Roundabout Design Manual

Prepared for

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TABLE OF CONTENTS

CITY OF REDMOND	**1**
FOREWARD	**4**
I. GENERAL ROUNDABOUT DESIGN REQUIREMENTS	**5**
II. DEFINITIONS	**6**
III. ROUNDABOUT PLANNING	**13**
IV. PUBLIC INVOLVEMENT	**15**
V. INTERSECTION CONTROL ANALYSIS	**16**
VI. DESIGN GUIDELINES	**19**
VII. PLAN SETS	**59**
VIII. SUBMITTAL REQUIREMENTS	**62**
IX. DESIGN DETAILS	**63**
X. SPECIFICATIONS	**76**

LIST OF FIGURES

Figure 2-1 Roundabout Geometric Elements	**8**
Figure 2-2 Mini Roundabout	**9**
Figure 2-3 Urban Compact Roundabout	**10**
Figure 2-4 Single Lane Roundabout	**11**
Figure 2-5 Multi-lane Roundabout	**12**
Figure 6-1 Approach Alignments	**34**
Figure 6-2 Entrance Geometry	**35**

Figure 6-3 Path Overlap	**36**
Figure 6-4 Consistent Flaring	**37**
Figure 6-5 Adjacent Legs	**38**
Figure 6-6 Splitter Island Configuration	**39**
Figure 6-7 Speed Radius Relationship	**40**
Figure 6-8(a-d) Single Lane Fastest Path Calculation	**41**
Figure 6-9(a-d) Multi-lane Fastest Path Calculation	**45**
Figure 6-10 Path Overlap Check	**49**
Figure 6-11 Roundabout Checklist	**50**
Figure 6-12 Stopping Sight Distance	**51**
Figure 6-13 Intersection Sight Distance	**52**
Figure 6-14 Landscaping Exhibit	**53**
Figure 6-15 Roundabout Grading	**54**
Figure 6-16 Roundabout Grading	**55**
Figure 6-17 Roundabout Illumination Standards	**56**
Figure 6-18 Channelization	**57**
Figure 6-19 Signing	**58**

FOREWARD

The design guidance standards contained in the following pages should never be viewed as an inflexible standard; rather, they provide procedures and methods of roundabout design that must be applied in conjunction with sound judgment to ensure a design that best facilitates all users: motor vehicles, pedestrians, bicyclists, and others.

Roundabout design is performance-based, utilizing the holistic effects of the major design elements (geometry, signing, striping, and landscaping) to elicit the desired user behavior. The complexity of roundabout design requires the engineer to make fundamental trade-offs that balance competing considerations within site-specific design constraints.

The intent of these guidelines is to provide the design engineer with sufficient information to prepare the plans for City review and approval. The principles detailed in these guidelines must be combined with a combination of training, mentoring, professional experience, and peer review as needed. Sound roundabout design remains the responsibility of the engineer.

I. GENERAL ROUNDABOUT DESIGN REQUIREMENTS

The Engineer preparing the roundabout design plans shall be a Civil Engineer with current Washington State registration, and shall sign and seal the finalized Plans. The Engineer must demonstrate roundabout design experience. The City of Redmond may choose to have the roundabout design peer reviewed, at the City's expense, after the conceptual level of design. The engineer performing the peer review must be approved by the City.

The Engineer preparing the design roundabout plans shall utilize the latest editions of the following:

- City of Redmond Standard Specifications and Details.
- Washington State Department of Transportation (WSDOT) *Standard Plans and Specifications.*
- *WSDOT Design Manual*.
- *Manual of Uniform Traffic Control Devices* (MUTCD) recommended design practices adopted by WSDOT, where applicable.
- NCHRP Report 672: *Roundabouts: An Informational Guide.*

II. DEFINITIONS

Definition of Roundabout
A roundabout is a circular intersection with traffic flowing one-way, counter-clockwise, around a central island. Before a vehicle enters a roundabout, it is slowed and deflected (pointed in the correct direction) with the use of curbing along a splitter island. Vehicles can enter the roundabout via different approaches simultaneously, but must yield at entry; that is, yield to the circulating traffic in the roundabout before entering the roundabout. Each roundabout is configured specifically for its intersection to provide optimum operational and safety benefits given the site constraints and traffic patterns. Typical roundabout elements are shown in Figure 2-1.

Roundabout Types
Roundabout designs within the City of Redmond are broken into four different categories. The differences between each of these are categorized in Table 2-1 and can be seen from the diagrams in Figures 2-2 through 2-5. It should be noted that the values given in this table represent typical values and may be adjusted depending on specific intersection characteristics. However, deviations from these values should be supported by sound judgment and reasoning from the engineer with consideration to the adverse impacts that these deviations may have on the roundabout design as a whole.

Mini Roundabouts
Mini roundabouts are small roundabouts used in low speed, urban neighborhood environments. The splitter and central islands are mountable, similar to the truck aprons of other roundabouts, to allow larger vehicles to maneuver through the intersection. A common application is to replace an all-way stop-controlled intersection with a mini roundabout to reduce delay and increase safety and capacity. Mini roundabouts are only to be used in neighborhood settings at intersections between two local streets due to their limits in capacity and physical geometry.

Urban Compact Roundabouts
Urban compact roundabouts are small roundabouts also used in low speed environments; however, they incorporate all of the design elements of a safe and efficient roundabout. They generally achieve speed control with tighter entry radii than the single lane roundabout, as they do not have to accommodate larger vehicles. Generally, Urban Compact Roundabouts do not incorporate multi-use trails, as the speeds are very low (under 30 mph), and right-of-way is constricted.

Single-lane Roundabout
A single-lane roundabout has a single, circulating lane with corresponding single-lane approaches and exits. It is composed of raised splitter islands and a non-traversable central island.

Multi-lane Roundabout
A roundabout with at least one entrance and a portion of the circulating lane with more than one lane is considered a multi-lane roundabout. It is necessary to design multi-lane roundabouts with natural drive paths that ensure passenger vehicles traveling side by side through the roundabout remain in their own lane. However, trucks are encouraged to claim more than one lane on the entrance of the roundabout to avoid pinching passenger cars in the circulating lane of the roundabout.

Table 2-1: Types of Roundabouts

Feature	Mini Roundabout	Urban Compact Roundabout	Single-Lane Roundabout	Multi-Lane Roundabout
Max Design Vehicle	Passenger Car/Bus/Emergency Response	Bus/WB-40/WB-50 for Thru Movements	WB-67	WB-67
Max Approach Roadway Speeds	30 mph	35 mph	No Max	No Max
Entry Speed	15-20 mph	20 mph	23 mph	25 mph
Inscribed Circle Diameter	50-85 ft	80-110 ft	110-150 ft	140-200 ft
Entry Width	14-15 ft	14-17 ft	14-19 ft	25-28 ft
Circulating Width	16-18 ft	16-18 ft	18-21 ft	28-32 ft
Splitter Island	Min 20' Mountable Splitter Island – there may not be enough room for pedestrian refuge area	Min 50' Raised Splitter Island with cut pedestrian refuge area	Raised Splitter Island with cut pedestrian refuge area	Raised Splitter Island with cut pedestrian refuge area
Typical maximum ADT (veh/day)	10,000 (Only appropriate in neighborhood local street intersections)	15,000	20,000 (A rule of thumb: if the sum of the entering traffic and circulating traffic at their merge point is below 1500 veh/hr a single lane is most likely adequate for that approach)	50,000 Dependent on operational analysis of specific design

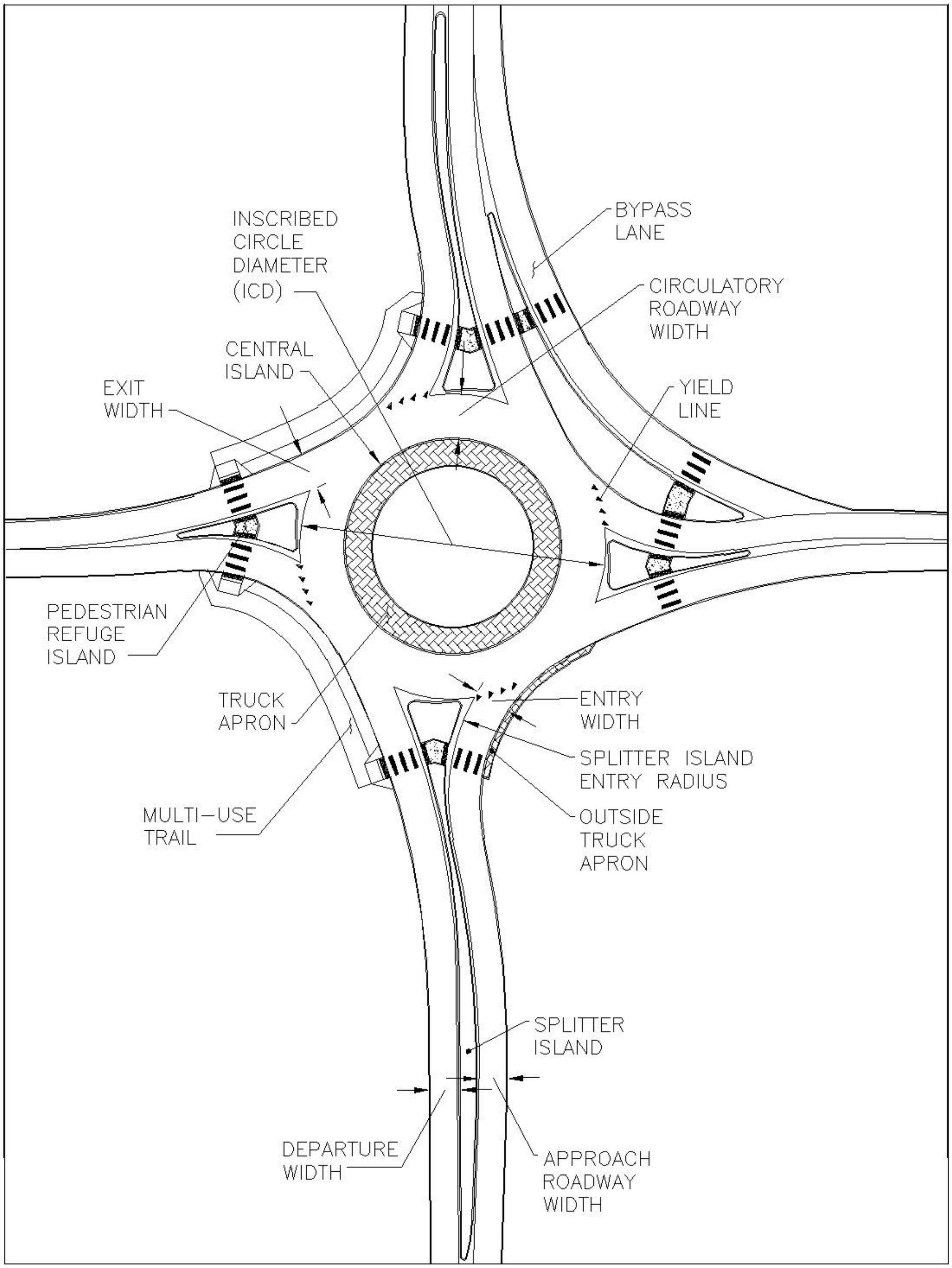
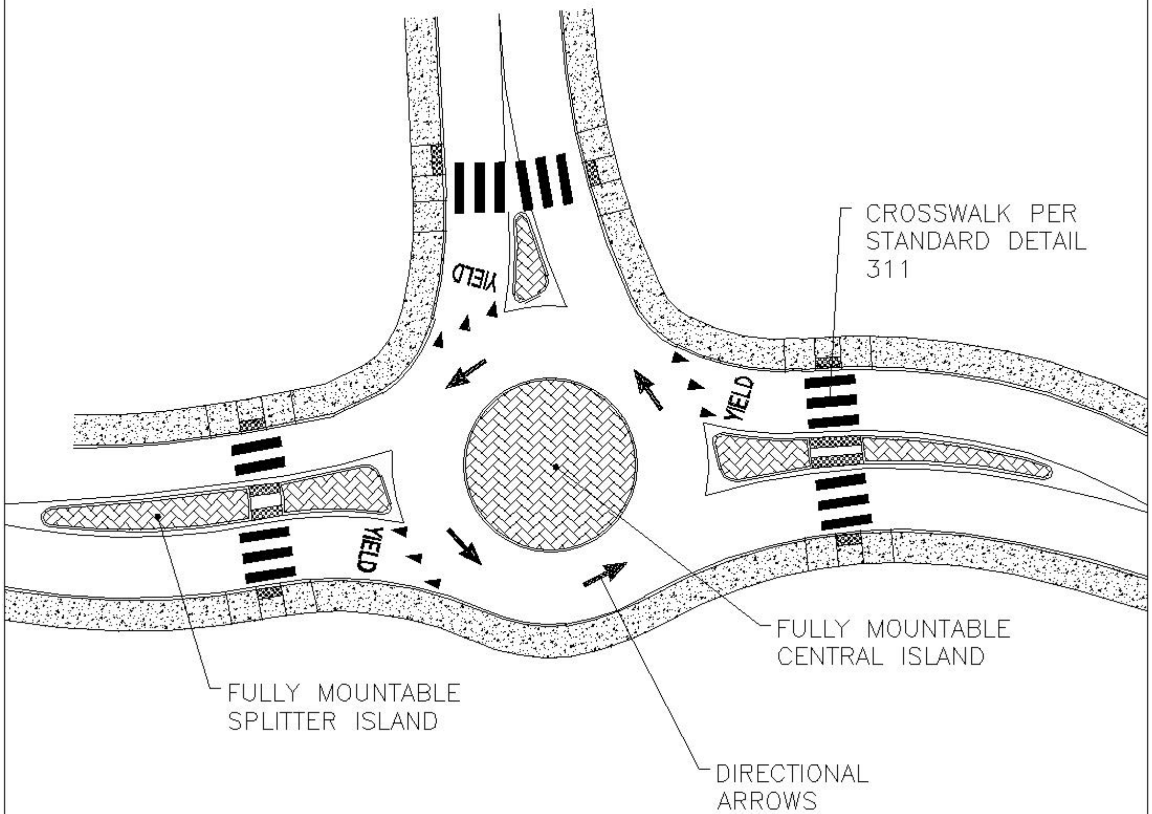
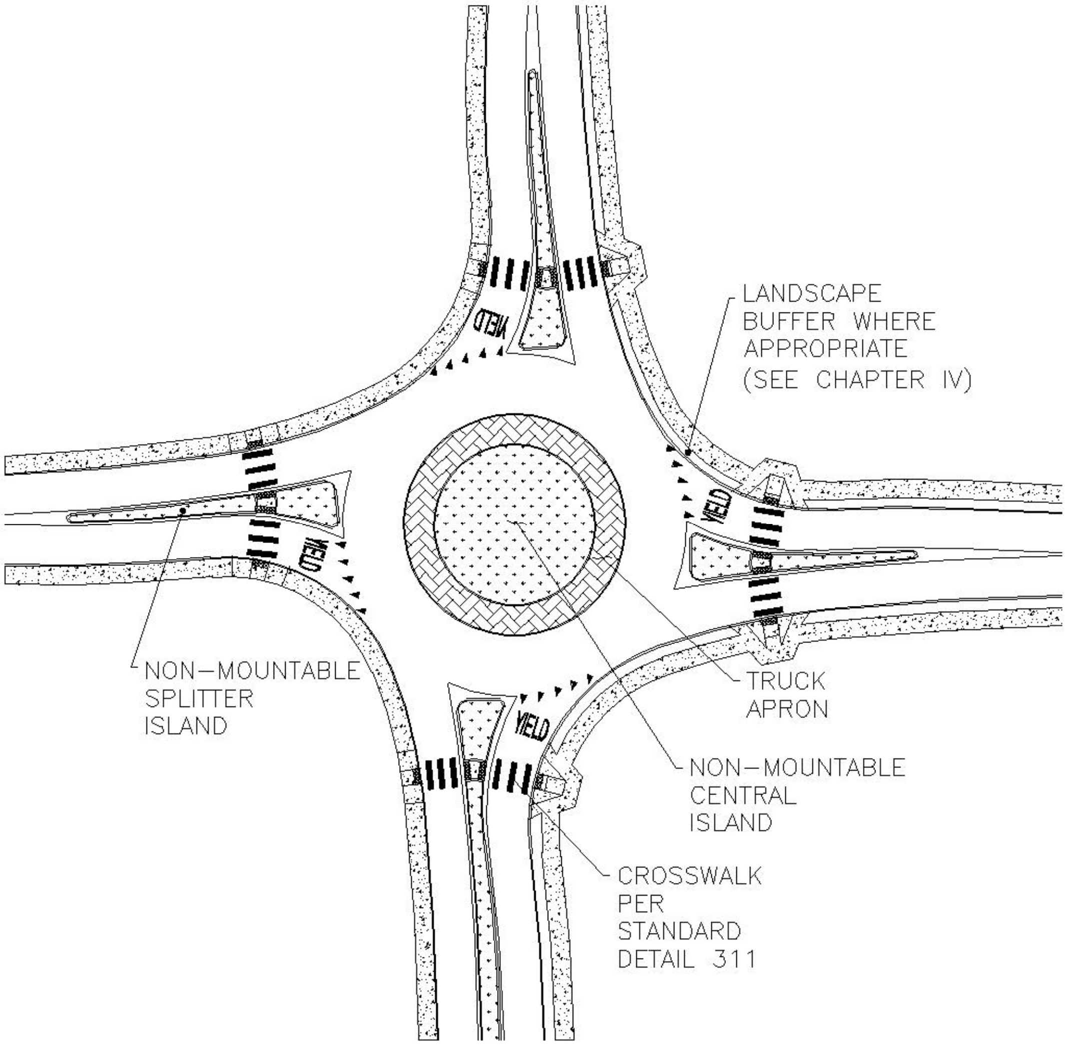


Figure 2-1 Roundabout Geometric Elements



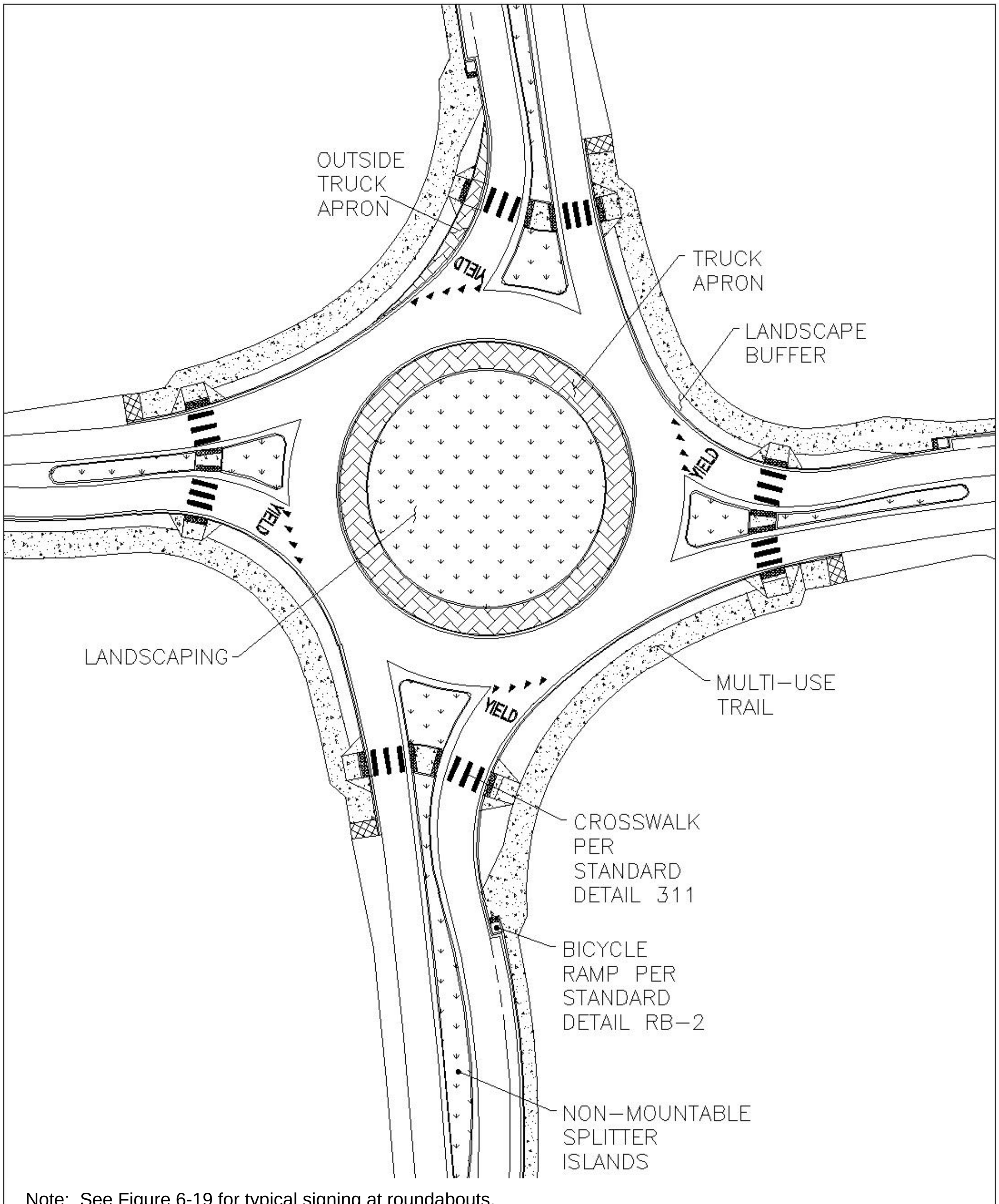
Note: See Figure 6-19 for typical signing at roundabouts.

Figure 2-2 Mini Roundabout



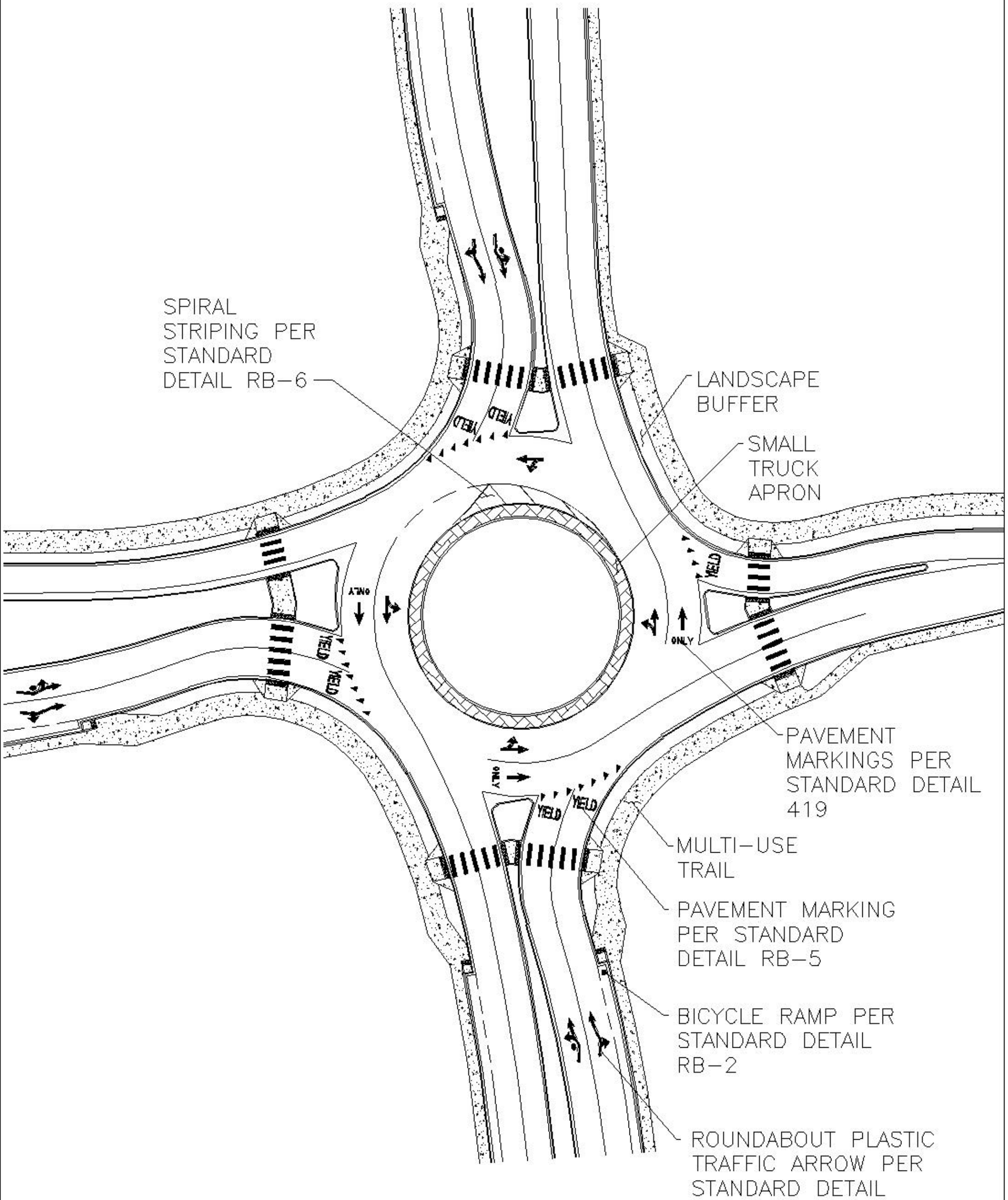
Note: See Figure 6-19 for typical signing at roundabouts.

Figure 2-3 Urban Compact Roundabout



Note: See Figure 6-19 for typical signing at roundabouts.

Figure 2-4 Single Lane Roundabout



Note: See Figure 6-19 for typical signing at roundabouts.

Figure 2-5 Multi-lane Roundabout

III. ROUNDABOUT PLANNING

Purpose of Roundabout

A roundabout causes each user (vehicle, pedestrian or cyclist) to look at the conflicting traffic and make a decision of when it is safe to proceed. Because of their inherent safety and efficiency, roundabouts should be a consideration at any intersection that meets warrants for a four-way stop or a traffic signal and/or is being modified, updated or newly constructed.

Advantages and Cautions of Roundabouts versus Other Intersection Controls

Safety

Advantages:

- Fewer conflict points, resulting in fewer collisions
- Eliminate right-angle, left–turn, and head-on collisions
- Slower speeds reduce the severity of collisions and allow for more reaction time to avoid potential collisions
- Consistent speeds between vehicles reduce the severity of collisions
- Simplified decision making at point of entry. Yield condition only.
- Features such as landscaping provide advance warning of intersection
- For a full report on safety statistics view NCHRP 572 at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_572.pdf

Cautions:

- Public education must be provided on how to drive roundabouts – especially multi-lane.
- Be cautious in constructing a roundabout where there is not sufficient right-of-way available to accommodate good geometry

Operations

Advantages:

- Continuous traffic flow reduces delays and improves traffic operations
- Often the need to widen the roadway between intersections is not necessary when using roundabouts
- Can accommodate high volumes of left turns
- Accommodates a high range of side street volumes without excessive delay even on the off-peak hours

Cautions:

- Nearby traffic signals must be analyzed to ensure harmony with the roundabout
- Access to adjacent properties must be analyzed to ensure adequate access and assess impacts
- Roundabouts must be designed to accommodate the design vehicle such as truck demands and emergency vehicle routes

Cost Analysis

Advantages:

- Often roundabouts use less impervious area, leading to storm water detention and water quality cost savings
- Societal costs for accidents is reduced due to lower collision rates and severity of collisions
- Right-of-Way acquisition, if needed, usually occurs at the intersection rather than along the corridor
- Maintenance and upkeep at a roundabout consists of landscaping, striping and power for illumination

Cautions:

- Roundabouts may have a higher construction cost
- Right-of-Way acquisition at intersection may be more expensive – this is especially true for existing intersections that need minor upgrades to function adequately

Pedestrian and Bicycle Users

Advantages:

- Splitter islands provide a pedestrian refuge area allowing pedestrians to cross only one direction of traffic at a time.
- All pedestrian crossings are 90 degrees to vehicle traffic to facilitate crossings by the visually impaired
- Drivers can focus on pedestrian conflicts separate from their negotiation of vehicle conflicts
- Low speed conditions improve bicycle and pedestrian safety

Cautions:

- Proposed ADA legislation may require pedestrian activated pedestrian signals on multi-lane approaches and exits.

Aesthetics and Environmental

Advantages:

- Reduction of vehicle starts and stops resulting in reduction of emissions and fuel consumption
- Landscaping in central and splitter islands improves aesthetics of an intersection
- Roundabouts can provide gateways to a community or city with use of landscaping in the central island

Locations for a Roundabout

Locations where roundabouts have a high potential of success

- Intersections with a severe and/or high collision rate history
- Existing intersections that are failing
- Intersections with high turning movements
- Intersections where a gateway to the community or aesthetics are an objective
- Transitions/intersections of roadway environments, such as function, class, speed or surrounding land-use
- In locations where platoons of vehicles are not desirable
- Three leg intersections
- Closely spaced intersections where signal progression is not feasible
- Intersections where U-turns are desirable
- Intersections where additional access may be added at a later date
- Intersections with access issues such as closely spaced driveways to the intersection or driveways with only right-in/right-out access
- Intersections with complicated or confusing geometry
- Ramp Interchanges
- Intersections which do not meet signal warrants

Locations where a roundabout may not be appropriate

- Highly constrained locations where good geometry is not readily achievable
- In a corridor of interconnected signals
- Existing intersections that need minor improvements to achieve the goals of the intersection (ie – longer turn pocket, or modified phasing)

IV. PUBLIC INVOLVEMENT

In projects where public involvement is necessary, as determined by the City, the City will coordinate with the designer on the specific public involvement elements required for their roundabout project. Various methods to communicate design ideas and solutions are detailed below:

Scale models
A two-dimensional scale model of the roundabout shows the workings of a roundabout while also answering specific questions about vehicle operations. The use of an HO scale model allows for a variety of HO scale vehicles.

Videos
Videos of similar roundabouts in operation are one of the most effective tools for alleviating roundabout anxiety. The public sees a real-life example of roundabout operations, which showcases roundabout safety benefits and intersection efficiency. In particular, citizens can see the degree to which traffic slows while navigating a roundabout. Often, citizens are surprised at the real-life traffic speeds and think the video has been slowed. Videos also provide visual proof that many vehicles can safely use a roundabout at the same time.

Photos
Photos show how different roundabouts can look and how they can be an aesthetically pleasing addition to a community. Images also demonstrate the many options are available for landscaping of the central island.

Full size roundabout mock-ups
Full size roundabout mock-ups can be laid out in parking lots to allow the public to see the exact size of the roundabout. This is a great way to show the public how the roundabout works and how easily it accommodates the design vehicle. For large trucks, offer a guide to ride through the roundabout and explain one-on-one to the driver the various roundabout operations.

Project brochures
Project brochures or other literature that relate specifically to the proposed roundabout solution are a good way to include basic rules of the road for all users of the roundabouts, including pedestrians, bicycles, motor vehicles, and emergency vehicles. Brochures can contain a graphic of the specific roundabout showing lane usage and street names. These can be mailed out with utility bills, and during construction handed out by flaggers to waiting motorists who are curious or concerned about the new intersection.

V. INTERSECTION CONTROL ANALYSIS

Selecting a roundabout as the preferred intersection type must be based on an engineering analysis. A feasibility study must be conducted which establishes the design criteria for a particular intersection and compares the different types of intersection control and their ability to accommodate various factors. Each intersection improvement must consider a roundabout as an alternative until the analysis indicates that the roundabout is not appropriate. In any alternative analysis, the proposed improvements should be compared to a "no action" alternative. The following information must be submitted with a recommendation of the selected alternative.

Table 5-1: Intersection Control Analysis

Factor	Description	Comments
Site Information	– Roadway Speeds – Roadway Classification (Reference Transportation Master Plan) – Environmental Constraints (i.e. wetlands) – Unique site constraints – Future land use or improvements – Existing Grades – Utilities	
Safety	– Collision history including rate, types, and severity – Unique characteristics that impact safety – Impact on non-motorized users	
Operations	– Existing and Design Year Peak Hour Volumes (AM/PM) – Existing and Design Year Peak Hour Turning Movements (AM/PM) – List any signal warrants for design year – Effect on surrounding roadway network	Analyze roundabout using current version of SIDRA® or City of Redmond approved equal
Geometry	– Right-of-Way Constraints – Adjacent Access	Provide Conceptual Drawing of Roundabout
Intersection Users	– Design Vehicle (Consider future development) – Bicycle Routes – Pedestrian Routes/Trails – Transit Routes	Preliminary AutoTURN® Movements should be provided for the design vehicle

Factor	Description	Comments
Costs	– Preliminary Construction Cost for each alternative – Provide yearly operation costs for the 10 years following construction for each alternative – Include savings in societal costs associated with the implementation of each alternative	
Practical Feasibility	List concerns of various alternatives	
Recommendation	Provide recommendation	

Site Information
Site specific information will establish design criteria which will be the basis for evaluating the strengths and limitations of each alternative.

Safety
Explain the effect on safety that each alternative would provide. A roundabout may be considered for safety reasons in locations where the traffic volume does not meet signal warrants.

Operations
For traffic signal analysis, refer to City of Redmond Traffic Signal Design Manual. At a minimum, each alternative must be analyzed for average delays, 95^{th} percentile queue lengths, and volume capacity ratios for each movement and the overall intersection. If the v/c ratio is above 0.85, care must be taken to ensure that the average delay will not increase exponentially with increased entering traffic.

To evaluate the capacity of the roundabout, SIDRA shall be used or a City of Redmond approved equal. The "environmental factor" should be no greater than 1.1 for design year analysis. If a nearby traffic signal will influence the roundabout, a bunching factor can be added to the input of SIDRA to account for the traffic approaching the roundabout in platoons. If there is some doubt as to how the roundabout intersection will tie into the existing network, use SIDRA, Version 6.0 to analyze interaction of adjacent intersections.

In some cases the analysis will indicate that a single lane roundabout will fail in the design year, however, before automatically designing a multi-lane roundabout, evaluate at what point the single lane roundabout will experience failure. If the year is 10 or more years out, it may be in the best interest of safety to plan for a multi-lane roundabout, but build an interim single lane roundabout.

In evaluating roundabout capacity, initial geometric assumptions including inscribed circle, circulating lane width, entry width, etc are used. It is important to rerun the analysis and quantify the performance of the final design with actual dimensions.

An electronic copy of the operational analysis (SIDRA files or City of Redmond approved equal) must be provided to the City of Redmond.

Geometry
Controlling vehicle speed and direction moderates driver behavior and remains the goal of any roundabout design. To achieve performance forecasted by the software, the roundabout design must have good deflection, speed control, and natural drive paths. The conceptual layout must be designed with enough detail to provide a realistic idea of the space required for a well-designed roundabout. The engineer should be prepared to state the reasoning behind geometrics that may not be ideal and the effects this will have on the operations and safety of the roundabout.

Intersection Users
A close look at current and proposed land use will help determine the required design vehicle. Manufacturing requirements using the intersection should be taken into account including mobile homes, farm equipment, and the occasional oversize loads. State routes through an intersection will be required to accommodate a WB-67. The engineer should keep in mind that an intersection may not always have the same design vehicle for every movement. The City of Redmond Transportation Master Plan (available on the City website) includes system plan maps showing street classification, freight corridors, and other model elements. It should be used by the design engineer to select the appropriate design vehicle. A truck classification study for the intersection may be required to confirm the design vehicle.

Once the design vehicle(s) is defined, a simulation for each turning movement must be created using AutoTURN. Care should be taken to drive the simulation vehicle through the roundabout in a manner replicating a true vehicle path. In other words, the AutoTURN must be natural with no unrealistic pivot turns. Do not model with wheel adjustments at turning from stopped position, but rather model heavy vehicle movements at 5 mph. A roundabout should be designed with a 1 foot clearance between the wheel path and any non-mountable curb face and 0.5 foot between the wheel path and mountable curb face (not including truck apron curbs). The front wheels of the design vehicle should not have to use the truck apron, which is reserved for the trailer wheels. In addition, all busses through the intersection should be accommodated without using the truck apron. Be sure to model every design vehicle path through the intersection.

For multi-lane roundabouts, the trucks may claim both lanes while entering and negotiating through the roundabout. Describe how each alternative accommodates pedestrian and bicycle users or affects non-motorized transportation.

Costs
A preliminary cost estimate for each alternative should be provided which includes the construction costs as well as yearly maintenance and operational costs.

Practical Feasibility
The preferred alternative should not be selected based on cost estimates alone. Each alternative must be carefully analyzed to assess how they fit within the goals of the project. Impacts on community life, businesses, parking, etc, must be considered when choosing the preferred alternative.

Recommendations
Based on the above considerations, a preferred alternative selection should be justified.

VI. DESIGN GUIDELINES

Roundabout design is not a linear process to be worked through with a series of checklists, but rather follows an iterative process to reach a final solution. The driver, pedestrian and bicyclist are influenced by several elements, including geometrics, channelization, and landscaping. Designing these features to holistically interact with one another is the key to good roundabout design. The following guidelines primarily pertain to single and multi-lane roundabouts. More latitude is given with mini roundabouts and urban compact roundabouts as they are usually in slow speed, constricted environments. The design values provided in Table 6-1 are meant to help the designer achieve the desired user behavior in a roundabout design. It is not enough, however, to create a design based on these requirements without an understanding of the intent behind the requirement. Well-designed roundabouts vary and are site specific. The following guidelines give parameters on geometric elements that if applied properly will result in safe and efficient roundabout designs: *Refer to Figure 2-1 for typical roundabout elements.*

Table 6-1: Typical Roundabout Standards

Element of Roundabout Design	Requirements	Comments
Lane Configuration	Base configuration on traffic analysis.	
	Vehicles should not need to change lanes in the circulating lane to exit where desired.	Perform a "Can you get there from here?" exercise.
Inscribed Circle Diameter (ICD)	The size of the ICD is based on traffic volume, number of legs, design vehicle, and right-of-way constraints.	
Circulating Roadway	For single lane roundabouts: The typical circulating width is 17 -19 feet. Maximum circulating width is 21 feet.	This maximum should be used only when the design vehicle is a WB-67.
	For multi-lane roundabouts: The typical circulating width is 28-32 feet. Maximum circulating width is 32 feet.	
Approach Alignment	The approach alignment can be centered, offset to the left, or offset to the right of the ICD.	See Figure 6-1
	When it is necessary to taper from the existing alignment, the taper ratio should be no steeper than 1:Posted Speed.	
Entry Geometry - Deflection	The splitter island entry radius (stripe) should be tangent to a 3 foot offset from the face of the truck apron curb or central island curb if no truck apron is proposed.	This is depicted in Figure 6-2, which also gives some typical values for reverse curves into a roundabout.
	The length of the splitter island entry radius should be a minimum of 40 feet for a single lane roundabout (length is measured to the yield line).	

Element of Roundabout Design	Requirements	Comments
Entry Geometry – Deflection (Cont'd)	The length of the splitter island entry radius for a multi-lane roundabout should be 60 feet (length is measured to the yield line).	This minimum length can be calculated based on the total length of consecutive splitter island entry curves.
	Avoid path overlap with multi-lane roundabouts. Do not use line tangents between curves to accomplish this; rather use successive curves that are tangent to each other.	See Figure 6-2 A check for path overlap is required for the Conceptual Submittal on multi-lane roundabouts. See Roundabout Performance Measures.
Entry Geometry - Good Speed Control	The entrance speed, R1, for a single lane roundabout should be 20 mph (or no more than 23 mph if accommodating a WB-67)	Speed Curves and Calculations are required for the Conceptual Submittal. See Roundabout Performance Measures.
	For a multi-lane roundabout, the entrance speed, R1 should be 25 mph or below.	
Entry Geometry - Natural Drive Paths	All adjacent radii should be tangent to one another. There should be no tangent sections between radii. For a single lane roundabout, the approach radii should get successively shorter and tighter as the yield line is approached. For multi-lane roundabouts, there may be some relaxing of the radii just before entering the roundabout to ensure that path overlap is avoided.	See Figure 6-2 See Figure 6-3
	The travel way width should be evenly flared from the standard travel way width to the entry width. The entry width should be larger than the standard travel way width to enhance capacity and ease the yielding process, but smaller than the circulatory roadway width.	See Figure 6-4
	The connection between the entry radius of each leg and the exit radius of the adjacent leg should be smooth and tangential. The entry radius of each leg should also be no more than 4 feet offset from the ICD.	See Figure 6-5
	For a single lane roundabout the max entry width should be 19 feet. For a multi-lane roundabout the max entry width should be 28 feet.	
Exit Geometry	The splitter island exit stripe radii should be a maximum of 700 feet with a minimum length of 20 feet.	

Element of Roundabout Design	Requirements	Comments
Exit Geometry (Cont'd)	The exit speed should be greater than the circulating speed.	
	The exiting speed at the crosswalk should be less than 30 mph. If the crosswalk is a school crosswalk, than the maximum speed should be 25 mph.	
	Avoid path overlap on the exits as well as the entrances.	
	The exit width should be smaller than the circulatory width but greater than the travel way width.	
Splitter Island	The pedestrian refuge island should be set back 20 feet from yield line.	See Figure 6-6
	The minimum length for a pedestrian refuge island within the splitter island is 6 feet from face of curb to face of curb.	
	The minimum width for a pedestrian refuge island within the splitter island is 6 feet. However, if a multi-use path is proposed, the minimum width for the pedestrian refuge island is 8 feet.	
	The minimum width of the splitter island, from face of curb to face of curb is 3 feet for hardscaped and 4 feet for landscaped.	
	The curb and gutter on the right side of the roadway (the outside approach curb) should extend the entire length of the splitter island.	
	The curb and gutter on the left side of the roadway (the outside exit curb) should extend through the crosswalk.	
	For high speed approach roundabouts (those over 45 mph), the minimum length of the splitter island should be 250 feet.	
	The minimum length of splitter islands for approach speeds less than 45 mph is 50 feet. However, splitter island lengths between 75 feet and 150 feet are preferred.	
	The splitter island curbs should be the Mountable Cement Concrete Traffic Curb found in the standard details.	See Standard Detail RB-9

Element of Roundabout Design	Requirements	Comments
Truck Aprons	The truck apron must be raised 3 inches from the roadway.	See Standard Detail RB-9 for curb details.
	Although appropriate in some locations (such as skewed intersections, or where WB-67's make right turns in constrained intersections), outside truck aprons are not ideal and should not be necessary for a design vehicle of a WB-50.	See Standard Detail RB-3 for outside truck apron treatment at crosswalks.
	School Busses and City Busses should be accommodated through roundabouts without the use of the truck apron.	
	The design vehicle should not have to use the truck apron with their front tires. The truck apron is reserved for trailer tracking.	It is allowable to design the roundabout so that specialty vehicles that only occasionally use the roundabout must utilize the truck apron with their front tires.
	The splitter island curb can be offset from the stripe up to 3 feet to help accommodate heavy vehicle movements.	See Figure 6-6
Bypass Lanes	If pedestrians are present, the speed of the bypass lane should be less than 30 mph.	
	The pedestrian refuge island length and width requirements stated above are also required for the pedestrian refuge island between the roundabout roadway and the bypass lane.	
	If the bypass lane merges with a downstream leg of the roundabout, the speeds of the bypass should be similar to the exiting speeds of the roundabout at the point at which they merge (within 6 mph).	
	The minimum width of the bypass lane is 15 feet and the maximum width is 21 feet. The width should be verified using AutoTURN.	
Roundabout Performance Measures	Truck Turning Movements	An exhibit with AutoTURN Movements is required for the Conceptual Submittal.

Element of Roundabout Design	Requirements	Comments
Roundabout Performance Measures (Cont'd)	Fastest Drive Paths	Speed Curves and Calculations are required for the Conceptual Submittal. See Figure 6-7, Figures 6-8(a-d), and Figures 6-9(a-d).
	Speed Continuity	
	Natural Drive Path	Check for path overlap using method detailed in Figure 6-10.
	Roundabout Calculation Sheet	A sheet similar to Figure 6-11 is required for the Conceptual Submittal.
	Traffic Analysis	An electronic file of SIDRA output and a copy of the Movement Summary based on the final geometrics are required for the Conceptual Submittal.
	Sight Distance	The sight distance triangles must be calculated and an exhibit depicting these triangles is required for the Conceptual Submittal. See Figure 6-12 through Figure 6-14.
Access Management	Full access, commercial driveway must be a minimum of 50 feet from the yield line.	
	Right-in/right-out commercial driveway access will normally be allowed as long as the driveway does not adversely interfere within the limits of the crosswalk.	
	Breaks in the splitter island will be allowed for private access as long as the driveway does not interfere within limits of the crosswalk.	The splitter island curb should continue through this break as a depressed curb. In addition, the rockscape used in the splitter island should continue through the break in the splitter island.
	Ensure adequate sight distance for vehicles exiting the driveways exists.	
	Ensure that no queuing occurs into the roundabout from downstream left turns.	
Pedestrians	Crosswalks should be perpendicular to the curb and in line with ADA ramps.	
	The curb in the pedestrian refuge island should not be rounded but meet adjacent curbs with squared off connections.	See Standard Detail RB-4
	If an outside truck apron exists, there must be a landscape buffer.	

Element of Roundabout Design	Requirements	Comments
Pedestrians (Cont'd)	A minimum landscape buffer of 2.5 feet (5 feet where right-of-way allows) should be provided between circulating roadway and sidewalk or multi-use path unless directed otherwise.	
Bicycle Facilities	The bicycle lane should end approximately 50 feet from the yield line.	See Standard Detail RB-1 and RB-2 for bicycle lane termination and ramps.
	The standard multi-use path is 10 feet and must be provided if bicycle ramp is present.	8 feet may be allowed for width of multi-use path in locations of constrained right-of-way if directed by the City.
	The necessity for a multi-use path must be considered on a case by case basis as directed by the City.	
Bus Facilities	Bus facilities (Bus Stops) should not be provided within limits of the splitter island downstream of roundabouts.	
	Bus Stops at intersection should be provided on approach leg of roundabout.	
Grading	The profile around the central island should not be steeper than 4% (there is not a minimum grade). The vertical curves for this profile should be designed for the circulating speed.	See Figure 6-15 through Figure 6-16
	The circulating roadway should be designed with a consistent 2% slope toward the outside of the roundabout.	This consistent 2% slope can vary from 1.5% (min) to 2.5% (max) to allow more flexibility.
	The splitter island curbs around the circulating roadway should be graded to promote positive drainage with a minimum of 0.5% slope.	
	The pedestrian refuge island within the splitter island should be graded with a maximum running slope of 4%. For a single lane roundabout, it is desirable to grade the cross-slope of the crosswalk and refuge island at 2%. However, a grade of up to 5% will be considered with justification. For a multi-lane crossing, the maximum cross-slope shall be 2%.	

Element of Roundabout Design	Requirements	Comments
Grading (Cont'd)	A profile along the outside curbs should be created using the design speed of the roundabout at the locations for which a vertical curve is necessary. The minimum slope allowed for this outside curb is 0.5%.	Refer to the section on Plan Sets for information on how to depict the grading in a roundabout.
	If the roundabout must tie into existing superelevation, the 2% cross slope toward the outside curb should be achieved by the crosswalk on the approach. Likewise, the change in superelevation may begin after the crosswalk on the exit leg.	
	The truck apron should be graded with a 2% slope toward the travel way.	
	The central island should be graded with a mound. Care must be taken that the grades will not adversely affect the sight triangles.	See Standard Detail RB-10 for typical section through center of the roundabout.
Drainage	Do not put catch basins within limits of pedestrian crosswalk.	.
Utilities	Do not put proposed utilities in circulating lane if possible.	
	Water mains shall not be placed under landscaped areas.	
	Access pads for vactor trucks must be provided in central island if sanitary sewer manholes are present.	
Illumination	For general illumination design standards, follow City of Redmond Illumination Design Manual.	See Figure 6-17
Landscaping	Unless directed otherwise, the splitter islands should be designed with a hardscape.	The hardscape of the splitter islands should be distinguishable from the textured concrete used for the truck apron. See Specifications
	Ensure that sight triangles are not compromised with proposed landscaping.	The landscaping must be compared with the sight triangle exhibit to ensure low growth and high growth areas are appropriate.
	6" Conduit should be added from the splitter island to the central island for future lighting, irrigation.	
	Use the Community Development Guide for design of any landscape up-lighting.	

Element of Roundabout Design	Requirements	Comments
Landscaping (Cont'd)	A maintenance pullout should be designed in the central island for landscaping and utility maintenance.	See Standard Detail RB-12
	Ensure that clear zone requirements are met with regard to central island art/objects.	The clear zone requirements are based on the design speed of the roundabout and follow WSDOT Standards.
Roundabout Materials	The asphalt section for roundabouts should follow the geotechnical recommendations and City Standards.	
	The truck aprons in roundabout should consist of 8 inches of textured cement concrete pavement, over 4 inches crushed surfacing top course. The color of the truck apron shall be "brick red" and the texture shall be "herringbone pattern"	See Standard Detail RB-10 See Specifications
	Sidewalks and multi-use paths should be constructed in accordance with City Standards.	
	If concrete pavement is desired for the circulating lane, the limits should extend to the crosswalk.	The specifications should require the contractor to submit a joint pattern prior to construction.
	Curbing materials shall follow City Standards.	See Standard Detail RB-9
Channelization	See text for direction on Signing and Pavement Marking.	See Figure 6-18 through Figure 6-19 See Standard Detail RB-5, RB-6, RB-7, and RB-11

Lane Configuration
It should be noted that the software will allow the user to input configurations that are not feasible in reality. For example, there will not be a red flag if the designer has two lane entrances and only one lane exits for all approaches. A good exercise to ensure that the lane configurations are realistic is to do a "Can you get there from Here?" exercise. Once the striping is sketched, the designer should take each lane of the approach and trace through to see if the vehicle will end up where the approach arrows indicate. The vehicle should not have to change lanes in the roundabout to exit where the approach arrows indicated. This is a critical exercise when dual rights or dual lefts are present in the roundabout configuration.

Inscribed Circle Diameter (ICD)
The values provided in Table 2-1 of this manual and Exhibit 6-9 from *NCHRP 672: Roundabouts: An Informational Guide* provide a place to start in the sizing process. The engineer should keep in mind any landscape buffer and sidewalk width which will be added to the ICD dimension to ensure the design is still within the proposed right-of-way limits.

Circulating Roadway
The width should be consistent around the roundabout unless the roundabout changes from a single lane to a multi-lane roundabout.

In areas with a high volume of traffic, especially heavy vehicle traffic, the engineer may consider using a concrete circulating roadway. The concrete should extend to the pedestrian crosswalk. If a concrete roadway is used, care should be taken to ensure the truck apron is easily distinguishable from the circulating roadway and the striping is visible.

Approach Alignment
The goal in designing the approach alignment is to provide good deflection and speed control into the roundabout while tying the entrance and exit approach to the existing alignment. Good deflection will point the vehicle into the circulating lane. This can be achieved by different methods depending on where the ICD is placed in relation to the approach alignment. See Figure 6-1.

- Case #1 Alignment is centered on ICD
- Case #2 Alignment is centered to the left of the ICD
- Case #3 Alignment is centered to the right of the ICD

As the approach alignment is offset to provide more speed control and deflection for the entrance, the exit geometry is often straightened out. This is usually an allowable trade-off in the design as the exit speeds are influenced by the circulating speed rather than the exit radius.

Entry Geometry
Emphasis is made to design roundabouts with proper deflection, good speed control and natural drive paths. The entrance geometry is a critical feature in achieving this goal.

Good Deflection
Good deflection is achieved when the vehicle crossing the yield line is pointed into the circulating lane. Without proper deflection, the vehicle crossing the yield line is often pointed into the central island. In single lane roundabouts this robs capacity; however, in a multi-lane roundabout lack of deflection leads to collisions. This is called path overlap and can be seen in Figure 6-3.

To ensure good deflection is achieved the entrance curve must be long enough so that the driver is following the curvature of the design. In a single lane roundabout, a curve length of approximately 2-3 car lengths will help achieve this. In a multi-lane roundabout, a series of successive curves may be necessary. In addition, the approach alignment curve should be tangent to a 3-5 feet offset of the central island. This is effectively adding in a spiral to the entrance geometry. The entrance geometry can be seen in Figure 6-2.

To avoid path overlap, sometimes the engineer will place a tangent from the last entry radius to the yield line. This is called the tangent method and is not allowed for the following reasons:

- Adding a tangent between curves does not provide a natural drive path.
- Often, when a tangent is added, the path overlap is not avoided, it is just shifted from the entrance to the exit, or from the entrance of the circulating lane to the entrance of the entry curve.
- Path overlap is a result of designing un-natural drive paths into the design and the tangent method can compound this issue.

Good Speed Control
The entry geometry also controls the speed at which a vehicle can enter the roundabout. Speed is not only controlled by the entry radius dimension, but also by the length of the entry radius. There is a balance in the design of the entrance radius. With a radius that is too tight there is potential for rear-end collisions. However, with a larger radius, sideswipe collisions may result. See Figure 6-2 for acceptable ranges of these design elements.

Natural Drive Paths
Designing a roundabout with natural drive paths is important in maintaining the capacity forecasted by the analysis software as well as for addressing safety concerns. An engineer should never design for something a driver will not drive. This includes angle points between curves, curves with very tight radii that will not be negotiated well, or uneven transitions between curves.

Exit Geometry
It is important to design the exit so that the exiting speed is faster than the circulating speed. This follows driver expectation and will mitigate rear end collisions due to unexpected braking in the roundabout. The appearance of an exit radius is necessary, because although it does not physically control vehicle speed it does play a role in reminding drivers that they are still in the roundabout. The exit speed is important because of the crosswalk located downstream of the exit. The speed of the exit is based on the circulating speed and the acceleration plus distance to the crosswalk.

Path overlap issues can also occur at the roundabout exits. There are two primary reasons that this can occur:

- The exit radius is too tight, and rather than slow down to negotiate the exit, vehicles encroach into the adjacent lane.
- The curbing is not a natural radius for the right turn movement and angle points exist. Vehicles tend to smooth out these curbing quirks by encroaching into adjacent lanes.

Splitter Islands
The splitter island effectively separates the entering traffic from the exiting traffic of the roundabout. Although it is not quantified in the capacity software, the entrance capacity is increased as the separation between the entrance and exit is increased. This is because the exiting traffic commits to exiting earlier if the separation between the two is greater. The entering vehicle can then move into the circulating lane, knowing they will not have to yield to the exiting vehicle. This can be used to the engineer’s advantage to increase the entrance capacity, or sometimes decrease the entrance capacity to provide gaps for the downstream legs.

The length of the splitter island helps control the speed of the approaching vehicles. This splitter island configuration for a high speed approach, as well as lower speed approaches can be seen in Figure 6-6.

Truck Aprons

Truck aprons are used to facilitate the movement of large vehicles. The trailer portion of the truck will track onto the truck apron. Truck aprons are typically designed around the central island but in site specific locations can be placed at outside curves. The truck apron is separated from the vehicle lane by a mountable curb, and must be easily distinguishable from the roadway as well as any pedestrian facilities. For this reason a colored textured concrete pavement is used. Roundabout curbing details can be found in the standard plans.

Pedestrian access across truck aprons must be clearly delineated for the safety of the pedestrian. The truck apron should not be part of the sidewalk ramp, and should be treated as the roadway in regard to pedestrian activity. See Standard Detail RB-3.

Bypass Lanes

The safety benefits of a single lane roundabout are significant and should be preserved as much as possible. When a single lane roundabout does not have enough capacity for the traffic volume in the design year, a bypass lane should be considered before proposing a full multi-lane roundabout.

Bypass lanes can be used for various reasons:

- To accommodate a high volume of right turning movements (or through movements on a three-leg roundabout)
- To reduce the queue length of a leg that is having difficulty finding gaps in the circulating traffic
- To accommodate heavy vehicles on a right turning movement when the radius of the right turn through the roundabout is too small.

Bypass lanes can either be designed as continuous bypass, such that the bypass ends in its own lane downstream of the roundabout, or it can be designed as a yielding bypass, such that the bypass vehicles must yield to the exiting vehicles downstream of the roundabout. If the design vehicle is unable to negotiate the bypass lane with the maximum width, a truck apron along the bypass lane should be considered.

Roundabout Performance Measures

After the initial roundabout design is completed, the following safety checks must be performed to evaluate the safety and performance of the roundabout. It is important to perform the following safety checks on the final roundabout geometric layout.

AutoTURN

The results of turning movements are used to determine the placement of larger entry curves or wider entry flares. It also dictates the width and placement of truck aprons.

Fastest Drive Paths

Roundabout vehicle speeds are quantified by examining the five critical path radii: R1, R2, R3, R4, and R5 curves. These are the radii of the entering, circulating, exiting, left-turn, and right-turn movements, respectively. See Figure 6-7. The procedure for calculating the fastest path is modified from one developed by the Ada County Highway District in Idaho. The purpose of this procedure is not to trace the actual spiral path through the roundabout, but rather to provide arc radii that match the fastest path spiral radii at their tightest points. The results from this method are intended to be objective, repeatable, consistent with NCHRP 672, and reflect anticipated driver behavior. Using the Speed Radius Relationship Table found in Figure 6-7, a speed can then be assigned to each of these arc radii. The exit speed is based on the circulating speed plus the distance to the crosswalk with an acceleration rate of 6.9 feet/second2. The method can be found in Figures 6-8(a-d) and Figures 6-9(a-d).

Speed Continuity
The speed differential between all conflicting movements must be calculated. For example, the path of an entering vehicle crosses with the path of a circling vehicle. By keeping the speeds between these two vehicles close, the severity of a collision, if one occurs, is very low.

Natural Drive Path
Ensure the design will accommodate a natural drive path and that path overlap is avoided. The method for determining the likelihood that path overlap will occur is modified from one developed by the Wisconsin Department of Transportation. This method can be seen in Figure 6-10.

Roundabout Calculation Checklist
Figure 6-11 is a checklist that can be used to analyze a roundabout's final design and verify that all design elements are working together to achieve appropriate driver behavior. This list serves as a reminder of the necessary safety checks associated with a well-designed roundabout.

Sight Distance
As part of any roundabout design, sight distance exhibits that determine where the tall and low plantings are required must be prepared. The process of creating these sight distance exhibits can be seen in Figure 6-12 through Figure 6-14.

As the driver approaches a roundabout, they must determine if it is necessary to yield to a pedestrian. The speed of these calculations should be based on the approach speed. For the pedestrian sight line, the sight triangle should encompass the pedestrian refuge island as well as the sidewalk ramps.

The driver must also have enough sight distance to be able to stop if another vehicle is at the yield line. This stopping sight distance should be calculated based on the average of the approach speed and the entering design speed (R1).

When the vehicle is at the yield line, a sight triangle must be clear for them to see the pedestrian activity on the downstream leg. This sight triangle must also include the pedestrian refuge island and the sidewalk ramps. As the vehicle is circulating the roundabout, a sight triangle must ensure a stopping sight distance if an object is blocking the circulating lane.

In addition to the stopping sight distance, an intersection sight distance must be calculated for each approach. This is the distance an approaching vehicle needs to judge whether an acceptable gap will allow them to enter the roundabout without stopping. This approaching vehicle needs to yield to the conflicting traffic made up of any vehicle within the circulating lane as well as any vehicle from the upstream approach entering the roundabout first. This sight line is calculated as the approaching vehicle is 50 feet from the yield line. The length of the path of the conflicting traffic assumes a driver's eye height of 3.54 feet and is measured by:

$$d=1.468(V)(t_c)$$

where: d = length of the path of the conflicting vehicle (feet)
V = speed of the conflicting vehicle (mph)
Circulating Vehicle Speed = Circulating Speed (R4)
Upstream Approaching Speed = Average of Entry Speed (R1) and Circulating Speed (R2)
T_c = critical gap for entering the circulating roadway (4.5 seconds)

Access Management
Commercial driveways accessing the intersection may be designed as a small leg of the roundabout. It is not desirable to have commercial driveways access the circulating lane without designing them as a leg of the roundabout. Because roundabouts provide U-turn capabilities, right-in/right-out access control may be successfully implemented. Gas stations require specific attention to ensure the fuel delivery routes can be accommodated.

Pedestrian
Pedestrian facilities must be compliant with ADA standards. The pedestrian refuge in the splitter island should have an angle point in the center of the island to help direct pedestrians. See Standard Detail RB-4.

Bicycle Facilities
A short taper is provided when ending the bike lane, in order to encourage bicyclists to get in the center of the travel lane. The bicycle lane should end approximately 50 feet from the yield line. In no case should the bicycle lane continue through the roundabout.

In some cases, a bicycle ramp to a multi-use trail should be provided where the bicycle lane has ended. See Standard Detail RB-1 and RB-2 for bicycle ramp guidelines.

Bus Facilities
Care must be taken so that pedestrians and critical signs are not blocked when bus is stopped, and vehicles can continue around the bus.

Grading
The roundabout grading is developed and modeled using design software. A proposed surface is built and used to extract quantities, cross sections, and obtain cut and fill lines. This surface is also used to determine the drainage structure requirements and proposed surface over the storm drainage lines. See Figure 6-15 and Figure 6-16.

Drainage
Drainage requirements for roundabout projects do not differ from other City roadway projects.

Utilities
Utility coordination (relocation and adjustments) for roundabout design does not differ from other City roadway projects.

Illumination
Provide illumination for each of the conflict points between circulating and entering traffic in the roundabout and at the beginning of the raised splitter islands. Position the luminaires on the downstream side of each crosswalk to improve the visibility of pedestrians. Ground-level lighting within the central island that shines upward toward objects in the central island can also improve their visibility. See Figure 6-17. When the luminaire pole is located within the Design Clear Zone, breakaway and slip base features are used to reduce the severity of an impact.

For additional information and requirements on illumination, see the City of Redmond Illumination Design Manual.

Landscaping:
Landscaping is an important element in roundabout design and, if done correctly, can enhance the safety and capacity of the roundabout. In a constructed roundabout, there are areas where tall plantings are desirable. Landscaping in the central island can provide the first indication from far away that the roadway context is changing and the driver needs to slow down to negotiate what lies up ahead. The center island landscaping, vegetation, and artwork also provide an aesthetically pleasing traffic-calming feature to the street network. Art work should be attractive but not so distracting, or elaborate as to invite pedestrians to the center island for inspection.

The sight distance triangles (Figure 6-12, through Figure 6-14) should guide on the placing of tall plantings and objects (above 18 inches) verses low plantings and objects (under 18 inches). Through the use of low and tall plantings, good landscaping will direct the driver's attention to what they should be focusing on and eliminate unnecessary confusion. Landscaping must not obscure pedestrians from the motorists' view. It is also necessary to provide enough sight distance for the approaching driver to make a decision as to whether they can safely enter the roundabout.

Ground level landscaping on the outside of the circulating lane provides a safety buffer between the motor vehicle and pedestrian traffic. It directs the pedestrian to their correct crossing location and discourages pedestrians from crossing through the circulating lane into the central island.

The designer is encouraged to use native and drought resistant plantings to reduce or eliminate the necessary irrigation. Fixed objects must be used with care and conform to clear zone requirements.

Roundabout Materials
See Table 6-1

Channelization

Signing
In general signing must be consistent with the pavement markings and provide reinforcement to the geometry and pavement markings. The following is a list of signs used in roundabout design and can be seen in Figure 6-20:

Roundabout Ahead Sign (W2-6) with Speed Advisory Plaque (W13-1P) – Follow the MUTCD guidelines for placement of this sign. The advisory sign should be the circulating speed of the roundabout.

Destination Sign (D1-5) – This sign does not need to be used in every roundabout design, but is useful in intersections with tourist destinations. This sign should be placed in accordance with MUTCD guidelines after the Roundabout Ahead sign, but before the Lane Usage Sign.

Lane Usage Sign (R3-8 MOD) – This sign must be consistent with the pavement markings, and should not be combined with the destination sign. This sign should use the fishhook arrows shown in MUTCD Figure 2B-5b and be placed according to MUTCD guidelines. A detail of this sign can be seen in RB-11.

Pedestrian Crosswalk Sign (W11-2) and Supplemental Arrow (W16-7p) – These should be placed near the outside curb of the roundabout on the entrance crosswalk and exit crosswalk. Care must be taken to avoid masking a pedestrian with this sign and the yield sign on the entrance.

Yield Sign (R1-2) – On a multi-lane roundabout this sign should be placed both on the outside of the roundabout curb and in the splitter island. On a single lane roundabout with a skewed approach, this sign must be placed on the outside (right) curb. A supplemental sign may be required on the splitter island, especially for approach speeds 45 mph or greater.

One Way Sign (R6-1R) and Chevron Sign (R6-4 or R6-4a) – This sign should be placed in line with drivers-eye view. The height of this sign is 4.5 feet rather than the typical 7.5 feet as pedestrian activity in the central island is discouraged. Use Chevron Sign (R6-4a) for approach speeds 45mph or greater

Street Name Signs (D1-1d) – The location for this sign is in the splitter island and should be orientated such that it is used to guide vehicles out of the roundabout on the correct exit.

Pavement Marking

Poor geometry cannot be mitigated with signing and striping. For example, a path overlap issue cannot be solved by designated striping. However, proper signing and striping is necessary to enhance the operations and safety of a roundabout. The striping should reinforce the geometry of the curb lines and follow a natural path to guide the users through the roundabout.

Channelization becomes critical in multi-lane roundabouts. Along with the signing, the channelization gives direction and reinforces the vehicles in their choice of lane to exit the roundabout on the appropriate leg. Figure 6-18 gives an example of channelization within a roundabout.

At intersections with a high volume of U-turn movements, the spiral striping should be used with care. A spiral stripe is often used in such cases for two reasons:

- It is desirable to spiral the inside lane toward the outside, so that when the vehicle is making the left turn, they do not hug the central island. If they stay to the inside of the roundabout, the outside vehicle on the approach has a tendency to edge into the roundabout without yielding and collisions occur when the circulating vehicle exits.
- Using the spiral stripe, the single lane exit of the roundabout is lined up for the circulating vehicle in a natural path.

Yielding is critical to roundabout operations and safety. To help reinforce this desired driver behavior, each entrance should be designed with “YIELD” pavement markings.

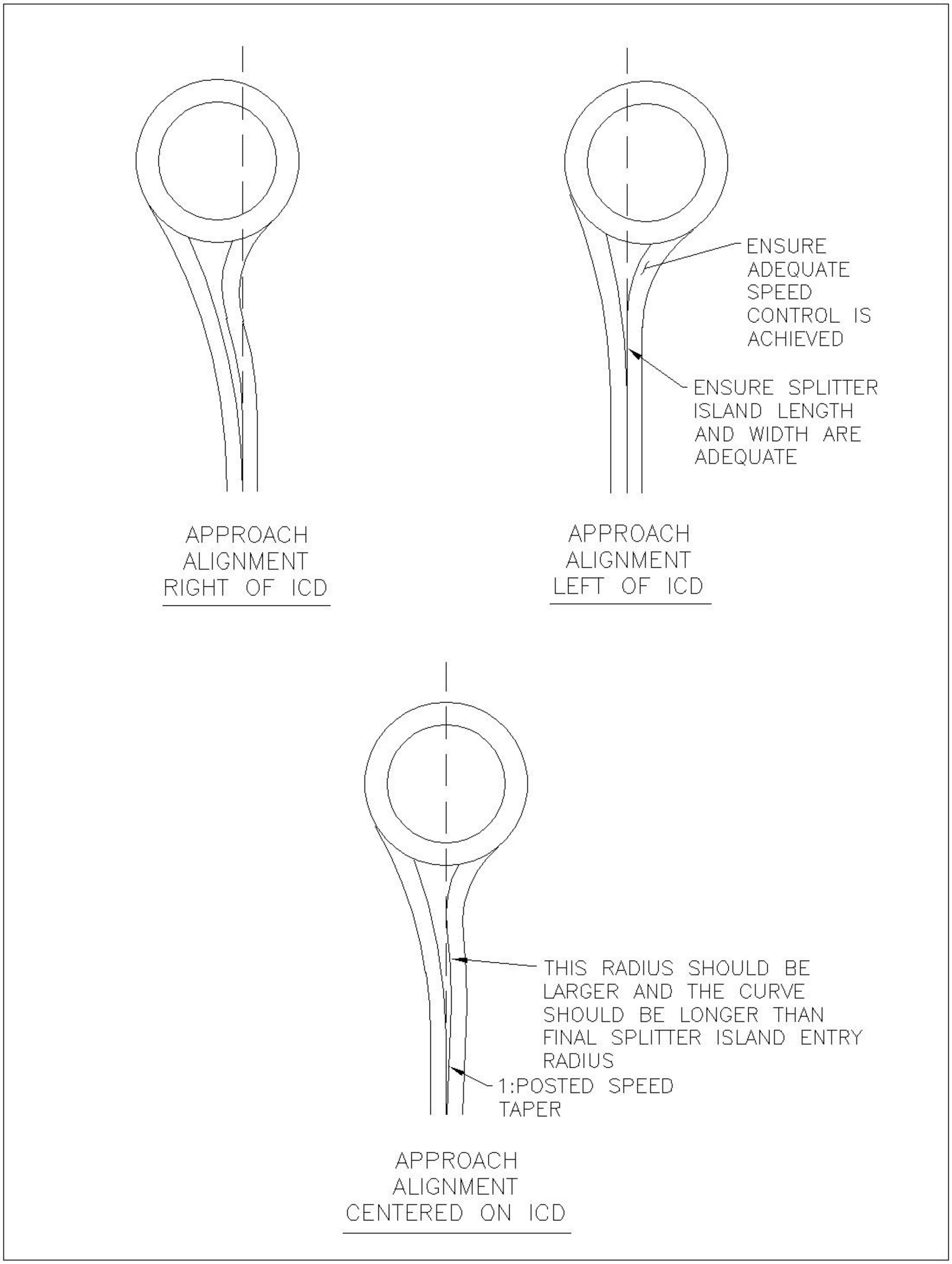


Figure 6-1 Approach Alignments

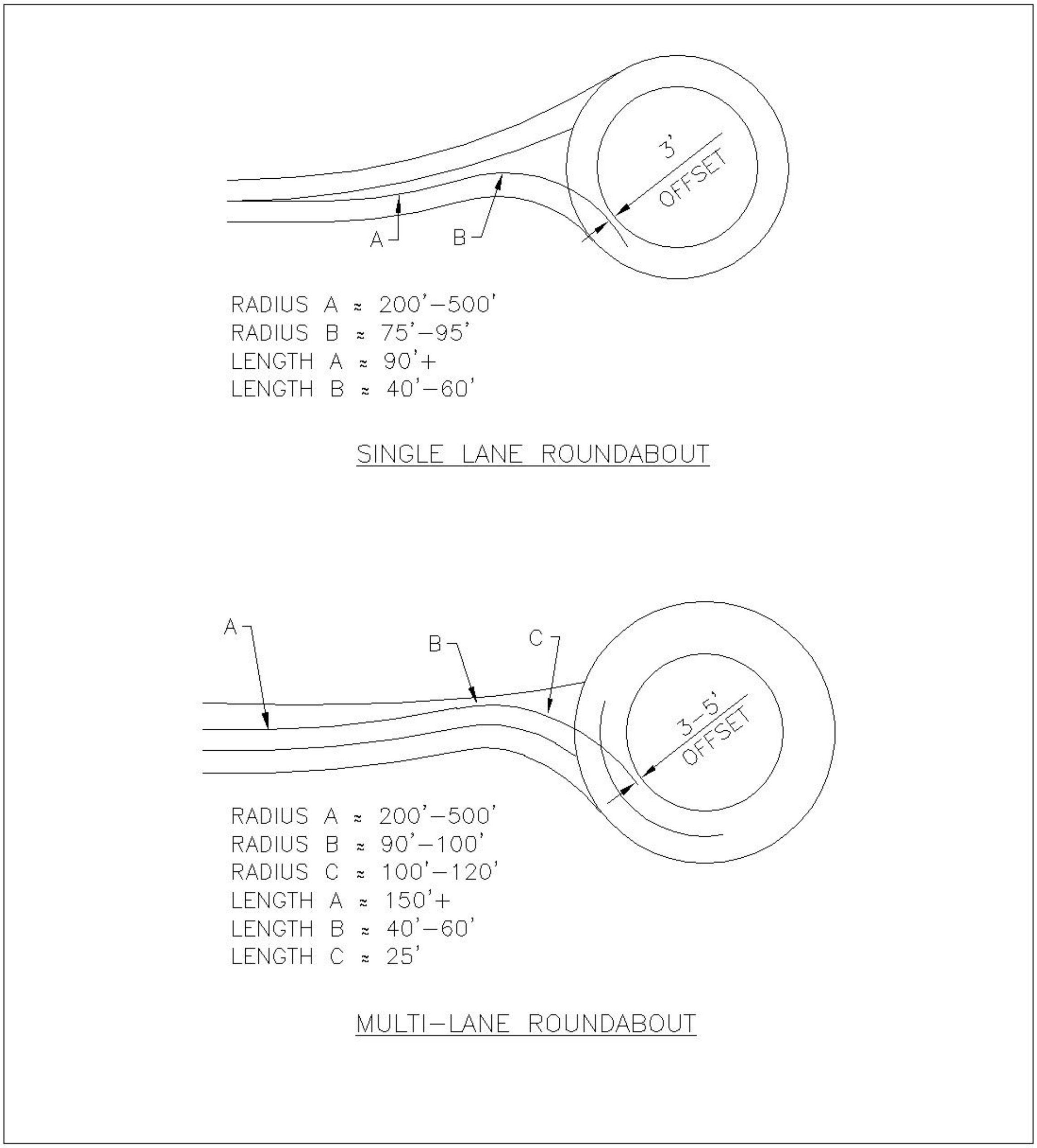


Figure 6-2 Entrance Geometry

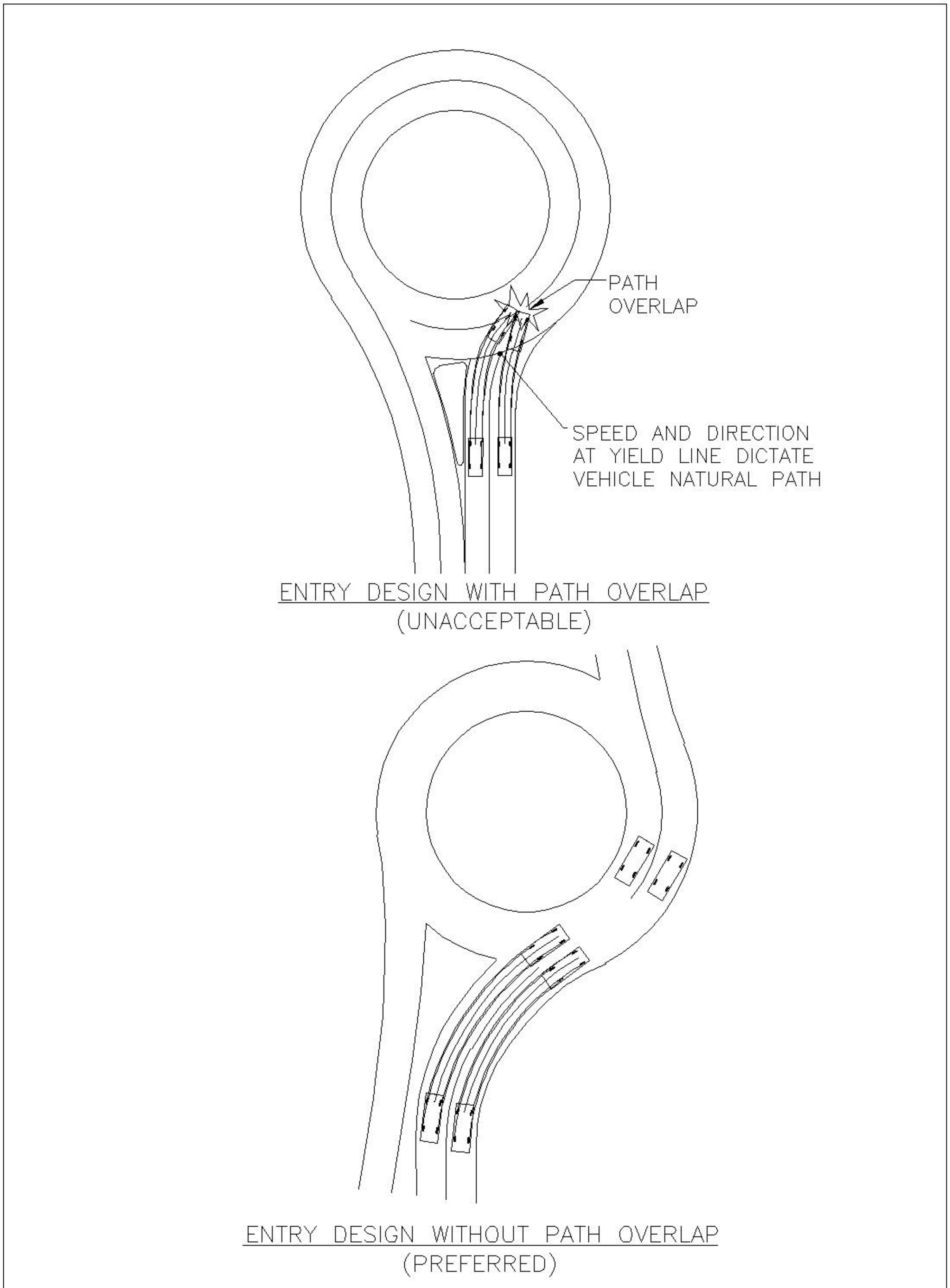


Figure 6-3 Path Overlap

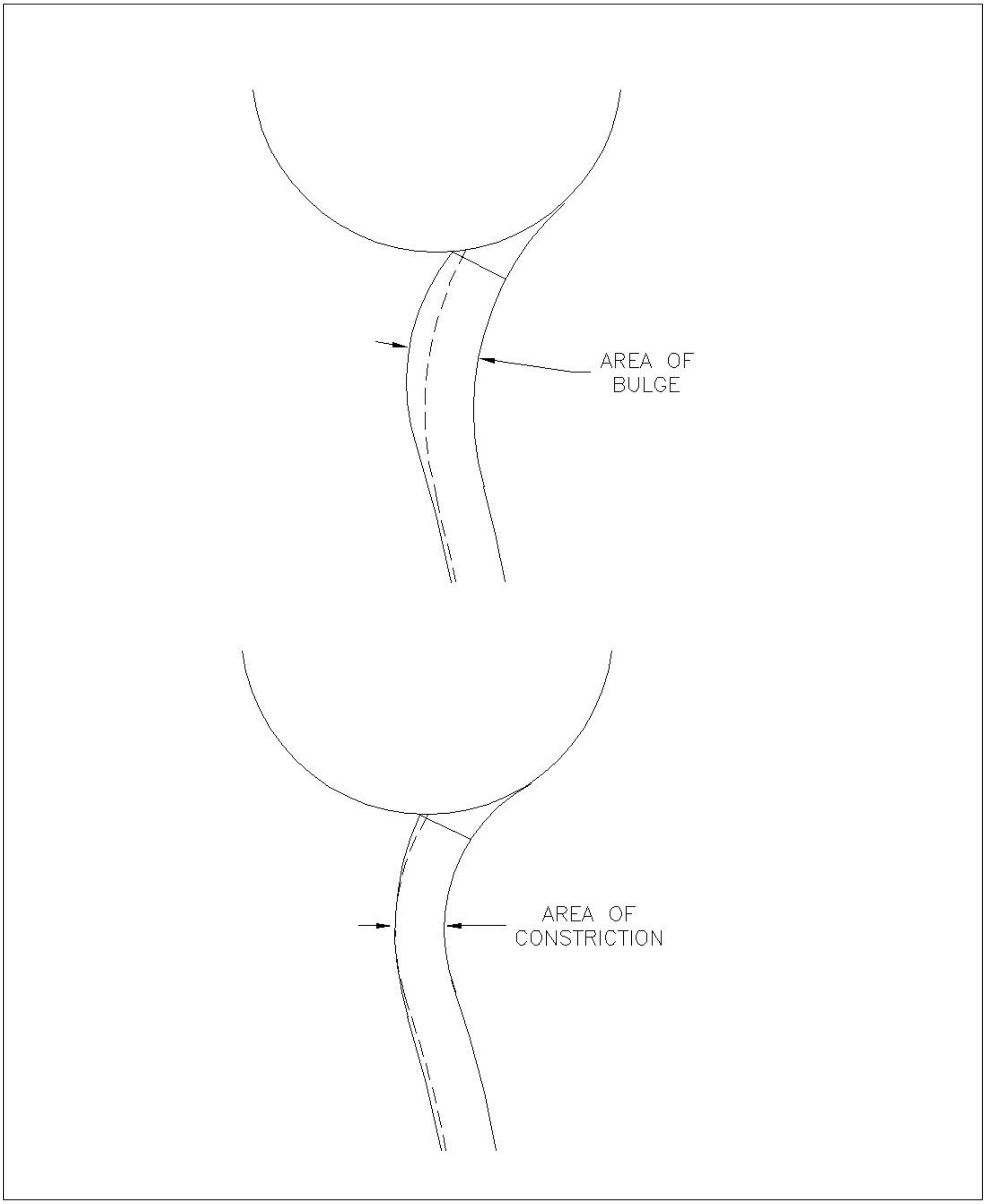


Figure 6-4 Consistent Flaring

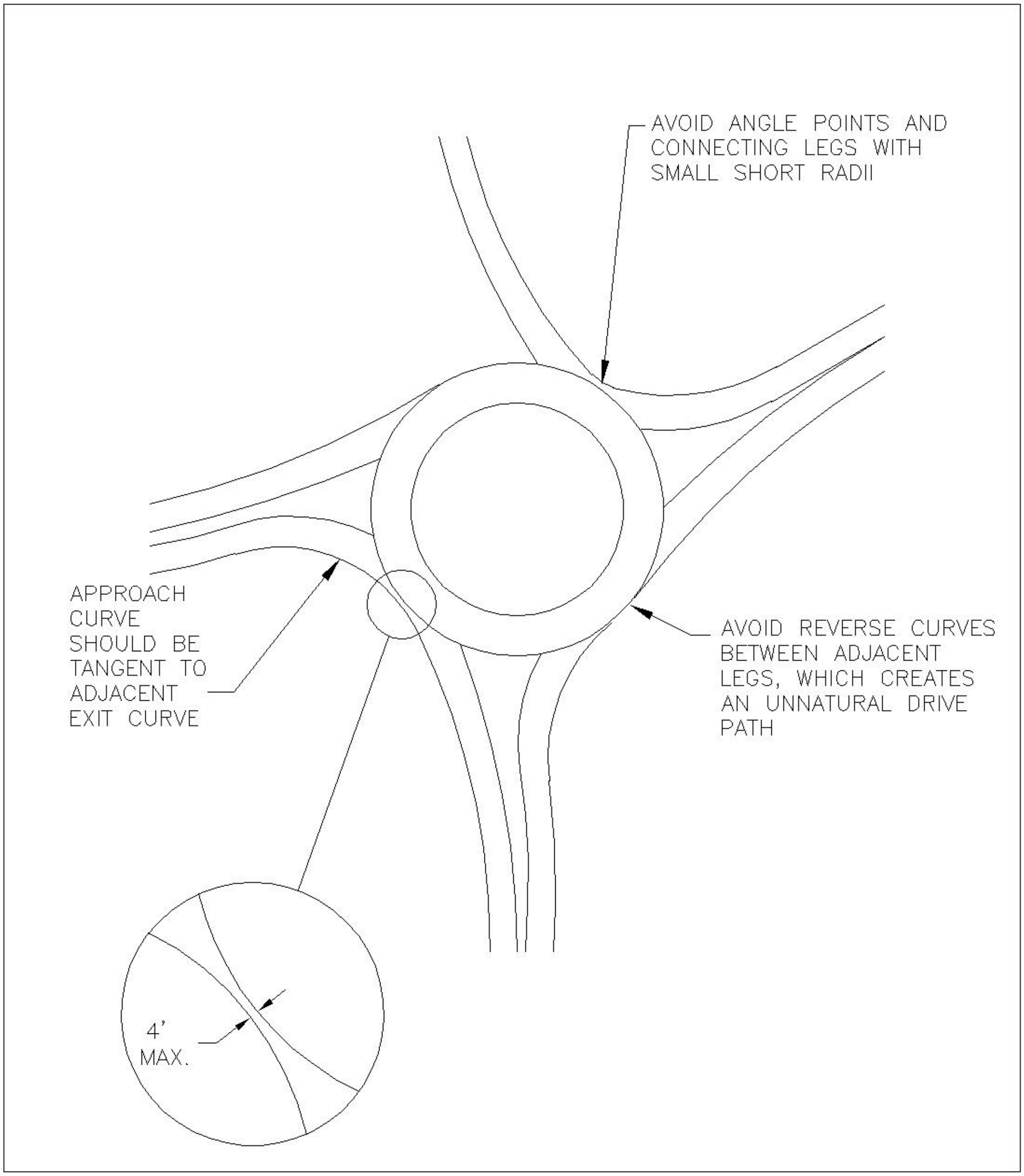


Figure 6-5 Adjacent Legs

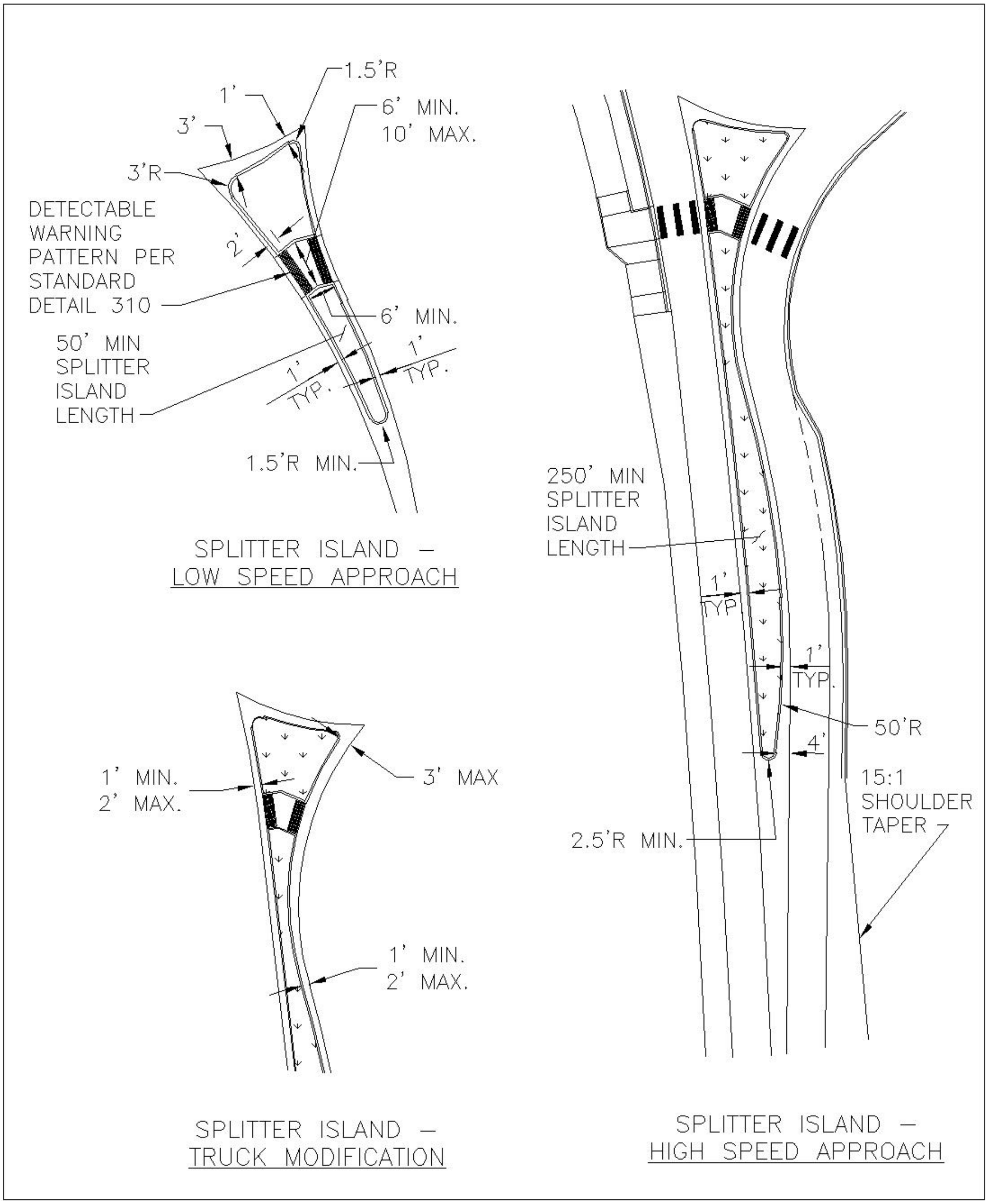


Figure 6-6 Splitter Island Configuration

Speed Radius Relationships

$V = \sqrt{15R(e+f)}$

V = Design speed, mph
R = Radius, ft
e = superelevation, ft/ft
f = side friction factor

Radius	R2 & R4 -.02 super	R1 & R3 & R5 .02 super	Radius
FT	Calculated V	Calculated V	M
50	15.0	16.0	15.2
55	15.6	16.6	16.8
60	16.2	17.2	18.3
65	16.5	17.7	19.8
70	17.1	18.3	21.3
75	17.6	18.8	22.9
80	18.0	19.3	24.4
85	18.2	19.6	25.9
90	18.7	20.1	27.4
95	19.1	20.5	29.0
100	19.6	21.0	30.5
105	19.8	21.4	32.0
110	20.3	21.9	33.5
115	20.4	22.0	35.1
120	20.8	22.5	36.6
125	21.3	23.0	38.1
130	21.5	23.3	39.6
135	21.7	23.5	41.1
140	22.1	23.9	42.7
145	22.5	24.3	44.2
150	22.4	24.3	45.7
155	22.8	24.7	47.2
160	23.1	25.1	48.8
165	23.5	25.5	50.3
170	23.4	25.4	51.8
175	23.7	25.8	53.3
180	24.0	26.2	54.9
185	24.4	26.5	56.4
190	24.7	26.9	57.9
195	24.8	27.0	59.4
200	24.8	27.1	61.0
205	25.1	27.4	62.5
210	25.4	27.8	64.0
215	25.3	27.8	65.5
220	25.6	28.1	67.1
225	25.9	28.4	68.6
230	26.2	28.7	70.1
235	26.5	29.0	71.6
240	26.5	29.1	73.2
245	26.6	29.3	74.7
250	26.9	29.6	76.2

V	f
mph	
15	0.32
16	0.31
17	0.30
18	0.29
19	0.28
20	0.27
21	0.261
22	0.252
23	0.243
24	0.234
25	0.225
26	0.219
27	0.213
28	0.207
29	0.201
30	0.195

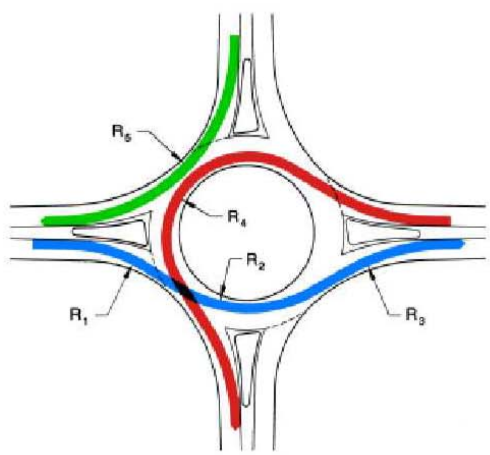


Figure 6-7 Speed Radius Relationship

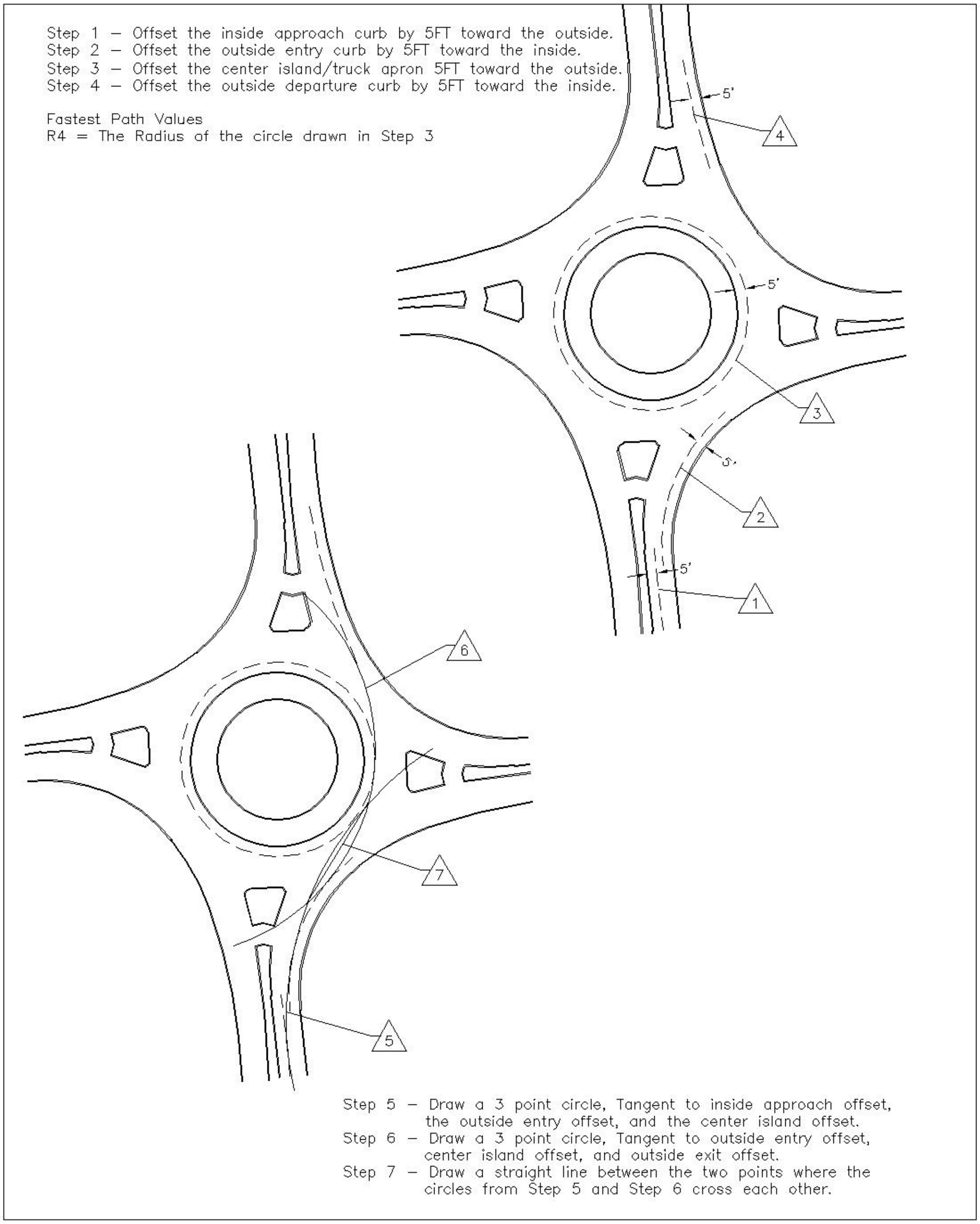


Figure 6-8a Single Lane Fastest Path Calculation

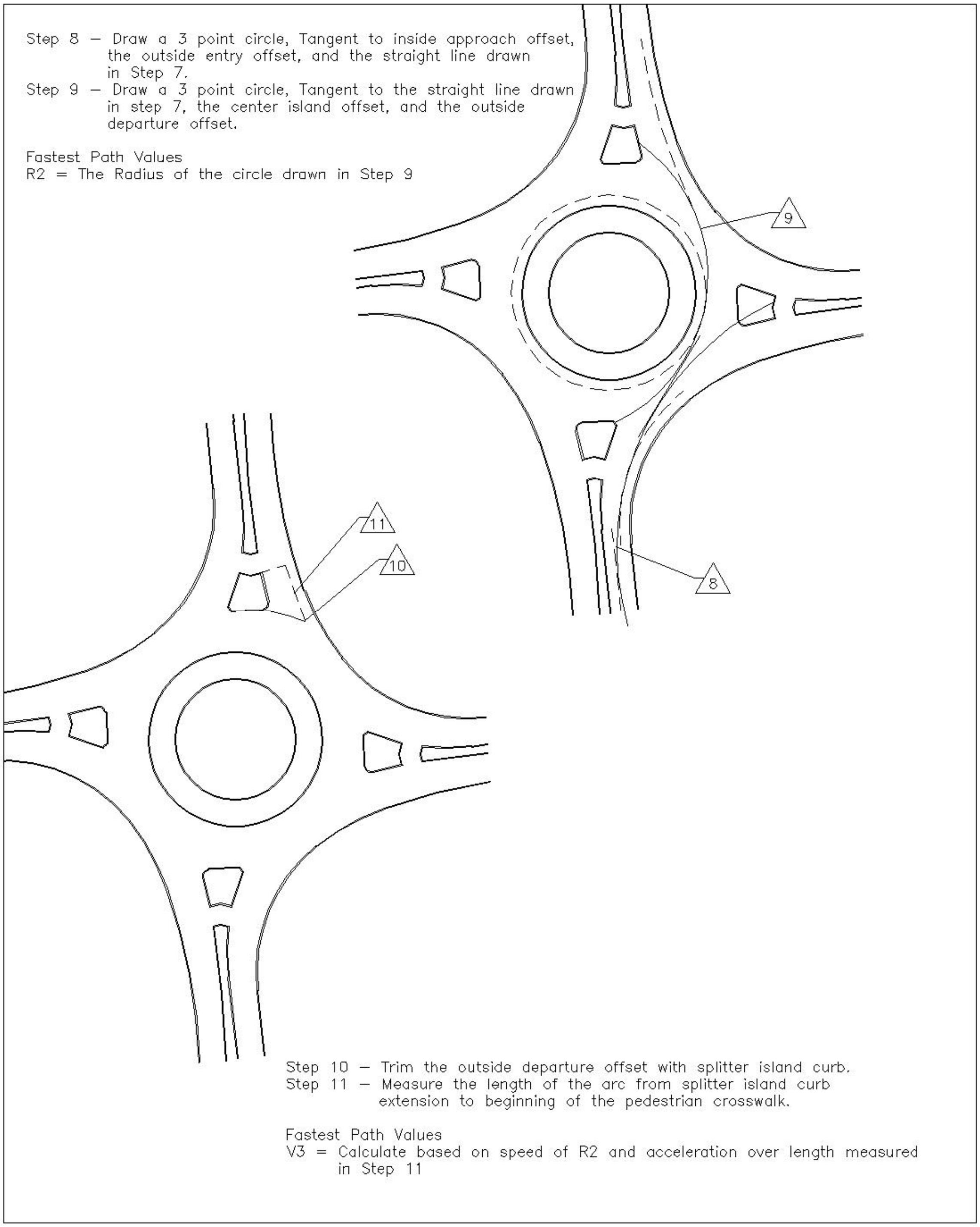


Figure 6-8b Single Lane Fastest Path Calculation

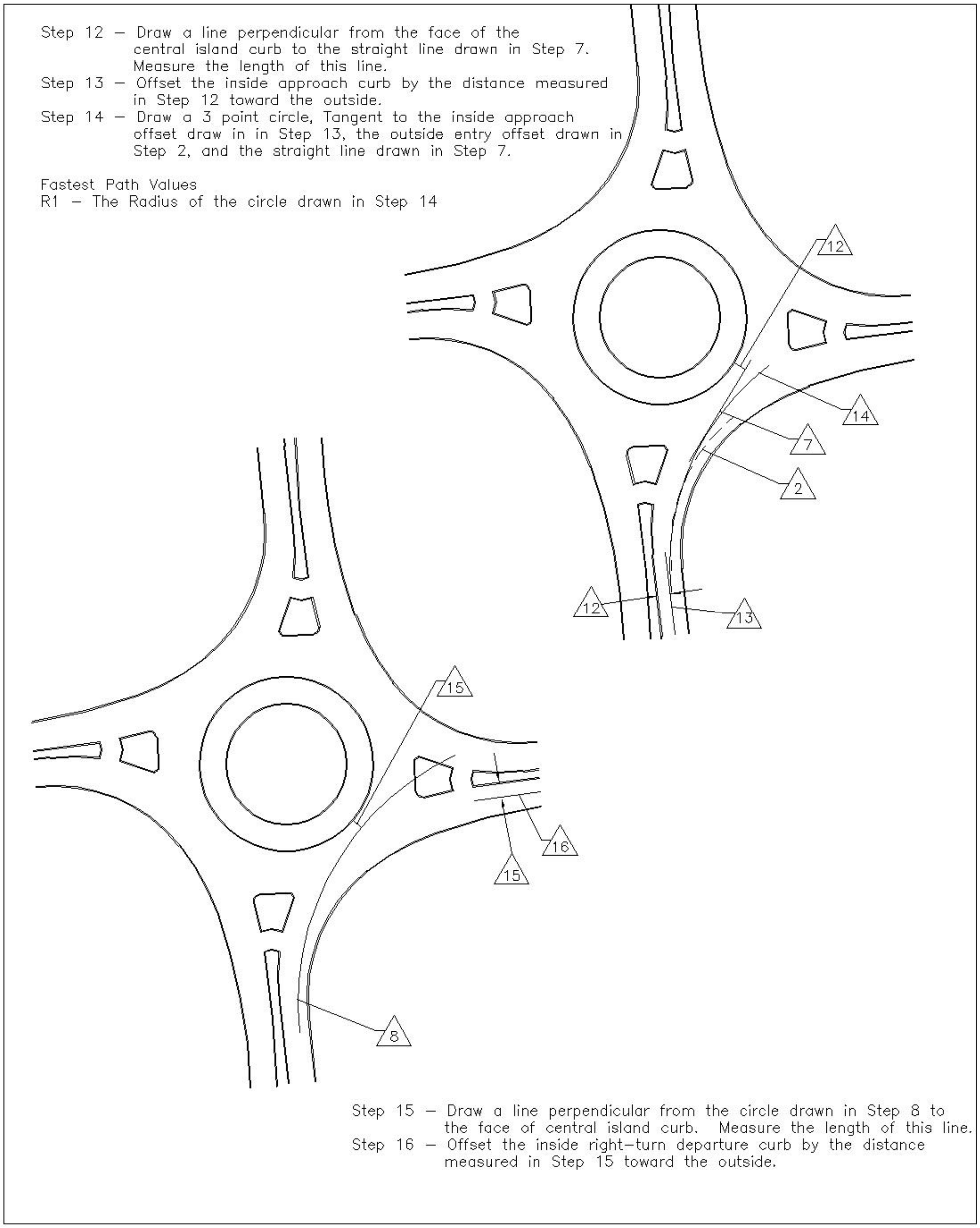


Figure 6-8c Single Lane Fastest Path Calculation

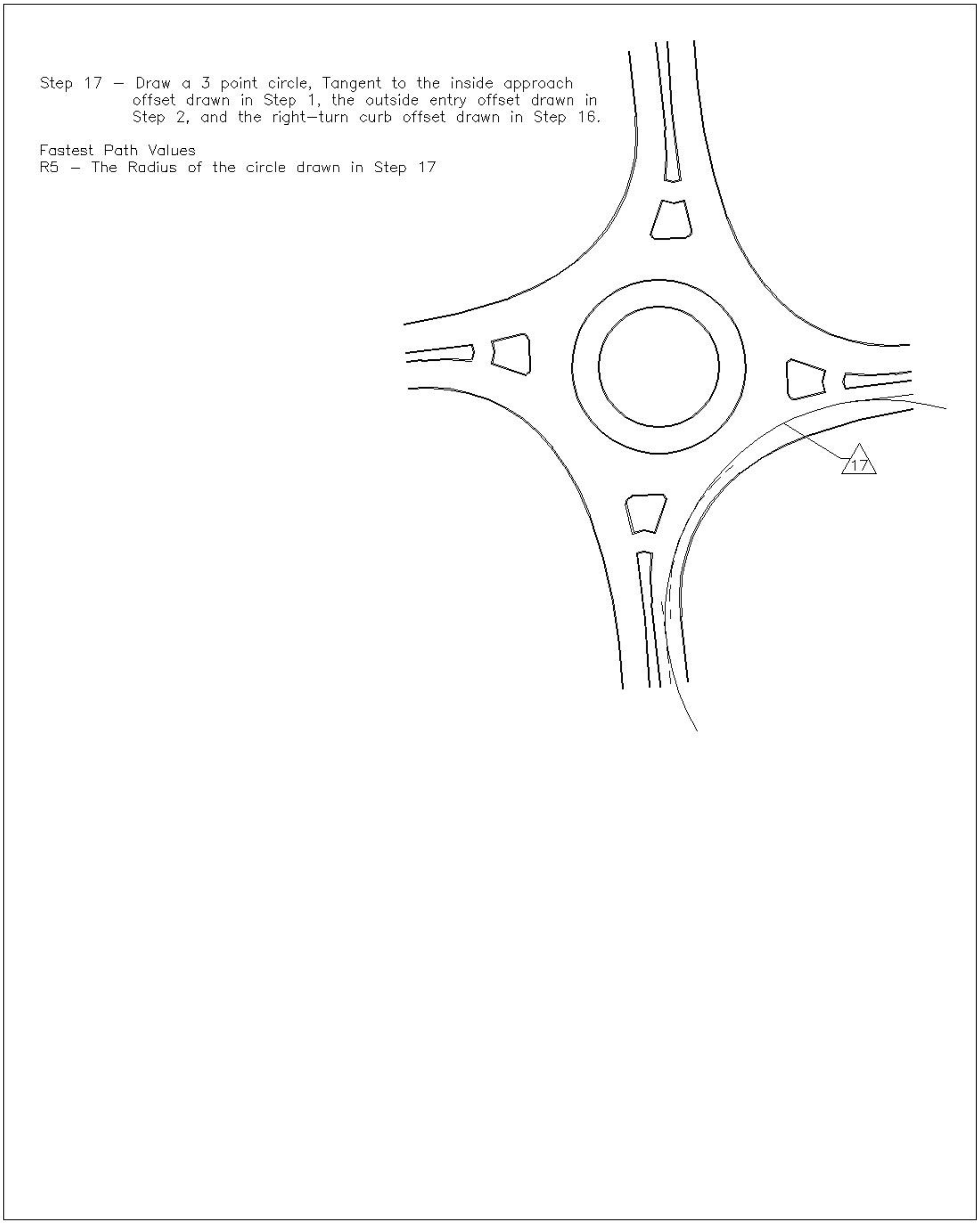


Figure 6-8d Single Lane Fastest Path Calculation

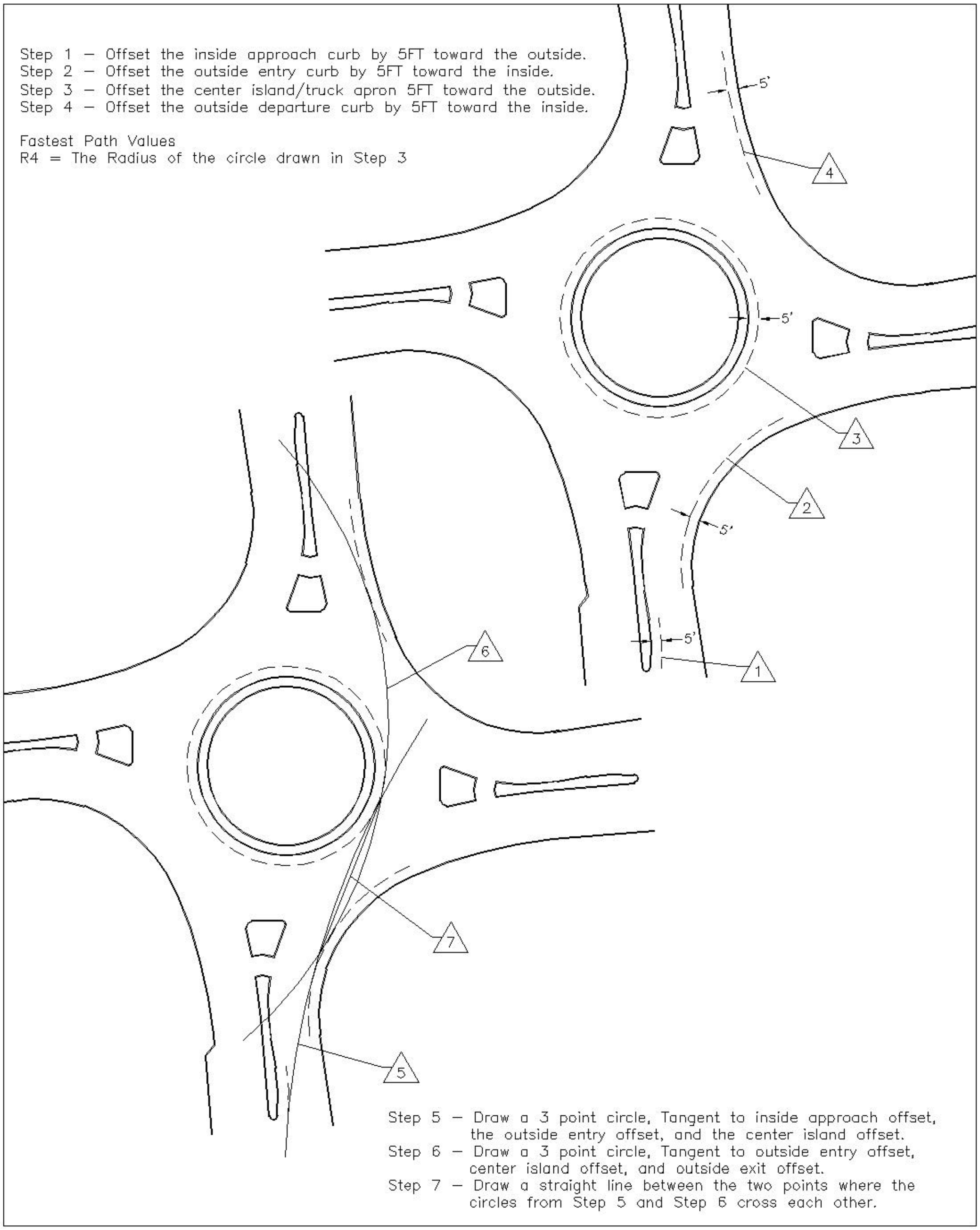


Figure 6-9a Multi-lane Fastest Path Calculation

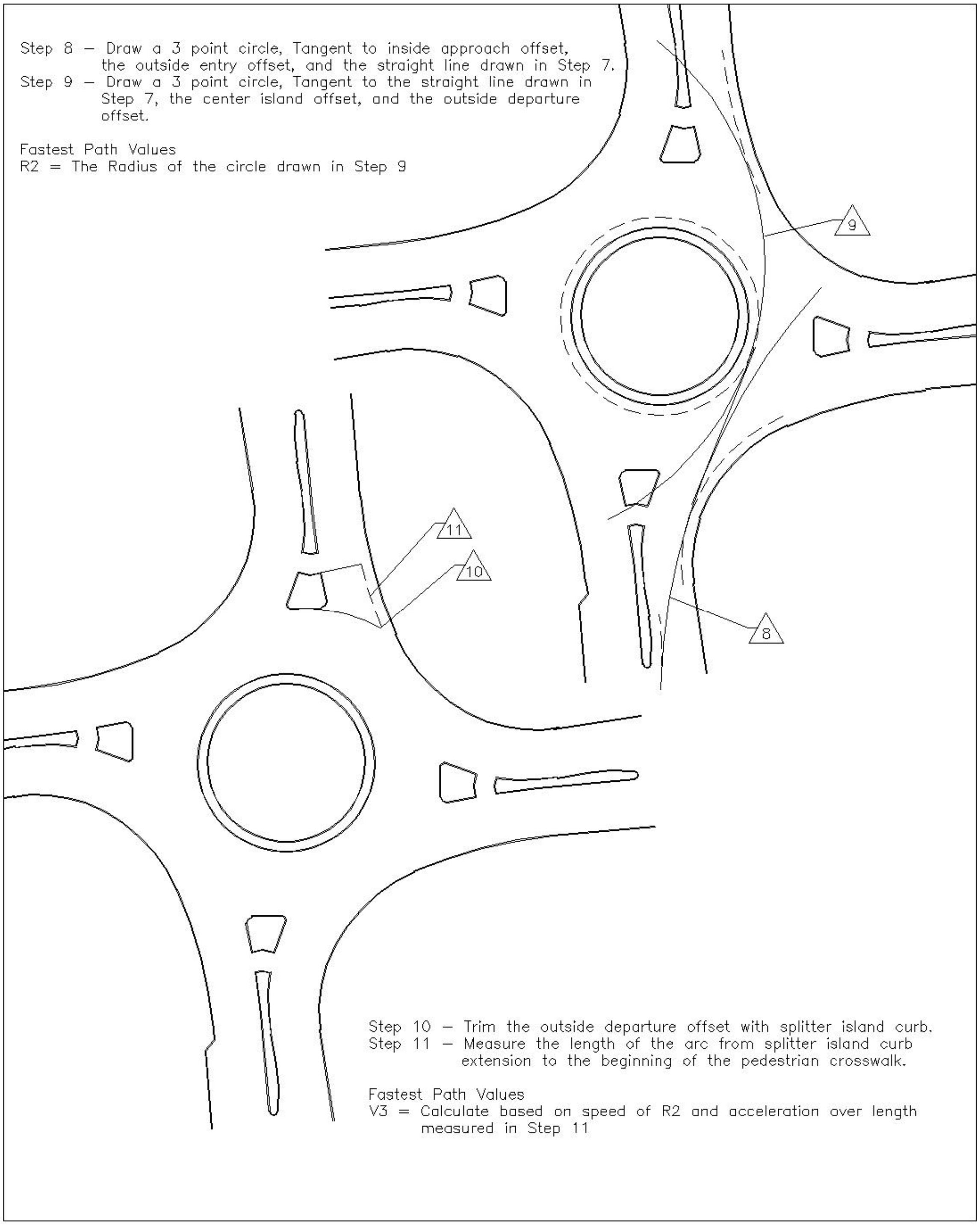


Figure 6-9b Multi-lane Fastest Path Calculation

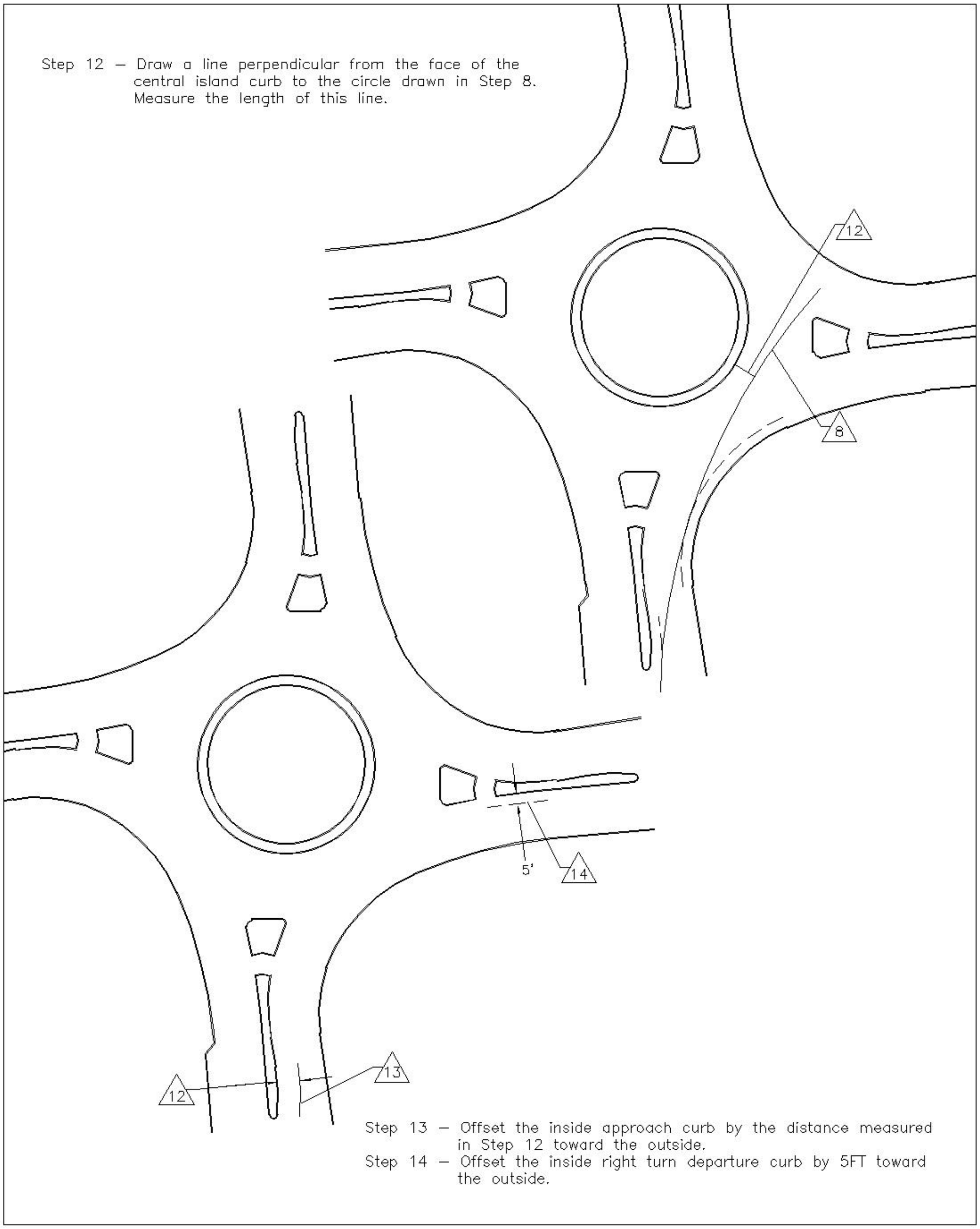


Figure 6-9c Multi-lane Fastest Path Calculation

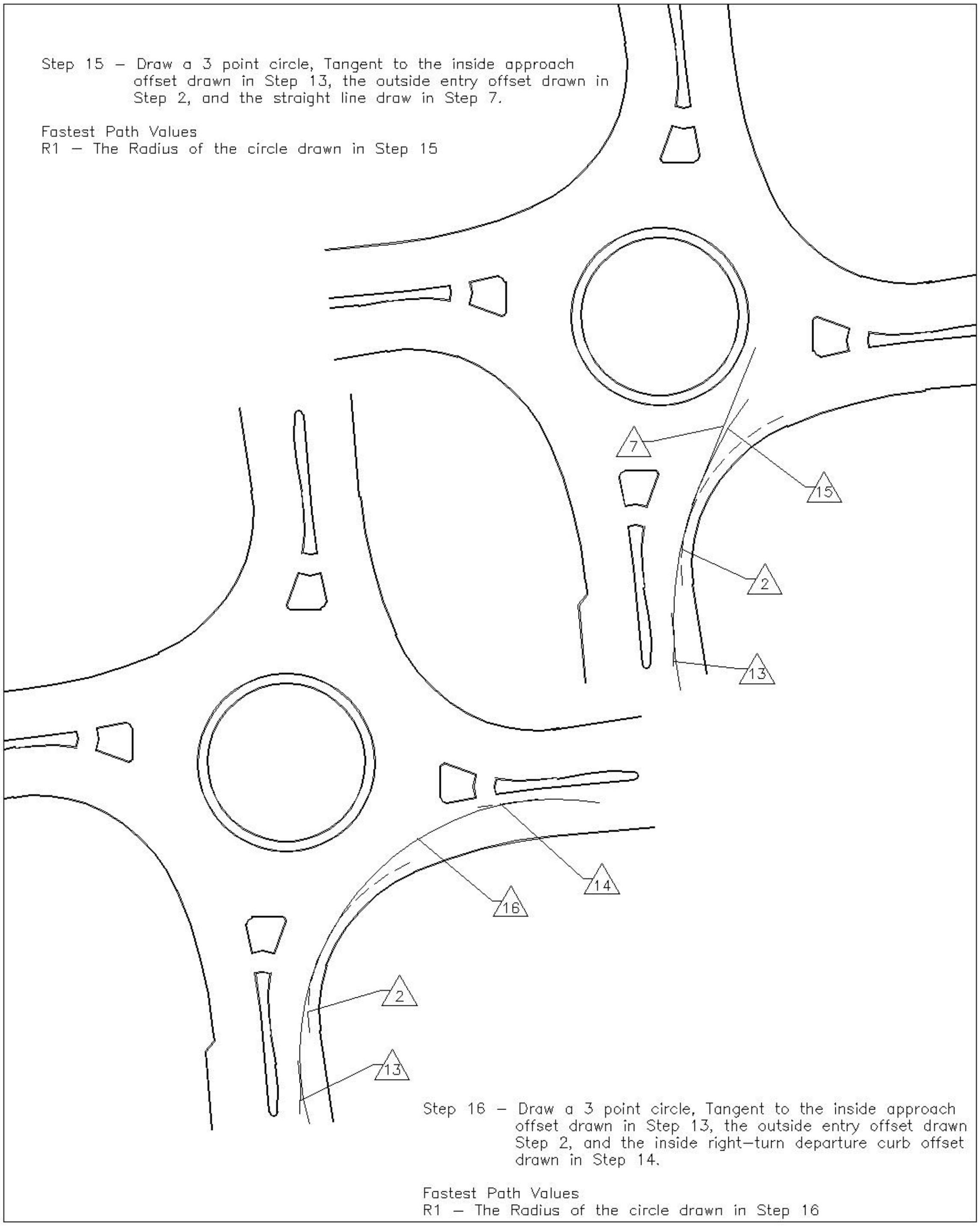


Figure 6-9d Multi-lane Fastest Path Calculationm

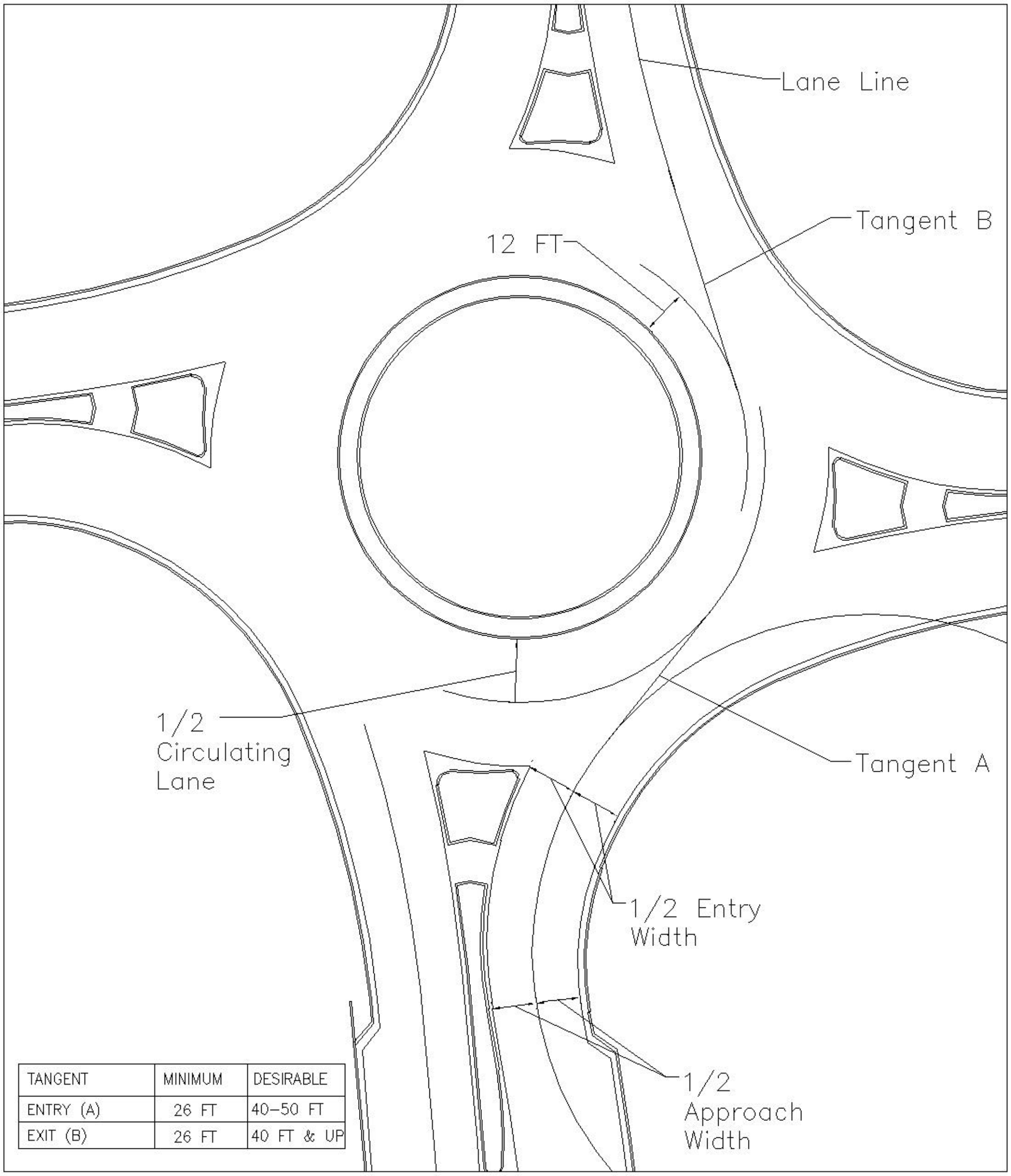


Figure 6-10 Path Overlap Check

General Characteristics

Circulating Roadway Width	
Inscribed Circle Diameter	
Central Island Diameter	
Truck Apron Width	
Design Vehicle	

	Southbound	Northbound	Eastbound	Westbound	Bypass
Approach Speed					
Approach Roadway Width					
Departure Roadway Width					
Entry Width					
Entry Angle					
Exit Width					
Bypass Width					
R1 - Entance Path Radius					
Superelevation					
Speed					
R2 - Circulating Path Radius					
Superelevation					
Speed					
R3 - Exit Path Radius					
Superelevation					
*Speed					
R4 - Left Turn Path Radius					
Superelevation					
Speed					
R5 - Right Turn Path Radius					
Superelevation					
Speed					
Intersection Sight Distance, S_1					
Intersection Sight Distance, S_2					
Approach Stopping Sight Dist					
Circ. Stopping Sight Dist					

* Exiting speed is calculated using the lesser speed from the measured radius or a standard acceleration and distance to crosswalk or merging point.

Figure 6-11 Roundabout Checklist

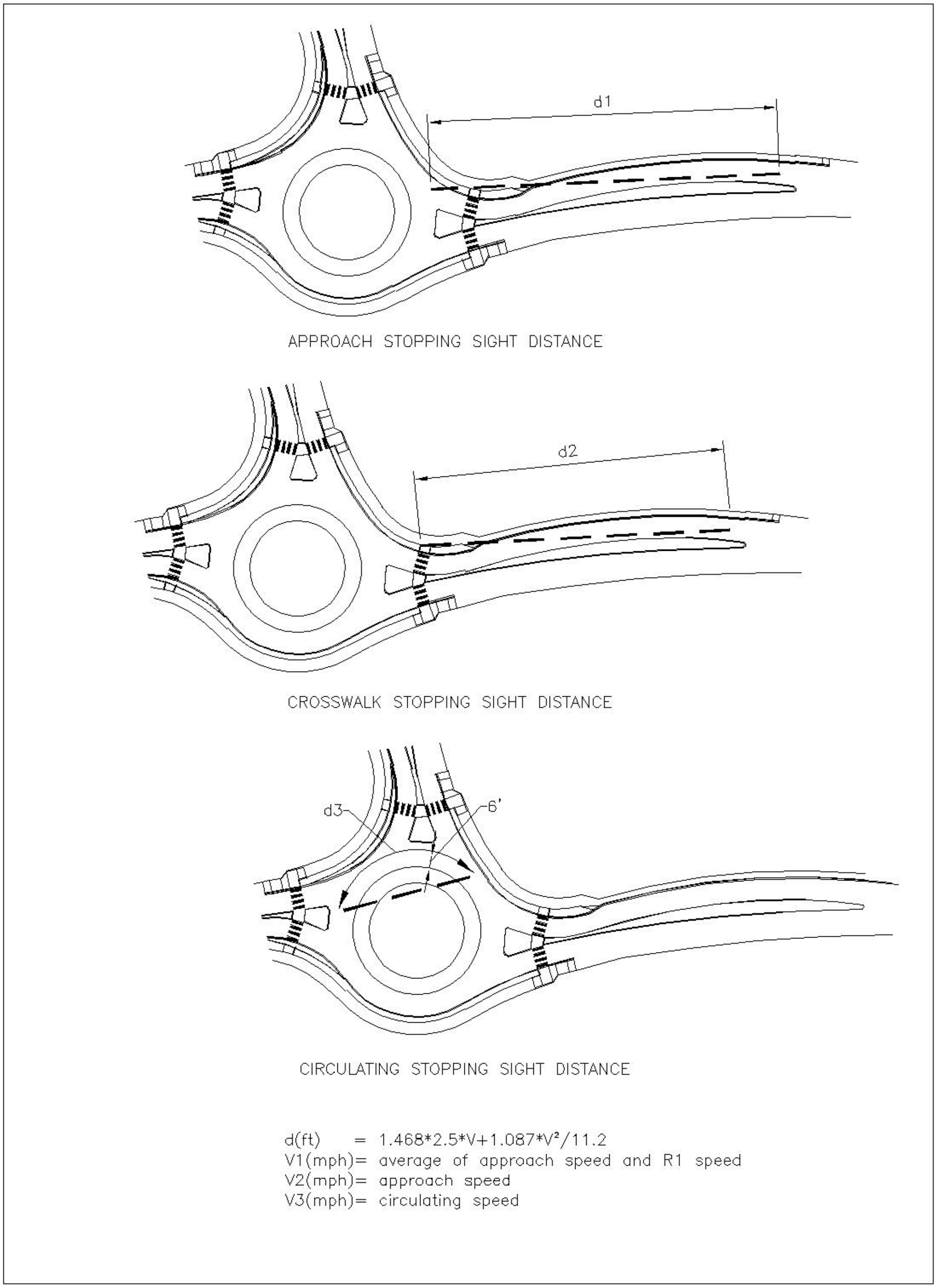
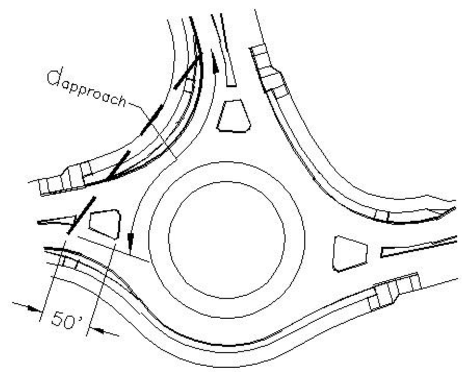
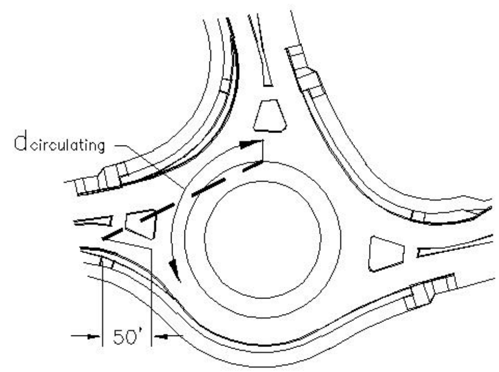


Figure 6-12 Stopping Sight Distance



APPROACH INTERSECTION SIGHT DISTANCE



CIRCULATING INTERSECTION SIGHT DISTANCE

d(ft)= 1.468*V*4.5
Vapproach(mph)= average of R1 and R2
Vcirculating(mph)= R4

Figure 6-13 Intersection Sight Distance

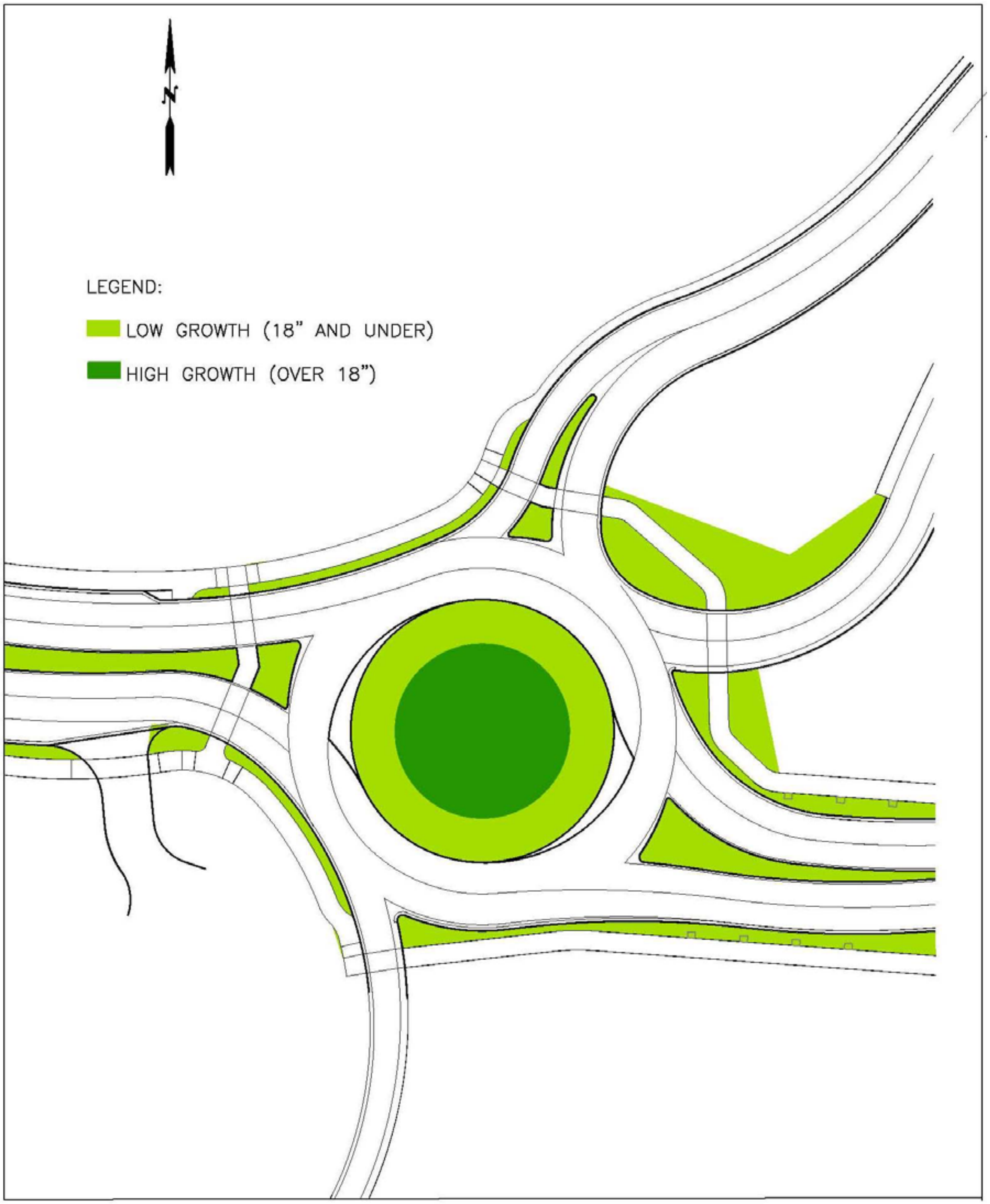


Figure 6-14 Landscaping Exhibit

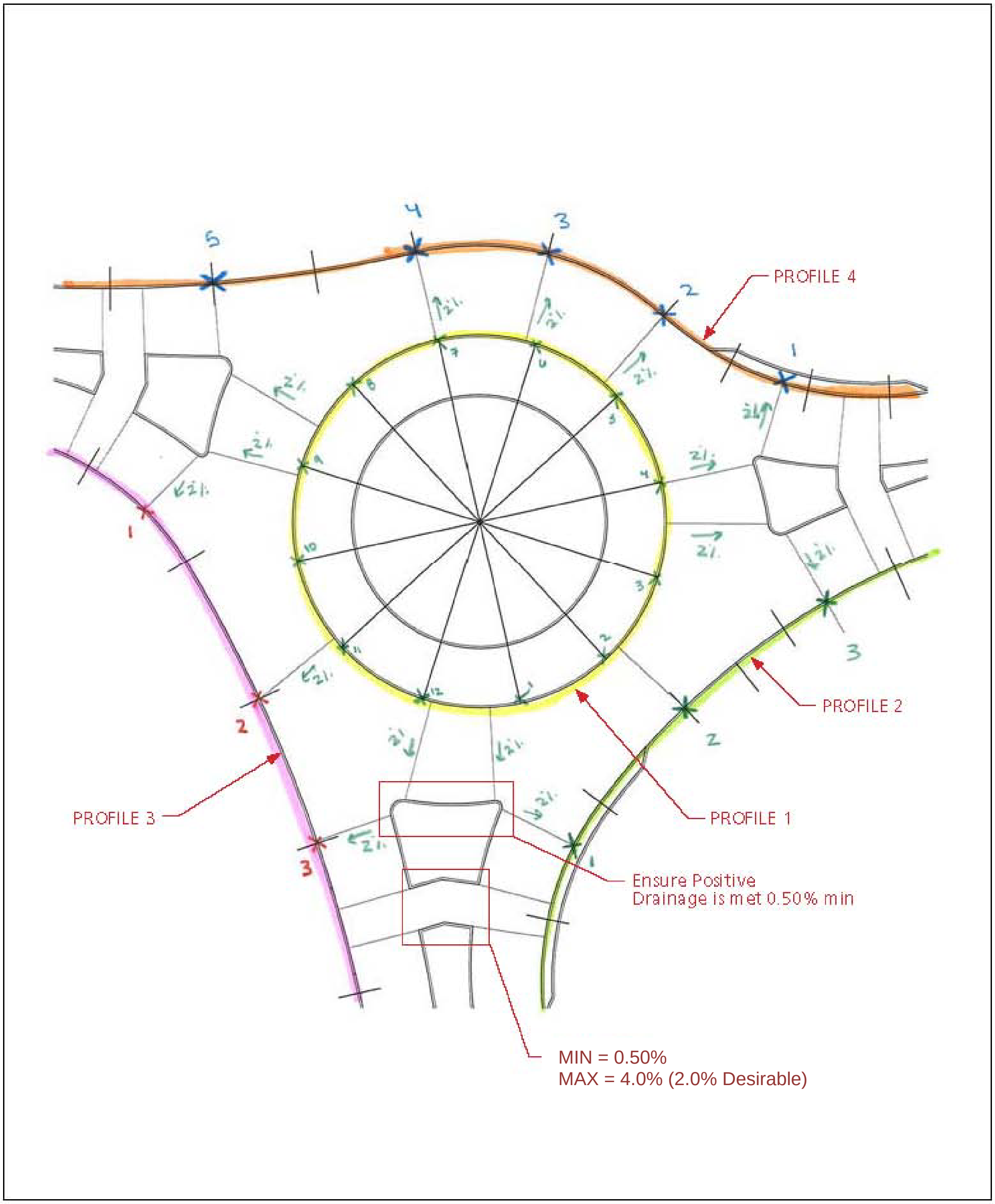


Figure 6-15 Roundabout Grading

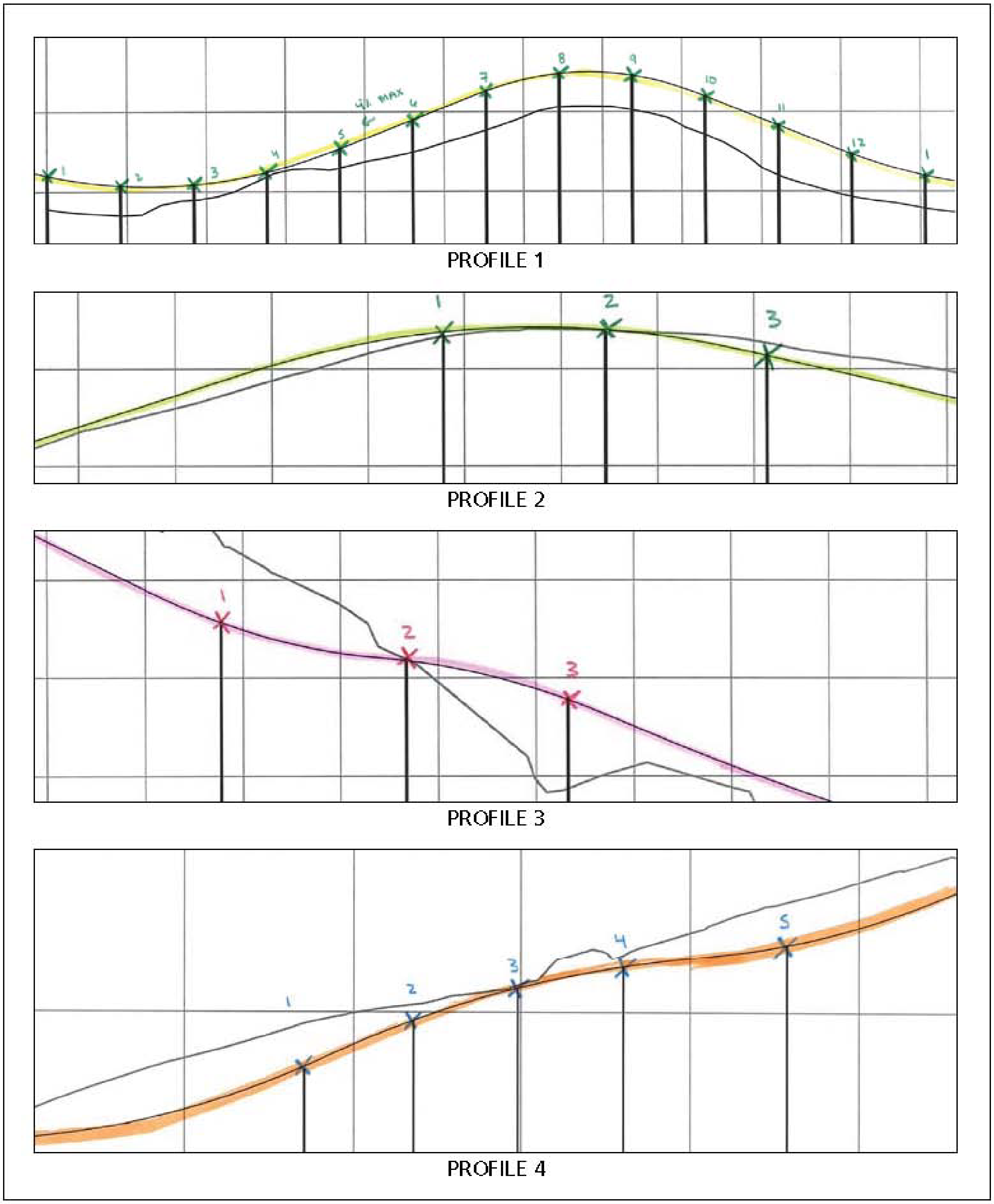
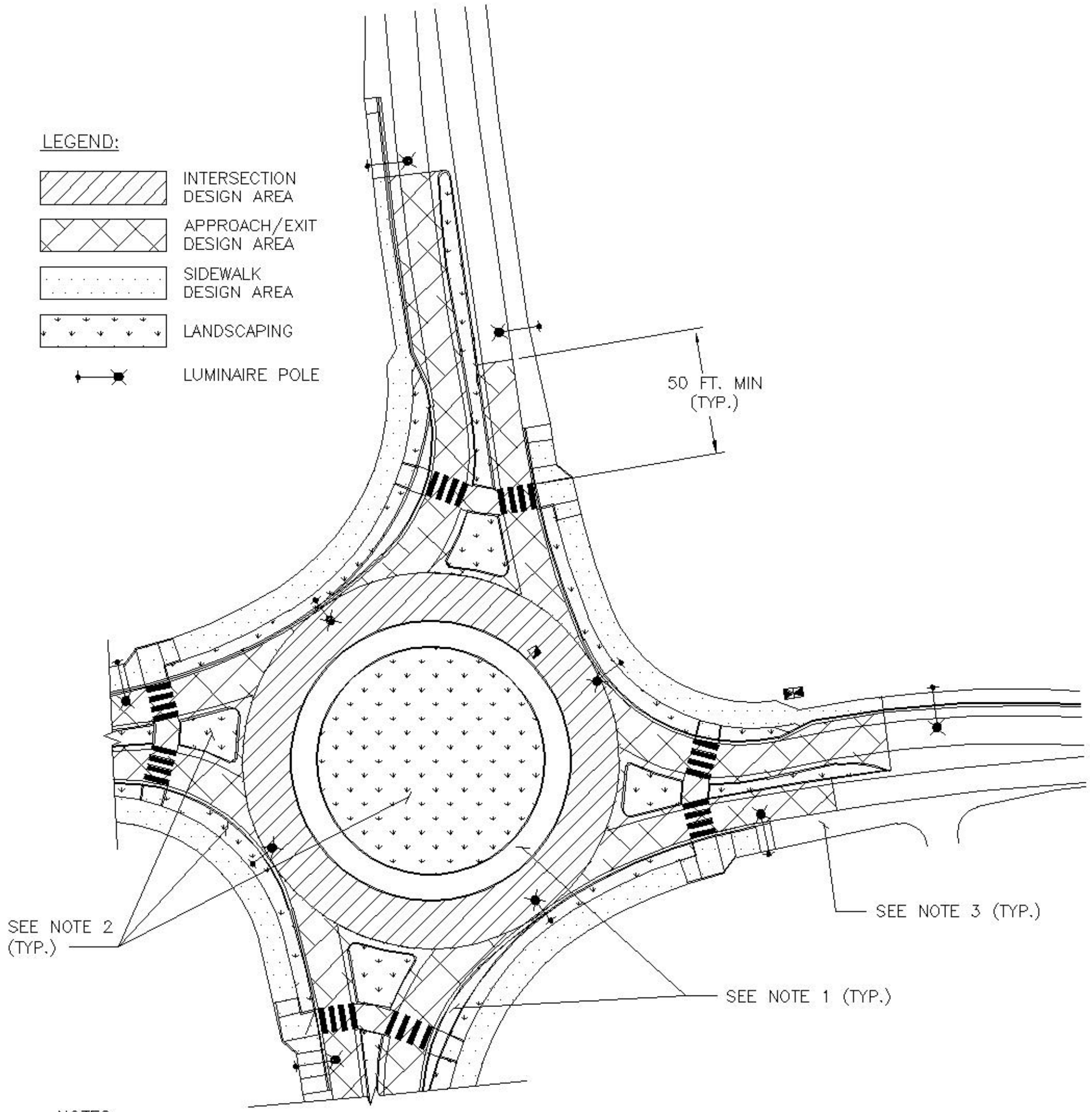


Figure 6-16 Roundabout Grading



NOTES:

1. EXCLUDE TRUCK APRON FROM LIGHTING CALCULATION.
2. EXCLUDE LANDSCAPING ISLANDS AND LANDSCAPING STRIPS FROM LIGHTING CALCULATION.
3. EXCLUDE SHOULDER FROM LIGHTING CALCULATION.
4. THE APPROACH DESIGN AREA STARTS AT THE BEGINNING OF THE RAISED CHANNELIZATION.
5. THE EXIT DESIGN AREA ENDS 50 FT MINIMUM BEYOND THE PEDESTRIAN CROSSING.
6. WHEN A LEG OF THE ROUNDABOUT IS ONE-WAY ROADWAY, THE APPROACH DESIGN AREA STARTS AT THE BEGINNING OF THE RAISED CHANNELIZATION, OR 50 FT MINIMUM FROM THE OUTSIDE EDGE OF THE CIRCULATING ROADWAY, OR 50 FT BEYOND THE PEDESTRIAN CROSSING, WHICHEVER IS FARTHER.
7. PROVIDE ILLUMINATION OF THE ROADWAY BEHIND THE PEDESTRIAN FROM THE DRIVER'S PERSPECTIVE.

Figure 6-17 Roundabout Illumination Standards

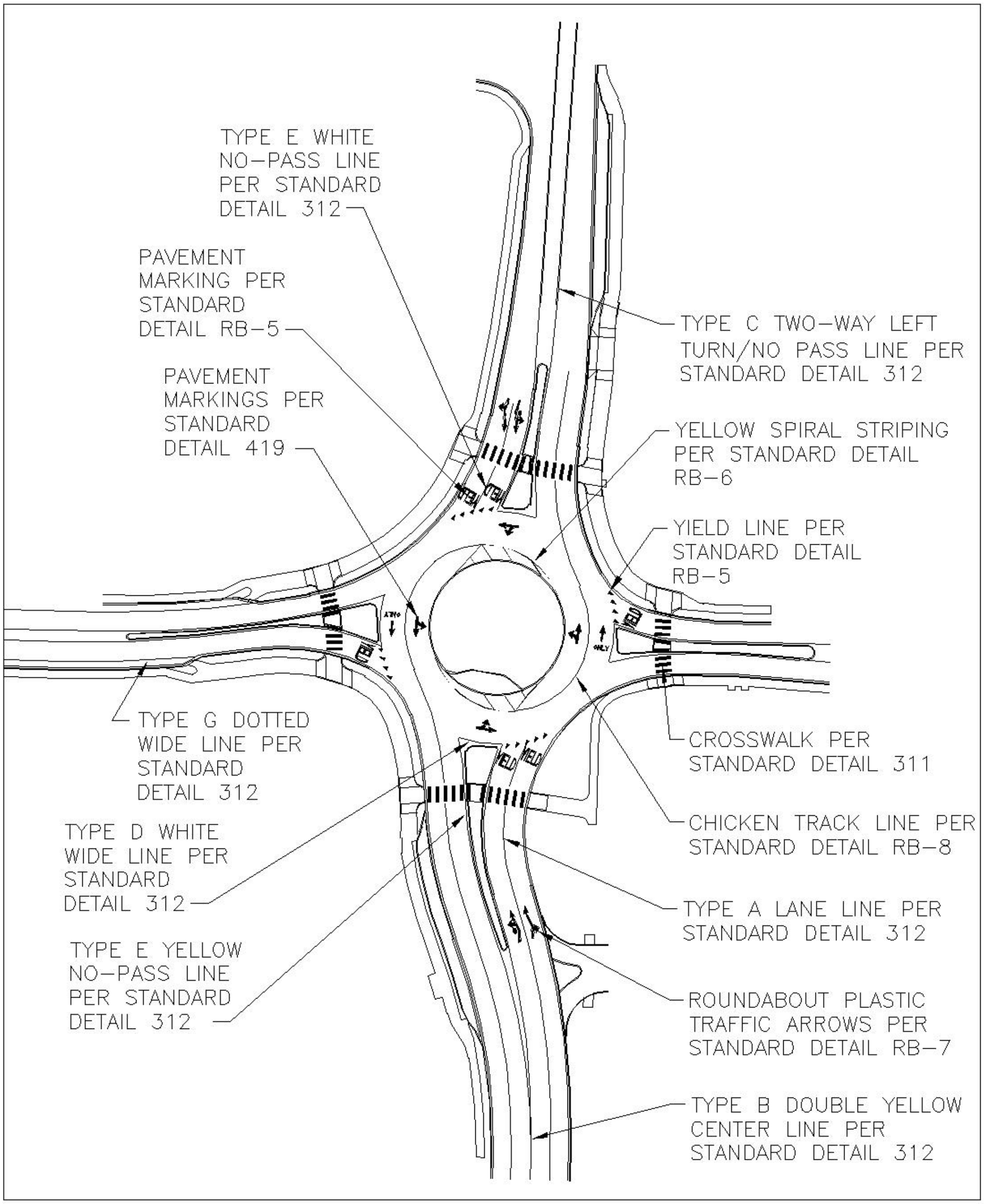


Figure 6-18 Channelization

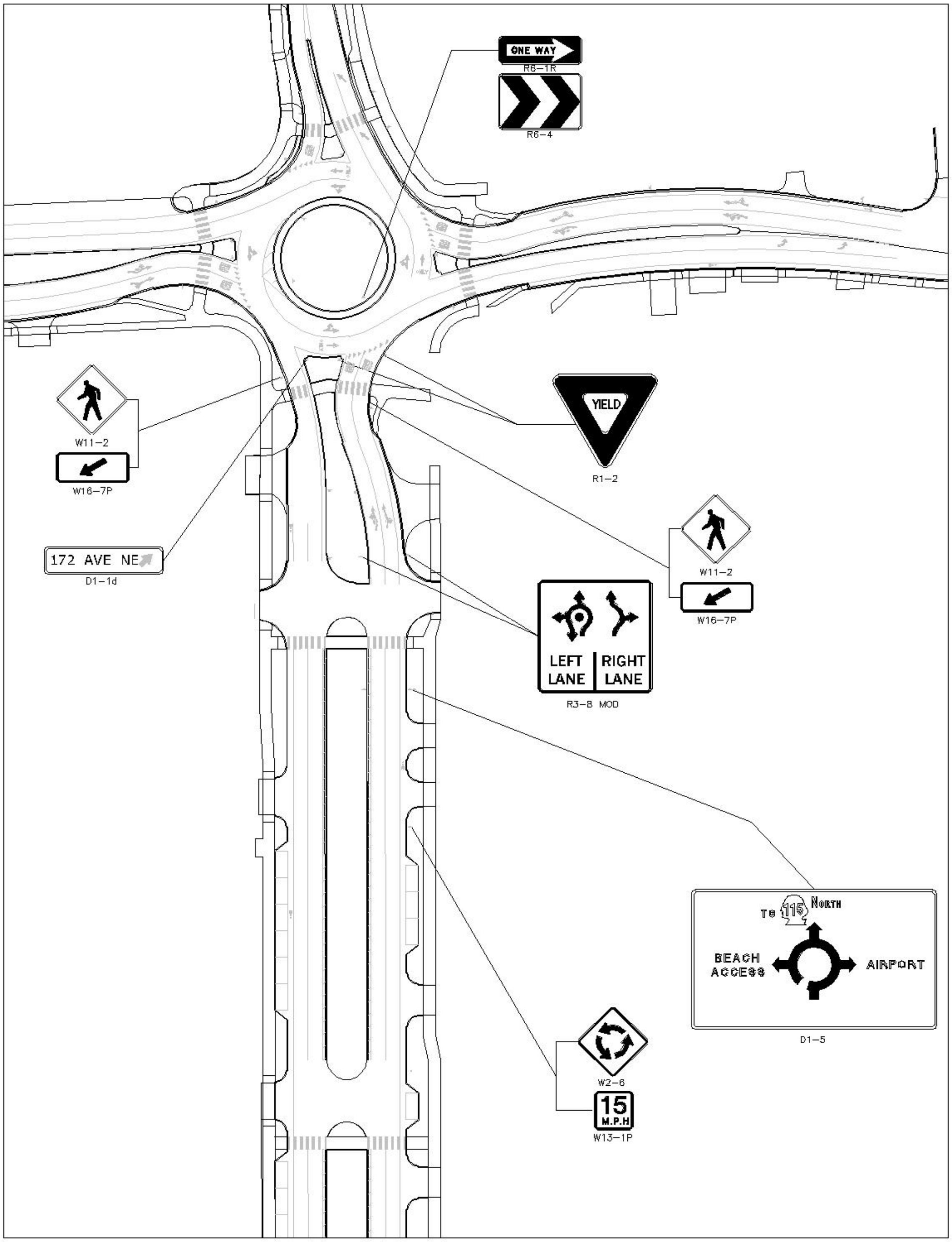


Figure 6-19 Signing

VII. PLAN SETS

There is a great deal of information that must be conveyed in a relatively small amount of space for a roundabout design. Instead of crowding the sheets with this information, it is preferable to create more sheets and break the information up. For example, on a typical plan and profile sheet the geometrics, grading, and drainage for the roadway would be shown on one sheet. In roundabout plan sets, this information is shown on three different sheets. The reason for this is that roundabouts have very few straight lines associated with their design. When the callouts for this geometry are combined with the storm drainage design the plans become very difficult to read.

Match lines for roundabout plan sheets are usually taken from the center point of the central island, dividing the central island in symmetrical pie shapes, the number of which depends upon the number of legs. Each leg is shown on a plan sheet in a scale legible on an 11x17 drawing. A key is provided on each sheet to help keep track of which leg is being portrayed on the sheet.

General

The plans shall conform to the City Standards

Cover sheet

The cover sheet shall include the following:

- Project name and number
- Vicinity map showing the project site and surrounding roads
- A City of Redmond construction signature block showing approval.
- An index to the drawings – Table 7-1 shows the typical sheets in a roundabout plan set.

Table 7-1 Typical Roundabout Plan Set

Sheet Number	Sheet Name	Sheet Description	Scale (For Full Size Plans)
1	COV1	Cover	N/A
2	LP1	Layout Plan	1”=40’
3-4	CP1-2	Construction Phasing Plan	1”=40’
5-6	EC1-2	Temporary Erosion Sedimentation Control Plan	1”=40’
7	EC3	TESC Plan Details	N/A
8-11	SP1-4	Site Preparation Plan	1”=20’
12-13	SEC1-2	Roadway Cross Sections	N/A
14-17	GP1-4	Grading Plan	1”=20’
18	GP5	Contour Grading Plan	1”=40’
19-22	P1-4	Paving Plan	1”=20’
23-26	U1-4	Utility and Illumination Plan	1”=20’
27	D1	Drainage Profiles	1”=20’
28	DD1	Drainage Details	N/A
29	I1	Illumination Details	N/A
30	MD1	Miscellaneous Details	N/A
31	C1	Channelization Plan	1”=40’
32	CD1	Channelization Details	N/A
33	S1	Signing Plan	1”=40’
34	SD1	Signing Details	N/A
35	LS1	Landscape Plans and Details	1”=40’

Using sheet names for referencing throughout the plans allows for the easy addition or removal of sheets that unavoidably occurs within the design process. This way when a sheet gets added to the plan set there is no need to re-define sheet references.

Layout Plan

The layout plan shows the construction alignment used to define the roundabout geometry. Typically it is the construction centerline or R/W centerline of the existing intersecting roadway. This line should have a minimum number of curves in order that the construction inspector might easily inspect the roundabout geometry and ensure good quality control.

A new alignment is not created along the centerline of the roundabout legs for the following reasons:

- Other survey alignments are usually already established and documented. There is less confusion for surveyors as only one alignment needs to be maintained.
- Slight adjustments to the geometry of the legs can change throughout the design, and these changes would create a domino effect for the downstream design.
- The definition of the centerline is not easily defined. Each leg is not symmetrical.

The Layout Plan is shown at a scale that allows the entire roundabout to be shown on one sheet. Contractors find this sheet valuable because it shows an overall picture of the completed roundabout in reference to the alignment lines and existing conditions. A sense of where the central island is located in relation to the intersection can be found on this sheet.

Surveyors find this sheet useful because it shows the survey control (Datum and any monumentation).

Construction Phasing Plan

These sheets provide one example of a way to construct the roundabout. It is important for the engineer to go through this exercise in order to have confidence in the constructability of the roundabout without bypass roads or road closures. The contractor will be responsible for the traffic control plans, however, if detours are allowed within the project these sheets can be included.

Site Preparation Plan

These sheets are similar to what would be included in a typical roadway plan set for site preparation. It clearly shows what needs to be removed or adjusted within the proposed cut and fill lines.

Roadway Cross sections

Due to the curvilinear nature of a roundabout, showing horizontal limits for the start and stop of each roadway element on the cross section sheets would be excessive. To eliminate the need for so many sheets of cross sections, only cross sections at key locations are shown. Basically the roadway cross sections are used to show the contractor material and depths of various roadway elements. The contractor should not lay out any horizontal geometrics of the roundabout, including curbs, sidewalks and truck aprons based on these sections.

A cross section key is provided to show where the sections are taken. The sections are not based on a “station to station” basis, but rather the cross section represents a graphical station taken from the location shown on the cross section key.

Grading Plan
These sheets provide the back-bone for the roundabout design, both horizontally and vertically. The contractor is provided with enough information to construct each curve individually. Each curve, representing curb flow lines, sidewalks, and truck aprons, is labeled and referenced to the construction alignment. There are no plan dimensions given on these sheets for several reasons. It is important that the contractor realizes that to properly construct the curbs of the roundabout, each curve needs to be surveyed. Adding plan dimensions may give the illusion that some of the curves are a constant offset from each other, and in roundabout design this is rarely the case. In addition, there is so much critical information shown on these plans, additional information tends to provide confusion rather than clarity.

After defining each curve, an elevation is assigned to its beginning, end, mid point and ¼ points as required. The roundabout grading is shown to the contractor more as a site design rather than a typical street design. Elevations are provided to construct the curbs of the roundabout.

Paving Plan
The paving plan shows the placement of geometric elements that are not defined using the curve delineations on the grading plans. This includes various curb types, landscaping, pull outs, and ramp placements. Minimal dimensions are included on this plan sheet to give the contractor a reality check on amount of material used. The paving plan references all the details that are useful.

Paving Details
These plan sheets do not vary significantly from typical roadway plan sets. There may be some details specific to roundabouts that need to be shown on these plans.

Utility and Illumination Plan
These plans show the storm drainage plan view design, utility locates, and illumination design as well as any other proposed utility work. Profiles for the storm water pipes are on a separate profile sheet.

The existing and proposed ground on the drainage profiles should be the actual ground above the utility. This is a good check on the accuracy of the proposed grading surface to ensure curb lines and low spots are represented correctly.

Channelization Plan
This plan sheet shows the pavement markings of the roundabout. It is helpful to show the entire roundabout on one sheet to get an overall picture of how the channelization fits together. Often in roundabout design, a stripe is not located at a constant offset from the curb so sufficient information must be shown in order that the contractor can correctly construct this stripe.

Signing Plan
This plan sheet shows the signing involved in roundabout construction. It is helpful to show the entire roundabout on one sheet to get an overall picture of how the signing fits together.

Landscaping Plan
This plan sheet shows the landscaping for the project and should follow City Standards. Ensure that the landscaping meets the requirements of the sight triangles.

VIII. SUBMITTAL REQUIREMENTS

Intersection Control Evaluation
This submittal is in conjunction with the traffic study/feasibility study report. At this stage, all the elements listed in the Intersection Control Analysis (Section V) should be submitted. The City will review this submittal and have the opportunity to concur or disagree with the findings. At this point the City retains the option to require the engineer to provide a Peer Review for the roundabout design. The engineer performing the Peer Review must be approved by the City.

Peer Review (if City determines to be necessary)

Roundabout Plans, Special Provisions, and Estimates
The submittal process shall follow the requirements found in Development Services. The following are key milestones in roundabout design that should be reached with the corresponding submittal.

Preliminary Design Submittal (ie 30%)

- The horizontal geometrics of the roundabout must be finalized. (Potential impacts to the intersection including utility structures, adjacent driveways, and specific site constraints should be noted with the necessary steps started to address these issues).
- The roundabout supporting documentation shall be submitted with the package, including the Operational Analysis and Roundabout Performance Measures
- At this point the City retains the option to require the engineer to provide a Peer Review for the roundabout design. The engineer performing the Peer Review must be approved by the City.

Mid Submittal (ie 60%)

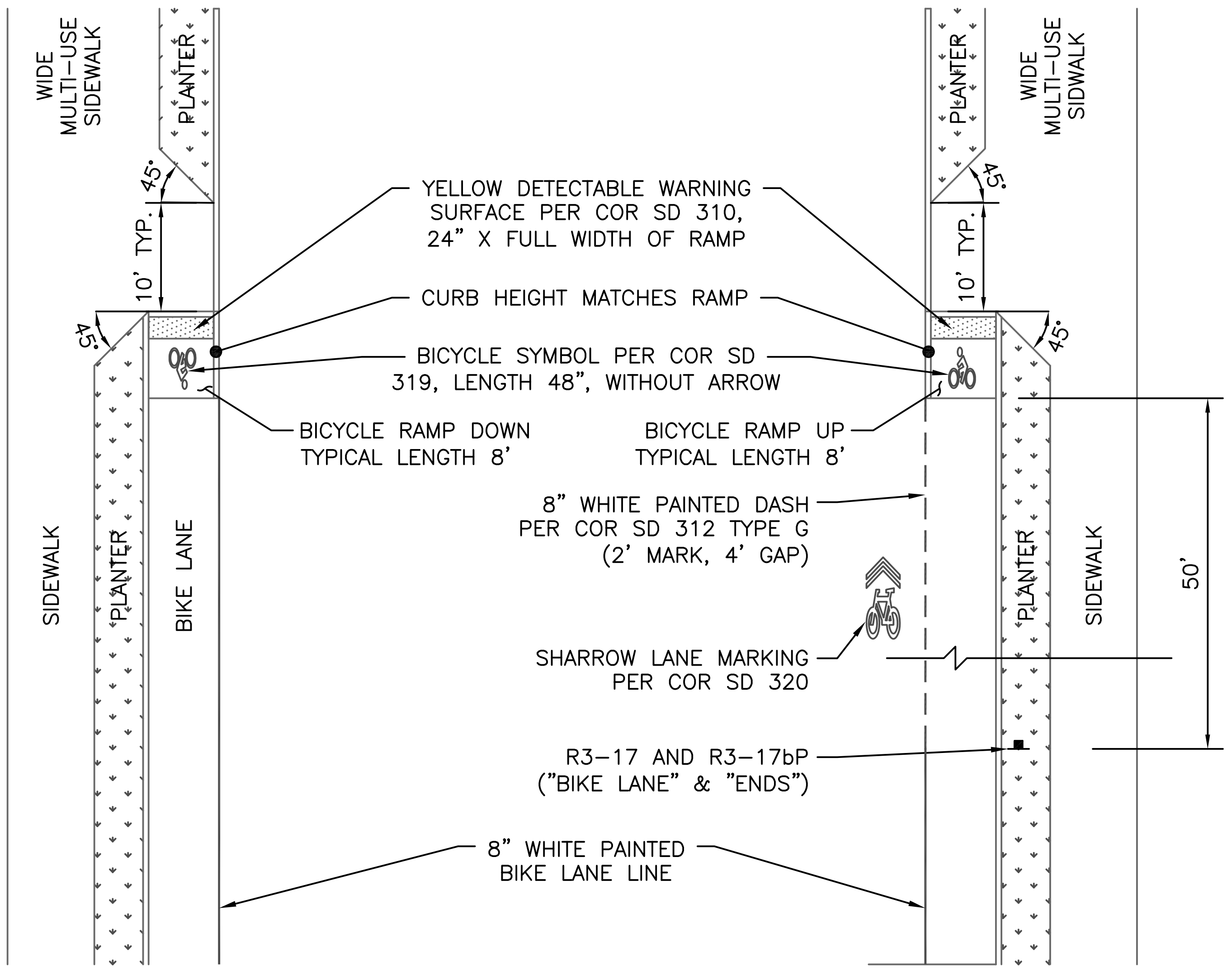
- This submittal shall incorporate (or state the reason for non-incorporation) of all comments from the 30% submittal, including the comments from any required peer review.
- The vertical grading should be designed and any additional right-of-way or easements required for the project can be shown and the acquisition process started. (Spot elevations spaced at no more than 30 feet and cut and fill lines should be detailed on the plans.)
- The plans should be sufficient to finalize environmental permitting.

Pre-Construction Submittal (ie 90%)

- This submittal shall incorporate (or state the reason for non-incorporation) of all comments from the 60% submittal, including the comments from any necessary peer review.
- The plan sheets should be approximately finalized at this submittal.

IX. DESIGN DETAILS

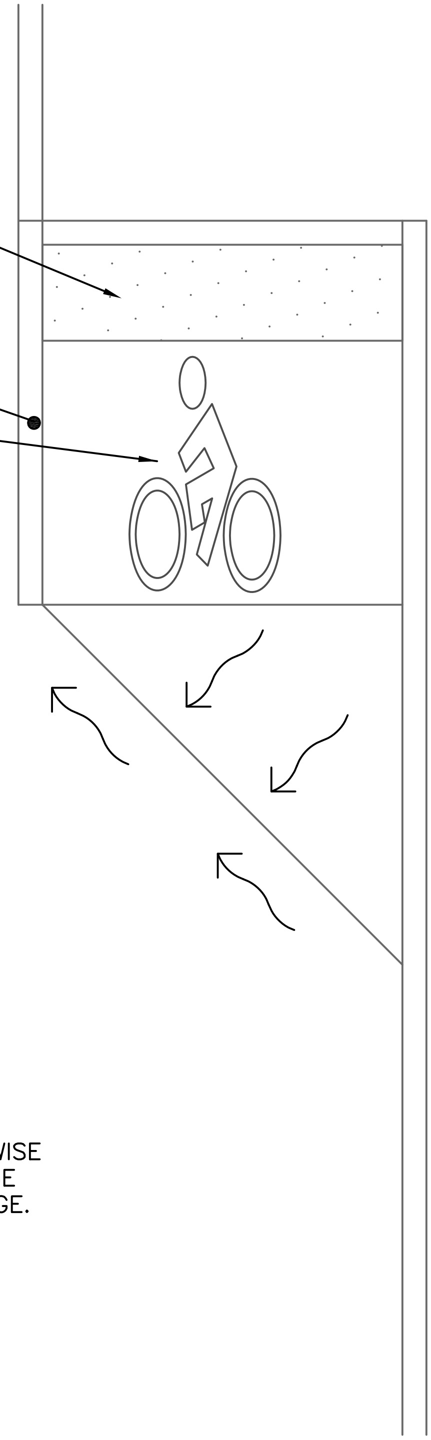
Roundabout Bike Ramps	Detail 1
Roundabout Bike Ramps	Detail 2
Pedestrian Treatment at Truck Apron	Detail 3
Pedestrian Treatment at Splitter Island	Detail 4
Roundabout Yield Markings	Detail 5
Roundabout Line Types	Detail 6
Roundabout Arrows	Detail 7
Sidewalk Ramp Type 3B	Detail 8
Roundabout Curb Types	Detail 9
Central Island Section	Detail 10
Roundabout Sign	Detail 11
Maintenance Pullout	Detail 12



ROUNDABOUT DOWN RAMP

ROUNDABOUT UP RAMP

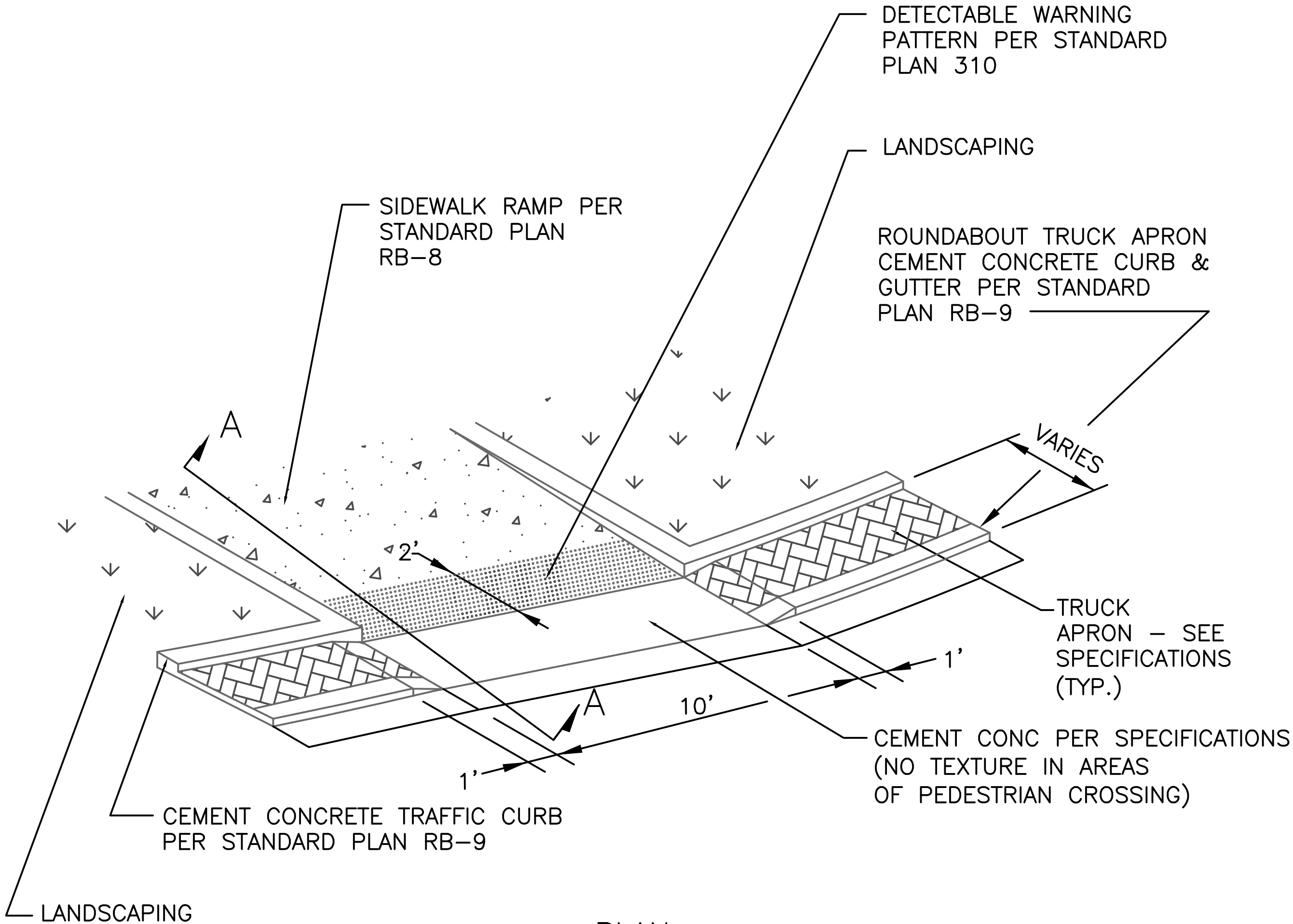
APPROVED: ________	City of Redmond WASHINGTON	STANDARD DETAILS
REV. DATE: ________		BIKE RAMPS AT ROUNDABOUTS (WITH LANDSCAPING)
TRANSPORTATION DIVISION		FILE XXX — DRAWING NO. RB-1



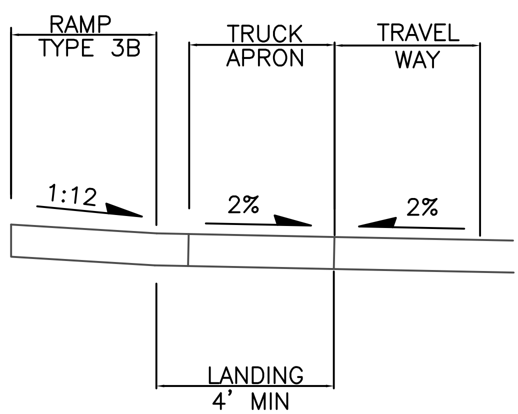
NOTE:
WHERE SLOPE DOES NOT OTHERWISE DRAIN, INSTALL TRIANGULAR WEDGE TO PROVIDE 2% POSITIVE DRAINAGE.

BIKE RAMP UP OR DOWN

APPROVED: ______	STANDARD DETAILS	
REV. DATE: ______	BIKE RAMPS AT ROUNDABOUTS (NO LANDSCAPING)	
TRANSPORTATION DIVISION	FILE XXX	DRAWING NO. RB-2

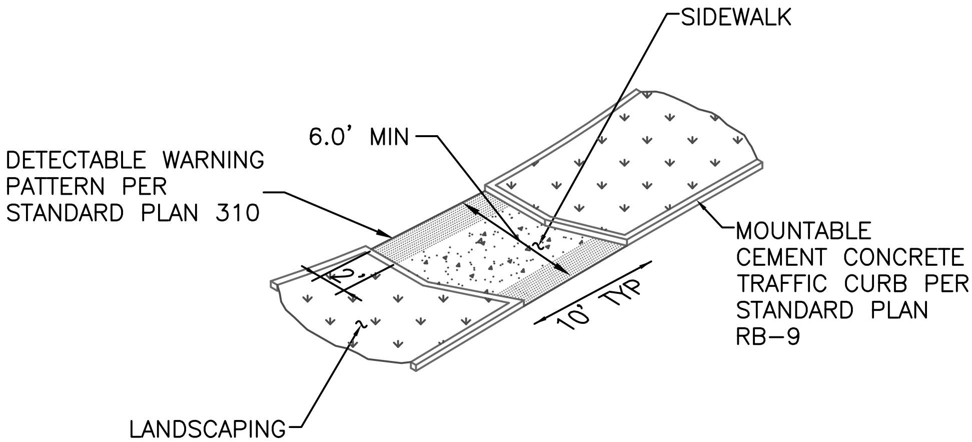


PLAN



A–A

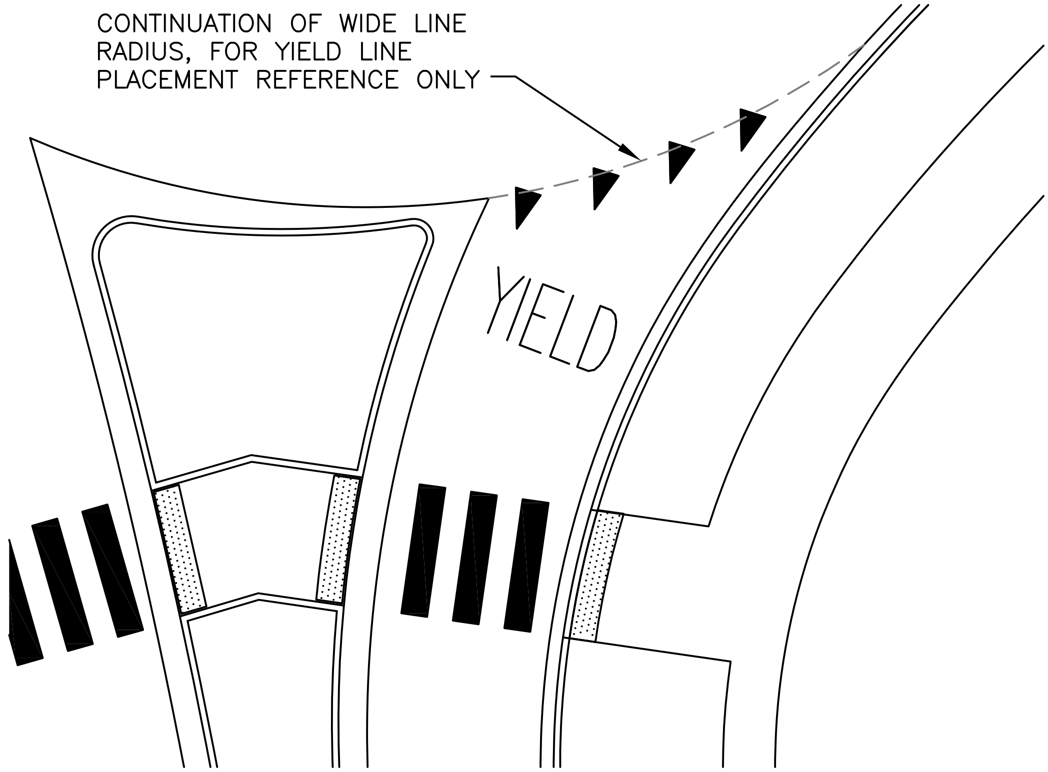
APPROVED:			STANDARD DETAILS
REV. DATE:			PEDESTRIAN TREATMENT AT TRUCK APRON
TRANSPORTATION DIVISION		City of Redmond WASHINGTON	FILE XXX / DRAWING NO. RB–3



PEDESTRIAN TREATMENT AT SPLITTER ISLAND

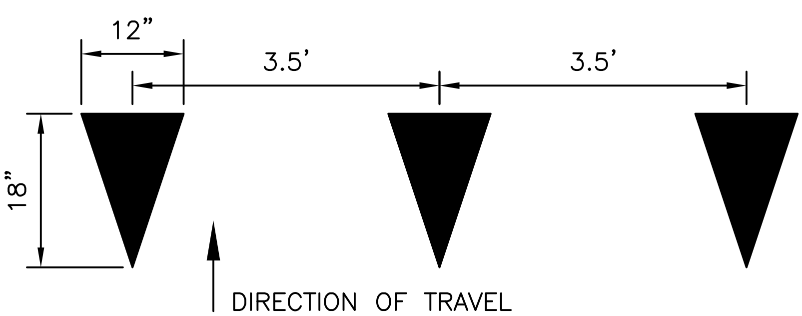
NOT TO SCALE

APPROVED: ______	City of Redmond WASHINGTON	STANDARD DETAILS
REV. DATE: ______		PEDESTRIAN TREATMENT AT SPLITTER ISLAND
TRANSPORTATION DIVISION		FILE XXX — DRAWING NO. RB–4



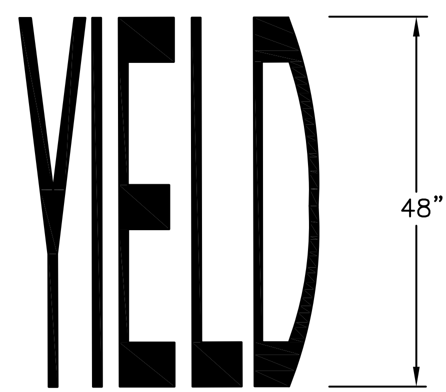
YIELD LINE PLACEMENT

NOT TO SCALE



PLASTIC YIELD LINE

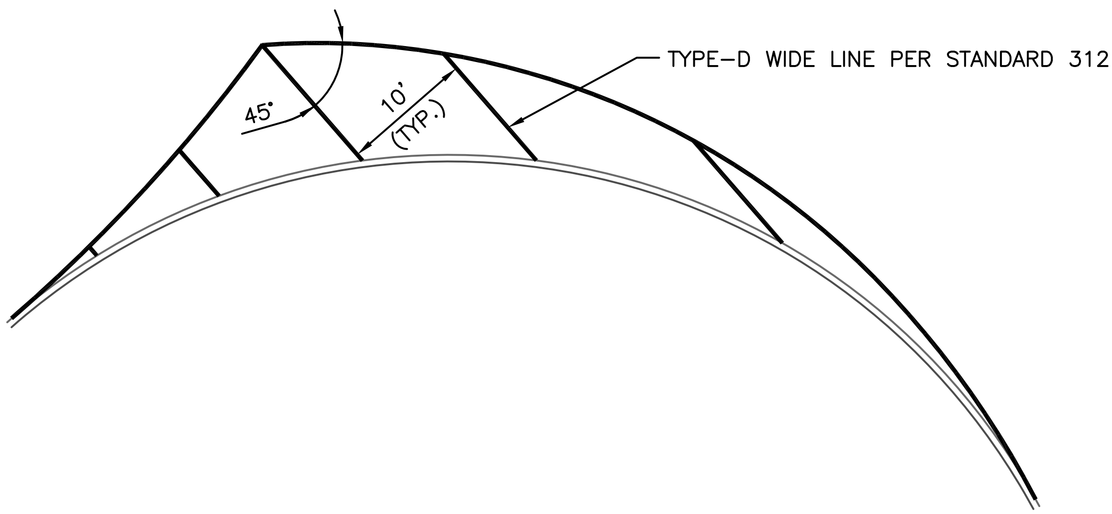
NOT TO SCALE



PLASTIC TRAFFIC LETTERS

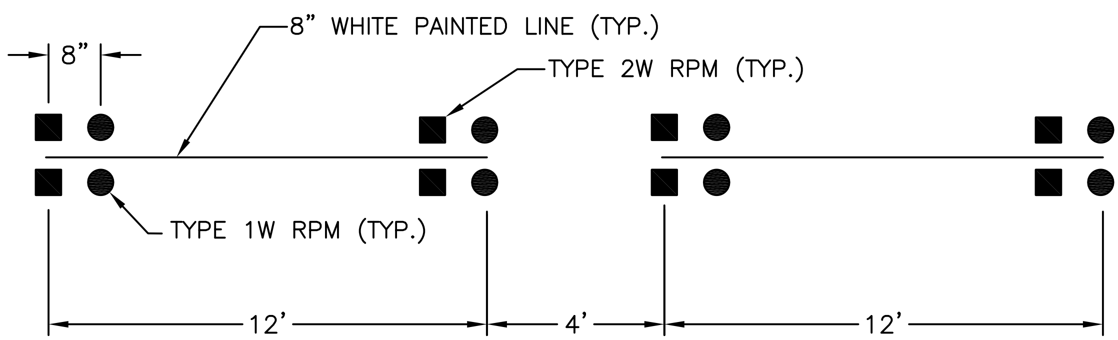
NOT TO SCALE

APPROVED: ____________	City of Redmond WASHINGTON	STANDARD DETAILS
REV. DATE: ____________		ROUNDABOUT YIELD MARKINGS
TRANSPORTATION DIVISION		FILE XXX | DRAWING NO. RB-5



SPIRAL STRIPES

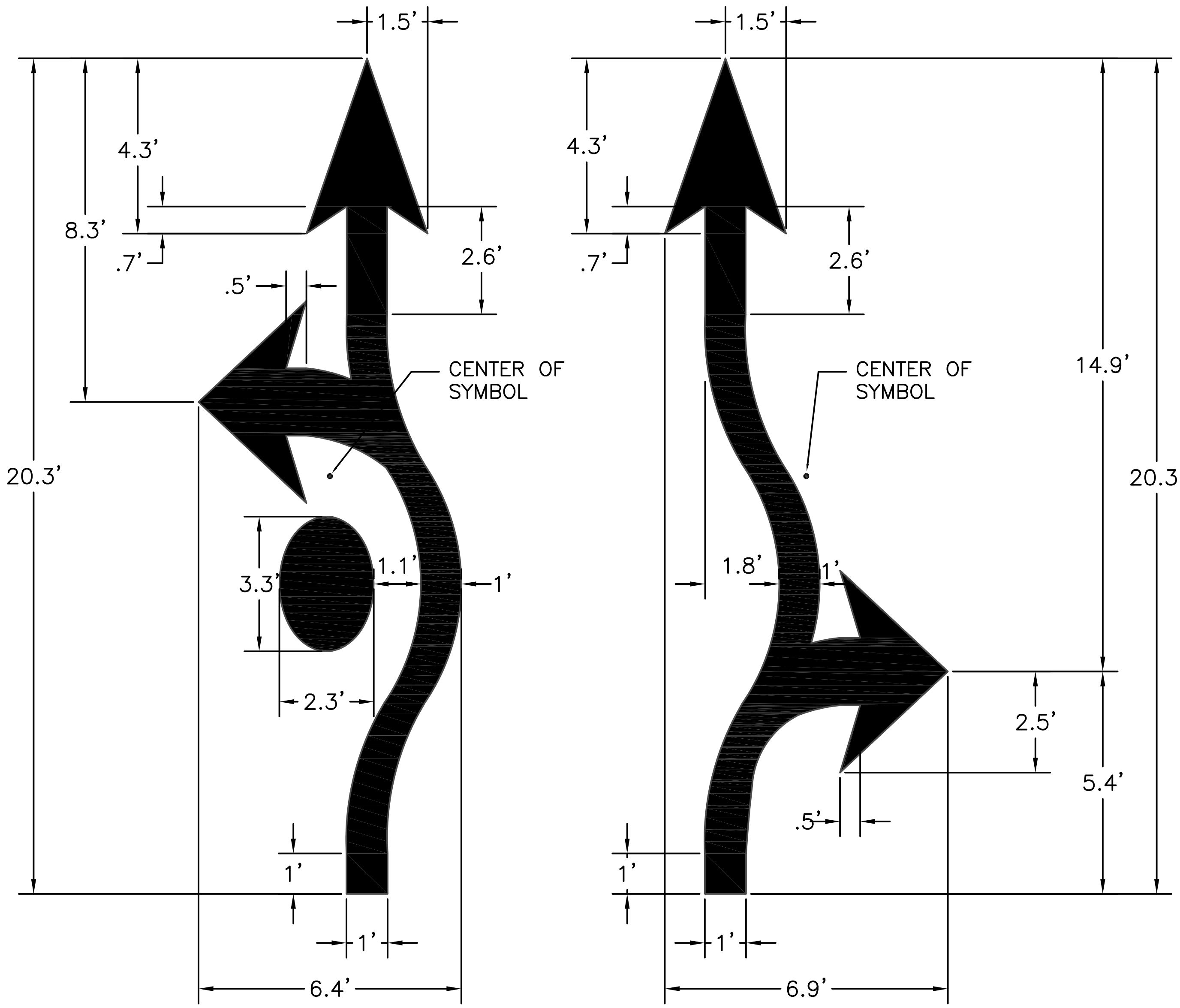
NOT TO SCALE



CHICKEN TRACK LINE

NOT TO SCALE

APPROVED: ______			STANDARD DETAILS
REV. DATE: ______		City of Redmond WASHINGTON	ROUNDABOUT LINE TYPES
TRANSPORTATION DIVISION			FILE XXX DRAWING NO. RB-6



ROUNDABOUT PLASTIC TRAFFIC ARROW

NOT TO SCALE

APPROVED: ____________

REV. DATE: ____________

TRANSPORTATION DIVISION

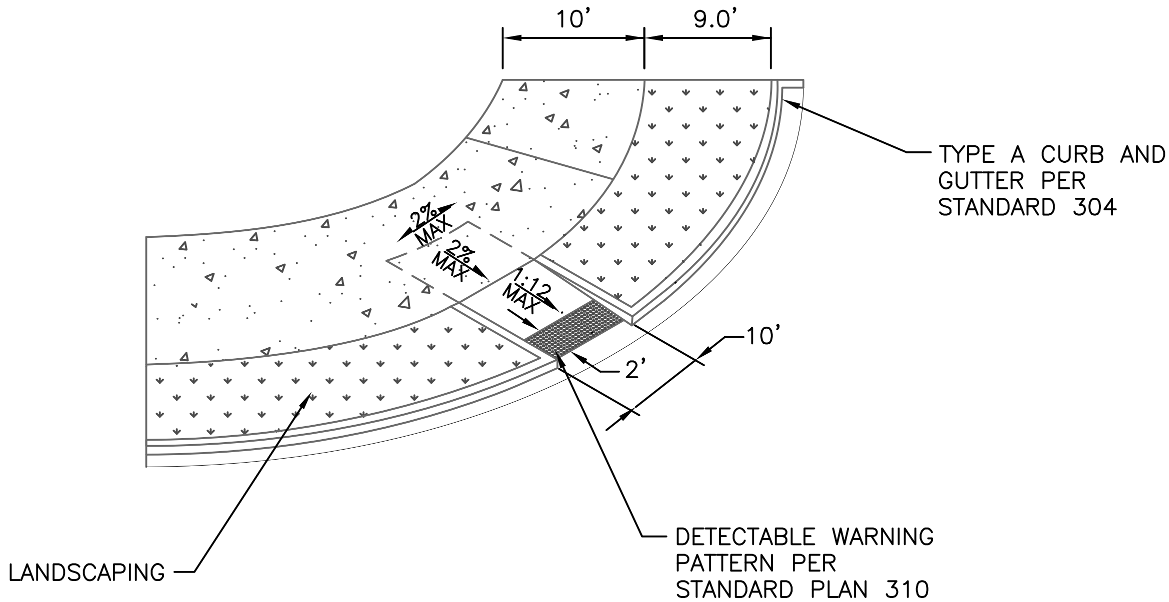
City of Redmond WASHINGTON

STANDARD DETAILS

ROUNDABOUT ARROWS

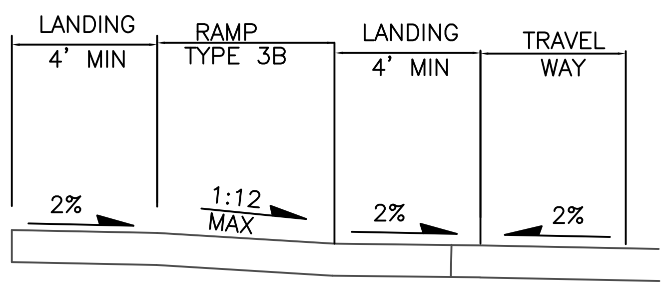
FILE XXX

DRAWING NO. RB-7



SIDEWALK RAMP TYPE 3B

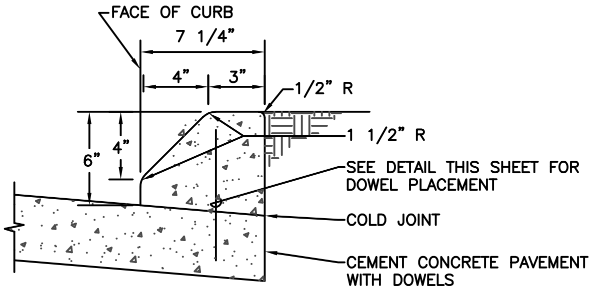
NOT TO SCALE



PROFILE – SIDEWALK RAMP TYPE 3B

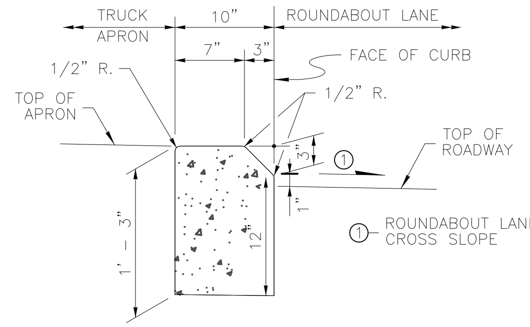
NOT TO SCALE

APPROVED: ____________		City of Redmond WASHINGTON	STANDARD DETAILS
REV. DATE: ____________			SIDEWALK RAMP TYPE 3B
TRANSPORTATION DIVISION			FILE XXX · DRAWING NO. RB–8



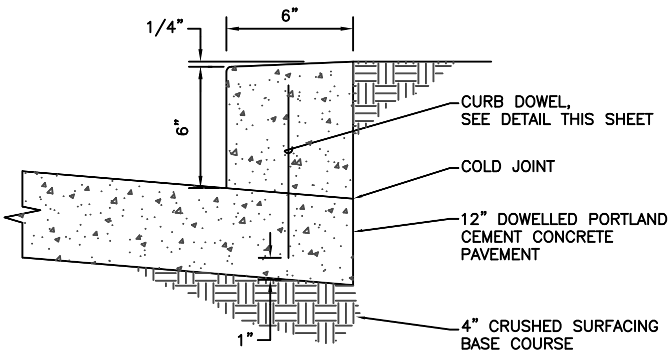
MOUNTABLE CEMENT CONCRETE DOWELLED TRAFFIC CURB

NOT TO SCALE



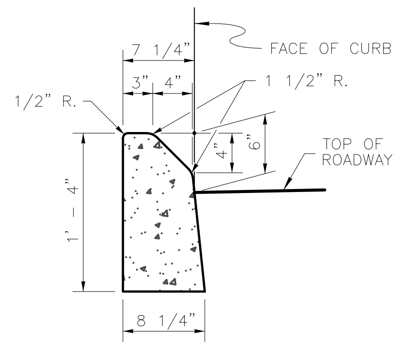
ROUNDABOUT TRUCK APRON CEMENT CONCRETE CURB

NOT TO SCALE



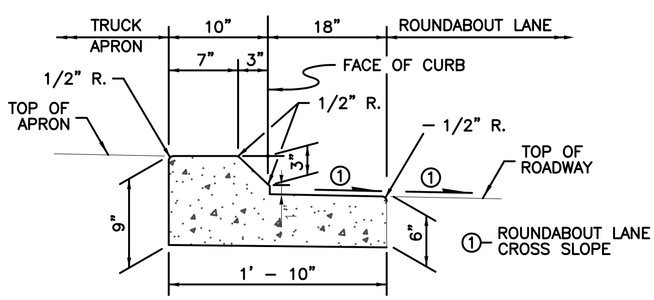
CEMENT CONCRETE DOWELLED TRAFFIC CURB

NOT TO SCALE



MOUNTABLE CEMENT CONCRETE TRAFFIC CURB

NOT TO SCALE



ROUNDABOUT TRUCK APRON CEMENT CONCRETE CURB & GUTTER

NOT TO SCALE

APPROVED: ____________

REV. DATE: ____________

TRANSPORTATION DIVISION

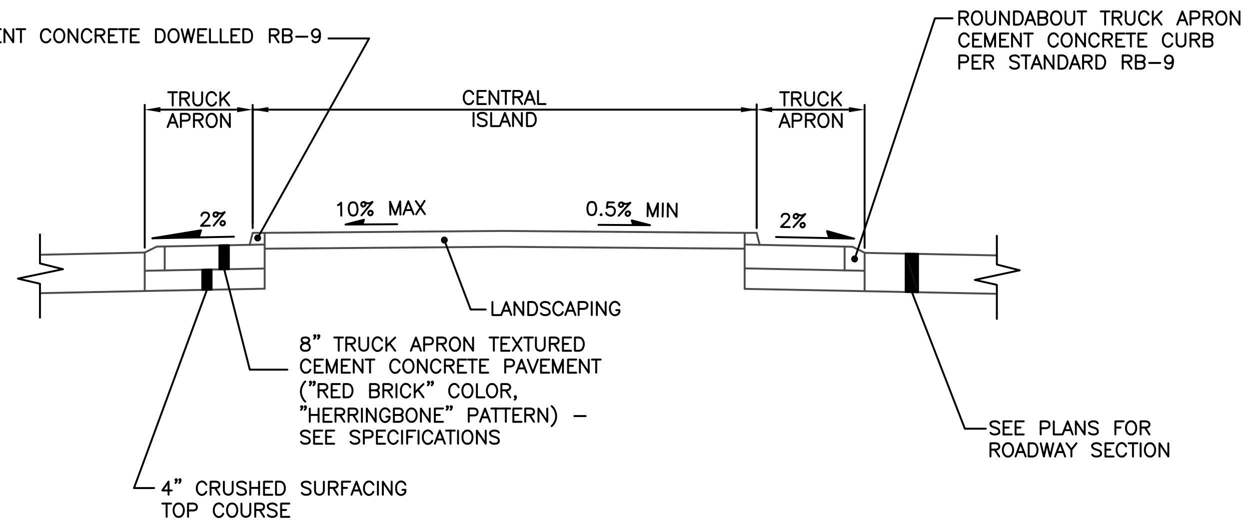
City of Redmond WASHINGTON

STANDARD DETAILS

ROUNDABOUT CURB TYPES

FILE XXX

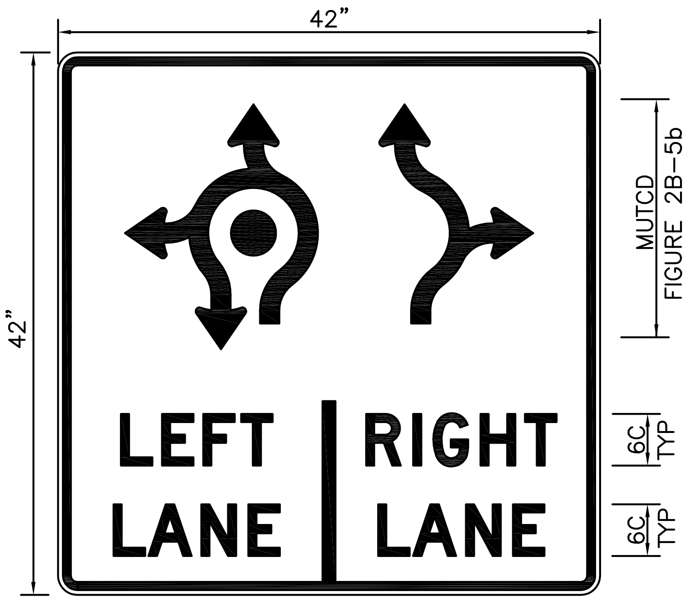
DRAWING NO. RB-9



CENTRAL ISLAND SECTION

NOT TO SCALE

APPROVED: ______		STANDARD DETAILS
REV. DATE: ______	City of Redmond WASHINGTON	CENTRAL ISLAND SECTION
TRANSPORTATION DIVISION		FILE XXX / DRAWING NO. RB-10



COLORS:
BACKGROUND – WHITE (REFLECTIVE)
LEGEND – BLACK (NON-REFLECTIVE)

R3-8 MOD
NOT TO SCALE

APPROVED: ____________

REV. DATE: ____________

TRANSPORTATION DIVISION

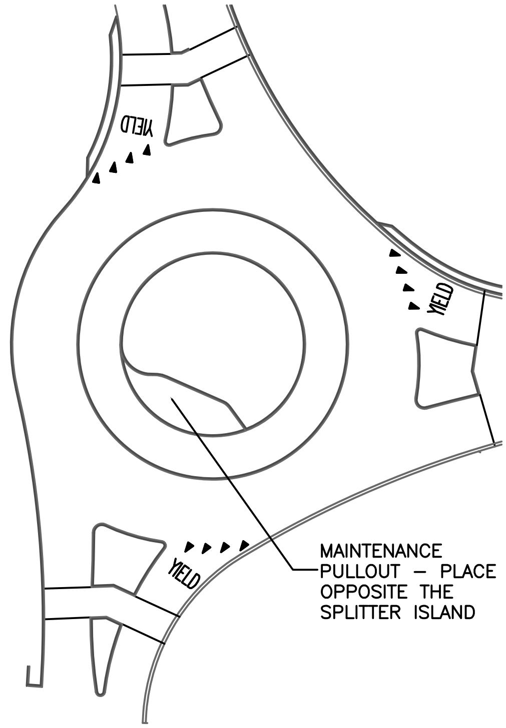
City of Redmond WASHINGTON

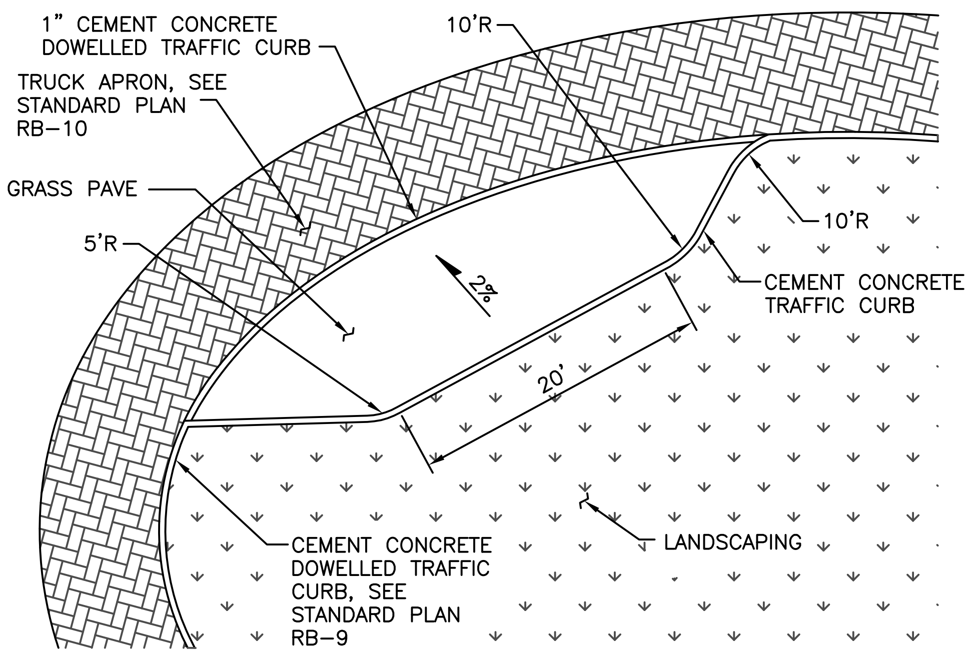
STANDARD DETAILS

ROUNDABOUT SIGN

FILE XXX

DRAWING NO. RB-11





MAINTENANCE PULLOUT

NOT TO SCALE

APPROVED: ________			STANDARD DETAILS
REV. DATE: ________		City of Redmond WASHINGTON	MAINTENANCE PULLOUT
TRANSPORTATION DIVISION			FILE XXX / DRAWING NO. RB–12

X. SPECIFICATIONS

Textured Cement Concrete Pavement	Section 5-05
Rockscape	Section 8-26

5-05 CEMENT CONCRETE PAVEMENT

5-05.3 Construction Requirements

Section 5-05.3 is supplemented with the following:

Textured Cement Concrete

The Contractor shall stamp the areas indicated on the Plans. The stamped concrete shall be a two color system with a base color hardener and a release color. Color shall be a red brick hardener with a Red Brick release. Color hardener and release shall be applied and installed in accordance with the manufacturer's written recommendations. The stamp pattern shall be Herringbone pattern or approved equal.

Work shall be performed by workers experienced with concrete stamping and concrete coloring. The Contractor shall provide certification that they have completed a minimum of three concrete stamping projects for roadway related projects.

The Contractor shall provide a job-site sample to be approved by the Engineer prior to placing textured cement concrete. The sample shall be a minimum of six feet by six feet, completed panel including stamp pattern, colored concrete and sealer.

Concrete shall be a minimum of 6 inches thick and shall be constructed using Class 3,000 concrete as specified in Section 6-02.3(2)A of the Standard Specifications. The slump of the concrete shall not exceed 3-½ inches. The concrete shall be air entrained concrete in accordance with the requirements of Section 5-05.3(4)A and shall be cured for 4 days in accordance with Section 5-05.3(13)B.

Transverse construction joints and transverse contraction joints shall be placed perpendicular or radial to the back of curb. Joint spacing shall be a maximum of 15' apart and equally spaced along the length of the textured cement concrete. Joints shall be constructed as shown in the WSDOT Standard Plan A-1.

Following placement, screeding and floating of the concrete, color hardener shall be troweled into the concrete. After troweling the hardener into the concrete, a second coat of color hardener shall be placed uniformly on top of concrete.

After 4 days of curing or according to the manufacturer's instruction, the color release shall be pressure washed and allowed to dry completely. When the textured concrete is dry, the Contractor shall apply a sealer to the concrete. Sealer shall be as recommended by the color hardener manufacturer's recommendation and as approved by the Engineer.

Concrete finishing for transitions to existing cement concrete shall match the existing surface as closely as possible.

5-05.4 Measurement

Section 5-05.4 is supplemented with the following:

> "Textured Cement Concrete Pavement" will be measured by the square yard of finished surface.

5-05.5 Payment

Section 5-05.5 is supplemented with the following:

> "Textured Cement Concrete Pavement," per square yard.
>
> The unit contract price per square yard for "Textured Cement Concrete Pavement" shall include all costs for the labor, materials, and tools necessary to construct the "Textured Cement Concrete Pavement," including all preparation of the subgrade, construction joints, contraction joints, through joints, sawcutting, keyways, sealing joints when required, dowel bars, any special forming around manhole lids or other utility features shown in the plans or as required to complete the work. No measurement for the job-site samples will be made and all costs in preparing and providing test samples shall be included in the unit contract cost for "Textured Cement Concrete Pavement" that is permanently placed.

8-26 ROCKSCAPE (NEW SECTION)

8-26.1 Description

This work consists of furnishing, placing, and constructing rock encased in concrete in all the roundabout splitter islands as detailed on the Plans.

8-26.2 Materials

Concrete shall be commercial concrete meeting requirements of Section 6-02 of Standard Specifications.

Rock shall be river cobble that is clean, smooth, and conforms to the following grading:

8 inch screen	100% passing
6 inch screen	50-85% passing
4 inch screen	0-50% passing

Crushed surfacing top course shall meet the requirements of Section 9-03.9(3) of Standard Specifications.

8-26.3 Constructions requirements

Prior to placement of CSTC, the areas to receive the rockscape shall be cleared of trash, debris, and weeds. Weeds shall be removed to ground level. After clearing, the area shall be either excavated or filled to depth as shown in Plans, and graded to a smooth uniform surface and compacted to a minimum relative compaction of 95 percent.

Rock shall be placed while concrete is still plastic, set at least 50% in concrete and spaced a maximum of ½ inch apart. The Contractor shall remove concrete adhering to the exposed surfaces of the rock. Loose rocks or rock with a gap greater than 3/8 inch, measured from the edge of the rock to the surrounding concrete bedding, shall be reset at the Contractor's expense.

8-26.4 Measurement

Rockscape will be measured by the square foot.

8-26.5 Payment

"Rockscape", per square foot.

The unit contract price per square foot for "Rockscape" shall be full payment for furnishing all labor, tools, materials and equipment necessary to furnish and install the finished project including commercial concrete, rock, crushed surfacing top course, and any other miscellaneous materials.