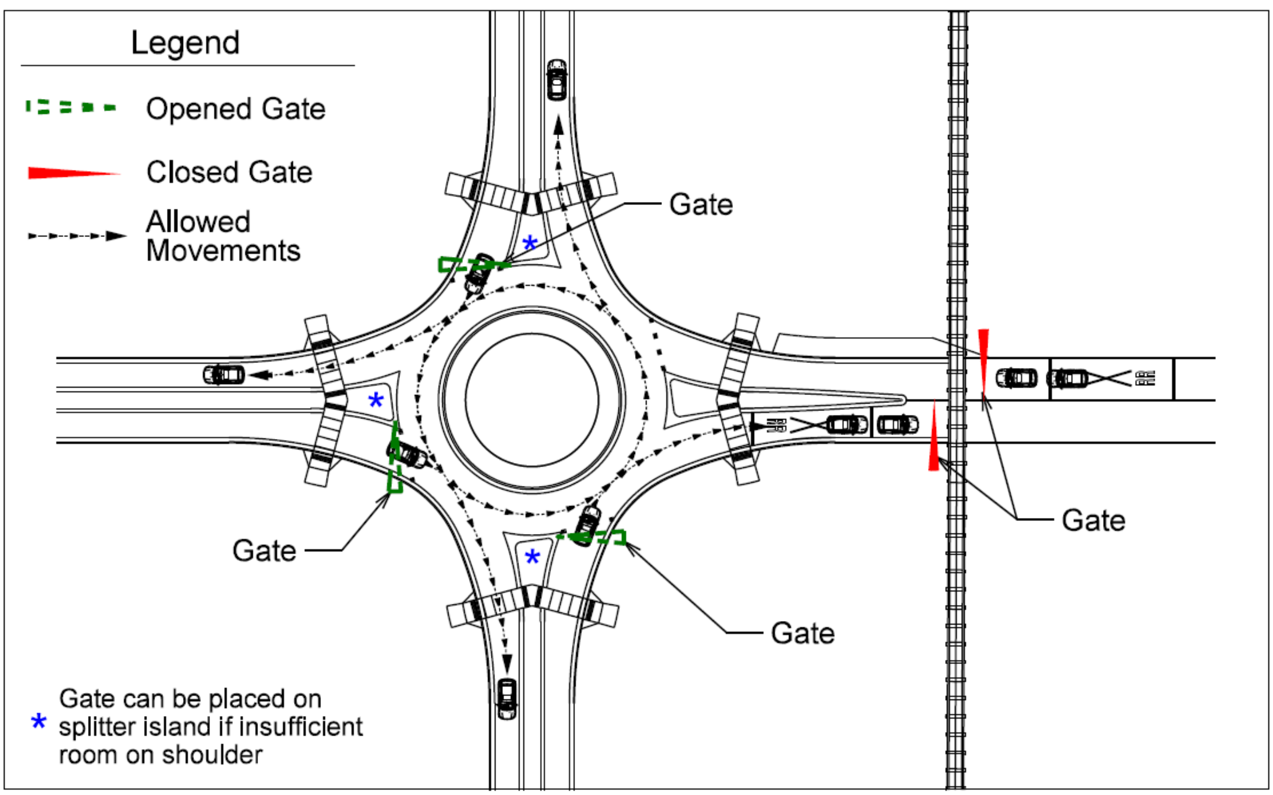

Figure 6-3C. Track hold stage with gated closures at railroad crossing only

6.1.4 Railroad through the Roundabout

A railroad through the roundabout is for cases where the railroad track crosses through the roundabout. For this scenario, gates are placed on splitter islands to prevent both entering and circulating vehicles from crossing the railroad while a train is present, as shown in Figure 6-4. Once the rail clearance is initiated, all gates are lowered preventing traffic from circulating, except the right turns on two approaches. After the train has cleared the roundabout, all gates are lifted, and the roundabout returns to normal operations.

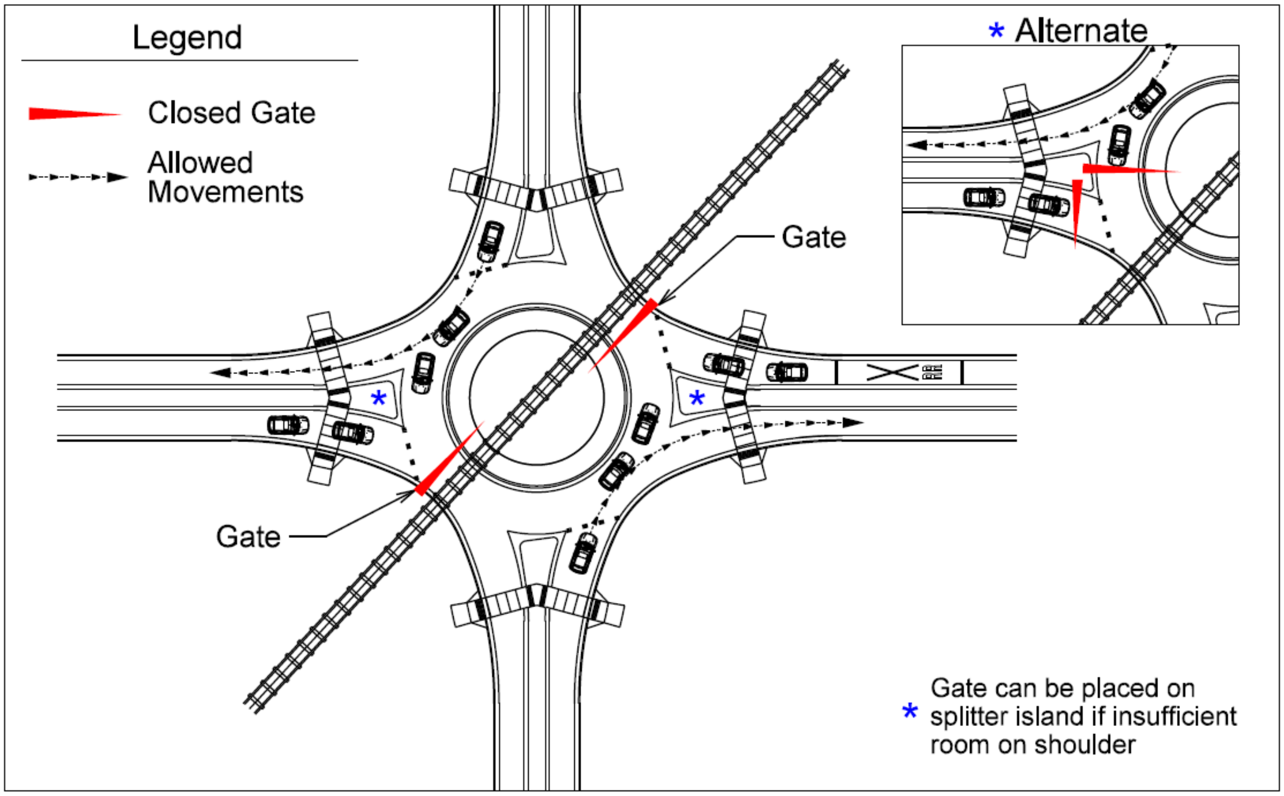

Figure 6-4. Railroad through the roundabout

6.2 Signalizing Approaches

Using signalization to control traffic in the roundabout is an alternative to roadway gates. Signalizing a roundabout near a railroad involves placing traffic signals at locations that will control departing traffic from the railroad tracks, as well as conflicting circulatory traffic. These signals are interconnected with railroad gates and vehicle detection systems on the approach to the railroad crossing, as shown in Figure 6-5.

This treatment is necessary if an engineering study has shown the potential for traffic from the roundabout to queue back to the railroad crossing. This treatment is an alternative to gating the circulatory roadway (as done in Treatments 6.1.2 and 6.1.3) to ‘flush’ the traffic off the crossing. If the railroad owner is not willing to install a gate in the roundabout, a signal could be used to clear traffic prior to gates down.

These signals will be dark when not operating and will operate like a ramp meter.

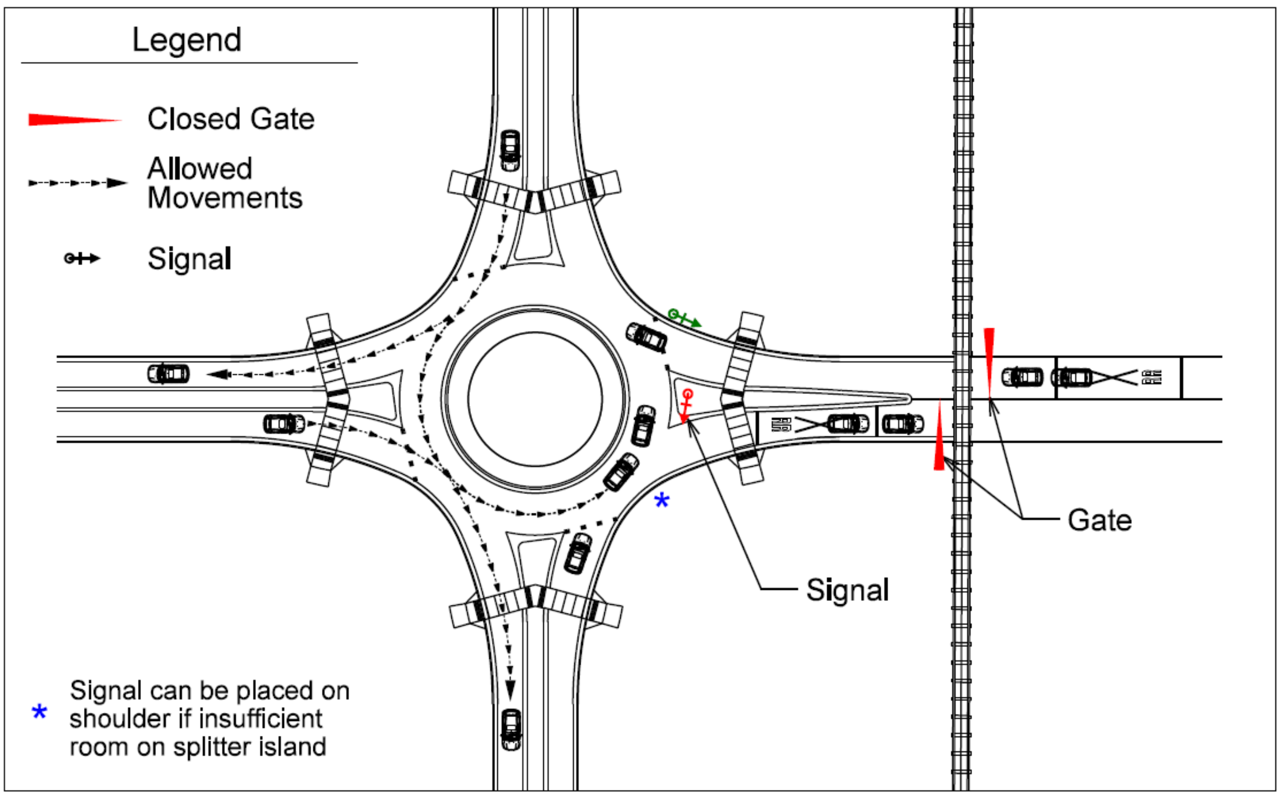

Figure 6-5. Signal at roundabout with gate at railroad crossing

6.3 Blank Out Sign

The use of blank-out signs in lieu of gates or signals, to control traffic in the roundabout adjacent to the railroad crossing, is shown in Figure 6-6.

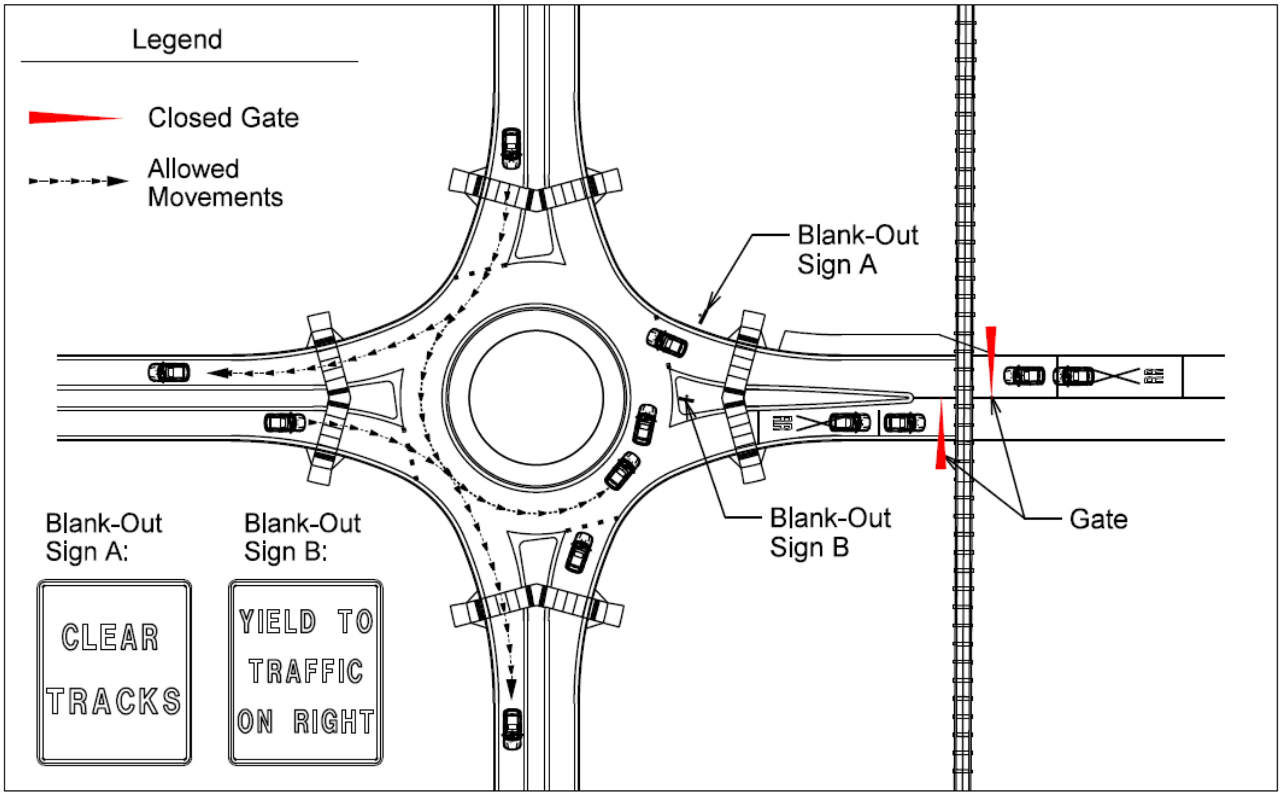

Figure 6-6. Blank Out Sign at railroad crossing only

Chapter 7. Lighting - Contents

Chapter 7. Lighting - Contents 7-i
7.1 Principles 7-1
7.2 Pole Placement Recommendations 7-2

Chapter 7. Lighting

7.1 Principles

The critical areas that require illumination are the entering/circulating conflict points, crosswalks, and transition points from pavement to raised channelization. If the approaching roadways are not continuously illuminated, transition lighting may be required. Refer to Section 14.3.3 of the GDOT DPM. GDOT is exploring ways to reduce the number of light poles on roundabouts. In some rural locations, lighting is reduced from approaches and is only used at the circulatory roadway. Using other visibility elements, such as internally illuminated bollards and raised pavement markers, are encouraged as a consideration for reduced lighting, subject to approval by the Office of Design Policy.

Lighting plans should be developed consistent with the guidelines presented in Chapter 14 of the DPM and ANSI/IES RP-8 (American National Standard Practice for Design and Maintenance of Roadway and Parking Facility Lighting).

7.2 Pole Placement Recommendations

An important function of lighting at a roundabout is to ensure that any pedestrian in the crosswalk is visible to vehicles approaching, entering, and exiting the roundabout. Roadway lighting also provides increased safety to cyclists, at the approach and throughout the circulatory roadway, where they may be integrated into the traffic stream. For these reasons, it is recommended that lighting be placed around the perimeter of the roundabout at locations upstream of the crosswalks, so pedestrians are in positive contrast (front-lit). Poles should be located to provide consistent lighting levels around the circulatory roadway. See Figure 7-1 for a basic example of pole placement.

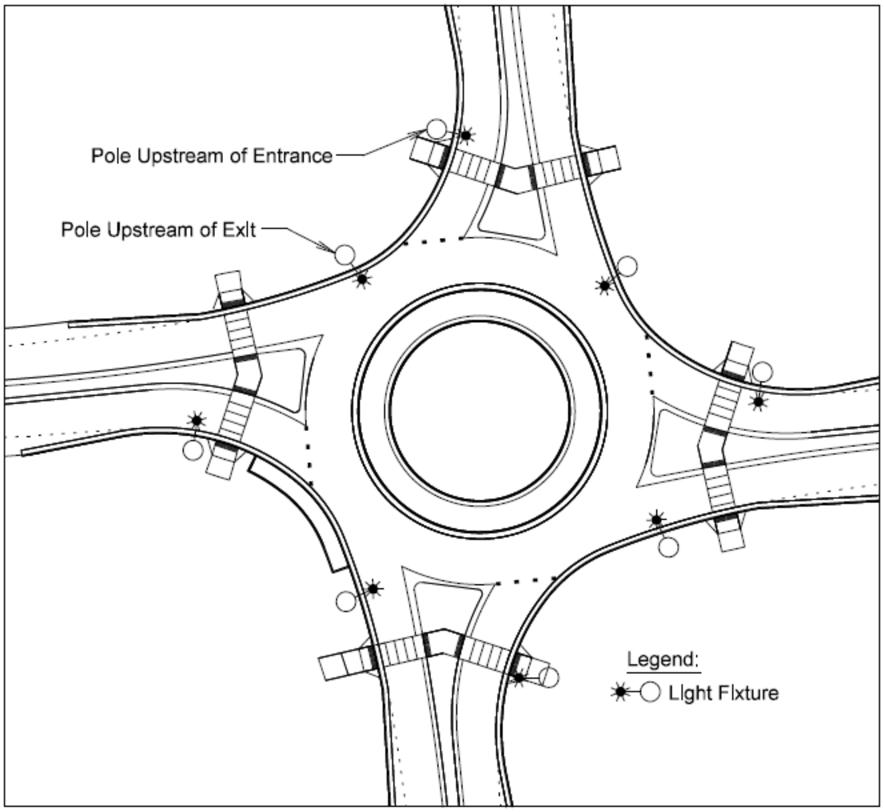

Figure 7-1. Perimeter Pole Placement

Chapter 8. Landscaping - Contents

Chapter 8. Landscaping - Contents 8-i
8.1 Central Island Grading.. 8-1
8.2 Landscaping 8-2
8.3 Color and Texture Treatments for Truck Aprons 8-5

Chapter 8. Landscaping

Central island grading and landscaping further improves safety performance and addresses aesthetics of a roundabout by:

- Increasing the roundabout visibility from a distance – this is particularly important on rural or high-speed approaches
- Blocking through sight across the circle – so drivers focus on the intersection and do not see headlights approaching from the other side
- Blocking excessive sight distance around the circle to encourage slower speeds

8.1 Central Island Grading

Non-traversable **central islands should be mounded** to improve the safety performance. They should have a maximum height of 6ft above the back of the truck apron curb, with slope grades between 10:1 and 6:1, as needed, to block through sight, see Figure 8-1. For tipped circles, the highest point may not be in the center, see Figure 8-2. The highest elevation and grades should be specified on a construction plan set.

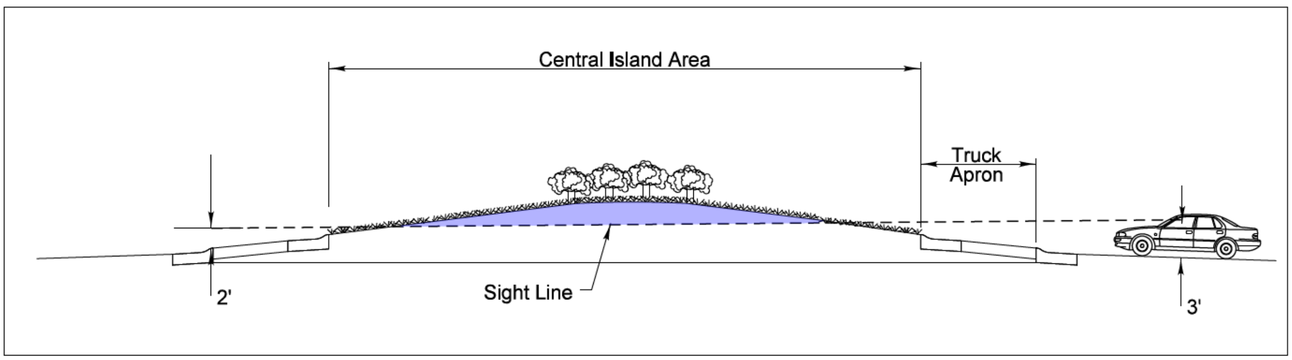

Figure 8-1. Blocked Through Sight

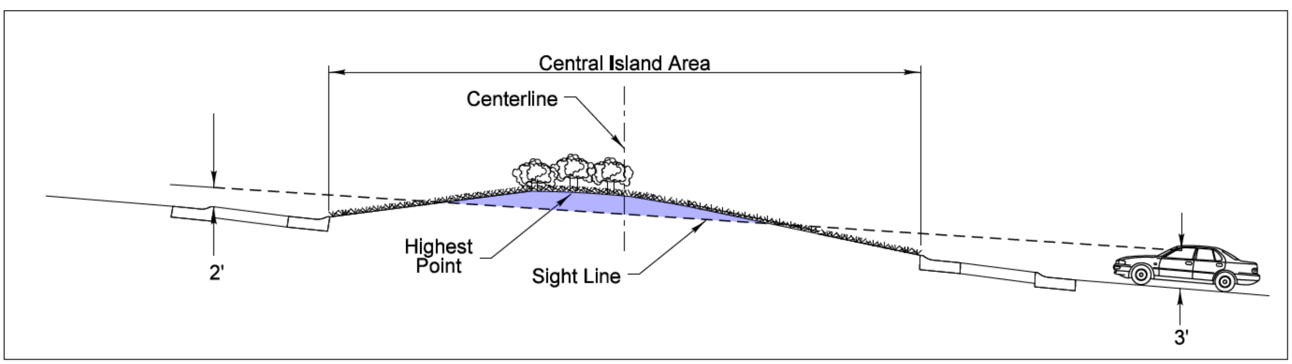

Figure 8-2. Tipped Circle Highest Point

8.2 Landscaping

Landscaping should be added in conjunction with grading to further improve safety performance and address aesthetics.

Proper landscaping prevents sight distance issues by effectively blocking through sight. It naturally slows down runoff to mitigate changing a natural area into a paved area. It also reduces the heat island effect. **Impervious material should be used as little as possible** to avoid a drainage burden on the circulatory roadway. Establishment of the landscaping, on GDOT maintained routes, is covered by Specification Section 702 — Vine, Shrub, and Tree Planting.

Landscaping typically consists of low-lying perimeter landscaping (sod) and inner central island landscaping (grasses, shrubs, or trees). See GDOT Construction Detail RA-1 for GDOT's standard low maintenance landscaping. Perimeter landscaping is needed when line of sight needs to be retained across part of the landscaped central island. Its width should be labeled on construction plan sets and is determined by intersection and stopping sight distance checks, as shown in Figures 8-3 and 8-4. Line of sight can be achieved within the truck apron without having to look through the central island; in which case, the perimeter landscaping does not have to be low lying.

If maintenance resources for landscaping is limited, please contact the Office of Traffic Operations to determine if an ultra-low maintenance option is available.

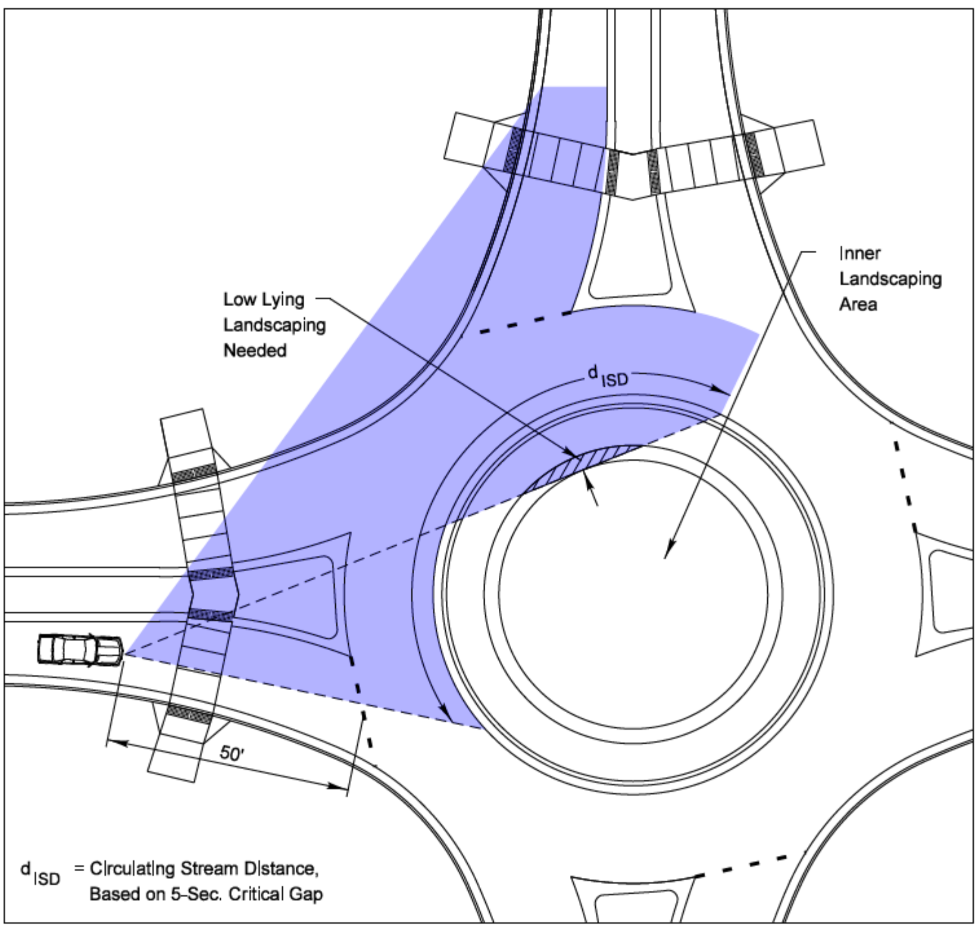

Figure 8-3. ISD Landscaping Check

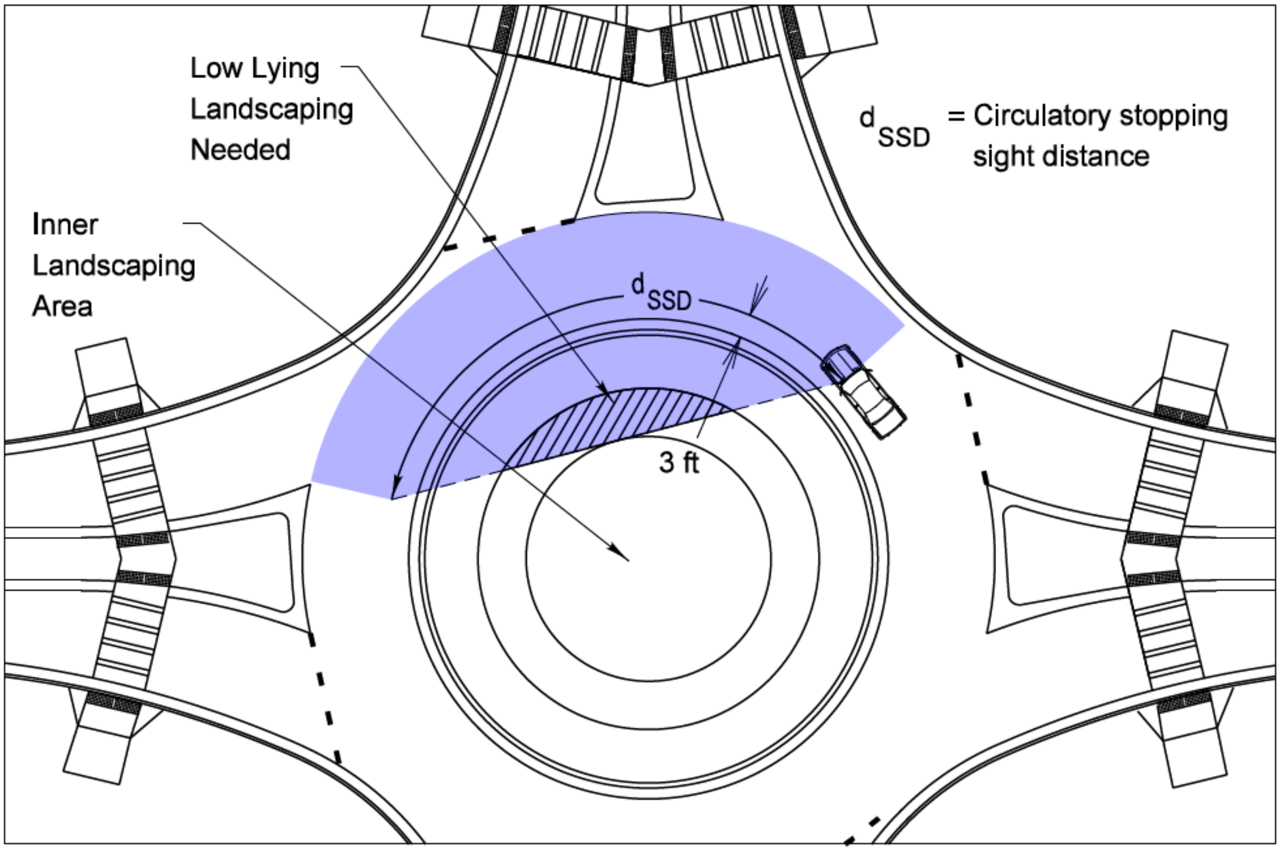

Figure 8-4. SSD Landscaping Check

Aesthetic value can be increased even further with higher maintenance landscaping if desired, see Figure 8-5 for an example. Landscaping can be considered for splitter islands and buffer strips between back of outside curb and sidewalk, if plantings do not restrict needed sight distance. Approval is required from GDOT Office of Maintenance if landscaping other than standard GDOT RA-1 detail is desired. In this case, sight distance is still the primary criterion. Trees with mature caliper size of greater than 3 inches should be avoided. Consult with the Office of Traffic Operations if fixed objects are to be considered in central island landscaping.

Figure 8-5. Turner Lake @ Clark Street, Newton County

Guidance for trees and shrubs allowed on state routes is found in Policy 6755-9 Policy for Landscaping and Enhancements on GDOT Right of Way. Additional guidance is provided in the GDOT Pedestrian and Streetscape Guide.

8.3 Color and Texture Treatments for Truck Aprons

Mountable (traversable) areas should be colored and may be textured with a stamped brick pattern or a simple broom finish, which adds skid resistance. If grass is not used, non-mountable areas, (such as medians, and buffer strips), should use stamped concrete (for sight impaired pedestrians) and colored differently so that drivers can distinguish mountable vs. non-mountable. Splitter islands can be designated with non-mountable landscaping, non-mountable patterned concrete, or brushed-finish concrete.

Table 8-1 shows GDOT approved color options for mountable vs. non-mountable areas. Figure 8-6 shows an alternative option for coloring and patterning of the truck apron.

For truck aprons, a contrasting chevron color pattern can be used to emphasize the one-way nature of a roundabout, see Figure 8-7.

Table 8-1. Concrete Coloring Options

Federal Standard 30108 Red Brown	Federal Standard 30152	Federal Standard 30266 Yellow Sand	Federal Standard 33446 Dessert Tan
Used for mountable areas, i.e. truck aprons, etc.		Use for non-mountable areas, i.e. splitter islands	

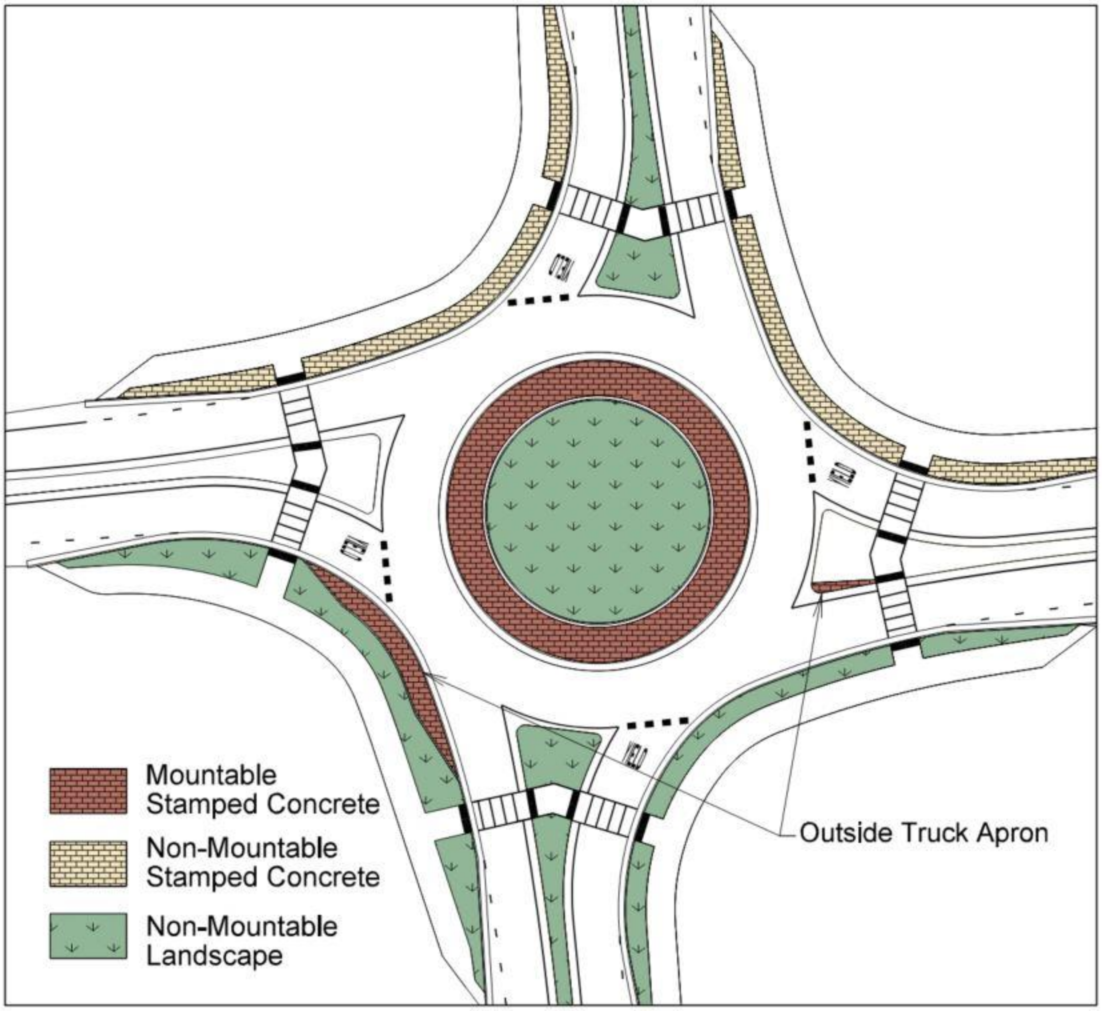

Figure 8-6. Truck Apron Coloring & Patterning

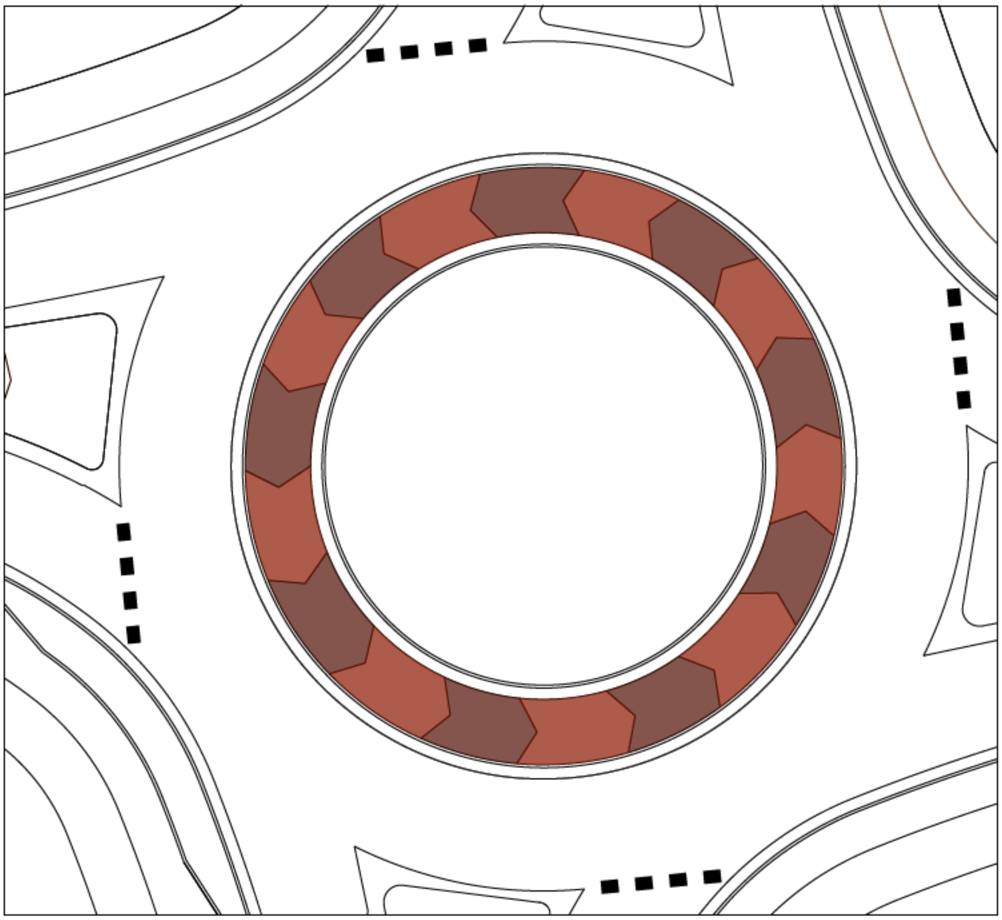

Figure 8-7. Truck Apron Chevron Patterning

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Chapter 9. Pavement Design - Contents

Chapter 9. Pavement Design - Contents 9-i
9.1 Pavement Type Selection..9-1
9.2 Axle Loading Analysis 9-2

Chapter 9. Pavement Design

9.1 Pavement Type Selection

Pavement type selection at a roundabout is determined by the existing pavement type, proposed pavement cost, projected traffic volumes, and constructability during staging. In most cases, asphalt is the most economical and is easier to stage roundabout construction. Staging is typically significantly simpler, and costs are typically lower, if the existing roadway can be asphalt overlaid instead of having to construct full depth pavement. Additional preference is given to asphalt for multilane roundabouts where the contrast of pavement marking for lane lines and directional arrows is essential for safe operation.

Concrete pavement should be considered for roundabouts; however, the above items should be factored into the decision and documented; see DPM Section 10.9 for more information. Consult with OMAT and refer to the Pavement Design Manual and PDP Section 6.4.2 for additional guidelines on pavement type selection.

9.2 Axle Loading Analysis

The heaviest circulating volume (per lane for multilane) is to be used for axle loading analysis. Roundabout circulating volumes are defined as the traffic that circulates upstream from a leg's approach, i.e. opposite the splitter island face. It is the sum of an approach's U-turns, left turns and through volumes, and the upstream approach's U-turns and left turns, and the further upstream approach's U-turns, see Figure 9-1. The highest circulating volume governs the axle loading calculation, e.g. 590 on Figure 9-1.

The Roundabout Traffic Tool for Pavement Design may be used to calculate circulating volumes, when the traffic diagrams do not contain circulatory flow traffic.

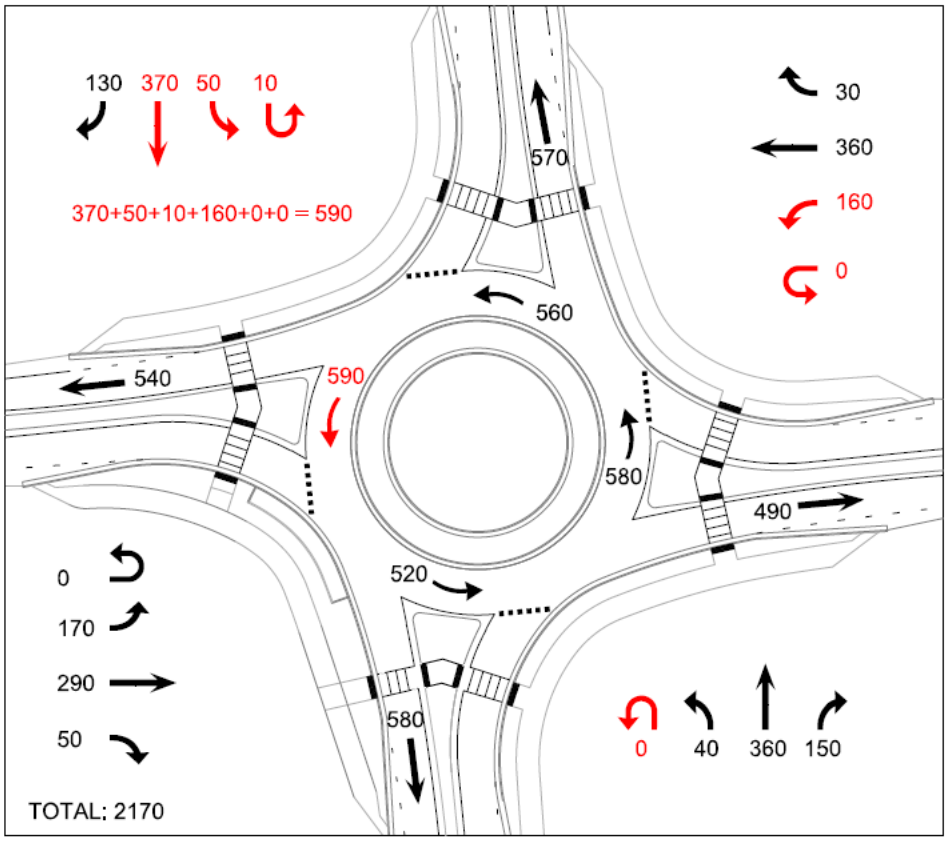


Figure 9-1. Circulating Volume Calculation

Chapter 10. Alternative Concepts for Staging Roundabout Construction - Contents

Chapter 10. Alternative Concepts for Staging Roundabout Construction - Contents 10-i
10.1 Short-Term Closure 10-2
10.1.1 Night Closure(s) 10-2
10.1.2 Weekend Closure(s) 10-2
10.1.3 Multiple Week Closure with Detour 10-3
10.2 Long-Term Closure with a Traffic Detour 10-4
10.3 Partial Detour (Close the Cross Road) 10-5
10.4 Construction of a Roundabout Off Alignment 10-6
10.5 Construction of the Roundabout Under Traffic 10-7
10.5.1 Undivided 2-Lane Roadway 10-7
10.5.2 Divided 4-Lane Roadway 10-8

Chapter 10. Alternative Concepts for Staging Roundabout Construction

A well-planned construction staging process is key to minimizing disruption and 'construction fatigue' – the tiresome experience of contending with the effects of construction on traffic and access. Maintaining existing traffic movements during construction of a roundabout can be very complex and may require multiple stages. Closure of the intersection and detouring traffic should be considered if there is a feasible detour route available.

The best-practice principles that apply to all roundabout construction staging and traffic management are as follows:

- Attempt to achieve circulating traffic, i.e. getting the intersection to operate as a roundabout as soon as possible. It reduces speeds, improves capacity and improves safety for workers. (This includes using cones/barrels during construction to create a temporary roundabout.)
- Minimize the number of stages to avoid 'construction fatigue', excessive duration and excess cost.
- Minimize the changes to traffic control on the roundabout. Avoid changing from yield to stop control and back again, to manage stages where traffic needs to use parts of the circle. Avoid running traffic in the contra-flow direction on the roundabout.
- Days if not weeks before the roundabout opening, attempt to have the normal priority rules of yielding at entry with traffic flowing counterclockwise.
- Signing, including way-finding (D and M series signs) and especially lane designation signs for multilane roundabouts, should be installed before the roundabout opens
- Use changeable message boards on each approach at the time of opening and for reasonable duration after opening. Advise using an alternating message of: "New Control" and "Yield Ahead".

The purpose of this guidance is to inform the designer of practical construction staging alternatives. Construction duration adds costs to projects, but intersection closure is not feasible in many cases. The alternatives presented herein represent a range of cases that are possible depending on the intersection context and constraints. There may be sub-alternatives to these general categories. These alternatives are presented in increasing order of traffic control costs and space requirements. Therefore, it is recommended to consider the alternatives in the order presented.

10.1 Closure of the intersection with a traffic detour for part or most of construction duration
10.2 Short term closure
10.2.1 Night closure(s) of the intersection
10.2.2 Weekend closure(s) of the intersection
10.2.3 Multiple week closure with a traffic detour
10.3 Partial detour (close the crossroad or one leg)
10.4 Construction of a roundabout off alignment
10.5 Construction of the roundabout under traffic
10.5.1 Undivided 2-lane roadway
10.5.2 Divided 4-lane roadway

10.1 Short-Term Closure

he duration of a short-term closure can be anywhere from a night, or a weekend, to multiple weeks. A portion of the widening would typically be completed prior to the closure/detour of the intersection.

10.1.1 Night Closure(s)

Night closures (evening to morning OR before AM peak to after PM peak) are preferred to long-term closures, as formalized detour plans are not needed. Night closures can be covered under GA Specification Book Section 150 (Traffic Control).

Typical construction activity is leveling the intersection for future weekend closure(s).

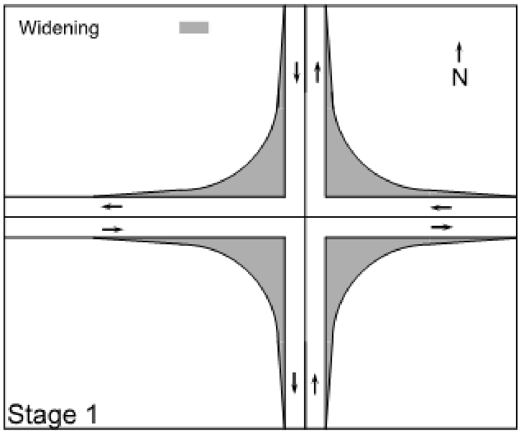
10.1.2 Weekend Closure(s)

Weekend closures (Friday evening to Monday morning) are preferred to long-term closures, as formalized detour plans are not needed. Weekend closures can be covered under GA Specification Book Section 150 (Traffic Control).

Typical construction activity is the pouring of the truck apron. After the traffic is placed back on the roadway system, splitter islands can be poured under traffic.

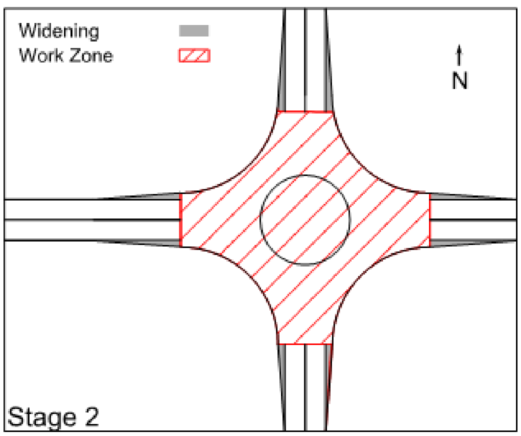
10.1.3 Multiple Week Closure with Detour

Multiple week closures are not preferred, as they require a formalized detour plan. However, this is an option when weekend closures are insufficient, and a long-term closure is not feasible.



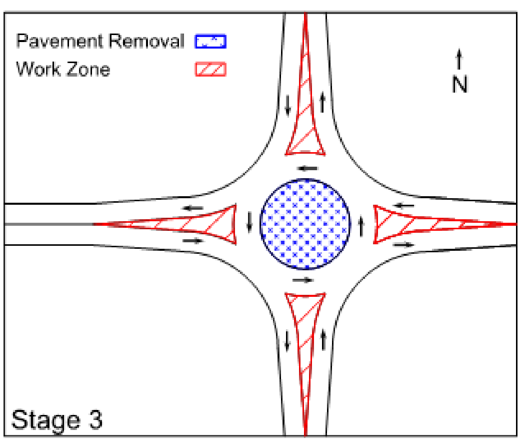
Stage 1

- Construct widening, etc. along the existing roadway
- Traffic remains on existing lanes.
- Construct the outside curb and gutter.
- Detour signing is put in place for the detour in Stage 2.



Stage 2

- Close the intersection to traffic, rerouting traffic on to a detour.
- Construct as much of the intersection as possible while intersection is closed.
- Primary construction should include central island and truck apron



Stage 3

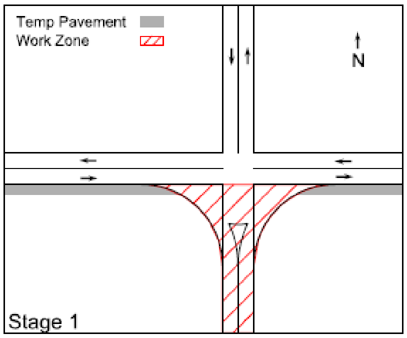
- Construct the splitter islands.
- Remove any unnecessary pavement.
- Pave surface course of asphalt

10.2 Long-Term Closure with a Traffic Detour

If there is an acceptable detour route, closing the roads to traffic and allowing the contractor the entire area to construct the roundabout allows the most efficient and cost-effective construction process. Provide a detour plan, subject to consultation with the District Traffic Engineer (who may discuss with local officials). Properties with driveways within the construction limits will still need access during the construction. A portion of the widening can be completed prior to the closure/detour of the intersection.

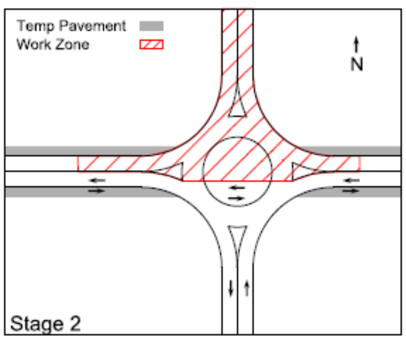
10.3 Partial Detour (Close the Cross Road)

This alternative is appropriate where the main road must remain open, but the minor route can be detoured or shifted temporarily.



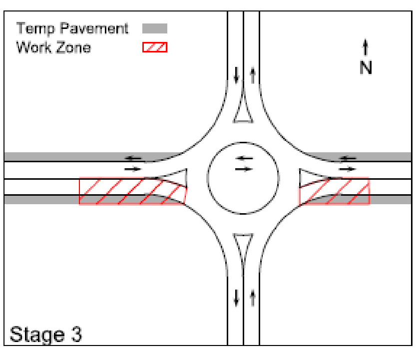
Stage 1

- Shift or close and detour traffic on south leg.
- Construct temporary widening along the south side of the mainline for future traffic switches.
- Complete full construction of the south leg.
- Construct as much as possible of the roundabout quadrants and circulatory roadway.



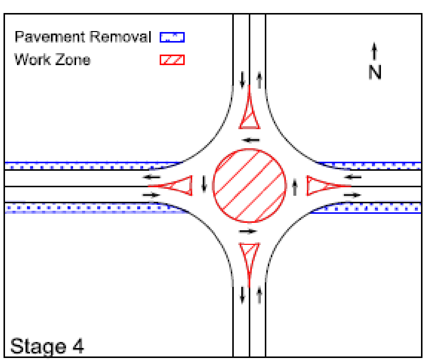
Stage 2

- Shift mainline traffic onto temporary widening and open the south leg to traffic.
- Close and detour traffic from the north leg.
- Complete full construction of north leg.
- Construct as much as possible of the roundabout quadrants and circulatory roadway.
- Construct westbound mainline approaches.
- Construct temporary pavement for traffic switches



Stage 3

- Shift mainline traffic on to new westbound lanes using temporary pavement in the islands.
- Open the north leg to traffic.
- Complete construction of eastbound mainline approaches.

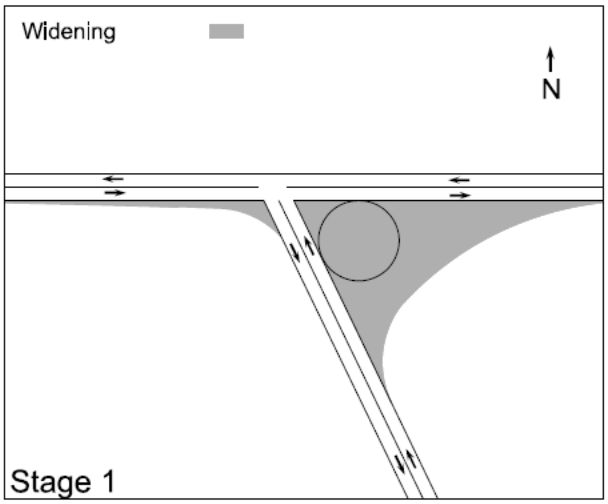


Stage 4

- Complete construction of central island and splitter islands.
- Remove pavement under the landscaping area and all temporary pavement and construct outside curb and gutter after central island is completed.
- Pave surface course of asphalt

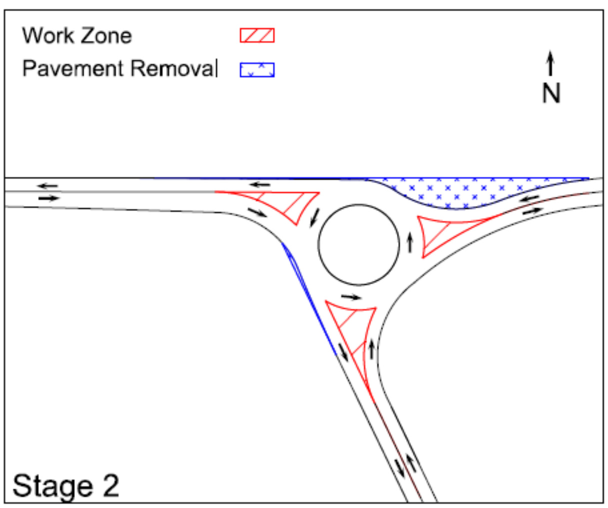
10.4 Construction of a Roundabout Off Alignment

This alternative is for construction of a roundabout with the circle shifted off the existing intersection. It is an especially viable alternative for T-intersections. It can significantly save staging/construction costs because less stages are necessary.



Stage 1

- Construct all truck apron and any widening out of existing asphalt
- Traffic remains on existing lanes.



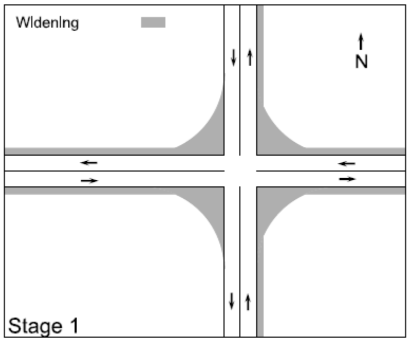
Stage 2

- Shift traffic to roundabout control
- Construct splitter islands, curb and gutter, etc.
- Remove excess pavement

10.5 Construction of the Roundabout Under Traffic

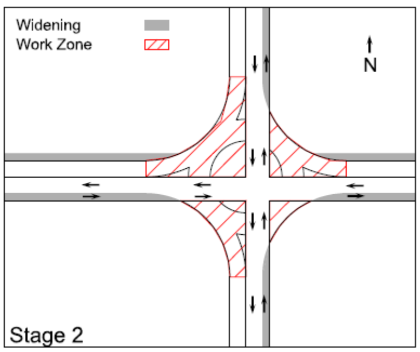
10.5.1 Undivided 2-Lane Roadway

This alternative is appropriate for an intersection of two-lane undivided roads that do not have a feasible detour route available.



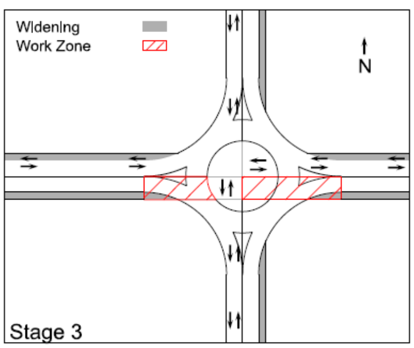
Stage 1

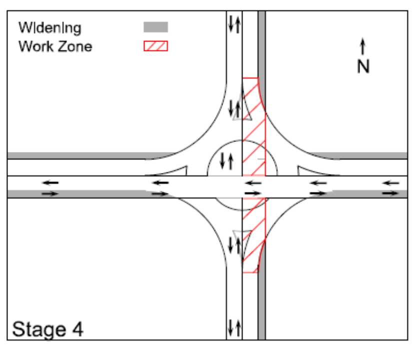
- Construct widening to one side of the roadway to accommodate traffic during the construction of the permanent pavement in stage 3.
- Traffic remains on existing lanes.



Stage 2

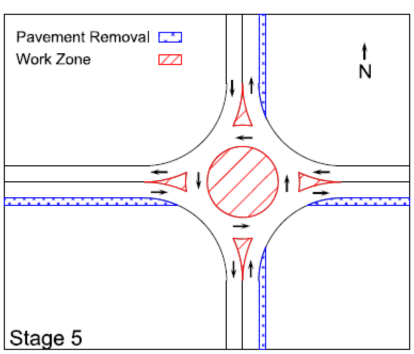
- Construct one quadrant of the roundabout and as much of the circulatory roadway as possible.
- Temporary leveling will likely be needed on existing lanes through the intersection to keep a smooth transition.





Stage 3 & 4

- Construct the remaining quadrants and the circulatory roadway.
- Consider adding leveling to roadway as needed to avoid drainage issues.
- Use the shoulder for a traffic lane or temporary pavement as needed to complete the roundabout construction.

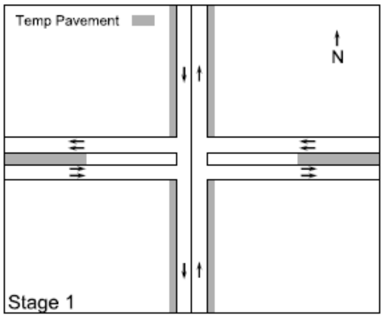


Stage 5

- Construct the remaining central island and splitter islands, quadrants and the circulatory roadway.
- Traffic is on the newly constructed pavement.
- Remove all temporary pavement and construct outside curb and gutter after central island is completed.

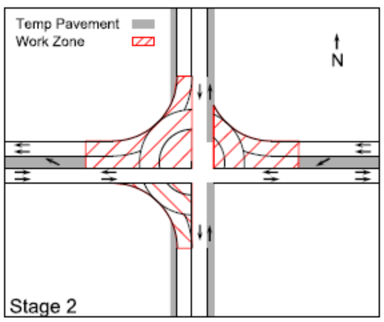
10.5.2 Divided 4-Lane Roadway

This alternative is appropriate for the intersection of a four-lane divided and a two-lane road that does not have a feasible detour route available.



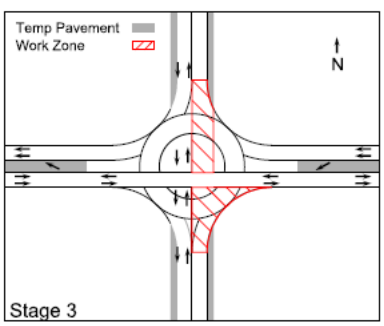
Stage 1

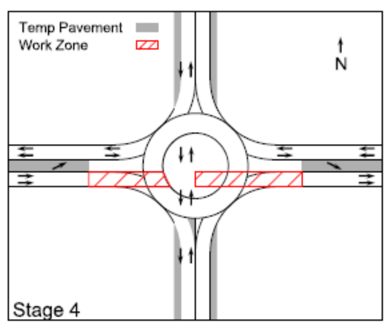
- Construct temporary pavement along one side of the two-lane road and crossovers on the four-lane road.
- Traffic remains on existing lanes.



Stage 2

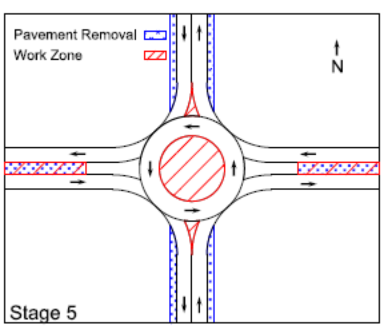
- Construct one quadrant of the roundabout and as much of the circulatory roadway as possible.
- Construct any additional temporary pavement needed for traffic switches.
- Restrict traffic to one lane in each direction through the intersection.





Stage 3 & 4

- Construct the remaining quadrants and the circulatory roadway.
- Use the temporary pavement as needed to complete the roundabout construction.



Stage 5

- Construct the remaining central island and splitter islands, Quadrants and the circulatory roadway.
- Remove all temporary pavement and construct outside curb and gutter after central island is completed.

Appendix A. Practical Design

A.1 Principles

Practical design is an approach to investigate the lowest cost of construction that produces the optimal functional, constructible, and serviceable installation. It can involve staged expansion of a roundabout or reduction of physical elements to improve the benefit/cost ratio of a roundabout. This principle should be accompanied with an assessment of the tradeoffs of the practical design: capacity, safety and serviceability.

Figure A-1 shows an example of a real project, through the course of practical design considerations, the red-line layout was reduced to the black-line layout. Cost savings on this roundabout are in the range of about 20%.

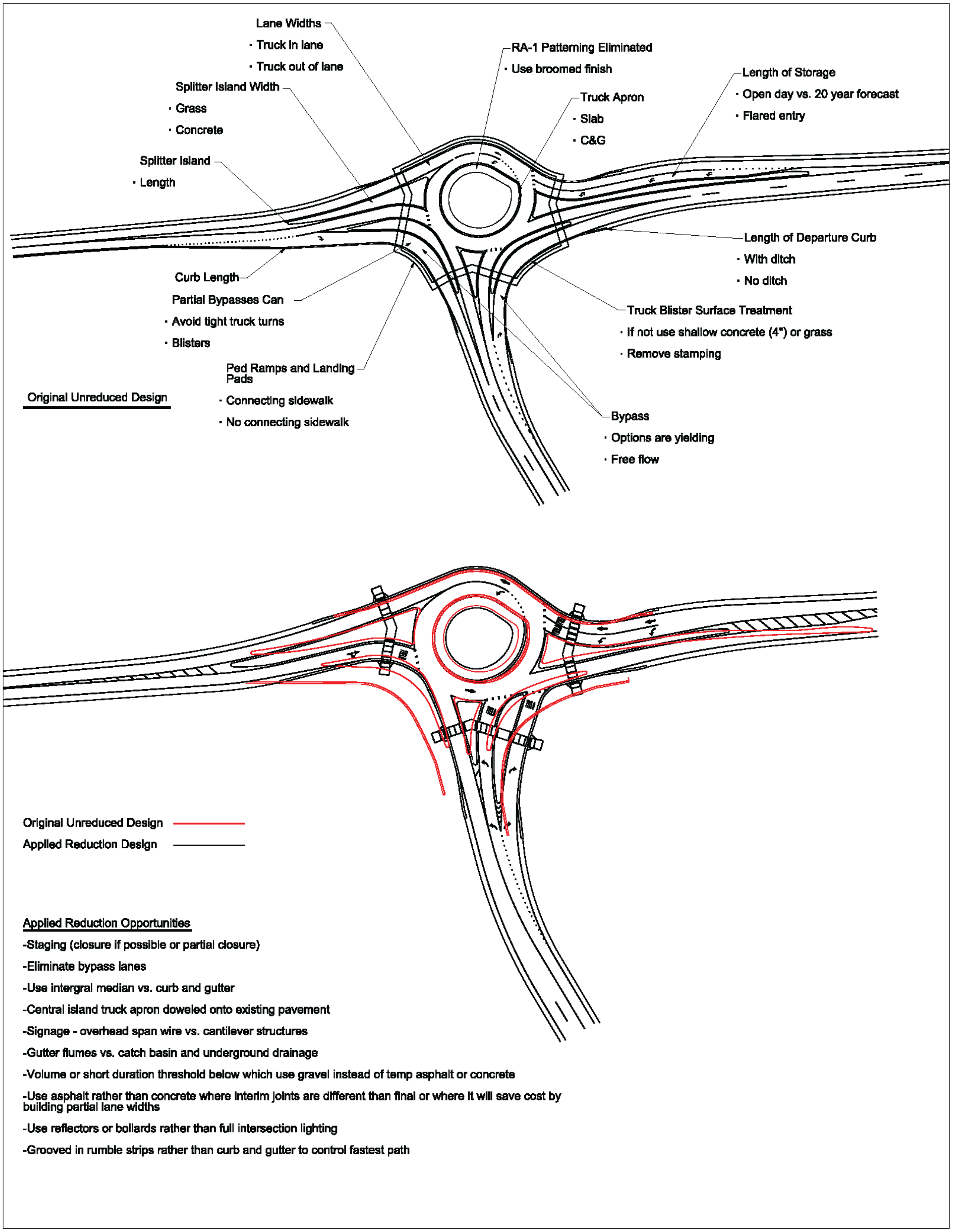


Figure A-1. Cost Reduction Opportunities

A.2 Left-Offset Approach Alignment

A left offset design is aligned so that the centerline of the approach passes to the left of the roundabout center. This creates more entry path deflection but results in less exit curvature. This allows for the use of a smaller ICD to create the same amount of entry path deflection for speed control. An example of a left offset design is demonstrated in Figure A-2 and Figure A-3.

Figure A-2. Offset Left Design Example

Figure A-3. Offset Left Design Example

A.3 Practical Design Alternatives

Figure A-4 and Figure A-5 demonstrate how an initial roundabout layout can be improved to a more practical design. Both layouts achieve the required design performance checks, but the second one uses practical geometry and costs less.

The original design, Figure A-4 was likely focused on achieving speed control with large chicanes on the approaches. The design has left-offset, but it is off the existing alignment with excessive chicanes. Besides costing much more, the forward sight of the roundabout is lost on the approach, which could result in poor safety performance and decreased functionality. In the refined design (Figure A-5), more of the existing pavement is used and the ICD was reduced, while still maintaining speed control. This design is more practical, being cheaper to construct and more functional in its operations.

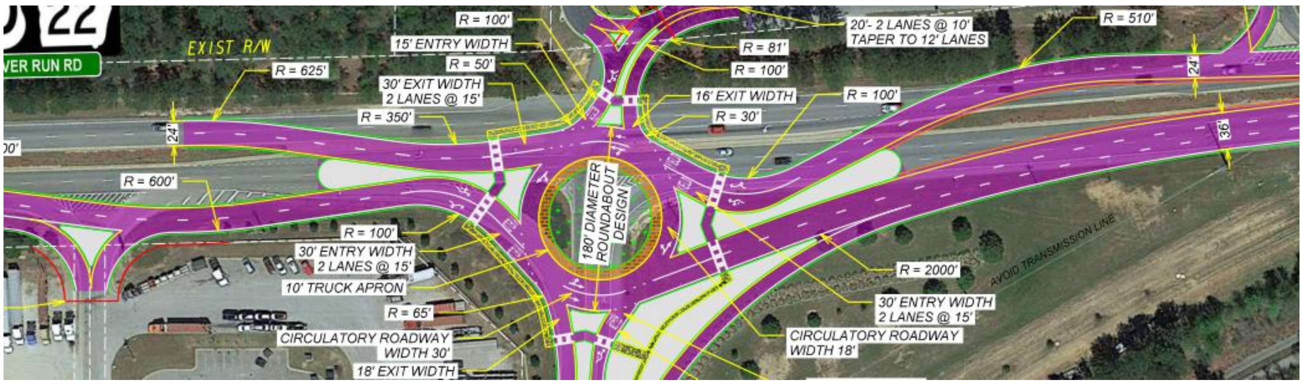


Figure A-4. Original Roundabout Design

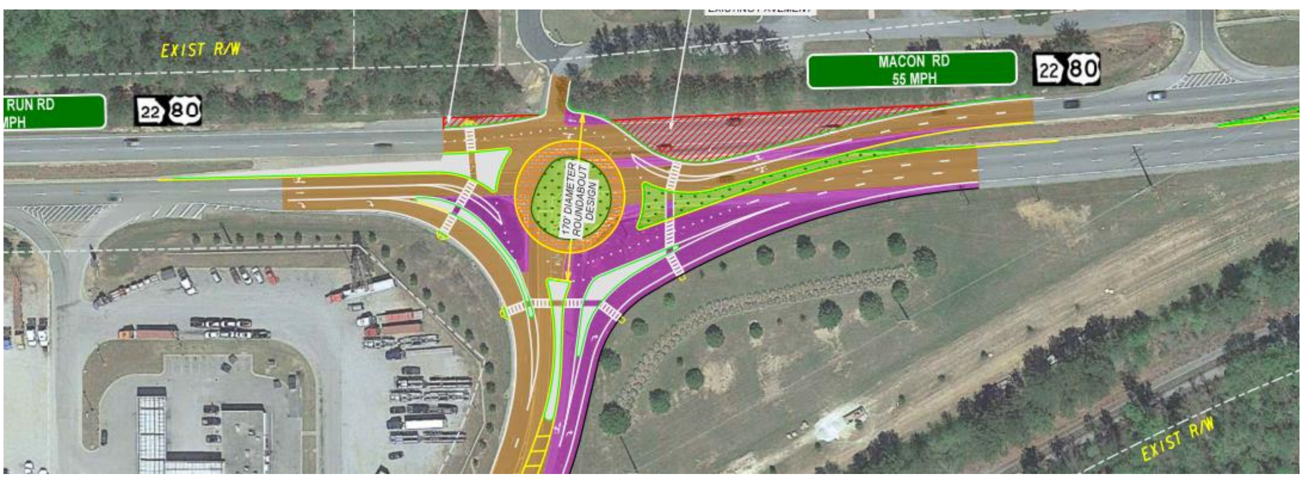


Figure A-5. Refined Roundabout Design

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Appendix B. OSOW

B.1 Review of OSOW Permits

The following is a list of steps and guidance on how to source and account for the space requirements of oversize vehicles (OSOW) in roundabouts.

Single Trip Permits

1. Request records from OSOW@dot.ga.gov at the subject intersection.
2. Tabulate truck movements by vehicle type and turning movement
   a. Ignore all records relating to one-time events, such as concrete beams for construction projects.
   b. Examine all records with a length of 100-ft or more.
   c. Truck type can be determined by examining the truck length, axle count, and load type. Cross-reference records with the GDOT OSOW template library catalog; see Appendix B.2.
      i. Load type can be useful in determining vehicle type, as mobile homes or specified loads with high centers of gravity that can indicate a lowboy trailer.
      ii. In some cases, the trucking company website can give an indication as to what type of vehicles they operate.
   d. The turning movement can be determined by examining the route, given by a string of sequential road names.
   e. Vehicles over 150 ft are assumed to have rear-steer capabilities.
   f. Remove redundant/repeated information (duplicated permit numbers)
3. Based on findings, design roundabout for appropriate vehicle on each movement.

Follow Table B-1 below during the review process.

Table B-1: Typical Assumptions Table

ASSUMPTION	REASONING
OSOW vehicle records with 3 or less trips through the intersection may not be accommodated by the roundabout per the discretion of GDOT. (These vehicles would still be run in the design file to understand their potential accommodations.)	The added cost for accommodations of these low frequency vehicles may not be cost beneficial.
Review and development of the routing matrix is mainly concerned with OSOW vehicles 100 ft and over in length. If there are concerns from the trucking industry and few or no records of vehicles greater than 100 ft, then an 85 ft lowboy vehicle can be modeled (for state route to state route movements).	The modeling of an 85 ft lowboy should ensure other large vehicles will be able to pass through the intersection.
Vehicles over 100 ft will be categorized into the standard OSOW template library developed by GDOT (See Appendix B.2)	Vehicles come in a wide range of lengths, axel spacing, pivot points, etc. categorizing the vehicles into a standard OSOW template library minimizes the need to develop vehicle profiles for every type of vehicle configuration that shows up in the records.
Vehicle movements are assumed to only be one-way trips unless a return trip is indicated in the records.	If there is a return trip, then the permit would show up in the records. Once OSOW vehicles deliver their load they may not use the same route back, or vehicle parts can be shortened or disconnected and loaded onto the trailer resulting in it not being an OSOW vehicle anymore.

This is an example of a single trip permit record.

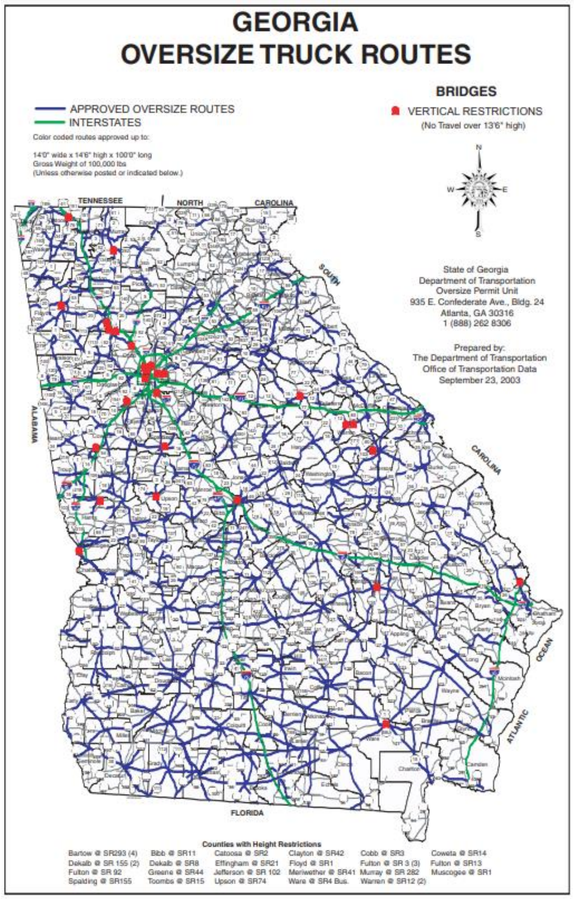
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Permit Number	Height (Inches)	Width (Inches)	Length (Inches)	GVW	Permit Type	Load Description	Company	Start Date	End Date	Origin	Destination	Route
2	P1186371	178	167	1116	160000	Superload	Excavator	BRAD COLE CONSTRUCTION CO INC	42056	42067	2250 LOVVORN RD Carrollton 30117	Intersection of ANVIL BLOCK and HOOD	>2250 LOVVORN RD, Carrollton 30117<LOVVORN RD W, JONESVILLE RD S, GA-166 E, GA-166 BYP E, GA-
3	P1518751	194	162	1188	135000	Superload	CHILLER MODULE	BENNETT MOTOR EXPRESS LLC	42132	42143	I-85;SC;Lavonia	I-20;AL;Waco	>I-85;SC;Lavonia<I-85 SW, Exit 177 SW, I-85 SW, GA-77 S, GA-59 SW, GA-106 S, GA-98 W, US-441 SW
4	P2015681	174	144	1080	150000	Single Trip	excavator	PROGRESSIVE LOGISTICS INC	42244	42256	700 PLANT YATES RD 30263	330 LEE INDUSTRIAL DRIVE 30168	>700 PLANT YATES RD 30263<PLANT YATES RD SE, DRYER RD NE, US-27 ALT NW, GA-166-BYP N
5	P2115911	174	144	1080	135000	Single Trip	excavator	PROGRESSIVE LOGISTICS INC	42269	42279	PLANT YATES RD, 2.1mi SE of Whitesburg, GA	330 LEE INDUSTRIAL BLVD 30168	>PLANT YATES RD, 2.1mi SE of Whitesburg, GA<PLANT YATES RD SE, DRYER RD NE, US-27 ALT NW

N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
Axle 1 Wt	Spacing	Axle 2 Wt	Spacing	Axle 3 Wt	Spacing	Axle 4 Wt	Spacing	Axle 5 Wt	Spacing	Axle 6 Wt	Spacing	Axle 7 Wt	Spacing	Axle 8 Wt
12000	15'6"	22000	4'6"	22000	4'6"	22000	33'3"	22000	4'6"	22000	4'6"	22000	14'1"	16000
15000	20'4"	20000	4'4"	20000	4'4"	20000	56'8"	20000	4'4"	20000	4'4"	20000		
10000	16'6"	20000	4'6"	20000	4'6"	20000	34'6"	20000	4'6"	20000	4'6"	20000	14'	20000
15000	16'	20000	4'6"	20000	4'6"	20000	33'	20000	4'6"	20000	4'6"	20000		

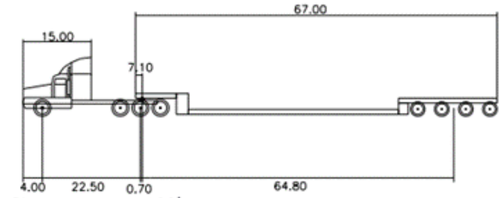
Annual trip permits

If the route is an approved oversize route, the default vehicle is the annual permit vehicle size. Check the annual permit route map [here](). Single trip permits still need to be reviewed to identify trucks larger than the annual permit vehicle size.

Review permit records to obtain the truck type and direction on which vehicle to model.

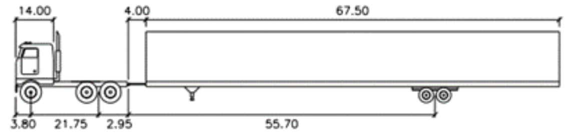


B.2 OSOW Template Library



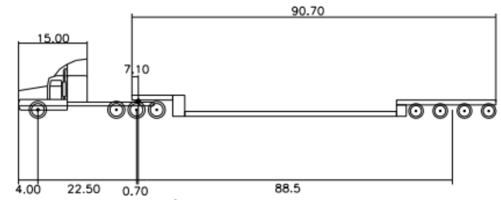
Simple Lowboy 100'
feet

Tractor Width	: 8.50	Lock to Lock Time	: 6.0
Trailer 1 Width	: 10.00	Steering Angle	: 28.4
Tractor Track	: 8.50	Articulating Angle	: 70.0
Trailer 1 Track	: 10.00		



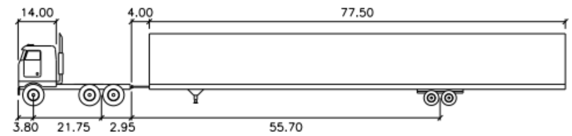
MH 100'
feet

Tractor Width	: 8.00	Lock to Lock Time	: 6.0
Trailer Width	: 14.16	Steering Angle	: 40.0
Tractor Track	: 8.00	Articulating Angle	: 70.0
Trailer Track	: 8.00		



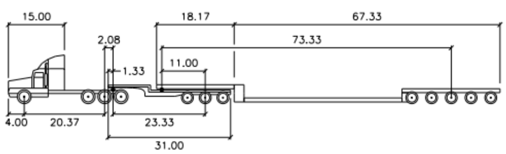
Simple Lowboy 125'
feet

Tractor Width	: 8.50	Lock to Lock Time	: 6.0
Trailer 1 Width	: 10.00	Steering Angle	: 28.4
Tractor Track	: 8.50	Articulating Angle	: 70.0
Trailer 1 Track	: 10.00		



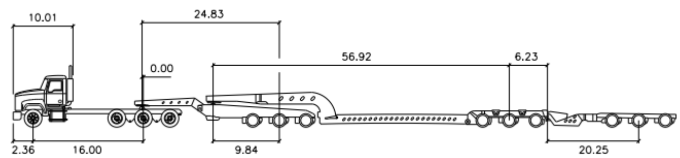
MH 110'
feet

Tractor Width	: 8.00	Lock to Lock Time	: 6.0
Trailer Width	: 16.00	Steering Angle	: 40.0
Tractor Track	: 8.00	Articulating Angle	: 70.0
Trailer Track	: 8.00		



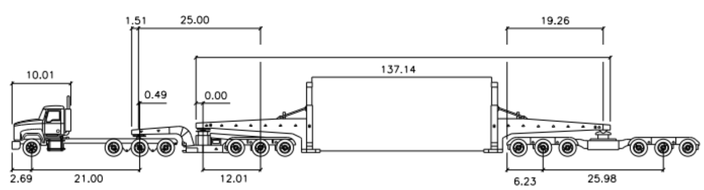
DST Lowboy
feet

Tractor Width	: 8.50	Lock to Lock Time	: 6.0
Trailer Width	: 10.00	Steering Angle	: 28.4
Tractor Track	: 8.50	Articulating Angle	: 70.0
Trailer Track	: 10.00		



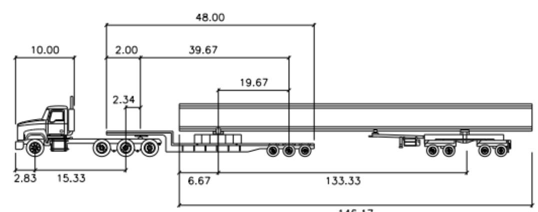
125–ft Booster Trailer
feet

First Unit Width	: 8.50	Lock to Lock Time	: 6.0
Trailer Width	: 8.50	Steering Angle	: 40.0
First Unit Track	: 8.50	Articulating Angle	: 70.0
Trailer Track	: 8.50		



195' 13–Axel
feet

First Unit Width	: 8.01	Lock to Lock Time	: 6.0
Trailer Width	: 4.00	Steering Angle	: 40.0
First Unit Track	: 8.01	Articulating Angle	: 70.0
Trailer Track	: 10.01		



180' Steerable Trailerless Load
feet

Tractor Width	: 8.50		
Trailer Width	: 8.50	Lock to Lock Time	: 6.0
Tractor Track	: 8.50	Steering Angle	: 28.4
Trailor Track	: 8.50	Articulating Angle	: 45.0

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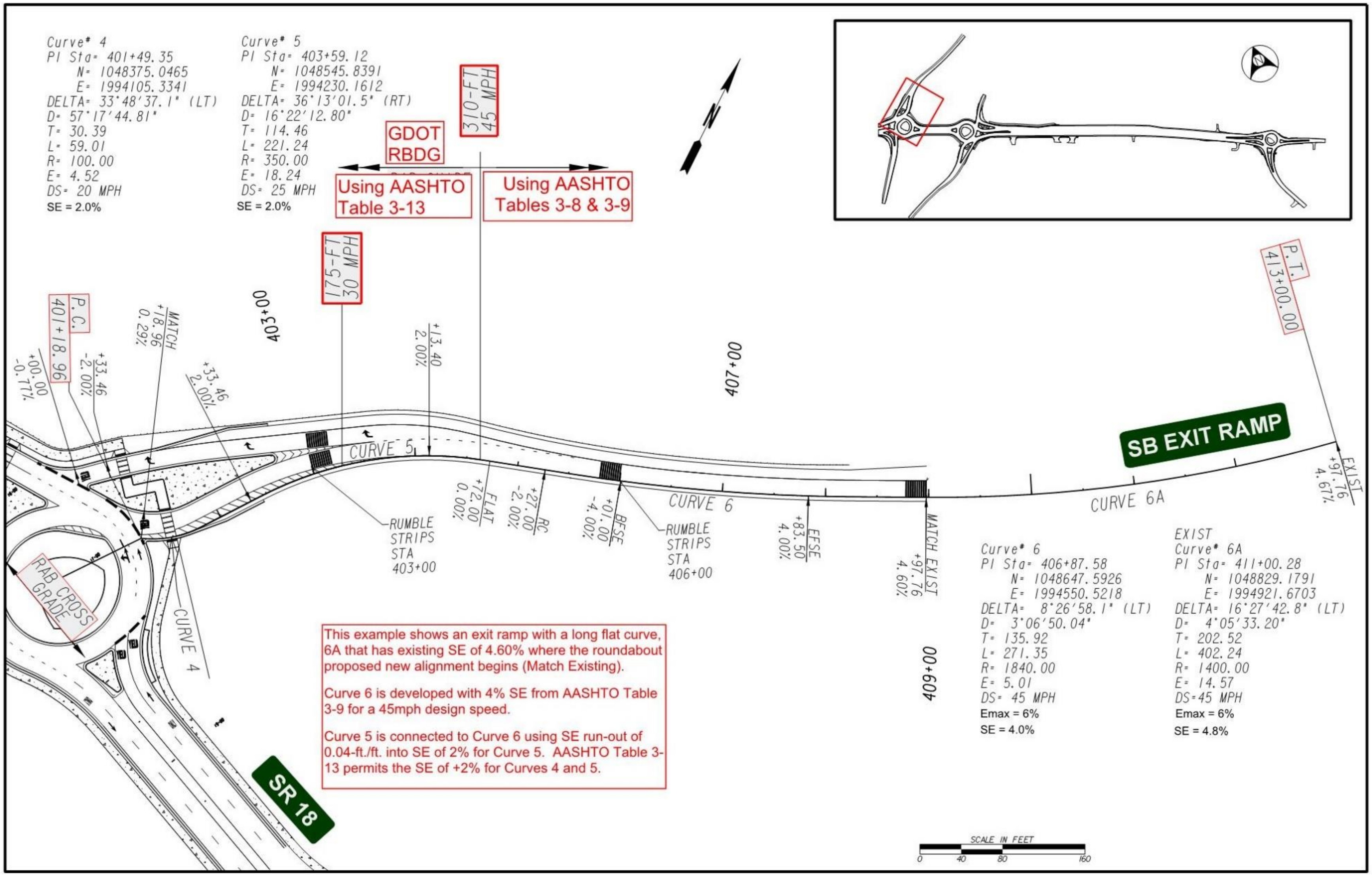
Appendix C. High Speed Approach Design



The image depicts an example of high-speed approach design with Emax as 6%, but approaches may have an Emax of 8% or 10% in some cases.

Appendix D. Roundabout Performance Checks

D.1 Entry Path Deflection – Permits

D.1.1 Drawing Fastest Paths

The centerline path of a standard passenger vehicle is best represented in Microstation by a spline – a curve of constantly changing radius. The fastest path speeds of the roundabout are located within approximately 165 ft of the circulatory roadway. Offset lines are drawn to help facilitate placement of the spline and limit how close a passenger vehicle will drive to the curb face or roadway centerline. They should be 5 ft from the face-of-curb, 5 ft from a centerline, and 3 ft from other pavement markings (such as a painted median or two-way left-turn lane).

- Select the “B-spline by Points” tool in Microstation and place them using the ‘Control Points’ or ‘Through Points’ method.
- Draw a spline for each movement using the minimum number of control points necessary to generate a smooth path.
    - Splines should start and end more than 165 ft from the edge of the ICD. For all movements, place three control points at the beginning and end of the spline beyond the 165 ft offset, to develop the starting and ending trajectory of the path. See Figure D-1.

      Tip: If control points are placed too close together, they don’t depict the natural driving path.
    - Place 3 points within the 165’ offset area, at the entry, circulating, and exiting locations. See Figure D-2.

      Tip: Control points placed inside the 165 ft offset area should be aligned approximately perpendicular to the location where the spline touches the offset line.
    - After the initial placement, iteratively modify the location of the control points so that the spline touches the offset guides but does not cross the lines.

Often, left-turn (R4) radii values can be determined based on the radius of the 5 ft offset from the truck apron; however, the R4 radii can be difficult to determine on non-circular roundabouts. When in doubt, draw the left-turn spline to determine the R4 value.

At T-intersections, draw the left-turn fast path spline to determine the R1 entry speed for the approach that does not have a through movement.

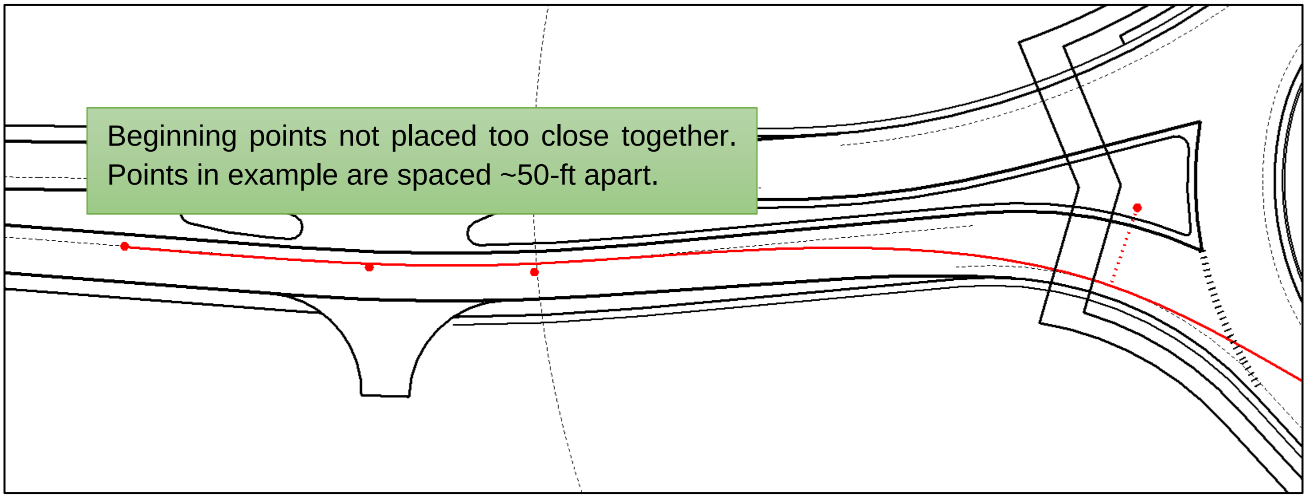


Figure D-1. Control Points on Approach

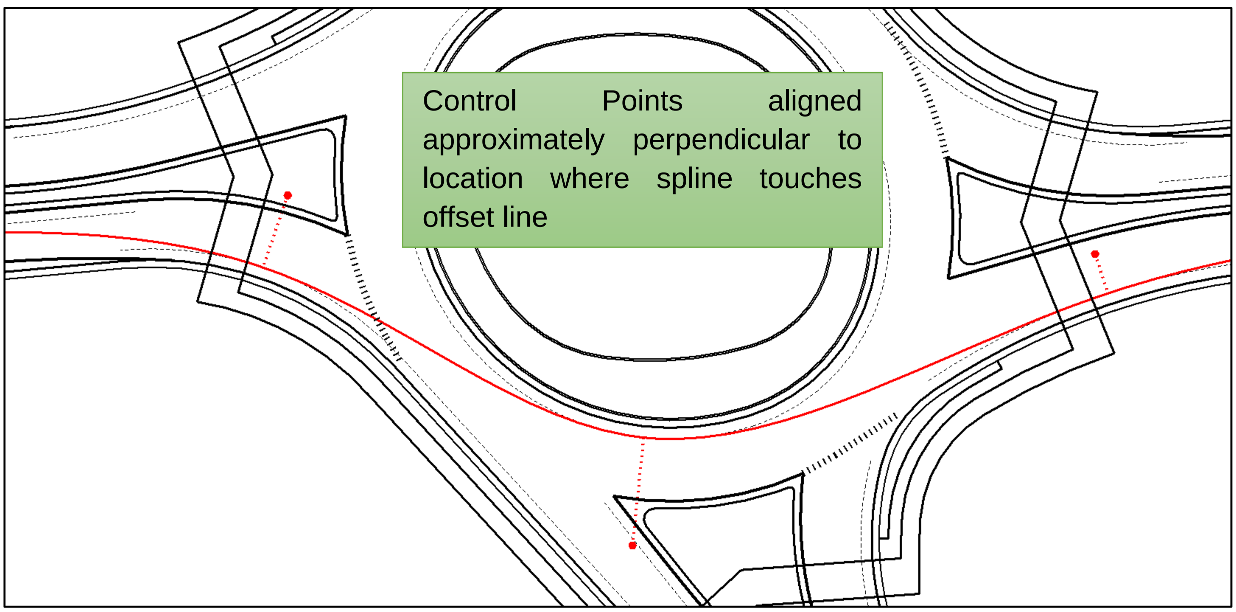


Figure D-2. Control Points Entry, Circulating, Exiting

D.1.2 Measuring the Critical RADII of the Spline and their Associated Speeds

Fastest path radii are calculated by measuring the smallest radius at critical locations (R1-R5) over a distance of 65 ft – 80 ft.

In Figure D-3, the center of a (65 ft – 80 ft diameter) circle is placed where the spline touches the offset line at the R1 through R5 locations.

- To measure the critical radius of the spline, draw a three-point arc snapped along the fast path spline within the confines of the circle. This helps the designer to quickly judge the length of the arc and to maintain consistent arc lengths for all radius measurements.
- Continue drawing arcs on either side of the circle until the smallest radius is found. This is the critical radius for speed control (R1 through R5).

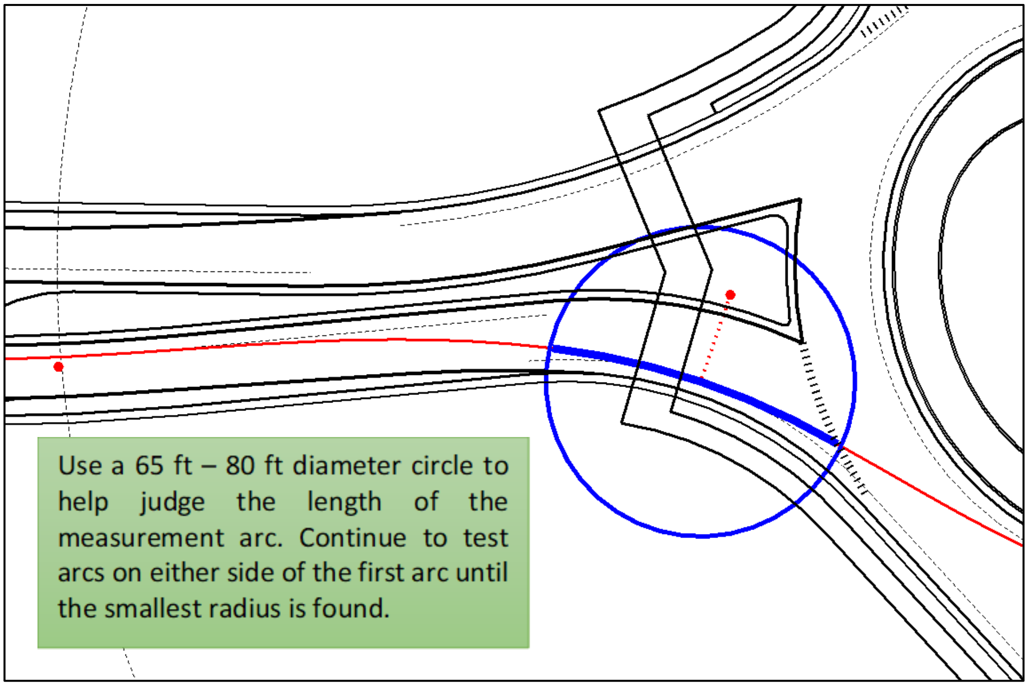


Figure D-3. Measuring Critical Spline Radius

- Use Equations 6-1 and 6-2 provided in NCHRP 672 to convert the R1 through R5 radius measurements to the actual critical speeds.

$$V = 3.4415R^{0.3861}, for\ e = +0.02$$

$$V = 3.4614R^{0.3673}, for\ e = -0.02$$

V = predicted speed, mph

R = radius of curve, ft

e = superelevation, ft/ft

Tip: Using a positive (favorable) 2% cross slope will provide the most conservative speed values and is recommended for all radius-speed conversions during the horizontal design stage. If the designer knows the entire circulatory roadway will be sloped toward the outside of the circle, a negative 2% cross slope may be used for the R2 and R4 radius to speed conversions.

- Often the R3 radius is large or nearly tangential, and a meaningful exiting speed cannot be determined with Equations 6-1 and 6-2 alone. The R3 critical exiting speed should therefore also be calculated based on vehicle acceleration from the measured R2 critical speed location to the point of interest on the exit (typically the crosswalk) using NCHRP 672 Equation 6-4 and as illustrated in Figure D-4.

$$V_3 = \begin{Bmatrix} V_{3pbase} \\ \frac{1}{1.47}\sqrt{(1.47V_2)^2 + 2a_{23}d_{23}} \end{Bmatrix}$$

V_3 = exit speed, mph

V_{3pbase} = V_3 speed predicted based on path radius, mph

V_2 = circulatory speed for through vehicles predicted based on path radius, mph

a_{23}= acceleration between the midpoint of V_2 path and the point of interest along $V_3\ path = 6.9 ft/s^2$

d_{23} = distance along the vehicle path between midpoint of V_2 path and point of interest along V_3 path, ft

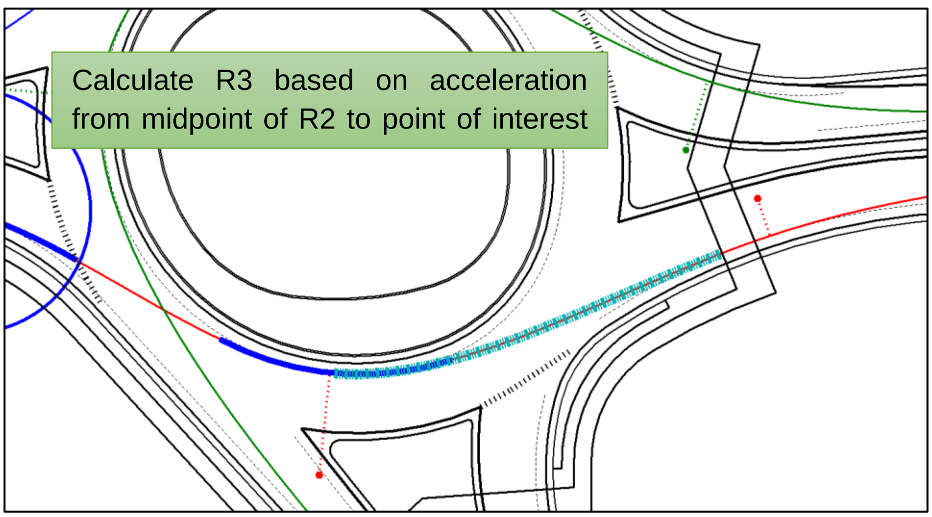


Figure D-4. Calculating R3

D.2 Sight Distance Envelopes

In accordance with the AASHTO Green Book, object heights should be restricted to 2 ft tall within SSD envelopes (which include Approach SSD, SSD for Bypass Lanes, Crosswalk SSD, and Circulatory SSD), and 3.5 ft tall within ISD envelopes (which include Entering and Circulating ISD). These envelopes should be hatched using the ***'Crosshatch Area'*** tool and the ***'Pattern Area'*** tool and clearly defined using a legend.

D.2.1 Stopping Sight Distance (SSD)

See NCHRP 672, Equation 6-5 when calculating stopping sight distances.

$$d = (1.468)(\mathrm{t})(\mathrm{V}) + 1.087(\frac{V^2}{a})$$

d = stopping sight distance, ft

t = perception-brake reaction time, assumed to be 2.5s

V = initial speed, mph

A = driver deceleration, assumed to be 11.2 ft/s^2

Checks should be provided for:

1. Approach SSD to the yield line and crosswalk on entry
2. Approach SSD to crosswalk on bypass lane
3. SSD to the crosswalk on exit
4. SSD around the circulatory roadway

D.2.1.1 Approach SSD to the Yield Line and Crosswalk on Entry

The approach SSD consists of sight lines to the yield line and crosswalk to provide drivers with clear visibility of objects in the roadway at the yield line, or pedestrians in the crosswalk. These sight lines are based on the design speed of the approach leg and should be constructed as shown in Figure D-5. These approach SSD checks also apply to yielding (partial) bypasses.

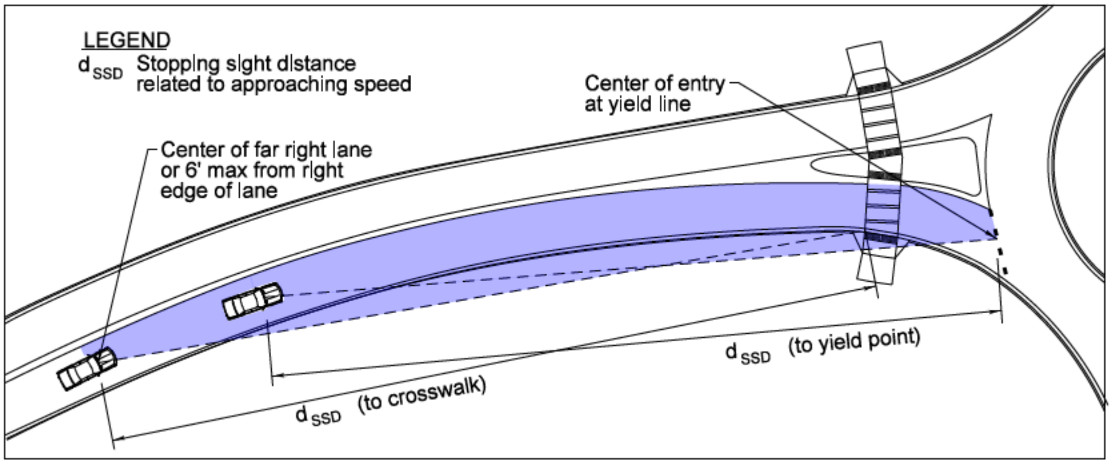


Figure D-5. Approach SSD

Drawing Tips

Approach SSD to Yield Line

1. Obtain the rounded Approach SSD (d).
2. Split the entry in half and use the 'construct line at active angle' tool (with an angle of 0.0°) to extend the offset arc to the yield line. This locates the center of the entry at the yield line. If the entry is two lanes, use the pavement markings to locate the center of the entry at the yield line.
3. Center a circle with radius (d) on the center of the entry at the yield line.
4. Offset a maximum of 6 ft from the right edge of the lane; or, for a multilane approach, split the far-right lane in half (if smaller than 12 ft wide).
5. Draw a line from the center of the circle to the point where the circle intersects the offset lane lines.

Note: these steps also apply to right turn partial bypass lanes with yield lines.

Approach SSD to Crosswalk

1. Obtain the rounded Approach SSD (d).
2. Center a circle with radius (d) on the intersection of the crosswalk paint line (farthest from the yield line) and the face of curb.
3. Draw a line from the center of the circle to the point where the circle intersects with the offset lane lines from Step 4 above.

D.2.1.2 Approach SSD for Free-Flow Right Turn Bypasses

At free-flow right turn bypasses, SSD should also be provided for drivers traveling around the corner to observe and react to an object in the roadway. The sight distance required is dependent on the right turn fast path R5 value and should be considered at all points along the bypass lane (Figure D-6).

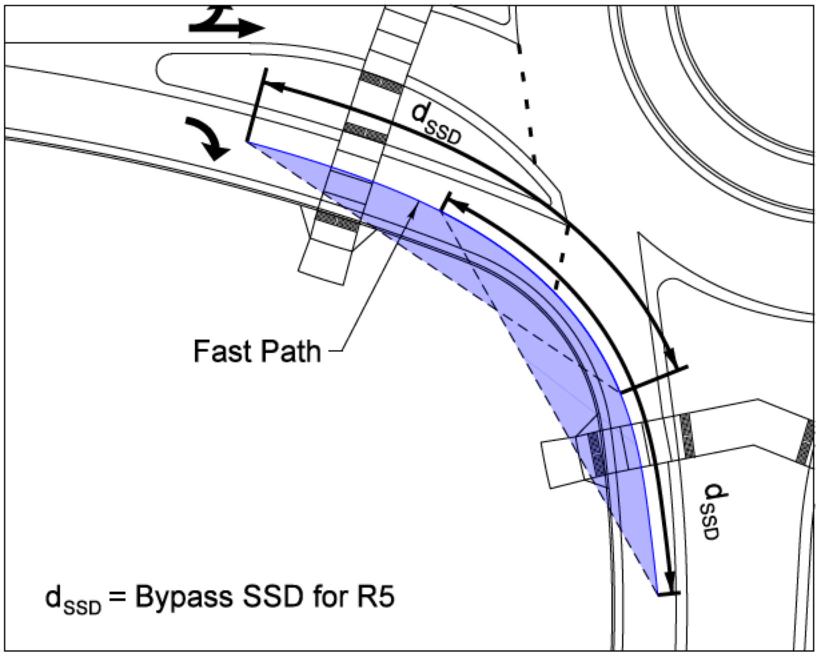


Figure D-6. Approach SSD for Free-Flow Right Turn Bypasses

Drawing Tips

1. Obtain the rounded Approach SSD (**d_b**) for the bypass lane (based on the bypass R5).
2. Measure **d_b** along the fast path in a few key places.
   a. Draw a line crossing the path where you would like to begin measuring **d_b**.
   b. Use the ***'trim elements'*** tool to trim the fast path to this line.
   c. From the ***'points'*** toolbox (accessed by going to Tools > Toolboxes) choose the ***'Point at a Distance Along***' tool.
      i. Choose a character or cell for the point and type the distance along the line to measure **d_b**.
      ii. Click the beginning of the line where you want to start measuring **d_b** and then click the line in the direction you want to measure. A point will be placed on the line at the distance specified. Trim the fast path line to this point to achieve **d_b**.

D.2.1.3 SSD to Crosswalk on Exit

Crosswalk SSD provides visibility for drivers to see pedestrians waiting to cross or in the act of crossing the downstream leg as shown in Figure D-7. The sight distance for crosswalk visibility is dependent on the right turn fast path R5 value. If a right turn bypass lane exists, the crosswalk stopping sight distance should be based on the fast path through the bypass lane. For roundabout exits, crosswalks can be placed further than the 20-25 ft to help with yielding rates and allow for more storage for exiting vehicles (see FHWA TOPR34 and NCHRP 834).

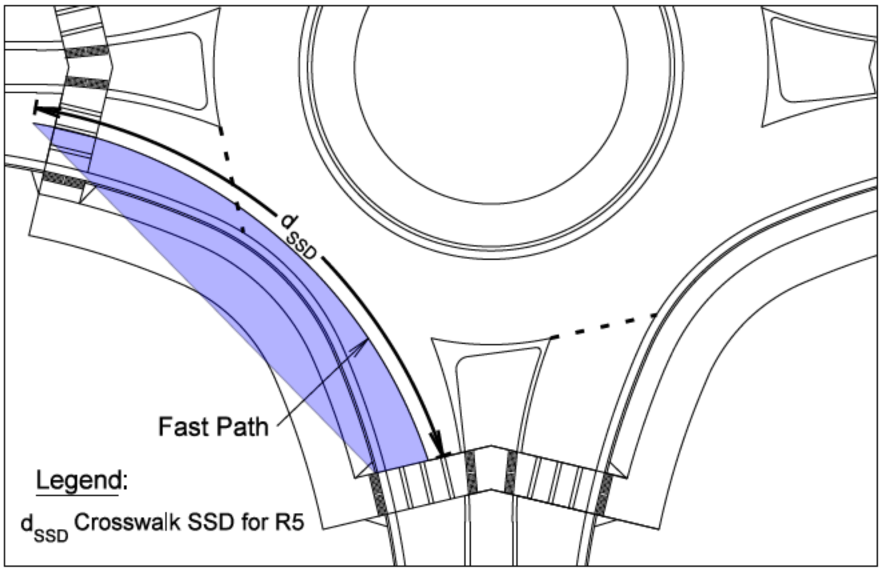


Figure D-7. SSD to Crosswalk on Exit

Drawing Tips

1. Obtain the Crosswalk SSD ($\mathbf{d_a}$), based on R5.
2. Trim the fast path to the near side of the crosswalk.
3. Measure $\mathbf{d_a}$ along the fast path using the same techniques described in Step 2 of the 'Drawing Tips' for 'Approach Stopping Sight Distance for Right Turn Bypass Lanes' in the previous section.
4. Connect the end of the fast path to the near side of the crosswalk at the face of curb to create the sight line.

D.2.1.4 SSD Around the Circulatory Roadway

Circulatory roadway SSD provides drivers traveling around the central island with visibility of objects in the circulatory roadway ahead. The sight distance is based on the left-turn fast path R4 value.

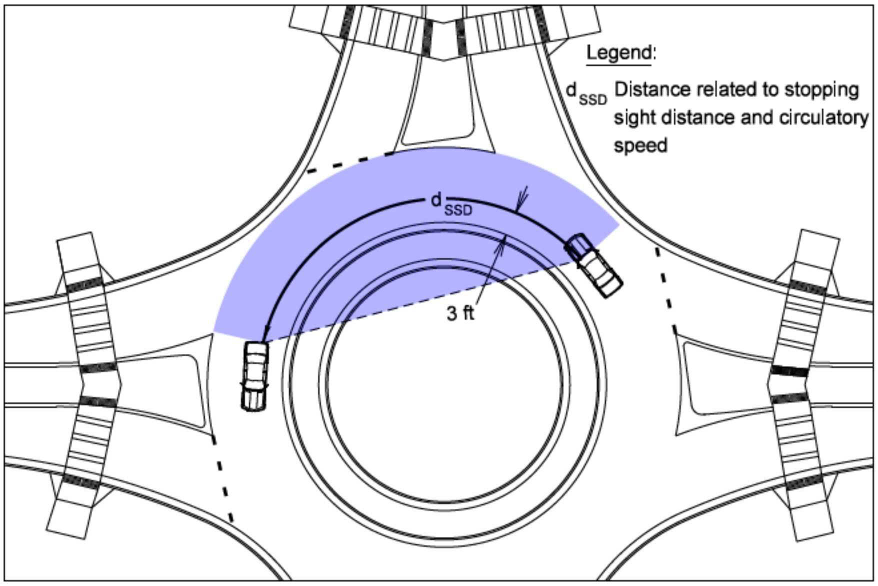


Figure D-8. Consistent R4 Values

Drawing Tips

For Consistent R4 Values

1. Obtain the Circulatory SSD (**d**), based on R4.
2. Offset the central island face of curb 3 ft and measure **d** along the offset line. (Use ***'Point at Distance Along'*** tool)
3. Connect both ends of the offset line to form the sight line.
4. Repeat Steps 2 and 3 for a minimum of four intervals around the central island.

Tip: For quick placement of the sight lines, rotate the first offset arc and sight line from steps 2 and 3 around the center point of the central island to get at least four intervals around the central island.

D.2.2 Intersection Sight Distance

Intersection sight distance (ISD) should be checked at entries for two conditions: (1) entering – sight to vehicles on the upstream approach, and (2) circulating – sight to vehicles within the circulatory roadway. The ISD maximum should be derived from these equations; however, at a minimum of 50 ft upstream of both approaches should be used.

See NCHRP 672, Equation 6-6 and 6-7 when calculating intersection sight distances.

$$d_1 = (1.468)(V_{major,entering})(t_c)$$

$$d_2 = (1.468)(V_{major,circulating})(t_c)$$

d_1= length of entering leg of sight triangle, ft

d_2 = length of circulating leg of sight triangle, ft

$V_{major,entering}$ = design speed of conflicting entry movement, mph – an average of the entering and circulating speeds (calculated from fastest path R1 and R2 values) for the upstream approach

$V_{major,circulating}$ = design speed of conflicting circulating movement, mph - the circulating speed for left turn movement (calculated from fastest path R4 value) from opposite entry

t_c = critical headway for entering the major road, s, equal to 5.0 s

D.2.2.1 Entering Intersection Sight Distance

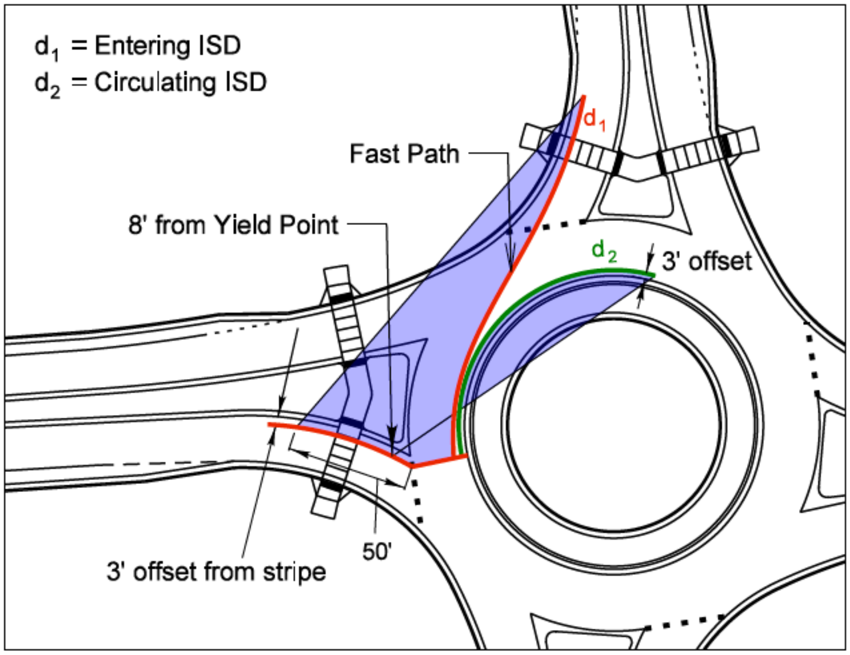


Figure D-9. Entering and Circulating ISD

Drawing Tips

1. Offset the far-left lane 3 ft from the left edge of curb/paint line or 5 ft from the face of curb. Use the ***'construct line at active angle'*** tool (with an angle of 0.0°) to extend the offset arc to the yield line.
2. Center a circle with radius 50 ft at the intersection of the yield line and active angle line. Draw two lines from the center of the circle, one that intersects the offset arcs with the edge of the circle and one that is perpendicular to the central island face of curb.
3. Trim the fast path of the immediate upstream entry to the line perpendicular to the central island using the 'trim elements' tool.
4. Obtain the Entering ISD (**d_1**), based on the average R1 and R2 speeds. Measure this distance along the fast path using techniques described in Step 2 of the ***'Drawing Tips'*** for ***'Approach Stopping Sight Distance for Right Turn Bypass Lanes'***.
5. Draw the Entering ISD sight line from the end of the 50 ft line to the end of the fast path.

D.2.2.2 Circulating Intersection Sight Distance

Circulating ISD provides the driver nearing the roundabout with sight to vehicles already circulating in the roundabout. The sight line is based on the R4 fast path speed upstream of the entry. Reference NCHRP 672 Equation 6-7.

Drawing Tips

1. Offset the central island face of curb 5 ft If a spiral exists, follow the lane lines (offset the lane lines 3 ft until the spiral disappears, then offset the face of curb 5 ft).
2. Trim the arcs to the line perpendicular to the central island constructed above in Step 2.
3. Obtain the Circulating ISD ($\mathbf{d_2}$), based on R4. Measure this distance along the offset arcs following the same hints described in Step 2 of the ***'Drawing Tips for Consistent R4 Values'*** for ***'Circulatory Stopping Sight Distance'***.
4. Draw the Circulating ISD sight line from the end of d2 to 8 ft behind the yield line representing a driver at the yield line scanning the circulatory roadway for oncoming circulating traffic.

D.3 Vehicle Analysis

Vehicle accommodation is checked using a vehicle analysis software such as AutoTURN. Horizontal accommodations (2D analysis) should be checked throughout the horizontal design process for both design vehicles and check vehicles. Vertical accommodations (3D analysis) should typically be checked for low-clearance vehicles (often OSOW trucks referred to as a “lowboys” or “gooseneck”-style trailers) as the roundabout moves into preliminary plan development and vertical geometrics are developed.

D.3.1 2D Analysis

Two methods exist for analyzing horizontal truck accommodations in 2D: Freehand (referred to as “Arc Path” in AutoTURN) and Offset Path (referred to as “Adaptive Simulation” in AutoTURN). A typical guideline for design and check vehicles is to provide 1 ft clearance from the tire of the cab to the curb face.

When conducting a 2D analysis, the designer should consider displaying, at a minimum, the following envelopes: front tires, rear tires, vehicle body, and load. Displaying the body envelope is often beneficial when analyzing vehicles with large front overhangs (common with city buses, fire trucks, and farm equipment). Displaying the load envelope is often beneficial when analyzing vehicles with large or long loads (common with OSOW trucks).

The Freehand Method

The Freehand method works well for determining approximate roadway width requirements and is ***the only method for analyzing trucks with independent rear-steering capabilities*** (such as tiller-aerial fire trucks and some OSOW trucks).

The **Freehand** method involves manually driving the truck through the desired turning movement. This method considers lock-to-lock steering time, steering angle locks, and trailer angle locks, but also accounts for a non-varying speed along the path set by the user. 9 MPH or less is desirable, 6 MPH is preferred for very large vehicles (for example, rear-steering vehicles). (Note that as the speed increases, maneuverability and net off-tracking decreases.) With practice, paths generated with this method can be as smooth as paths generated with the Offset Path method.

It should be noted that with the freehand method is related to the "turn wheels from stop" which, when applied for typical design vehicles, creates a path with many kinks in it that does not reflect the path a vehicle may actual take. For vehicles that need to use the "turn wheels from stop" feature, extra care is needed to obtain a smooth path.

If a vehicle has independent rear-steer capabilities, care should be taken to not overstate the maneuverability of the actual vehicle. A good rule-of-thumb is to turn the rear wheels 4-degrees for every 17 ft of travel path. The designer should minimize rear steering.

The Offset Path Method

This method works well for paths that need to be repeatable in order to check multiple vehicle types for each movement; however, the path may not be suitable for all vehicle types. This method also typically provides a smoother path than the Freehand method, which may be desirable for exhibits.

The **Offset Path** method involves drawing a centerline path for the truck to follow. This method considers the same factors as the Freehand Method. Speed is indirectly accounted for but is not a direct input. The speed varies as the vehicle navigates the path; the smaller the arc, the slower the vehicle will negotiate the curve turn.

The path is created by offsetting known elements of the design (such as edge of pavement, curb face, and/or pavement markings) and turning the elements into a complex chain. A typical offset from the face of curb is 6 ft; however, offsets may vary depending on the size of the truck and the width of the gutter pan.

D.3.2 3D Analysis

A 3D analysis considers the ground clearance component of the 2D swept path. Usually, ground clearance is only a concern for lowboy (“gooseneck”-style trailer) vehicles. A typical lowboy-style vehicle will have a ground clearance of 6-inches. We recommend analyzing the vehicle with 5-inches of clearance to be conservative. Currently, there are no federal specifications as to how much ground clearance a vehicle must provide. Typical areas where ground clearance can be an issue are shown in Figure D-10. The longer the depressed section of the trailer, the greater the clearance concern will be.

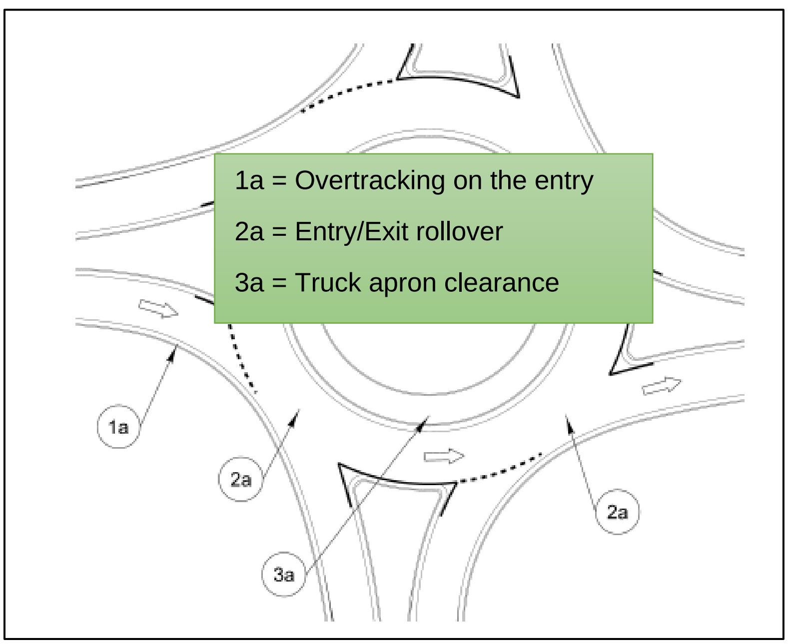


Figure D-10. Typical Ground Clearance Concern Areas

To conduct a 3D analysis, a 2D vehicle path and a combined 3D surface are needed. The surface should cover the entire area of the 2D path and needs to include the following areas: circulatory roadway, truck apron, outside curb and gutter, entries, and exits. The surface should be free of extraneous triangles and large gaps, which may affect the accuracy of the 3D analysis. It should be noted that changes to the surface to correct one problem might result in issues in other areas. Therefore, ***if changes are made to a surface, the vertical checks need to be re-analyzed***.

1. Use a 3D DGN file for this analysis.
2. Select the proposed DTM surface (mesh) and the 2D AutoTURN swept path (that has already been run).
3. Click on **“Convert 2D to 3D”** button to convert the 2D AutoTURN swept path to a 3D path (make sure to keep the original 2D path when asked by AutoTURN).

This step will analyze the vehicle’s vertical profile on the proposed DTM surface and check for areas of scrapping.

A completed 3D analysis can be seen in Figure D-11. The green hatching indicates there is adequate vertical clearance. The red hatching indicates areas where there are potential conflicts.

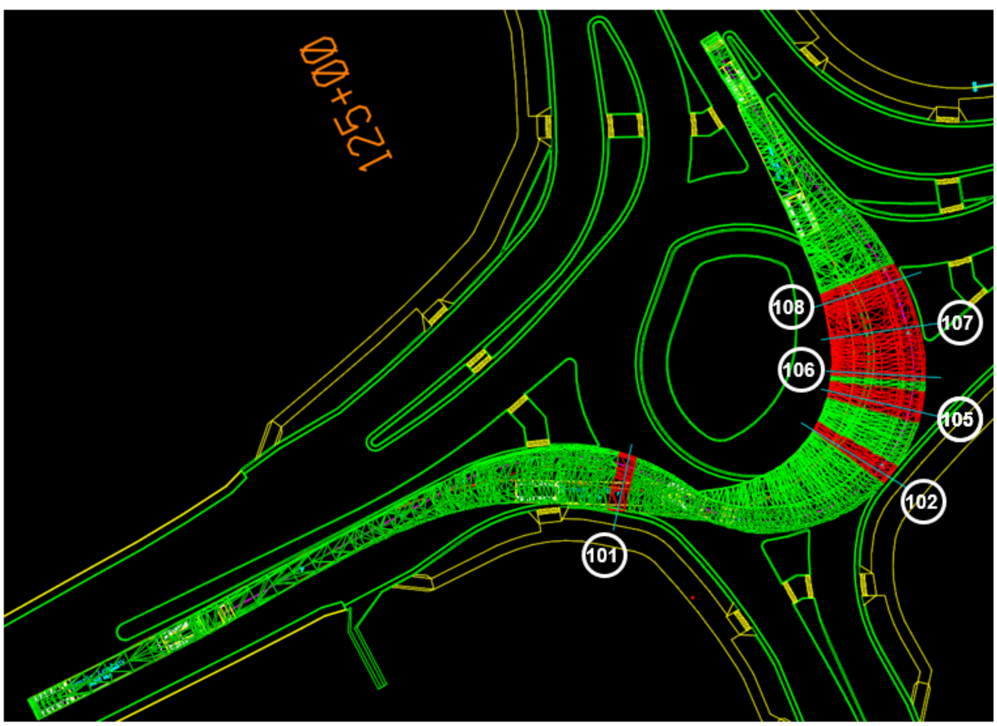


Figure D-11. Vertical Check Example

Areas of concern should be reviewed in the 3D cross-section analysis, also known as “Punch Through”. These cross-sections identify the extent of the scrapping and will help to determine where adjustments to the grading design are needed.

1. Start by placing perpendicular lines across the red hatching areas where cross-sections will be cut (shown as lines 101 to 108 in Figure D-11, for example).
2. Click on the ***"Analyze Punch Through"*** button.

3. Select the AutoTURN swept path and a perpendicular line from step 1.

Figure D-12 shows an example of a "Punch Through" cross-section with the vehicle's vertical clearances displayed (1" tolerance built-in).

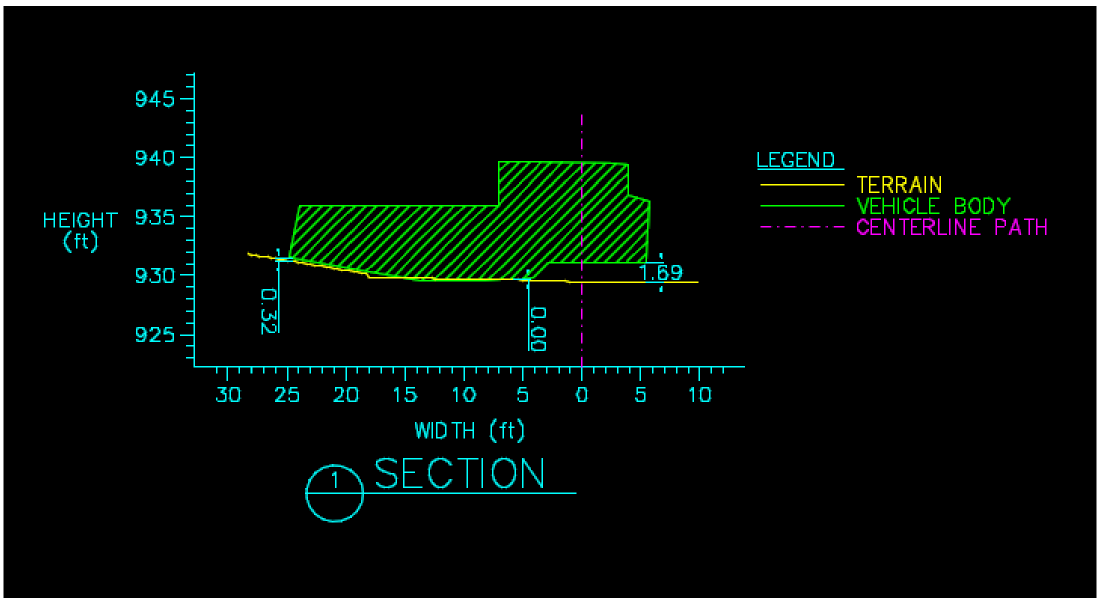
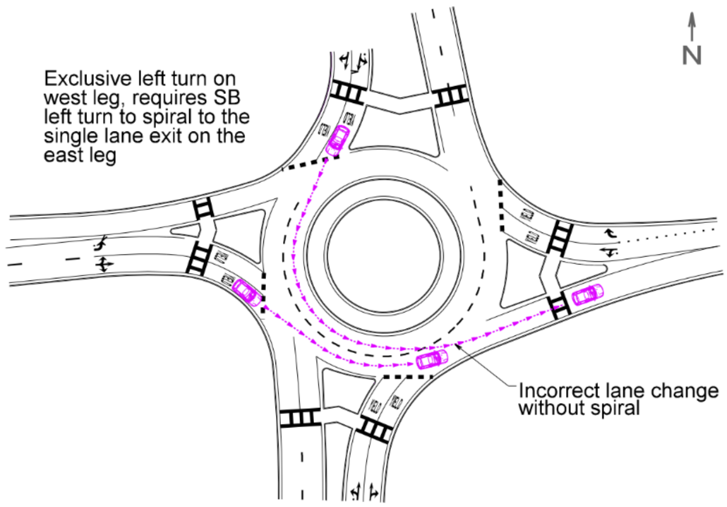


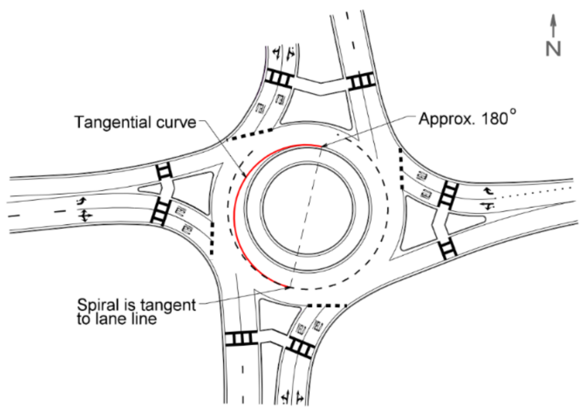
Figure D-12. Vertical Check Punch Through Example

Appendix E. Spiral Design



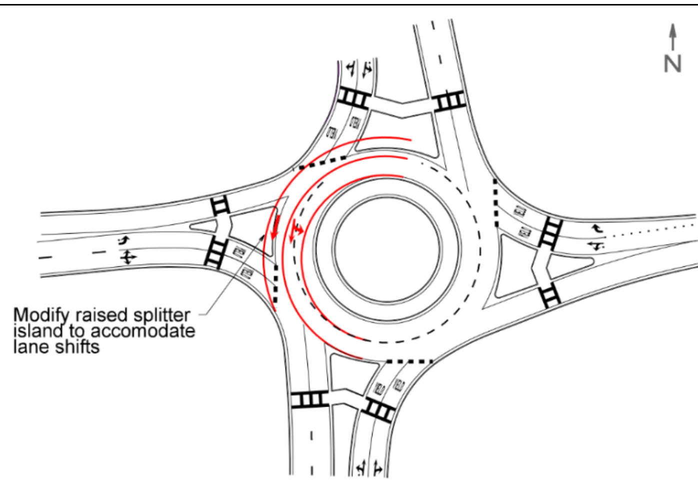
1. In cases where 2 lane entries have an exclusive left turn lane, a spiral is necessary.

- Start with original central island, identify potential conflict points [due to incorrect lane change]:
    - Multilane with left turn to single lane exit [SBL conflicts NBT]
    - Exclusive turn lanes



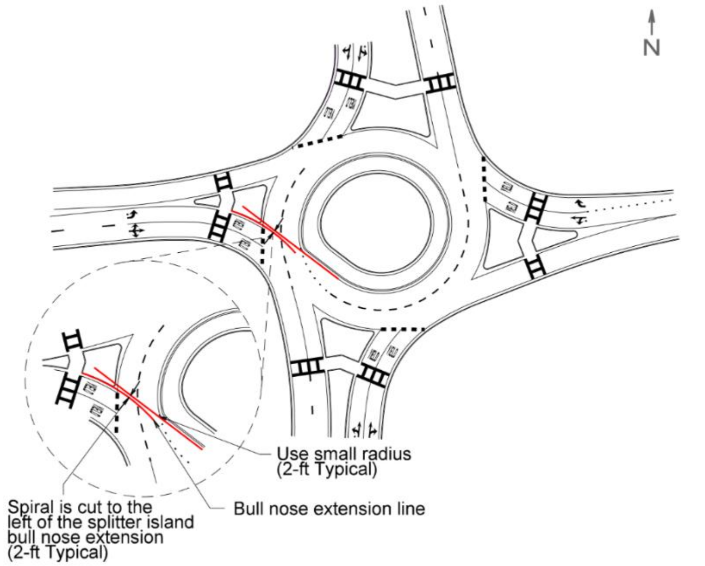
2. Spiraling the driver from the inside lane to the outside lane requires placement of an arc.

- Place the arc at approximately 180 degrees from where the spiral begins on the existing truck apron
- Extend the arc from the truck apron to the outer lane line.



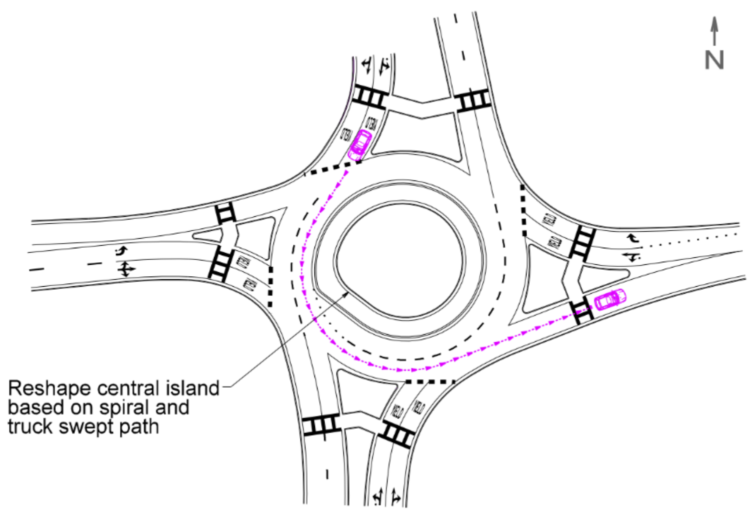
3. Modify the geometry to account for the use of a spiral.

- Offset impacted circulating movements (SBT and SBL) from tangential curve by circulating lane width.
- By introducing the spiral, it requires trimming of the impacted splitter island face and shifting the outer geometry to maintain the multilane portion of the roundabout.



4. Cut the spiral slightly to the left of the exclusive lane alignment trajectory into the circle.

- Apply short skip markings to join the spiral to the lane line
- Extend inside radius of left lane and draw tangent to the curve 1-2' offset inside the circulatory roadway
- Modify truck apron to compensate for lane shifts



5. Check truck movements for reshaped apron and central island

Appendix F. Vertical Design Best Practice

F.1 Alignments and Profiles

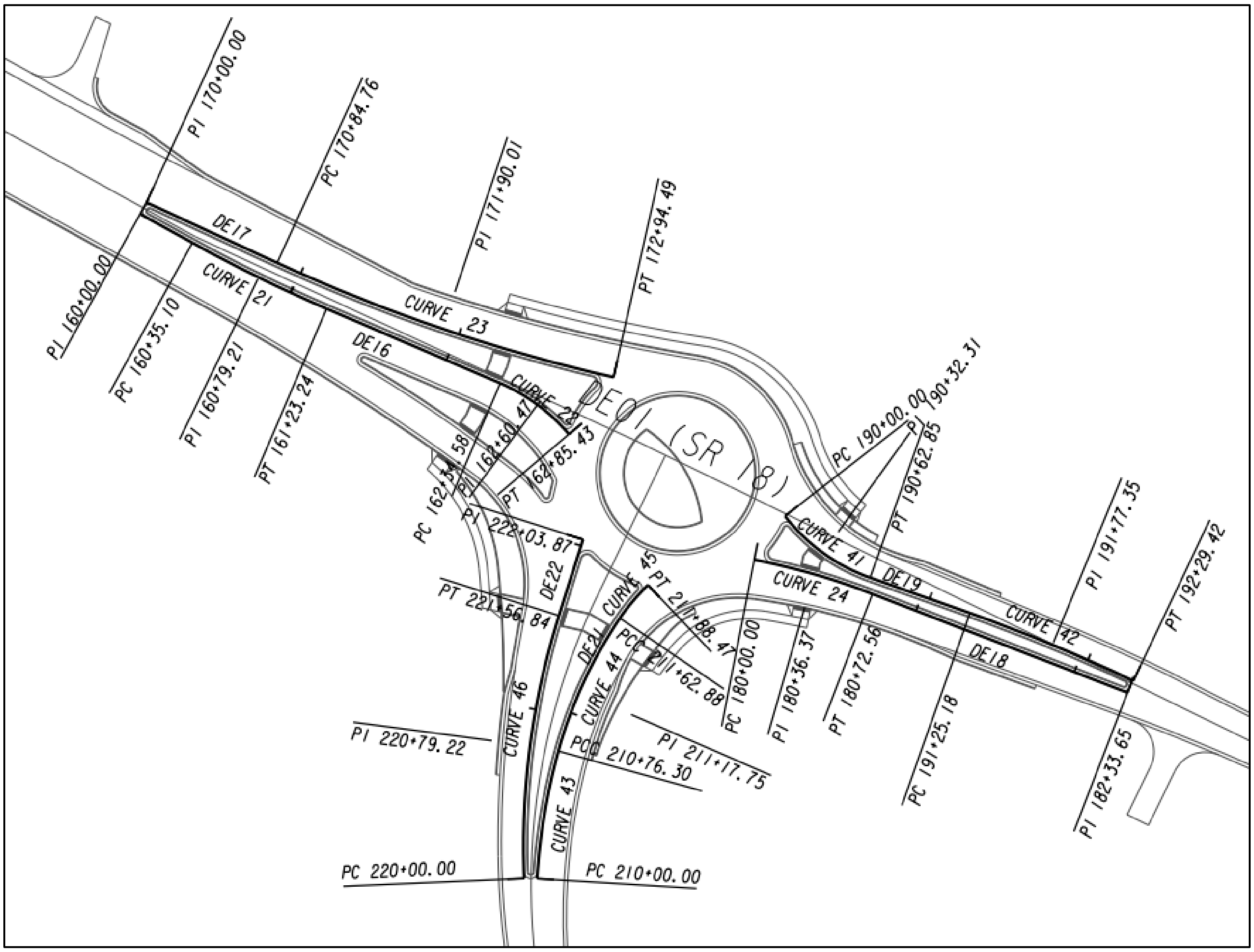


Figure F-1. Splitter Island Alignments

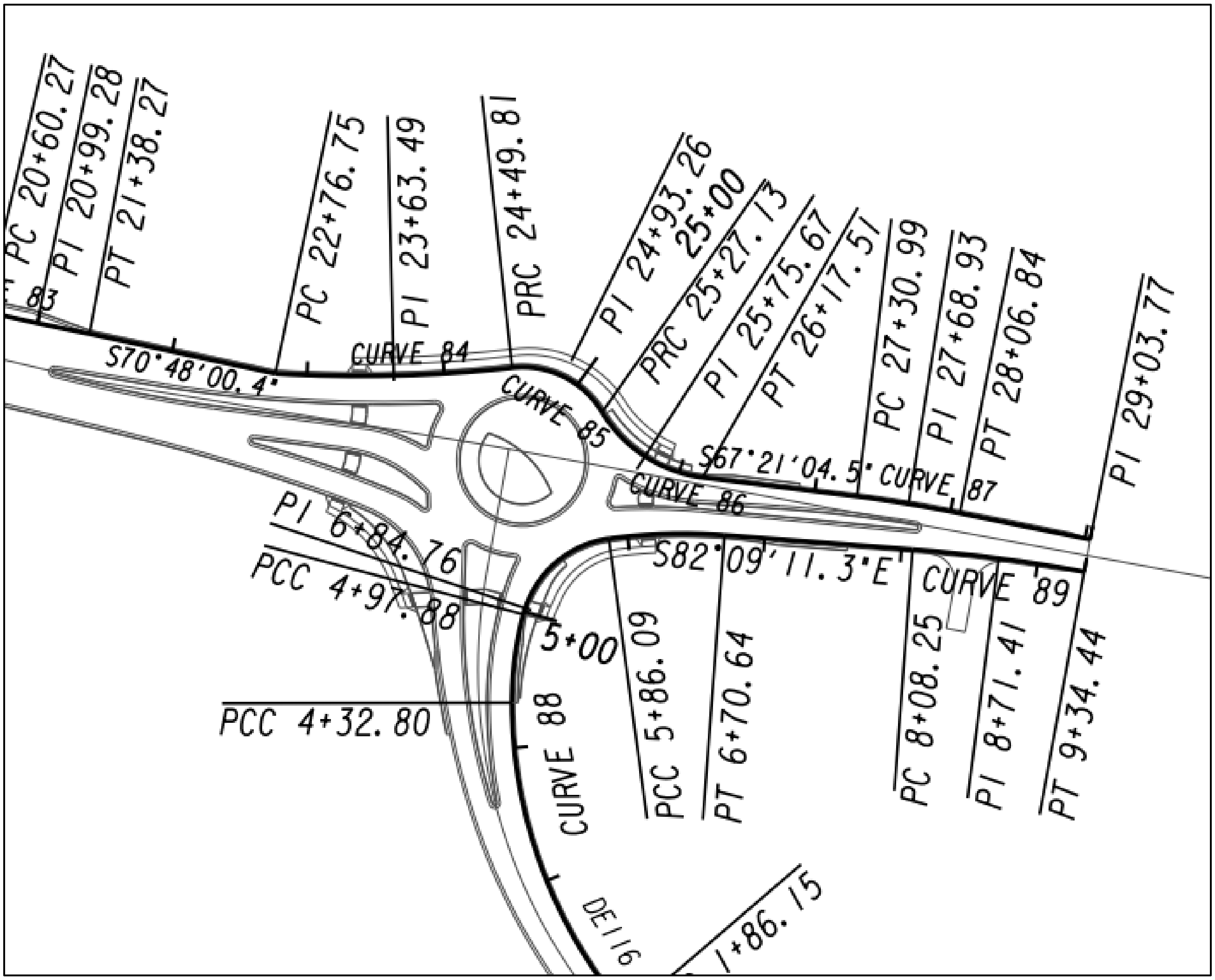


Figure F-2. Outside Curb Alignments

F.2 Example Profile Creation

1. Create a circulatory roadway alignment

In the example shown on F-3 and F-4 below, the circulatory alignment begins at 90+00 and ends at 93+01.59 (which is essentially 90+00). Note that 90+00 is set to be in between the LP near 90+75 and the HP near 92+26. In the following profile, we can see that the elevation at 90+00 and 93+01.59 is identical at 648-ft, and that the crest curve shows where the HP is, and the sag curve goes where the LP is to be.

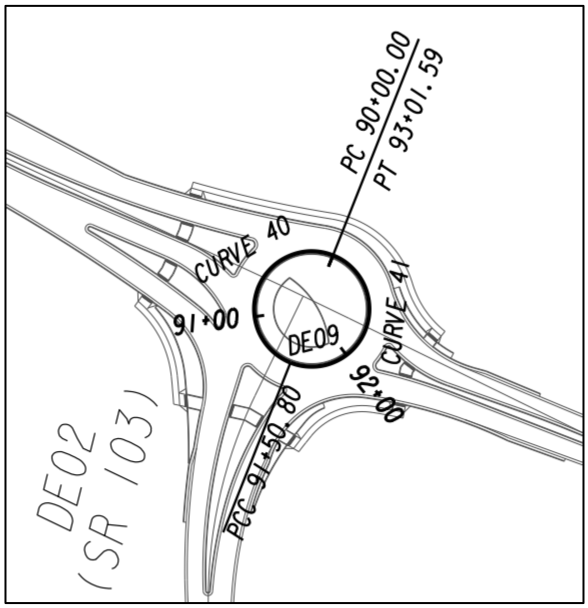


Figure F-3. Station of Circulatory Alignment

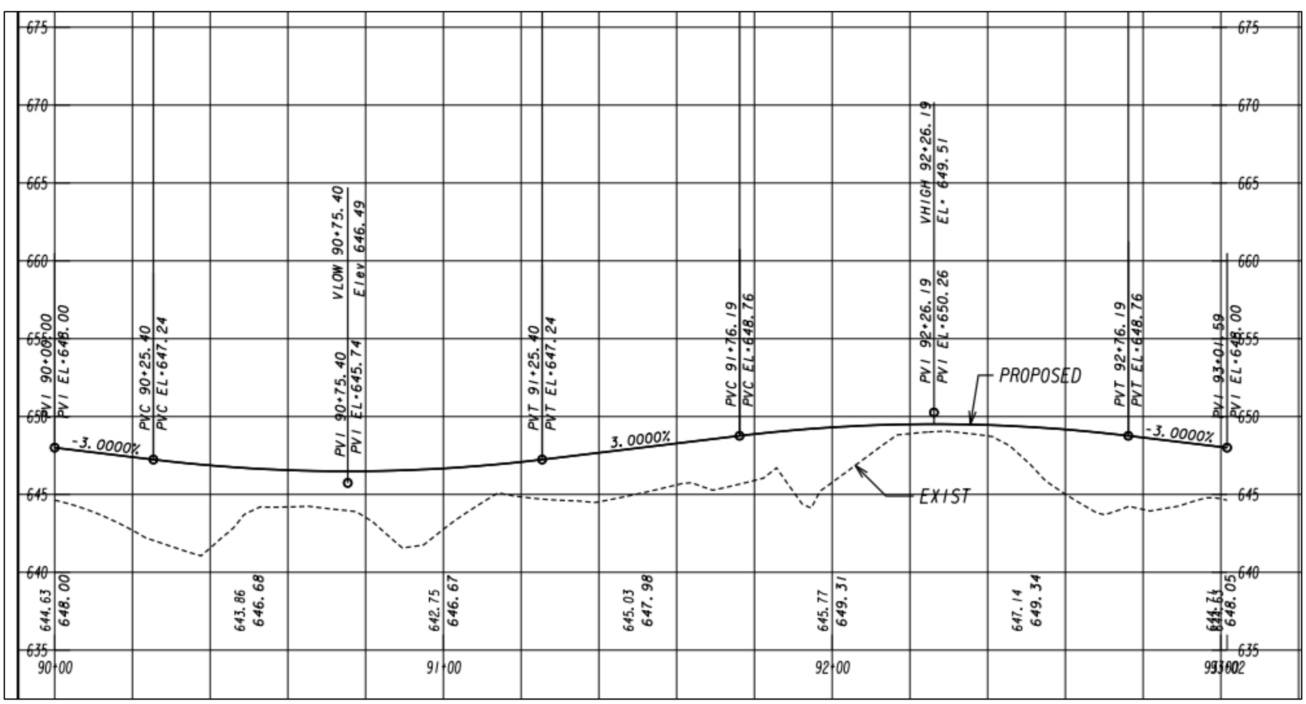


Figure F-4. Circulatory Roadway Profile

2. Develop a profile for each of the splitter island alignments

Tie in to the outside edge of pavement of the circulatory roadway. The elevations of these tie-in points can be determined from the circulatory roadway's profile and its cross-slope(s). The circulatory roadway profile can be adjusted as necessary during this process to ensure optimal tie-in to maintain comfortable break-overs between the entry/exit lane and the circulatory roadway (see Figure F-5).

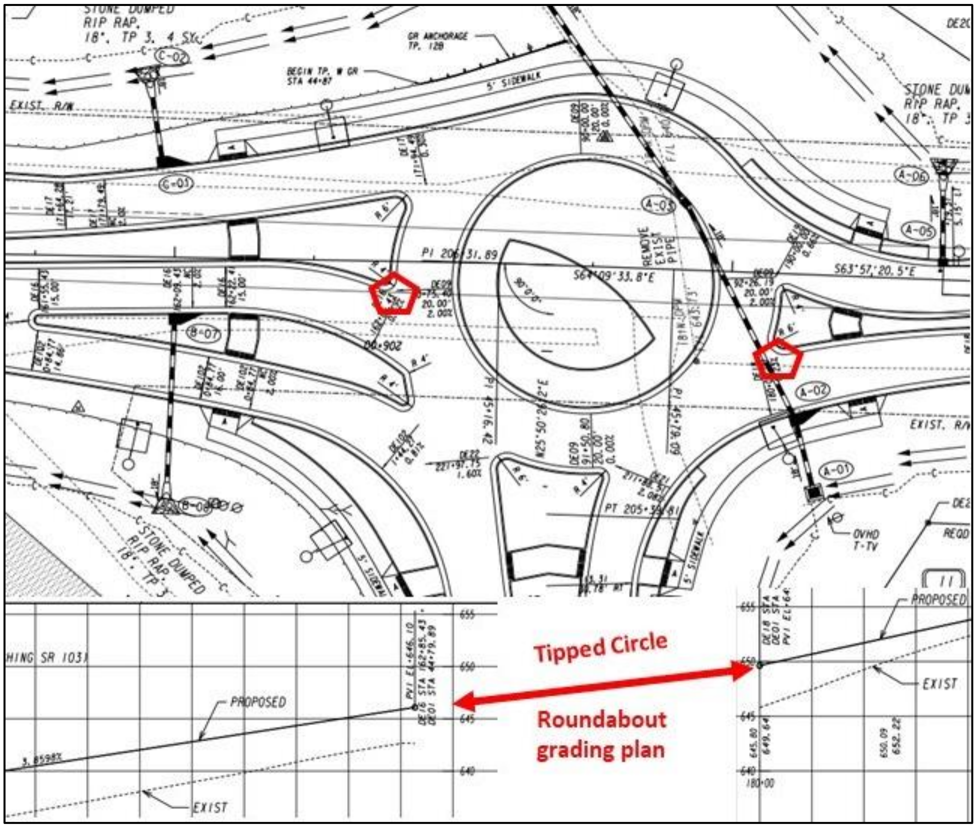


Figure F-5. Splitter Island Profiles

3. Develop a profile for outside edges of pavement

Along the outside edges of pavement, along the C&G lines at locations with varying widths (usually from bike ramp to bike ramp), and along the C&G lines for both sides of right turn bypass lanes.

F.3 Grading Design

If the circle is tilted and the circulatory lane slopes into the apron on the high side while sloping away on the low side (i.e. the circulatory lane has variable cross-slopes), the designer can calculate a uniform rate of cross-slope transition by dividing the change from the high side to the low side over half of the apron circumference (or the high side to the low side back to the high side over the full circumference). For example, if the cross-slope is 2% into the apron on the high side and -2% away from the apron on the low side, the total change would be 4% over half of the circumference, or 8% over the full circumference.

With a uniform rate of transition (calculated from GDOT DPM Section 4.5.4), it is simple to calculate the cross-slope at any given point along the apron's alignment. For example, the cross-slope from point A to B or from point C to D in Figure F-6 has elevations at points B and D that can be calculated to determine the cross-slope from point B to D, which is the necessary cross-slope to tie the entry into the circle.

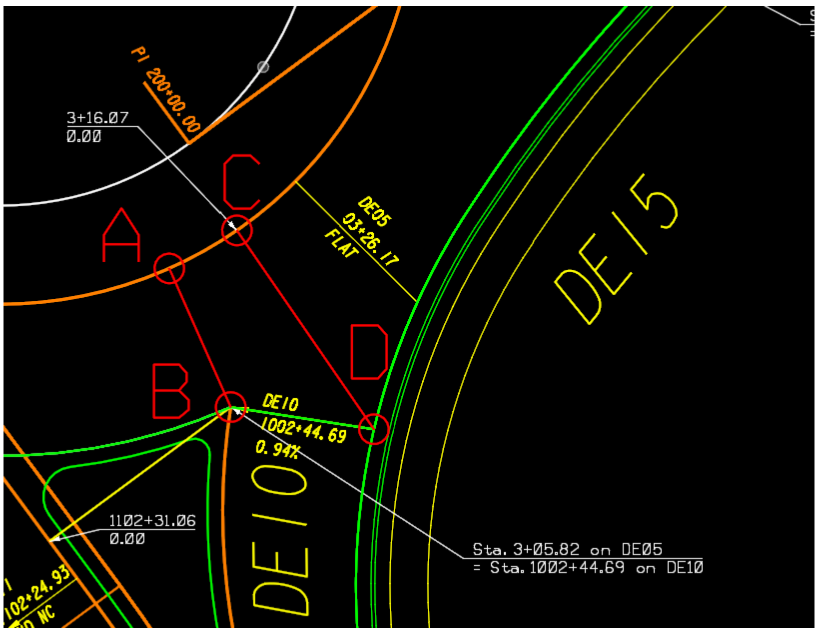


Figure F-6. Points of Station Equivalents

This tie-in cross-slope is then transitioned back to Normal Crown at a rate that will range from 0.02%/ft up to 0.04%/ft (Figure F-7) to limit maximum relative gradients.

This exercise is repeated for each entry and exit at the roundabout. A spreadsheet is highly recommended for refinement of adjustments.

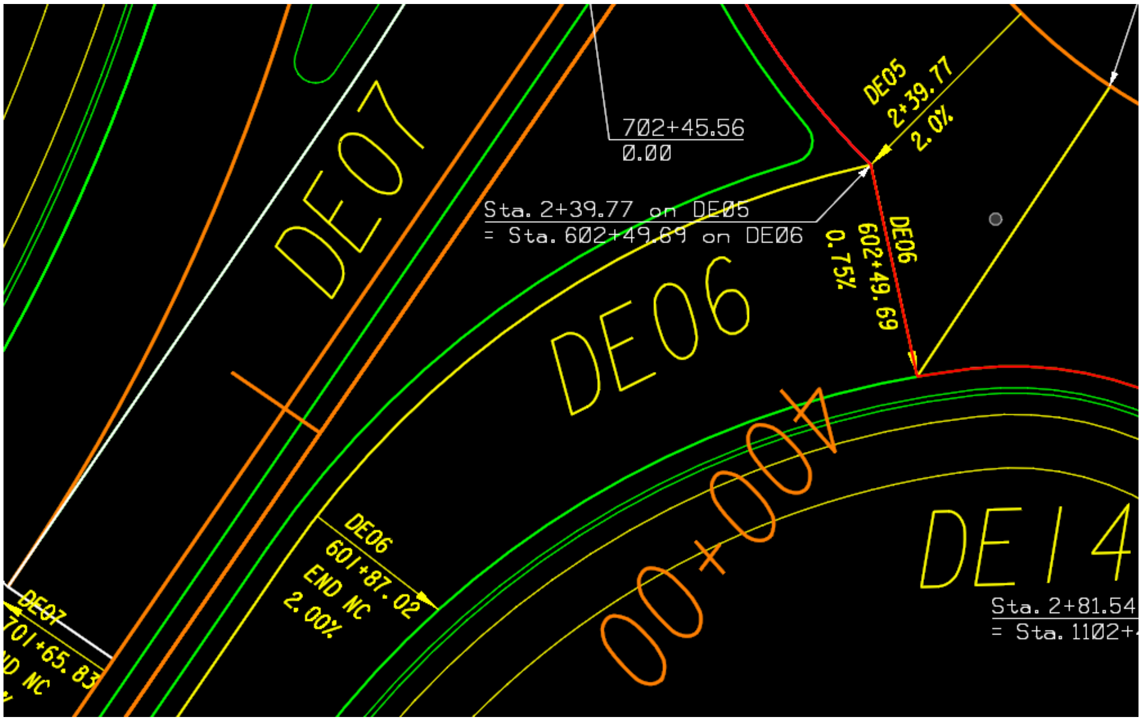


Figure F-7. Cross Slope Transition at Entry or Exit Tie-in

Check the outside EOP (produced from the proposed DTM surface) and make adjustments if there are local low points along the gutter that shouldn't be there. Adjustments can be made through manipulation of the cross-slopes (or the outside EOP profile). In either case, cross-slopes (calculated from GDOT DPM Section 4.5.4) should be maintained under 4% on the high side and 2% on the low side of the circle. A cross-slope transition rate between 0.02%/ft and 0.04%/ft will result from this calculation.

Cross-section corridors utilizing proper tie-ins and transitions will result in a smooth and seamless surface with minimal gaps or overlaps, as shown in Figure F-8.

Figure F-9 shows SE changes around the circle, cross slopes, and elevation points making it easy to check the vertical design.

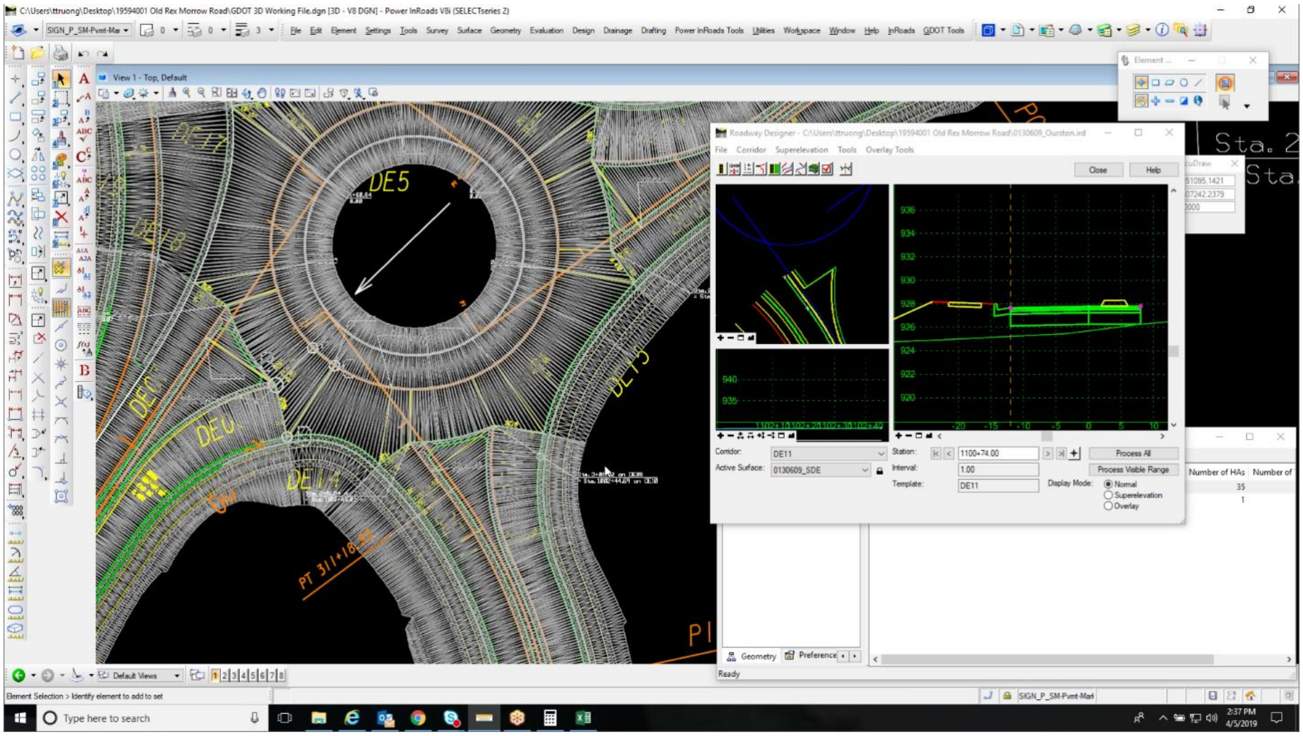


Figure F-8. Seamless Surface

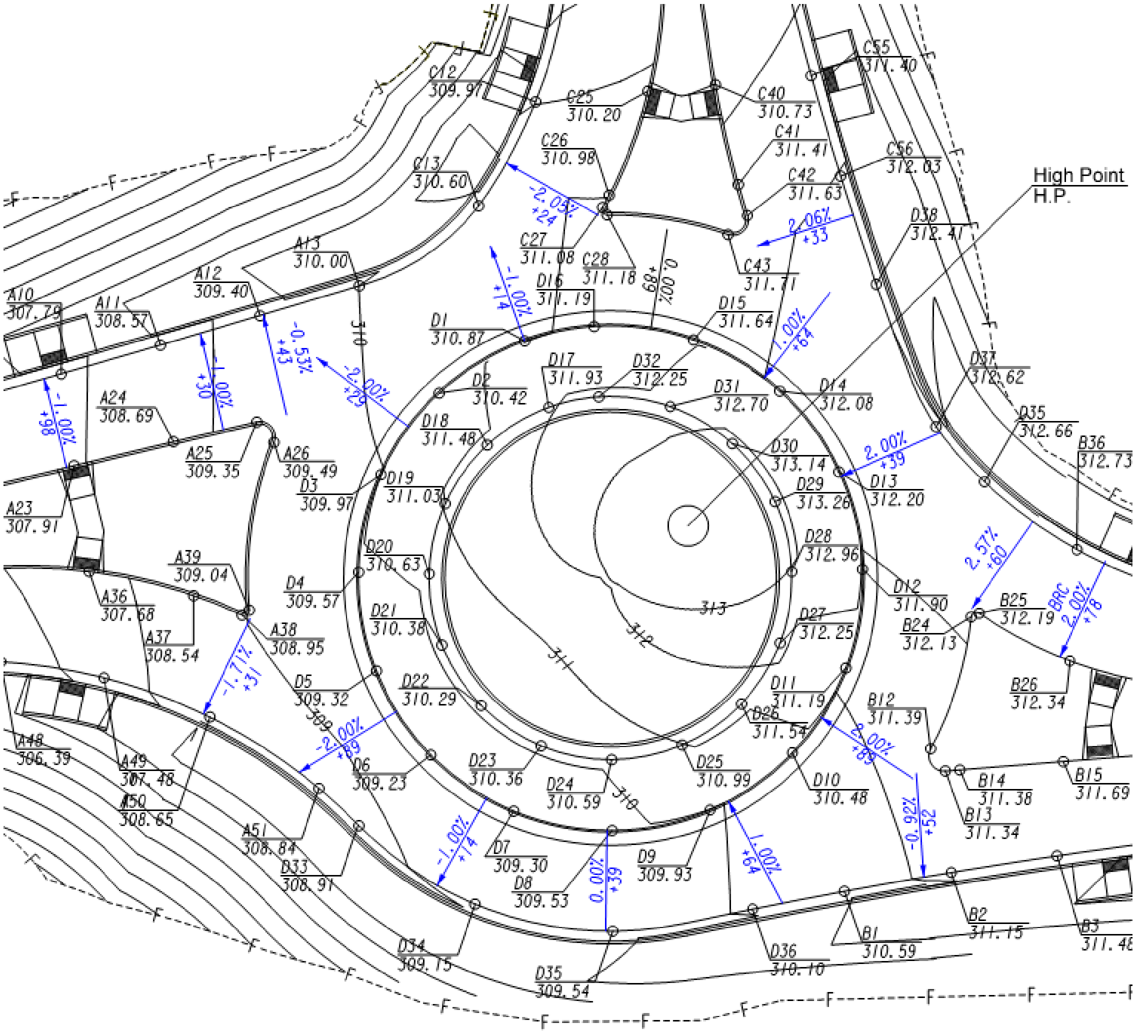


Figure F-9. Special Grading Annotations