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APPENDIX A –ROUNDABOUT KEY FEATURES

A.1 Introduction and Key Features

The modern roundabout is characterized by three basic principles:

- Yield-at-Entry - Vehicles approaching the roundabout must wait for a gap in the circulating flow, or yield, before entering the circle.
- Deflection - Traffic entering the roundabout is directed or channeled to the right with a curved entry path into the circulatory roadway.
- Geometric Curvature - The diameter of the circulatory roadway and the angles of entry are designed to slow the speed of vehicles.

The key features of roundabouts are illustrated on Figure A-1, Figure A-2, and Table A-1.

Figure A-1. Key Roundabout Features

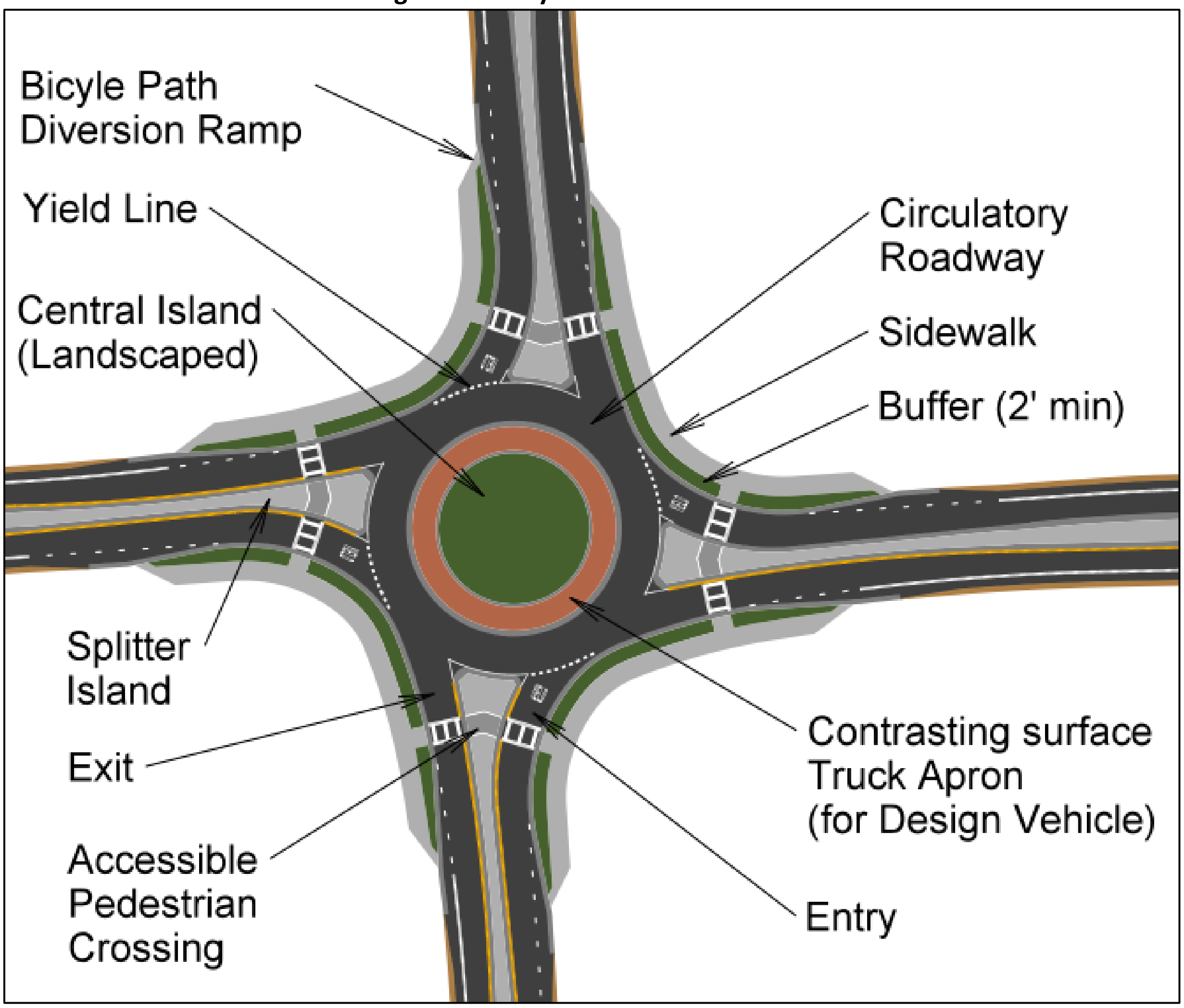


Figure A-2. Key Roundabout Features (Bypasses and Spirals)

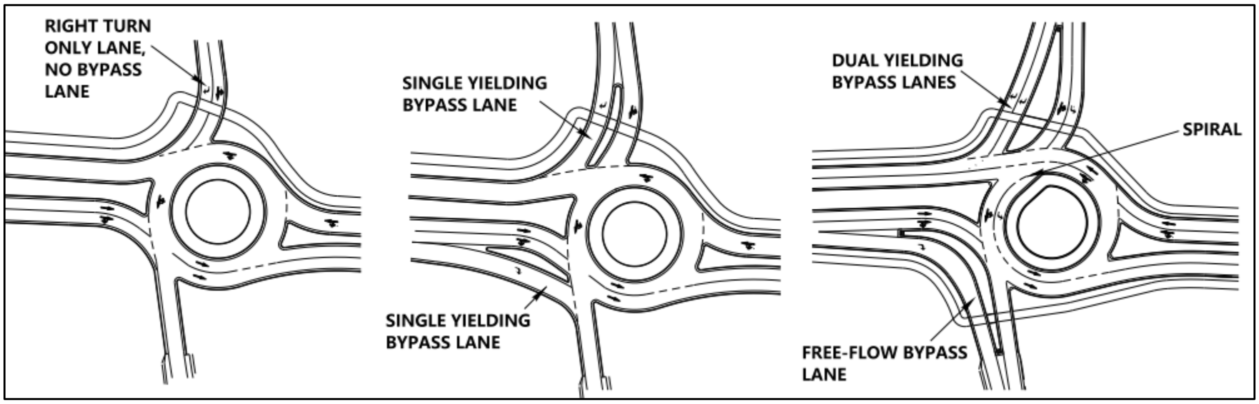


Table A-1. Key Roundabout Features

Feature	Description
Central Island	The raised area in the center of a roundabout, around which traffic circulates. The central island does not necessarily need to be circular in shape.
Splitter Island	A raised median on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and to provide refuge for pedestrians crossing the road in two stages.
Circulatory Roadway	The curved one-way roadway used by vehicles to travel in a counterclockwise fashion around the central island. The width of the circulatory roadway is typically 1.0 to 1.2 times the widest entry width.
Raised Truck Apron	The mountable portion of the central island adjacent to the circulatory roadway. It is required to accommodate the wheel tracking of long or oversized vehicles Oversize/Overweight vehicles (OSOW). It is usually concrete with a contrasting color to delineate the apron from the normal vehicle path.
Edge Line Extension (Yield Line)	A pavement marking line of demarcation separating traffic approaching the roundabout from the traffic already in the circulating roadway. The yield line is usually defined by a wide dotted edge line extension.
Accessible Pedestrian Crossings	Pedestrian crossings provided at roundabouts must be accessible to and usable by all pedestrians; including the visually impaired, wheelchairs, strollers and pedestrians walking bicycles. Ideally, non-motorized users will be provided the opportunity to cross the street in a two-staged crossing with a refuge cut into the splitter island. The crossing location is set back from the yield line, typically one car length (~25 ft.)
Bicycle Path Diversion	Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either by riding in the travel lane as a vehicle, or by exiting the roadway and if available using a shared-use path, depending on the bicyclist's level of comfort.

Feature	Description
Sidewalk / Shared-Use Path	It is common to provide a shared-use path at the perimeter of the roundabout to provide both pedestrians and bicyclists off-road accommodation. Standard sidewalks are provided in lieu of a shared-use path when bicycle traffic is expected to use the roadway through the roundabout.
Right-turn Free-flow Bypass Lane	Right-turn free-flow bypass lanes allow vehicles to bypass the roundabout and then continue in a dedicated lane or merge into an exit lane. A high right-turn demand when coupled with other approaching traffic may indicate the need for a full bypass lane in order to avoid a wider, faster entry. Right-turn full bypass lanes create an additional conflict for pedestrians and bicyclists and should be avoided, if possible, particularly near schools, senior citizen centers, and similar facilities that serve the most vulnerable roadway users.
Right-turn Partial (Yielding) Bypass Lane	A right-turn yielding bypass lane with either a curbed or a painted channelization requires approaching vehicles to yield to traffic leaving circulatory roadway at the adjacent exit. This alternative prevents ('snags') the right turner from making a through movement while preserving good sight lines to the left for conflicting circulating/exiting traffic. Generally, an intersection angle of 70 degrees or higher is desirable.
Spiral (not to be confused with a highway curve spiral)	A spiral prevents left-turning vehicles from becoming trapped on the inside lane of a multilane roundabout. It allows drivers to make the desired exit without changing lanes. A spiral accomplishes this by aiding the development of a lane gain to facilitate the shift of the circulating vehicle as it circulates past an entry that has an exclusive left-turn lane.
Landscape Buffer	Separation between the curb and sidewalk, 2-ft. minimum to place signs, is provided to set apart vehicular and pedestrian traffic and to help direct pedestrians to cross only at the designated crossing locations. Landscaping can also significantly improve intersection aesthetics and contribute to traffic calming provided it is placed outside the required sight limits. The buffer must be detectable by people of all abilities.

APPENDIX B – PRACTICAL DESIGN

B.1 PRINCIPLES

Practical Design emphasizes a focus on scoping projects to best serve the project's core purpose and need. It is essentially design optimization with a greater emphasis on cost conservation versus capacity and safety.

There are typically three main competing factors when developing a roundabout design: capacity, safety and cost. A roundabout could be designed with an emphasis on safety and capacity but the cost of the project could be higher. Conversely, a roundabout could be cost-effective, but not have optimal safety benefits of a conventional roundabout. Practical design seeks to balance all three competing objectives, but with a slightly greater emphasis on cost factors while still achieving a safe and capacity-efficient roundabout. There is no bullseye in achieving optimal design. It depends on context and project goals. Figure B-1 illustrates cost reduction opportunities at a roundabout.

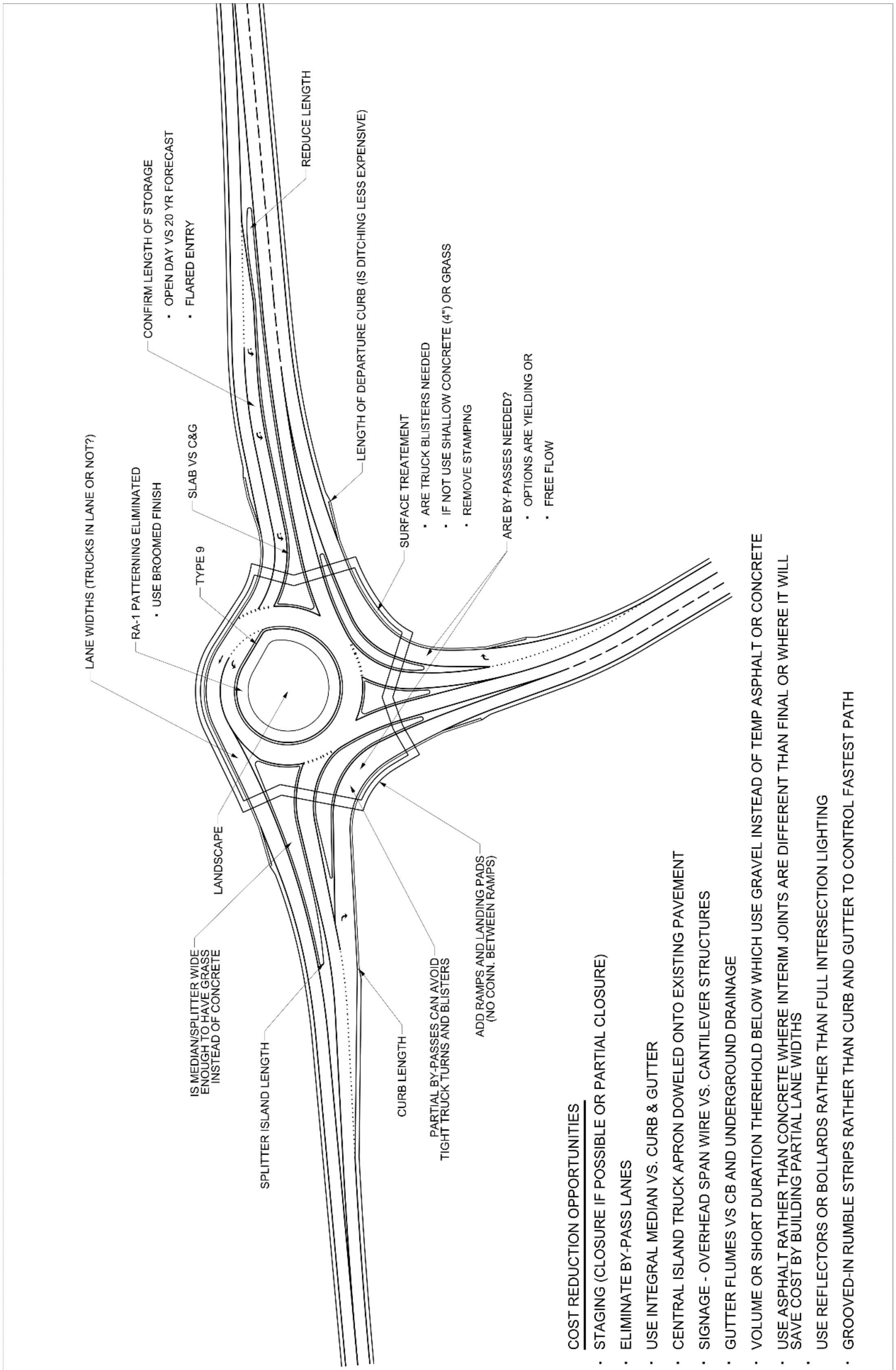


Figure B-1. Cost Reduction Opportunities

B.2 LEFT-OFFSET APPROACH ALIGNMENT

To achieve a practical design in terms of minimal circle size, offset left design is recommended and is GDOT's strong preference. An offset left entry is aligned so that the centerline of the approach passes to the left of the roundabout center. This creates more entry path deflection, but results in less exit curvature. This allows for the use of a smaller ICD to create the same amount of entry path deflection for speed control. An example of an offset left design is demonstrated in Figure B-2 and Figure B-3, additional advantages to an offset left design are listed below:

- Increased deflection – best for speed control with rural design
- Maintains clear sight of the central island
- Beneficial for accommodating large trucks
- Allows for larger entry radius while maintaining deflection and speed control
- May increase exit radius which reduces control of exit speeds/acceleration, but improved SSD of exit crosswalk
- Improved capacity – no turbulence
- It gives good 'body language' – driver adaptability is eased

Figure B-2. Offset Left Design Example

Figure B-3. Offset Left Design Example

B.3 Practical Design Alternatives

Figure B-4 and Figure B-5 demonstrate how an initial roundabout layout can be improved to a more practical design. Of note is the fact that both layouts achieve the required design performance checks, but one is more geometrically efficient and costs less. This is the most common dilemma: a design might meet policies but might not be well composed.

The original design, Figure B-4 was likely focusing on just achieving speed control with large chicanes on the approaches. The design has left-offset but it is overdone with additional chicanes. Besides costing much more, the forward sight of the roundabout is lost on the approach, which could result in poor safety performance and decrease functionality. Since the design is also off existing alignment, it would also be too expensive to build. In the refined design (Figure B-5), more of the existing pavement is used; the ICD was reduced while still maintaining speed control. This design will be cheaper to construct and more functional in its operations.

Figure B-4. Original Roundabout Design

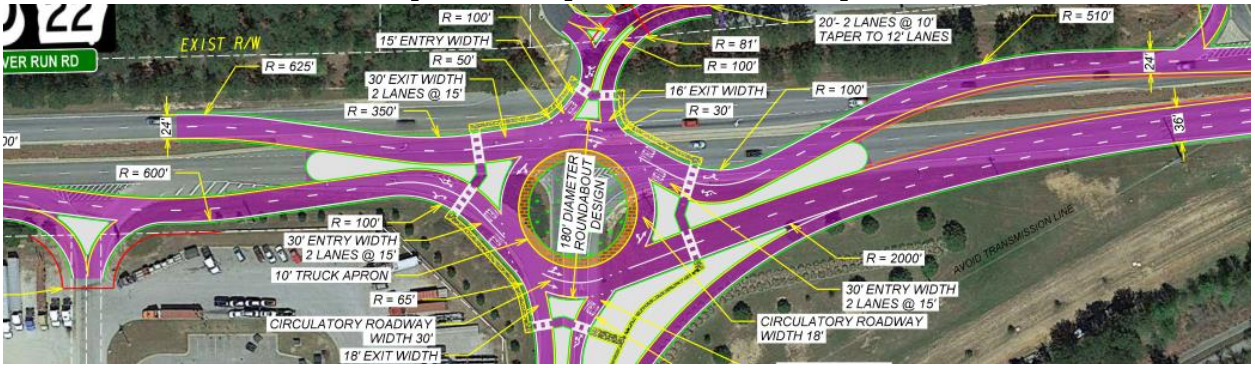


Figure B-5. Refined Roundabout Design

Figure B-6 and Figure B-7 present additional examples of practical design considerations applied through design review. On Figure B-7 practical considerations for approach alignment are exemplified with these considerations:

- In addition to roundabout size and location, alignment of approaches impacts the amount of entry path deflection that can be developed and how the design vehicle is accommodated
- Acute angles between legs make it more difficult for the design vehicle to make right turns
- Obtuse angles between legs make it more difficult to control right turn speed
- Ideally, angles between legs should be balanced with 180° between opposing legs

Figure B-6. Practical Design Considerations

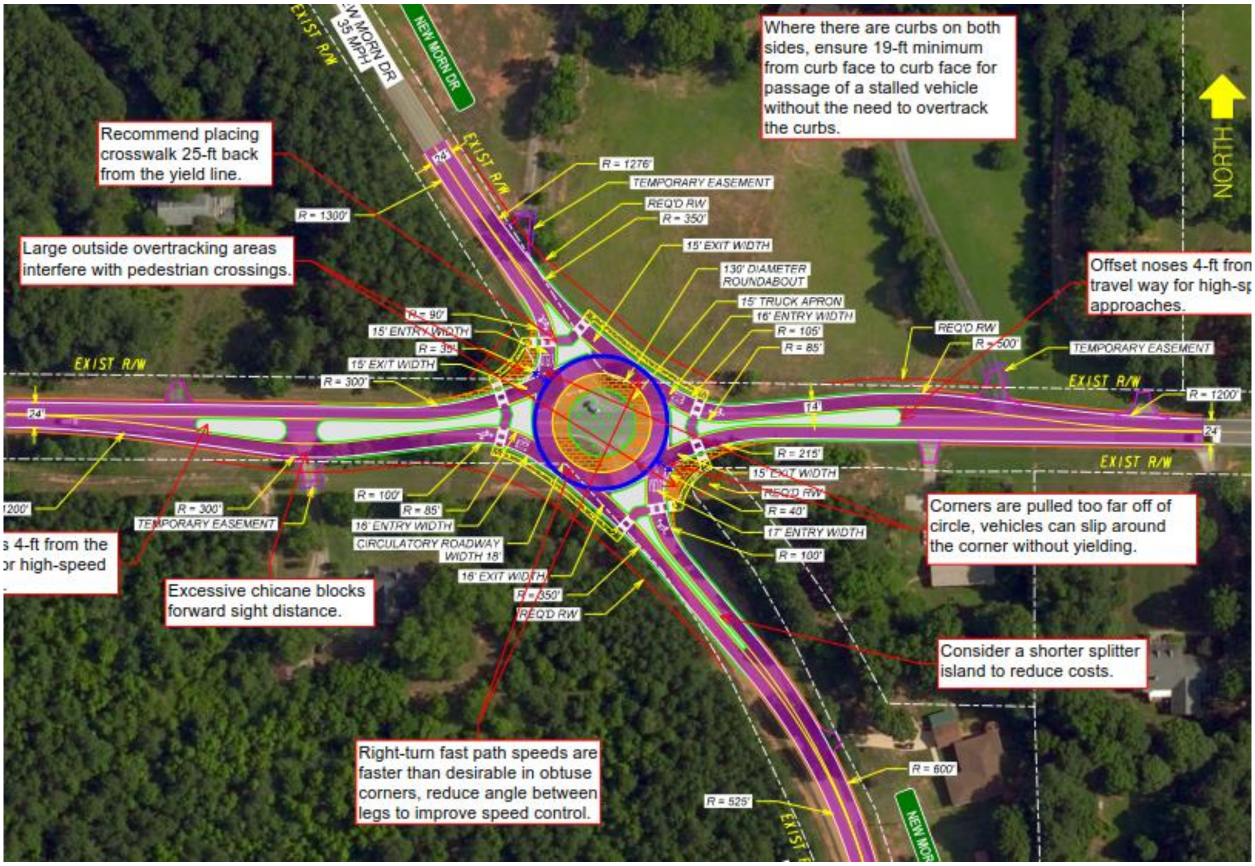


Figure B-7. Practical Design Considerations

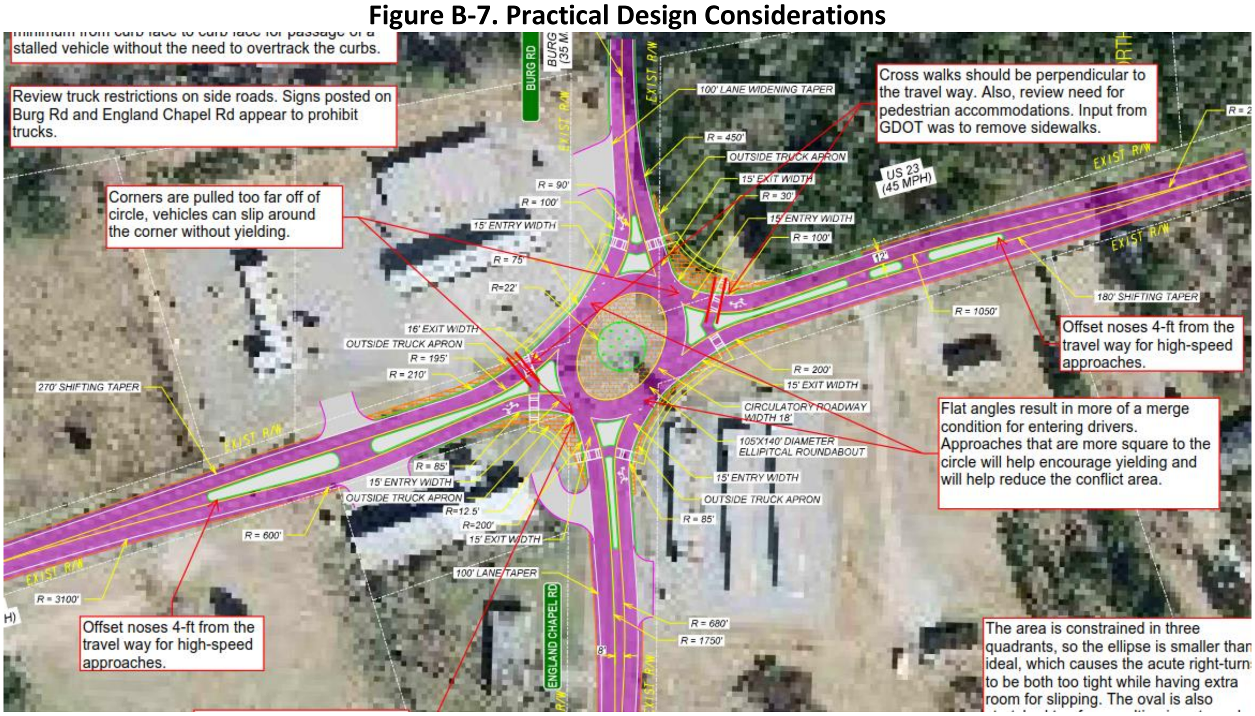
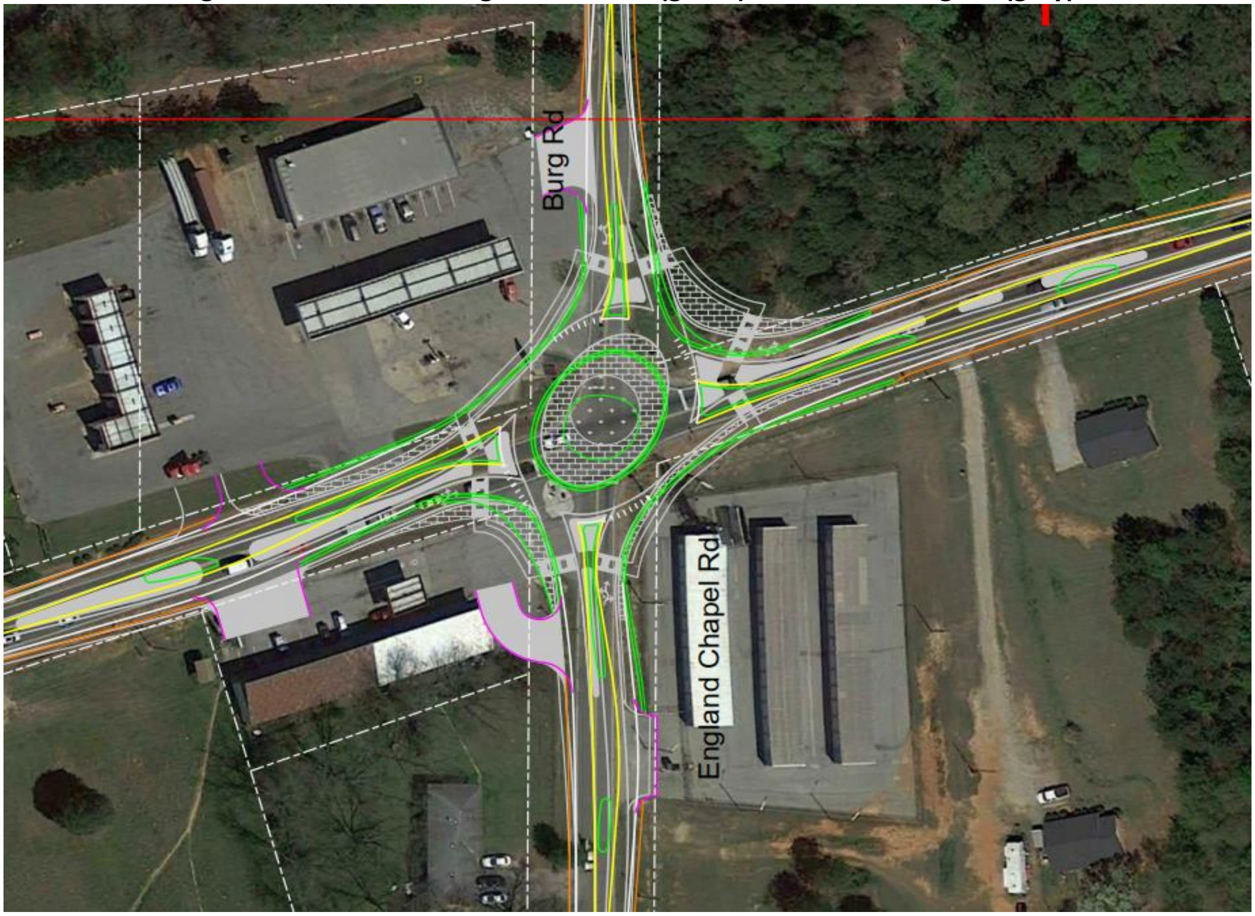
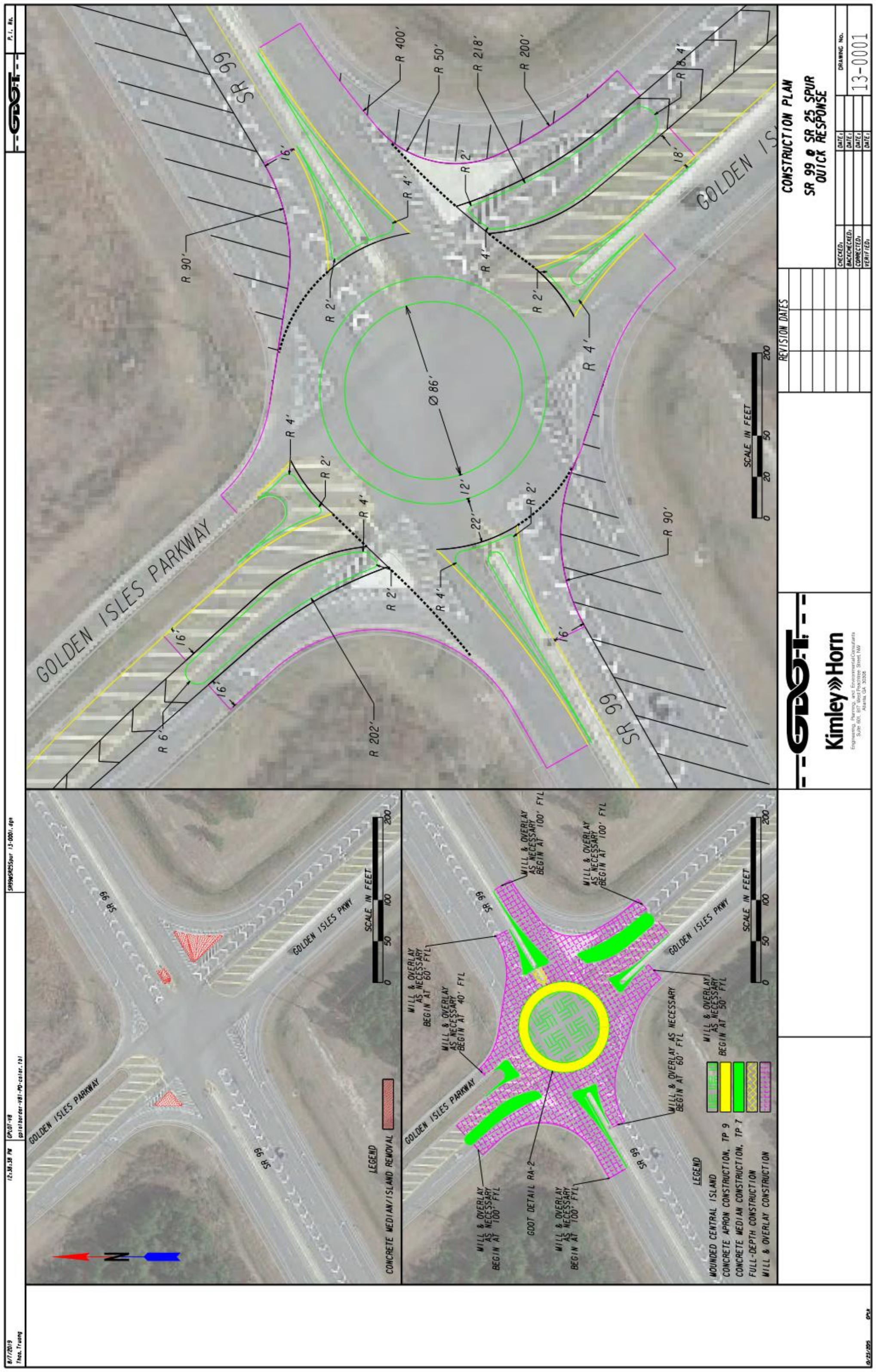


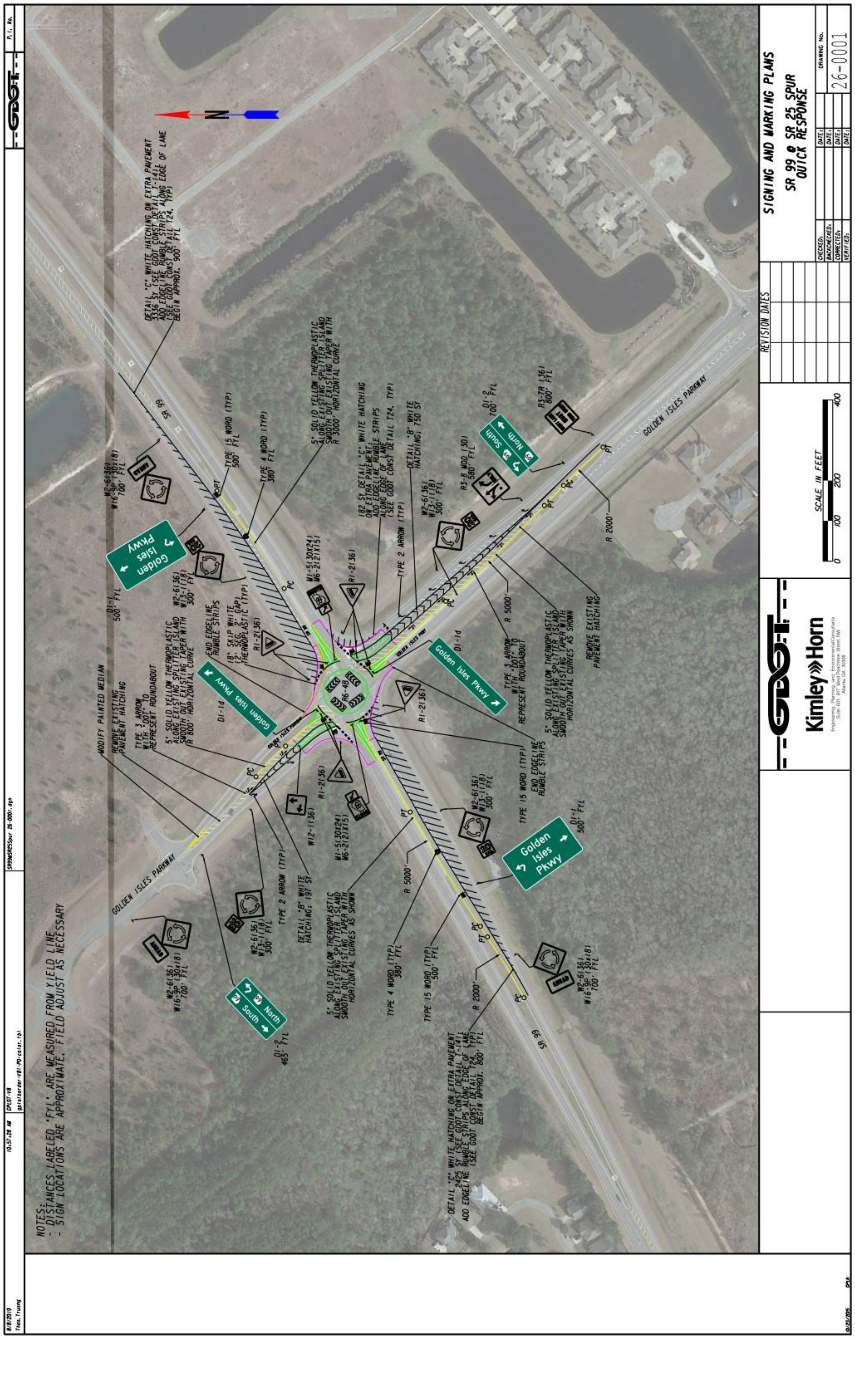
Figure B-8 shows the original layout and a practical alternative overlaid on the original.

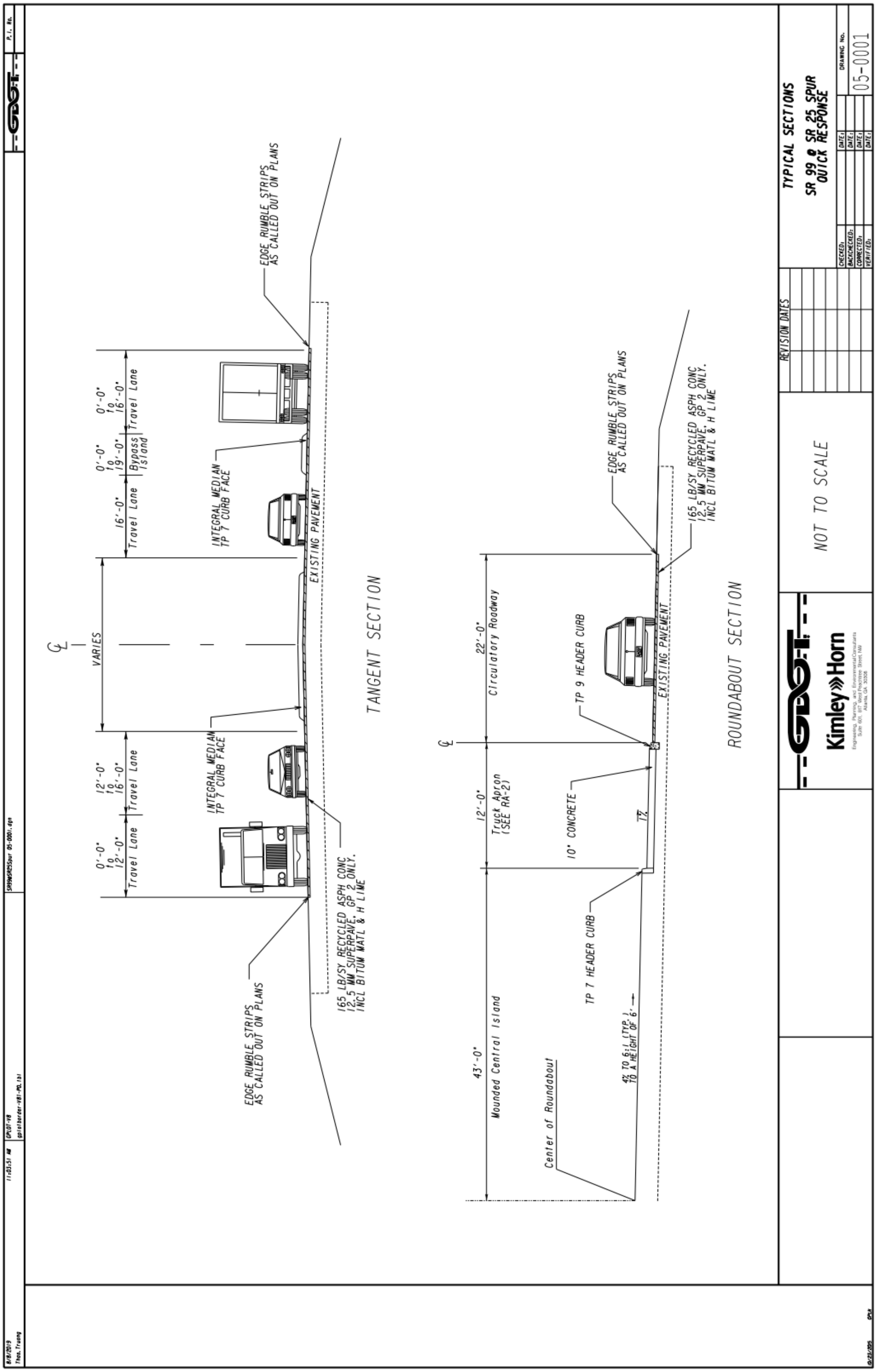
Figure B-8. Practical Design Alternative (green) Overlaid on Original (gray)



B.4 Example of a Quick Response Project Using a Mini Roundabout




SIGNING AND MARKING PLANS
SR 99 @ SR 25 SPUR
QUICK RESPONSE
REVISION DATES
SCALE IN FEET
DRAWING No.
26-0001
Kimley-Horn
GOLDEN ISLES PARKWAY
SR 99
Golden Isles Pkwy
NOTES:
- DISTANCES LABELED 'FYL' ARE MEASURED FROM YIELD LINE
- SIGN LOCATIONS ARE APPROXIMATE. FIELD ADJUST AS NECESSARY


TYPICAL SECTIONS
SR 99 @ SR 25 SPUR
QUICK RESPONSE
DRAWING No.
05-0001
REVISION DATES
NOT TO SCALE
Kimley»Horn
TANGENT SECTION
ROUNDABOUT SECTION
EDGE RUMBLE STRIPS AS CALLED OUT ON PLANS
INTEGRAL MEDIAN TP 7 CURB FACE
EXISTING PAVEMENT
165 LB/SY RECYCLED ASPH CONC 12.5 MM SUPERPAVE, GP 2 ONLY. INCL BITUM MATL & H LIME
VARIES
Travel Lane
Bypass Island
0'-0" to 12'-0"
12'-0" to 16'-0"
16'-0"
0'-0" to 19'-0"
0'-0" to 16'-0"
43'-0"
Mounded Central Island
12'-0"
Truck Apron (SEE RA-2)
22'-0"
Circulatory Roadway
Center of Roundabout
4% TO 6:1 (TYP.) TO A HEIGHT OF 6'
TP 7 HEADER CURB
10" CONCRETE
TP 9 HEADER CURB
1%

APPENDIX C –ROUNDABOUT PERFORMANCE CHECKS

C.1 ENTRY PATH DEFLECTION – FASTEST PATHS

Fast path splines are drawn to estimate the fastest speed of a vehicle making a through (R1, R2, & R3), left-turn (R4), or right-turn (R5) movement in the roundabout, ignoring all pavement markings and lane assignments. Fast paths should be drawn with splines (as opposed to arcs and tangents) because splines, which have constantly changing radii, provide the best representation of the spiral curves that cars take when navigating a roundabout. Splines also allow analysts to draw the smoothest, most natural vehicular path.

C.1.1 DRAWING FASTEST PATHS

Analysts should draw fast paths using the “B-spline by Points” tool in Microstation and place them using the “Control Points” method in Microstation. ‘Through Points’ is another method of setting a spline.

The spline represents the centerline path of a standard passenger vehicle. The critical entry path speeds of the roundabout are located within approximately 165-ft. of the circulatory roadway. Offset lines are drawn to help facilitate placement of the spline and limit how close a passenger vehicle will drive to the curb face or roadway centerline.

Offsets should be 5-ft. from the face-of-curb, 5-ft. from a centerline, and 3-ft. from other pavement markings (such as a painted median or two-way left-turn lane). Draw a spline for each movement using the minimum number of control points necessary to generate a smooth path. Splines should start and end more than 165-ft. from the inscribed circle diameter (ICD). For all movements, place three control points at the beginning and end of the spline, beyond the 165-ft. offset, to develop the starting and ending trajectory of the path (do not place the points too close to each other, otherwise they become ineffective). Placement of three other critical points with curb offsets of 5-ft: entry, circulating and exiting points are located and adjusted to determine the fastest through path for a vehicle. Points vary by movement also. Figure C-1 and Figure C-2 illustrate typical control point placements for a through movement. After the initial placement, iteratively modify the location of the control points so that the spline nearly touches the offset guides, but does not cross the lines.

> ***Tip: Control points placed inside the 165-ft. offset area should be aligned approximately perpendicular to the location where the spline touches the offset line.***

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

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

Figure C-1. Control Points on Approach

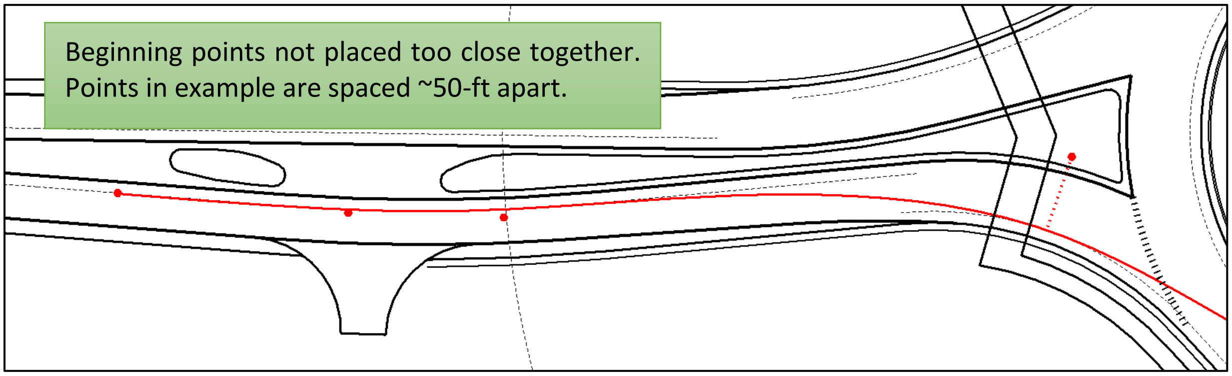
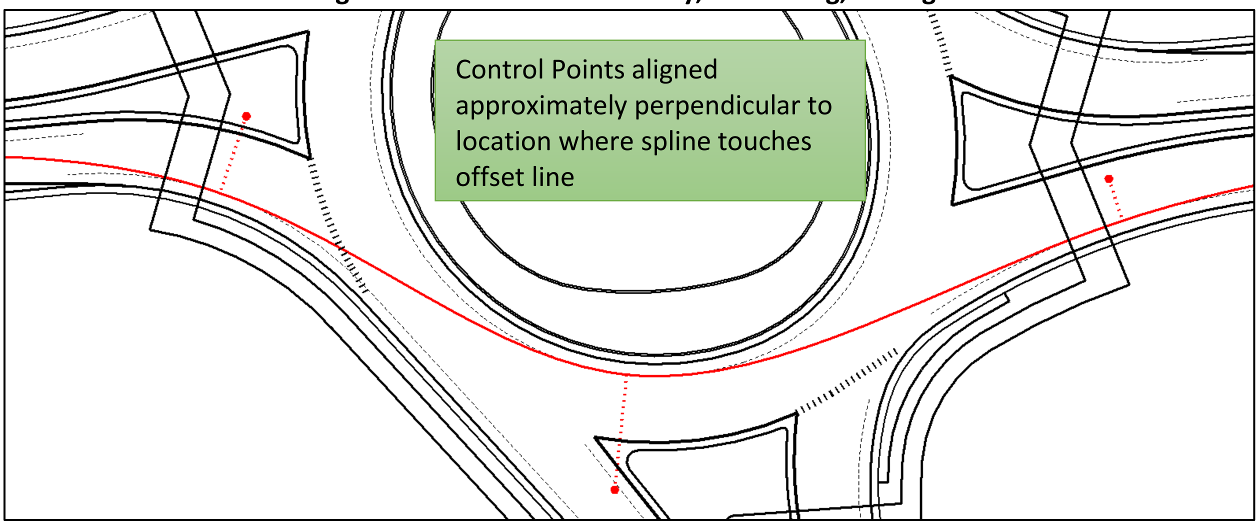


Figure C-2. Control Points Entry, Circulating, Exiting

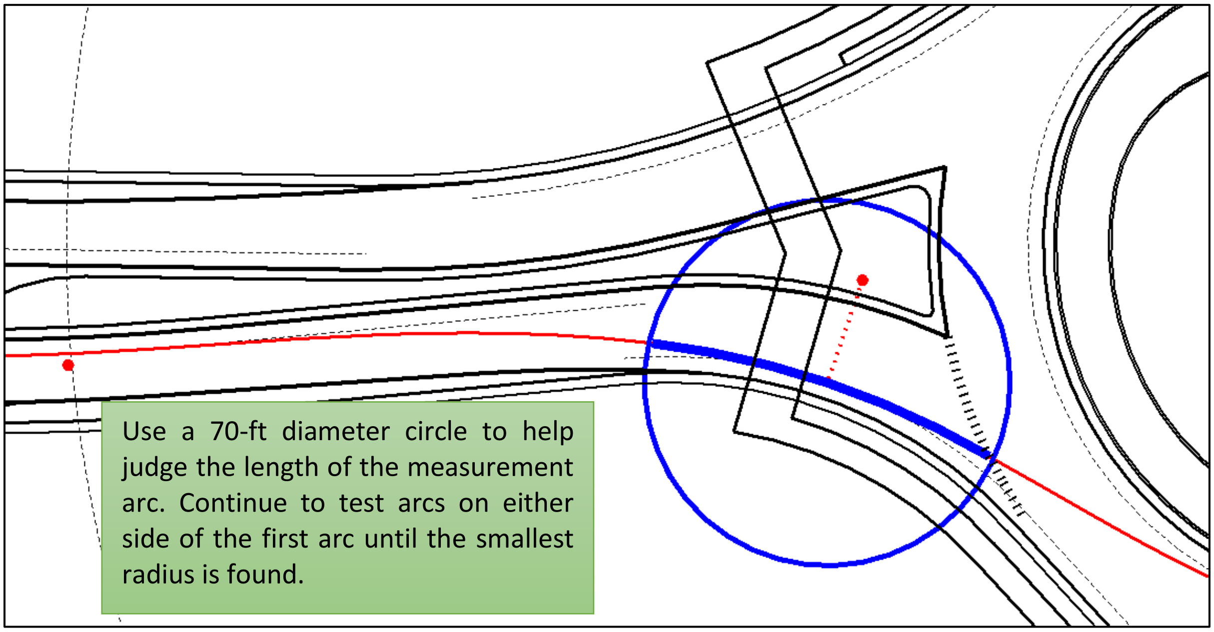


C.1.2 MEASURING THE CRITICAL RADII OF THE SPLINE AND THEIR ASSOCIATED SPEEDS

Using an arc, measure the smallest radius at all critical radius locations (R1 through R5) over a distance of 65-ft.to 80-ft.

> ***Tip: In*** Figure C-3, ***the center of a 70-ft. diameter circle is placed where the spline touches the offset line at the R1 through R5 locations. To measure the critical radius of the spline, draw a three-point arc snapped along the fast path spline within the confines of the circle. This helps the designer to quickly judge the length of the arc and to maintain consistent arc lengths for all radius measurements. Continue drawing arcs on either side of the circle until the smallest radius is found – this is your critical radius for speed control (R1 through R5).***

Figure C-3. Measuring Critical Spline Radius

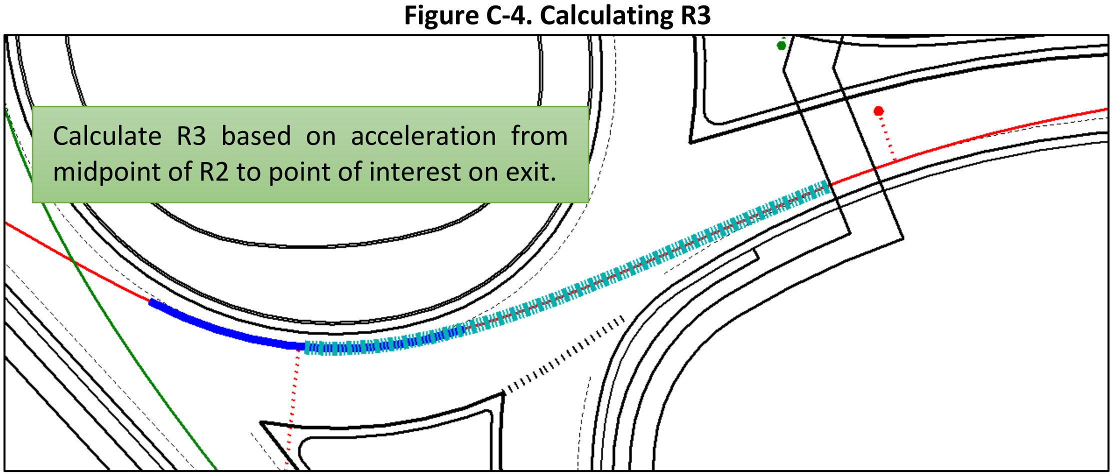


Use equations 6-1 and 6-2 provided in NCHRP 672 to convert the R1 through R5 radius measurements to the actual critical speeds.

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

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

Figure C-4. Calculating R3



C.2 Sight Distance Envelopes

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

C.2.1 Stopping Sight Distance (SSD)

See NCHRP Report 672, equation 6-5 "$d=(1.468)(t)(V)+1.087(v^2/a)$" when calculating stopping sight distances.

d=stopping sight distance, ft
t=perception-brake reaction time, assumed to be 2.5s
V=initial speed, mph
A=driver deceleration, assumed to be 11.2 ft/s^2

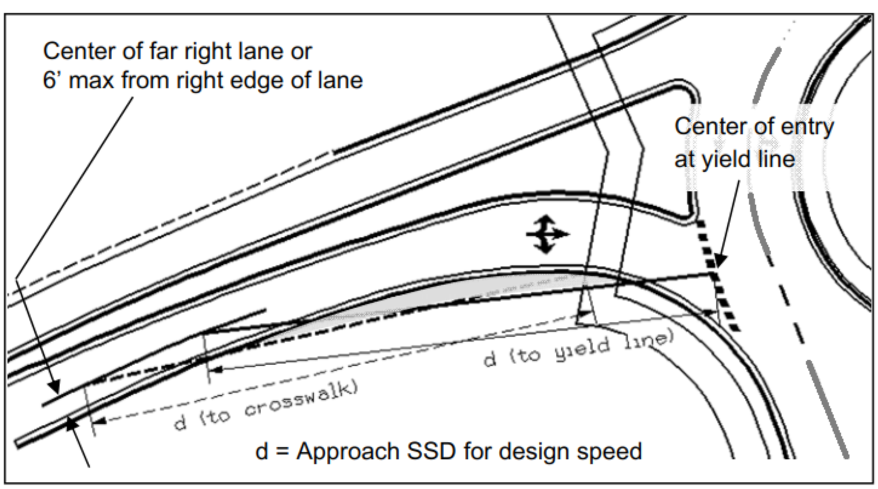
Checks should be provided for:

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

C.2.1.1 Approach Stopping Sight Distance to the Yield Line and Crosswalk on Entry

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

Figure C-5. Approach SSD



Drawing Tips

Approach SSD to Yield Line

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

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

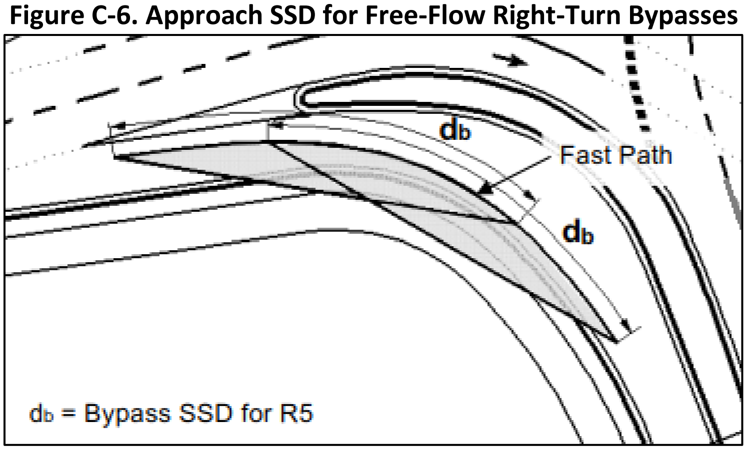
Approach SSD to Crosswalk

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

C.2.1.2 Approach Stopping Sight Distance for Free-flow Right-Turn Bypasses

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

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



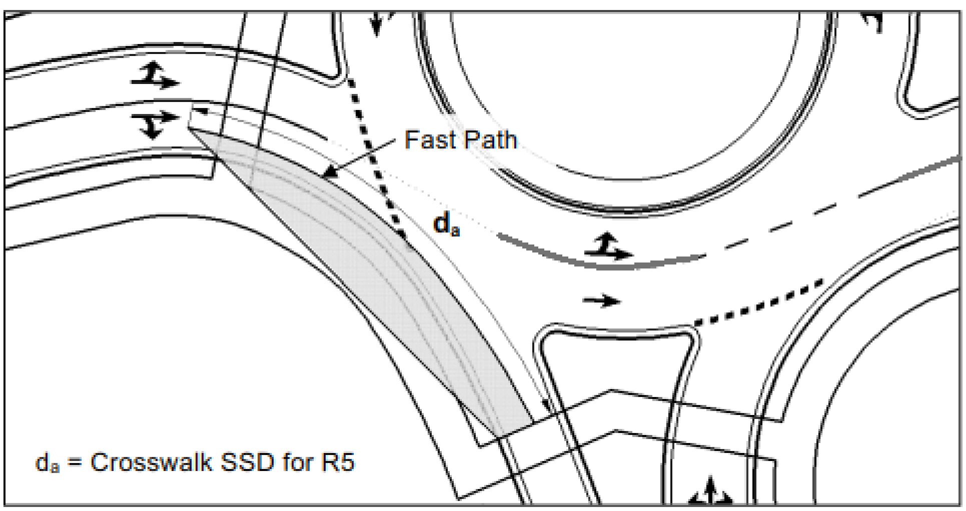
Drawing Tips

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

C.2.1.3 STOPPING SIGHT DISTANCE TO CROSSWALK ON EXIT

Crosswalk SSD provides visibility for drivers to see pedestrians waiting to cross or in the act of crossing the downstream leg as shown in Figure C-7. The sight distance for crosswalk visibility is dependent on the right-turn fast path R5 value. If a right-turn bypass lane exists, the crosswalk stopping sight distance should be based on the fast path through the bypass lane.

Figure C-7. SSD to Crosswalk on Exit



Drawing Tips

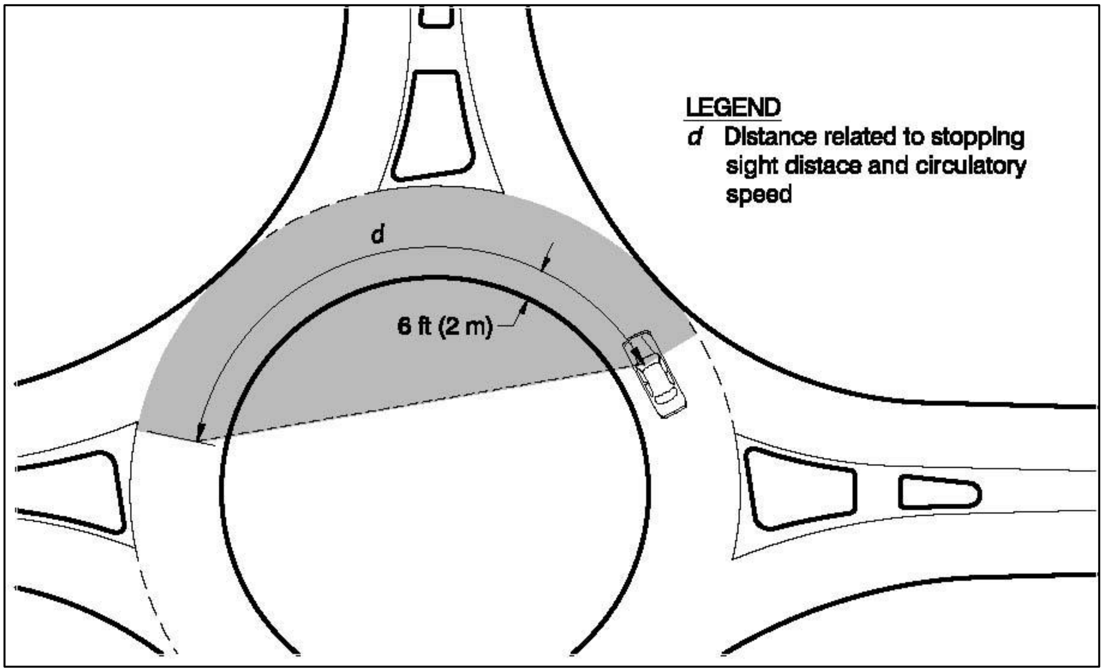
1. Obtain the Crosswalk SSD (**d_a**), based on R5.
2. Trim the fast path to the near side of the crosswalk.
3. Measure **d_a** along the fast path using the same techniques described in Step 2 of the 'Drawing Tips' for 'Approach Stopping Sight Distance for Right Turn Bypass Lanes' in the previous section.

4. Connect the end of the fast path to the near side of the crosswalk at the face of curb to create the sight line.

C.2.1.4 STOPPING SIGHT DISTANCE AROUND THE CIRCULATORY ROADWAY

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

Figure C-8. Consistent R4 Values



Drawing Tips

For Consistent R4 Values

1. Obtain the Circulatory SSD (**d**), based on R4.

2. Offset the central island face of curb 6 ft. and measure **d** along the offset line. (Use ***'Point at Distance Along'*** tool)

3. Connect both ends of the offset line to form the sight line.

4. Repeat Steps 2 and 3 for a minimum of four intervals around the central island.

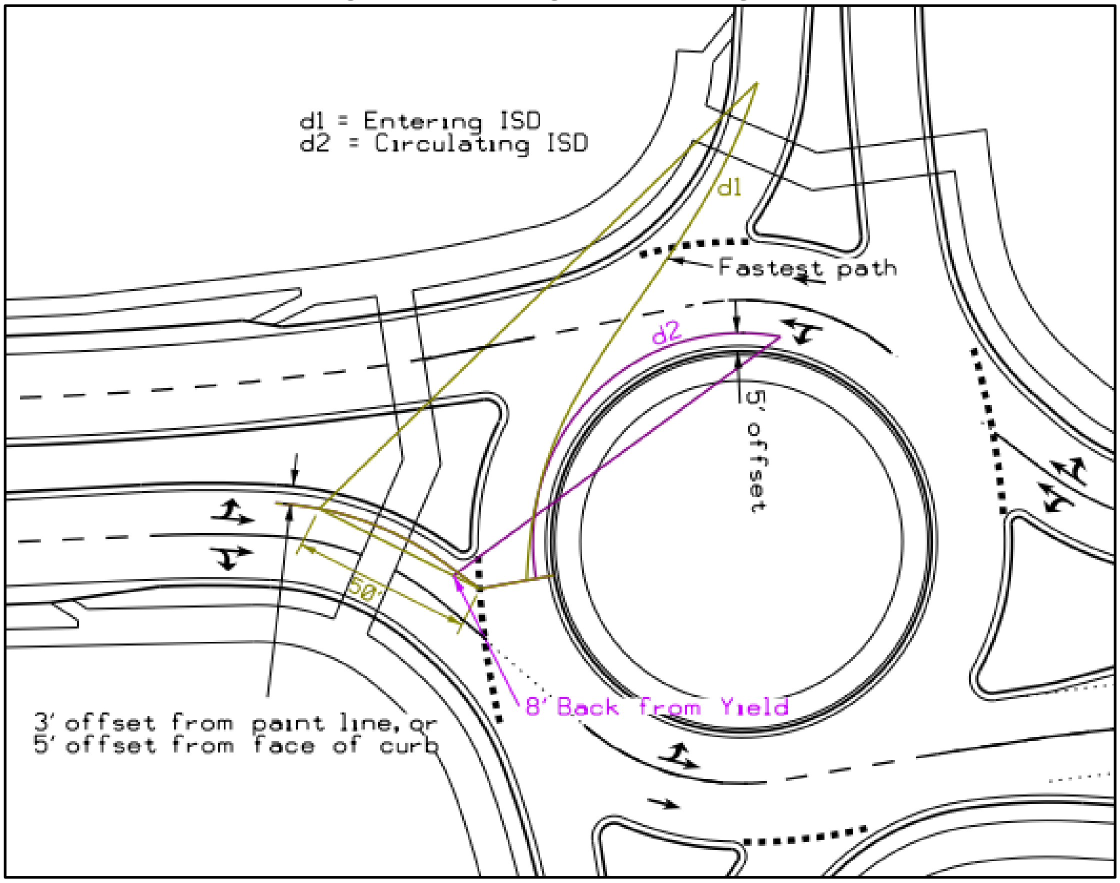
Tip: For quick placement of the sight lines, rotate the first offset arc and sight line from steps 2 and 3 around the center point of the central island to get at least four intervals around the central island.

C.2.2 INTERSECTION SIGHT DISTANCE

Intersection sight distance (ISD) should be checked at entries for two conditions: (1) entering – sight to vehicles on the upstream approach, and (2) circulating – sight to vehicles within the circulatory roadway.

C.2.2.1 ENTERING INTERSECTION SIGHT DISTANCE

Figure C-9. Entering and Circulating ISD



Drawing Tips

1. Offset the far left lane 3 ft. from the left edge of curb/paint line or 5 ft. from the face of curb. Use the ***'construct line at active angle'*** tool (with an angle of 0.0°) to extend the offset arc to the yield line.

2. Center a circle with radius 50 ft. at the intersection of the yield line and active angle line. Draw two lines from the center of the circle, one that intersects the offset arcs with the edge of the circle and one that is perpendicular to the central island face of curb.

3. Trim the fast path of the immediate upstream entry to the line perpendicular to the central island using the 'trim elements' tool.

4. Obtain the Entering ISD (**d_1**), based on the average R1 and R2 speeds. Measure this distance along the fast path using techniques described in Step 2 of the ***'Drawing Tips'*** for ***'Approach Stopping Sight Distance for Right Turn Bypass Lanes'***.

5. Draw the Entering ISD sight line from the end of the 50 ft. line to the end of the fast path.

C.2.2.2 CIRCULATING INTERSECTION SIGHT DISTANCE

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

Drawing Tips

1. Offset the central island face of curb 5 ft. If a spiral exists, follow the lane lines (offset the lane lines 3 ft. until the spiral disappears, then offset the face of curb 5 ft.).

2. Trim the arcs to the line perpendicular to the central island constructed above in Step 2.

3. Obtain the Circulating ISD ($\mathbf{d_2}$), based on R4. Measure this distance along the offset arcs following the same hints described in Step 2 of the ***'Drawing Tips For Consistent R4 Values'*** for ***'Circulatory Stopping Sight Distance'***.

4. Draw the Circulating ISD sight line from the end of $\mathbf{d_2}$ to 8 ft behind the yield line representing a driver at the yield line scanning the circulatory roadway for oncoming circulating traffic.

C.3 VEHICLE ANALYSIS

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

C.3.1 2D ANALYSIS

Two methods exist for analyzing horizontal truck accommodations in 2D: Offset Path (referred to as “Adaptive Simulation” in AutoTURN) and Freehand (referred to as “Arc Path” in AutoTURN). A typical guideline for design vehicles is to provide 2-ft.desirable (1-ft.minimum) clearance from the tire to the curb face. A typical guideline for check vehicles is to provide 1-ft.desirable (0.5-ft.minimum) clearance from the tire to the curb face.

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

The **Offset Path** method involves drawing a centerline path for the truck to follow. This method takes into account lock-to-lock steering time, steering angle locks, and trailer angle locks. Speed is indirectly accounted for, but is not a direct input. The speed varies as the vehicle navigates the path; the smaller the arc, the slower the vehicle will negotiate the curve turn.

The path is created by offsetting known elements of the design (such as edge of pavement, curb face, and/or pavement markings) and turning the elements into a complex chain. A typical offset from the face of curb is 6-ft; however, offsets may vary depending on the size of the truck and the width of the gutter pan. This method works well for paths that need to be repeatable in order to check multiple vehicle types for each movement; however, the path may not be suitable for all vehicle types. This method also typically provides a smoother path than the Freehand method, which may be desirable for exhibits.

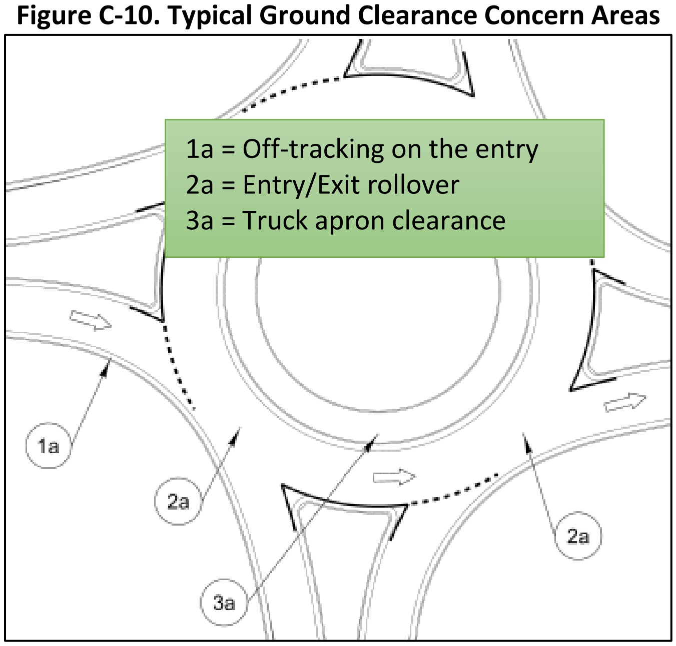
The **Freehand** method involves manually driving the truck through the desired turning movement. This method takes into account the same factors as the Offset Path method, but also accounts for a non-varying speed along the path set by the user. 9 MPH is desirable, but may be decreased to 6 MPH for very large vehicles. (Note that as the speed increases, maneuverability and net off-tracking decreases.) The Freehand method works well for determining approximate roadway width requirements, and is ***the only method for analyzing trucks with independent rear-steering capabilities*** (speed limited to 6-mph or less in AutoTURN). With practice, paths generated with this method can be as smooth as paths generated with the Offset Path method.

If a vehicle has independent rear-steer capabilities, such as tiller-aerial fire trucks and some OSOW trucks, the Freehand method must be used. Care should be taken to not overstate the maneuverability of the actual vehicle. A good rule-of-thumb is to turn the rear wheels 4-degrees for every 17-ft.of travel path. The designer should minimize the amount the rear steering is used to the extent possible.

C.3.2 3D Analysis

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

Figure C-10. Typical Ground Clearance Concern Areas



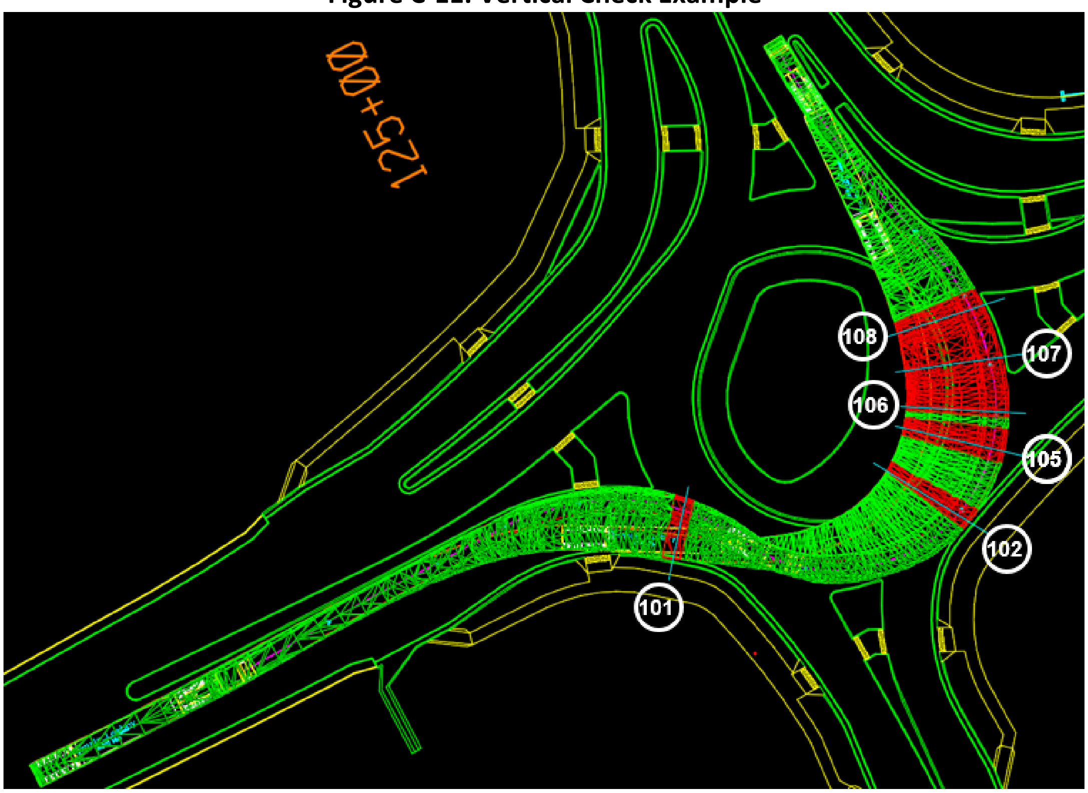
To conduct a 3D analysis, a 2D vehicle path and a combined 3D surface are needed. The surface should cover the entire area of the 2D path and needs to include the following areas: circulatory roadway, truck apron, outside curb and gutter, entries, and exits. The surface should be free of extraneous triangles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

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

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

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

Figure C-11. Vertical Check Example



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

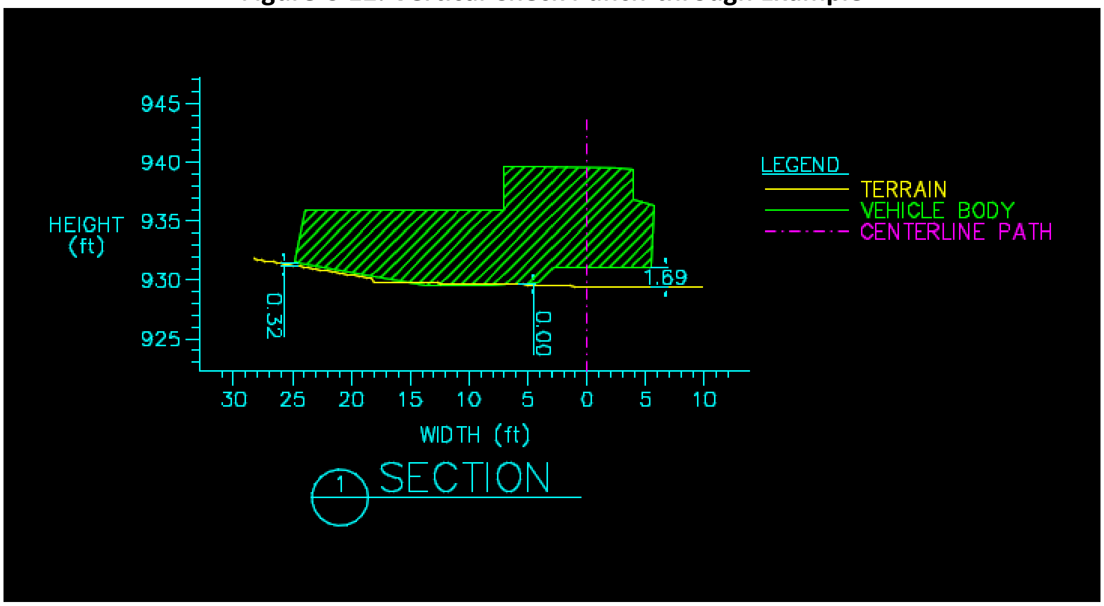
1. Start by placing perpendicular lines across the red hatching areas where cross-sections will be cut (shown as lines 101 to 108 in Figure C-11, for example).

2. Click on the ***"Analyze Punch Through"*** button.

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

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

Figure C-12. Vertical Check Punch-through Example



APPENDIX D – OSOW

D.1 Review of OSOW Permits

After a roundabout is programed to be constructed, OSOW single-trip permits need to be requested for the past three years from OSOW@dot.ga.gov. The permit records tabulated to help evaluate the size and direction of oversize vehicles and how many times they have traveled through the intersection in the past three years. GDOT Office of Traffic Operations recommends accommodation of a vehicle if it has more than 3 occurrences over a three-year period. Refer to Section 3.2 of the GDOT Design Policy Manual for information relating to the selection of design and check vehicles. Typical assumptions during the review process include:

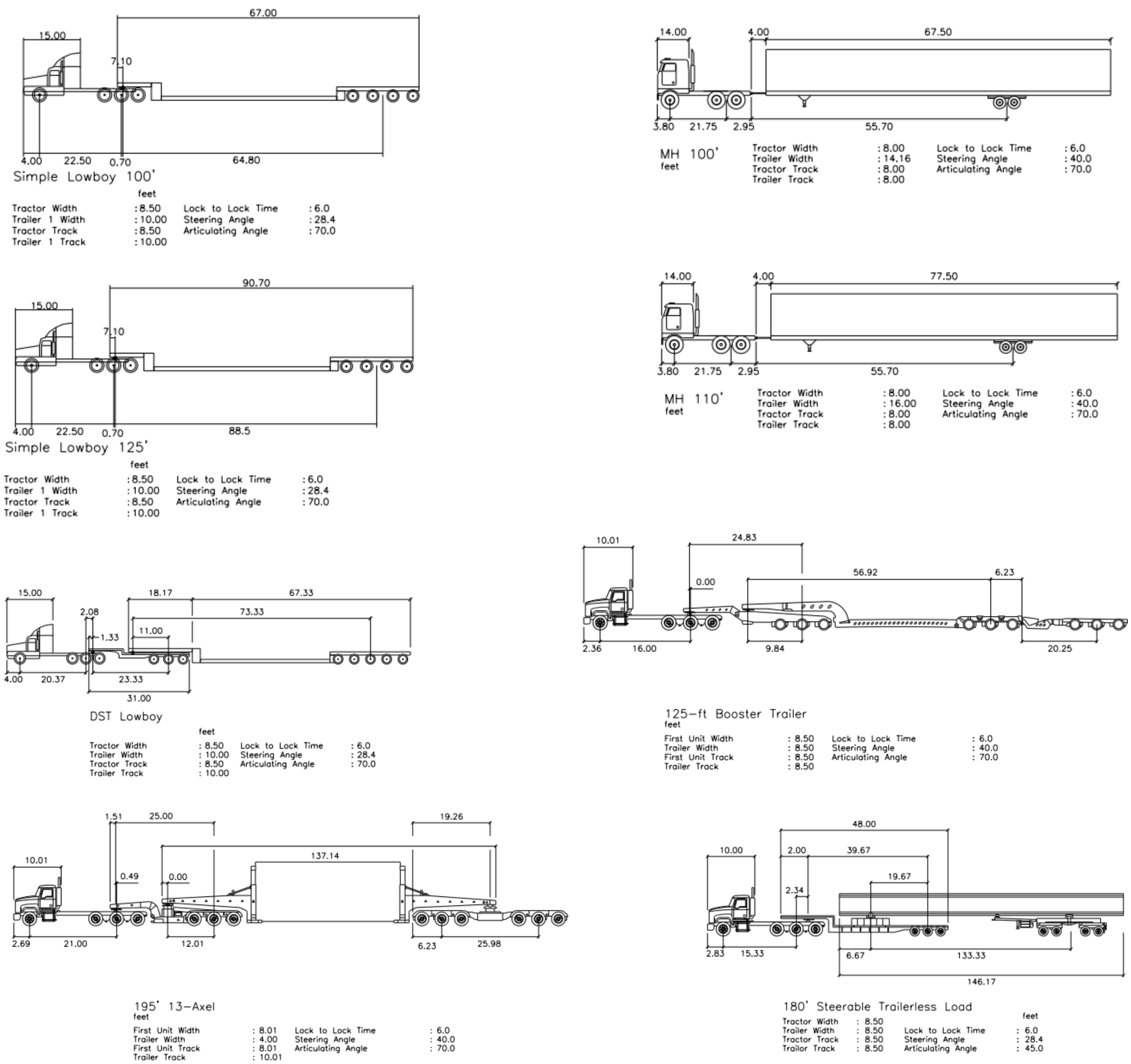
ASSUMPTION	REASONING
OSOW vehicle records with 3 or less trips through the intersection may not be accommodated by the roundabout per the discretion of GDOT. These vehicles will still be run in the design file to reference their needed accommodations.	The added cost for accommodations of these low frequency vehicles may not be cost beneficial.
Review and development of the routing matrix are only concerned with OSOW vehicles 100 ft. and over in length. If there are few or no records of vehicles greater than 100 ft. then an 85 ft. lowboy vehicle will be modeled to ensure multi-trip permitted vehicles can pass through the intersection.	Vehicles shorter than 100 ft. can traverse the intersection without extra accommodations. Since multi-trip permit records are not usually included and if the single-permit records are minimal the modeling of an 85 ft. lowboy should ensure other multi-trip permit vehicles will be able to pass through the intersection.
Vehicles over 100 ft. will be categorized into the standard fleet developed by GDOT (See Appendix D2), this will be discussed in the following section.	Vehicles come in a wide range of lengths, axel spacing, pivot points, etc. categorizing the vehicles into a standard fleet minimizes the need to develop vehicle profiles for every type of vehicle configuration that shows up in the records.
Vehicle movements are assumed to only be one way trips unless a return trip is indicated in the records.	If there is a return trip, then the permit would show up in the records. Once OSOW vehicles deliver their load they may not use the same route back, or vehicle parts can be shorten or disconnected and loaded onto the trailer resulting in it not being an OSOW vehicle anymore.

D.2 OSOW Fleet

From reviewing the permit data at various intersections, an OSOW vehicle fleet has been developed to standardize swept path checks for GDOT projects. Although OSOWs vary in size and width, it is reasonable to assume that there are commonalities between various OSOW vehicles. These commonalities allow for the development of a fleet of trucks that can be used for the purpose of conceptual design. Data from

OSOW carriers' equipment list, permit record information, and AutoTURN's base vehicle library (available from the Office of Traffic Operations) were used to develop the OSOW fleet listed and illustrated below:

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



Review permit records to obtain the truck type and direction on which vehicle to model. Vehicles over 150 feet are assumed to have rear-steer capabilities. Custom OSOW vehicles may need to be created for a specific intersection if it can't be categorized into one of the vehicles in the standard fleet. Review of the surrounding area should be completed to determine if facilities in the area may produce a custom vehicle type, i.e. flatbed log truck with an overhang. These vehicles may not show up in the OSOW single-vehicle permits due to it being a multi-trip permit or not within the OSOW requirements, while, as an example, the overhang from a log or pole truck may require special attention to where light poles and/or signs are placed.

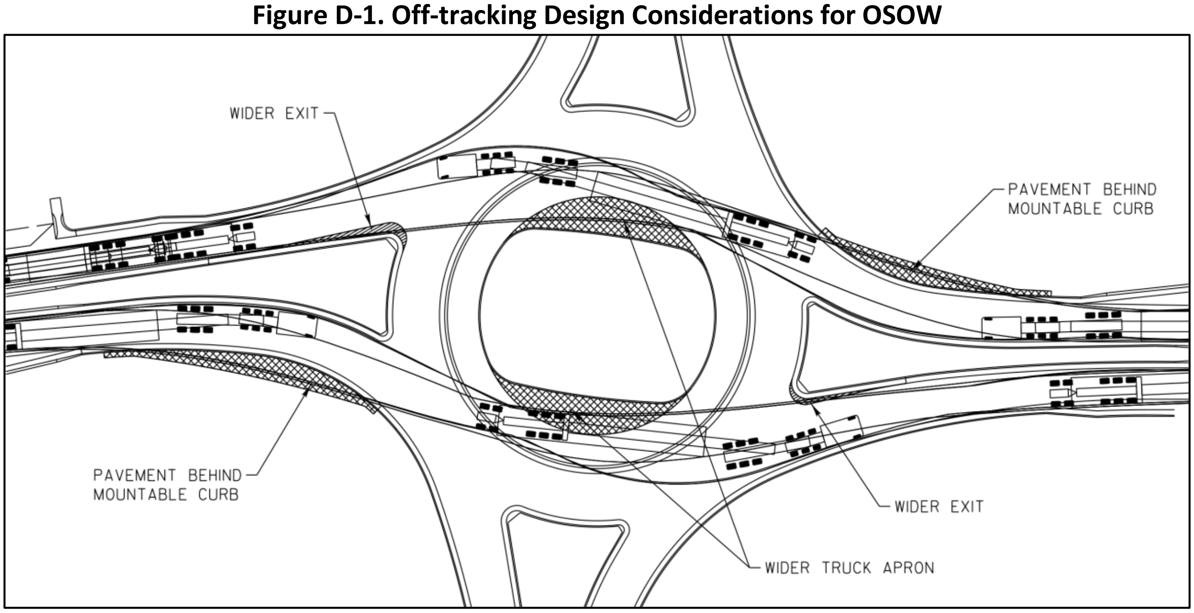
D.3 VEHICLE ANALYSIS

A check vehicle should be accommodated at the intersection, but the design of the roundabout should not be compromised to accommodate the check vehicle. When conducting a swept path analysis for the check vehicle, provide 0.5-ft. minimum (1-ft. desirable) clearance from the tire to the curb face. Where these minimum clearances cannot be provided, special accommodations may be made. Examples are in the bullet list below. If the turning movements require extremely wide truck aprons (i.e. the remaining central island is significantly reduced), consider counter-flow movements where practical. Counter-flow movements do not compromise the size of the central island, which is important for increasing the visibility of the intersection, and for blocking sight across the intersection. Special accommodations may include (but are not limited to):

- 4-in mountable curbs on splitter islands (e.g. Type 1 or Type 9)
- Paved overtracking pads behind outside curb radii
- Counter flow travel
- Gated bypass lane just for the OSOW vehicles to use
- Full depth shoulders
- Wide shoulders
- Relocation of signals, poles, signs, street appurtenances, etc.
- Removable signs and street appurtenances
- Pavement grades and cross slopes that ensure vehicle body clearance to prevent “hanging up” or scraping

See Figure D-1 for an example of the central island modifications and the added tracking areas to accommodate an OSOW vehicle making through movements.

Figure D-1. Off-tracking Design Considerations for OSOW



APPENDIX E – VERTICAL DESIGN BEST PRACTICE

E.1 ALIGNMENTS AND PROFILES

When considering the location of alignments the designer should consider their usefulness in generating cross-sections, profiles, layout details, and ease of use during construction layout. It is therefore recommended that several horizontal alignments be developed (See Figures E-1 and E-2):

1. Along the curb line between the truck apron and the circulatory roadway and along the curb or gutter flange lines of splitter islands.
2. Along the outside edges of pavement, along the C&G lines at locations with varying widths (usually from bike ramp to bike ramp), and along the C&G lines for both sides of right-turn bypass lanes.

Figure E-1. Splitter Island Alignments

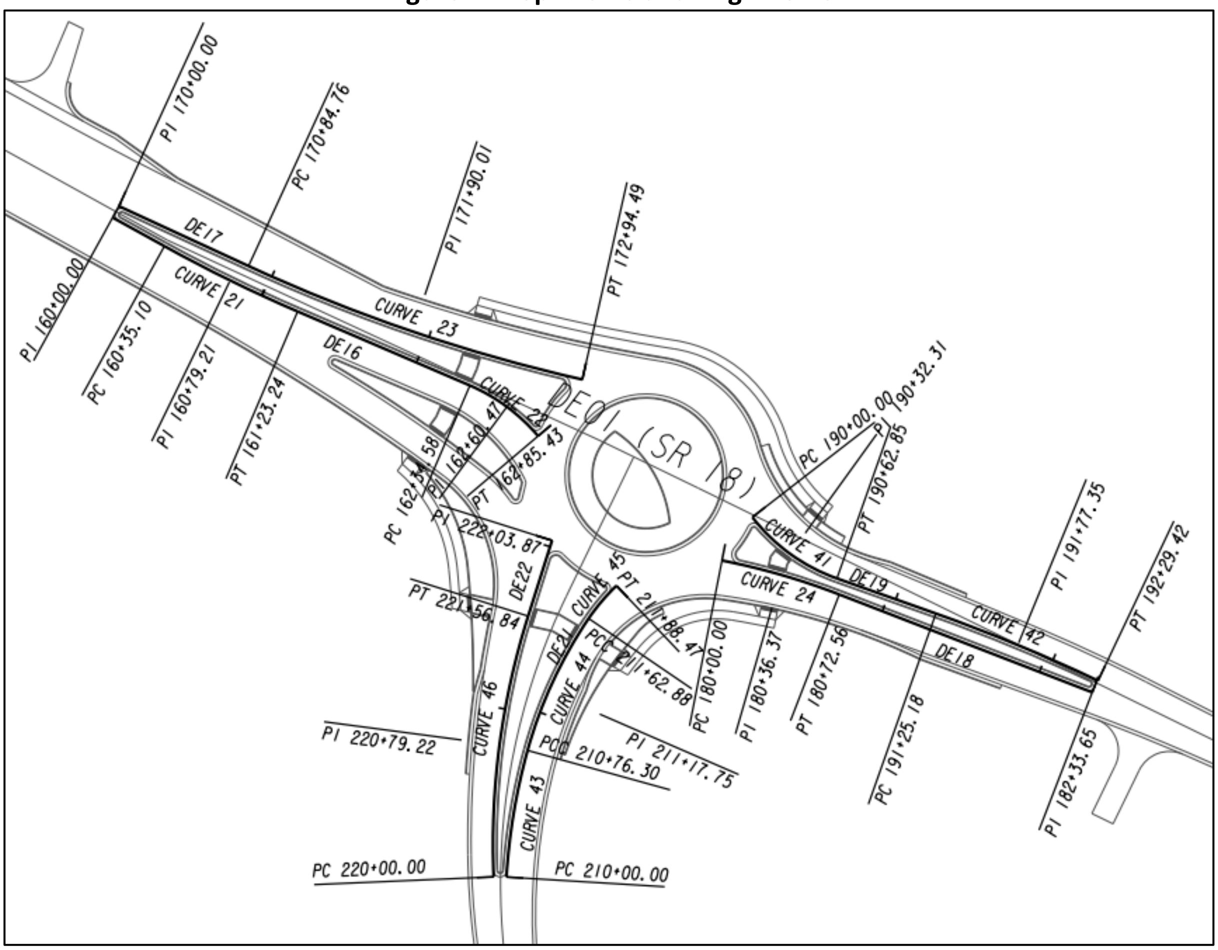
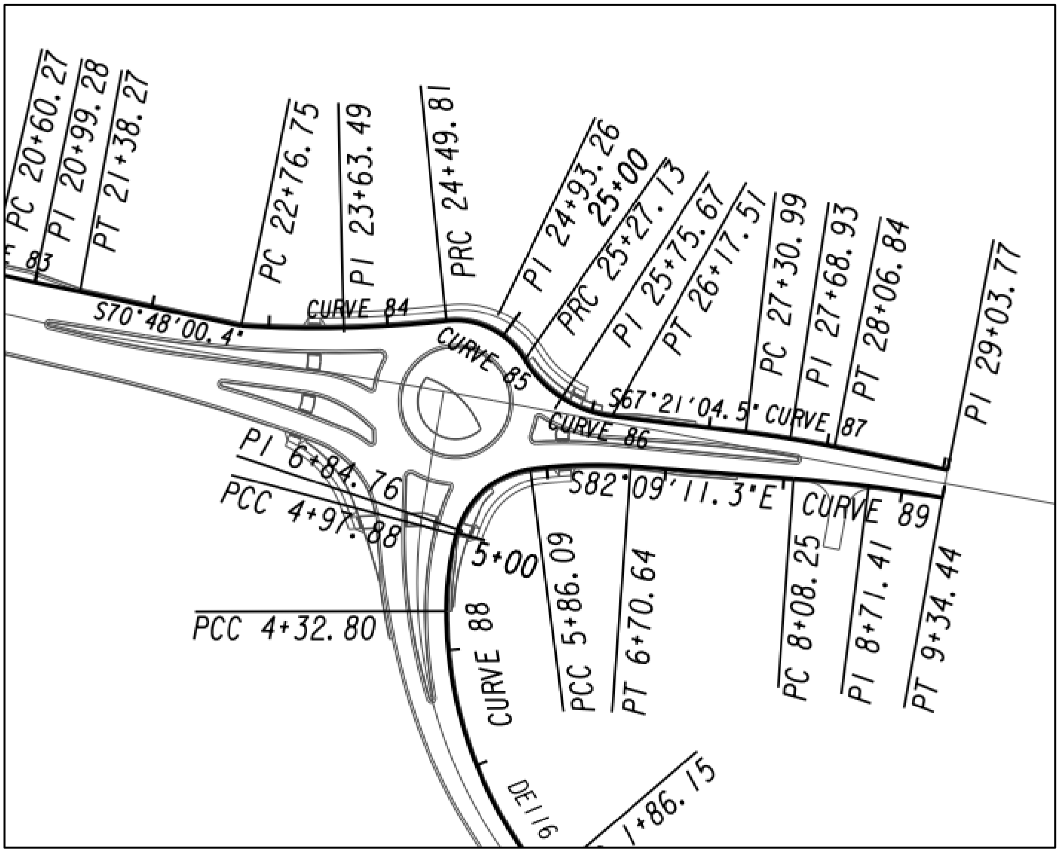


Figure E-2. Outside Curb Alignments



E.2 PROFILE INFORMATION

Developing profiles is an iterative process that involves both a macro and micro approach. It is important to understand what the existing terrain and roadways are doing before the finer details can be tackled. Additionally, since profiles should be developed for the horizontal alignments that will be used in constructing the roundabout, the many interrelating profiles must be developed with a compositional context in mind.

1. Macro approach:

The mainline centerline is typically only used for staking and setting right-of-way plats. A profile developed for this centerline will therefore only be used to get a general idea of what the existing terrain is doing and how the proposed roadway might behave.

2. Micro approach (Preferred):

Set a profile for the circulatory roadway. If the roundabout is thought of as a dish tilting on a plane, then there will be one high point and one low point along a continuous profile that closes on itself. Begin the profile (and therefore horizontal alignment) at a point about halfway between the low point and the high point, rather than at the LP or HP themselves so that the vertical curves will not get cut in half. The circulatory roadway profile will be designed from short curves and tangents and it is recommended to have short curves (K values for 15 to 25 mph), especially near the sag, without flat tangents for drainage purposes. The grades for the circulatory roadway should not exceed 4% while maintaining at least 0.5% in the outside curbs.

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

Figure E-3. Station of Circulatory Alignment

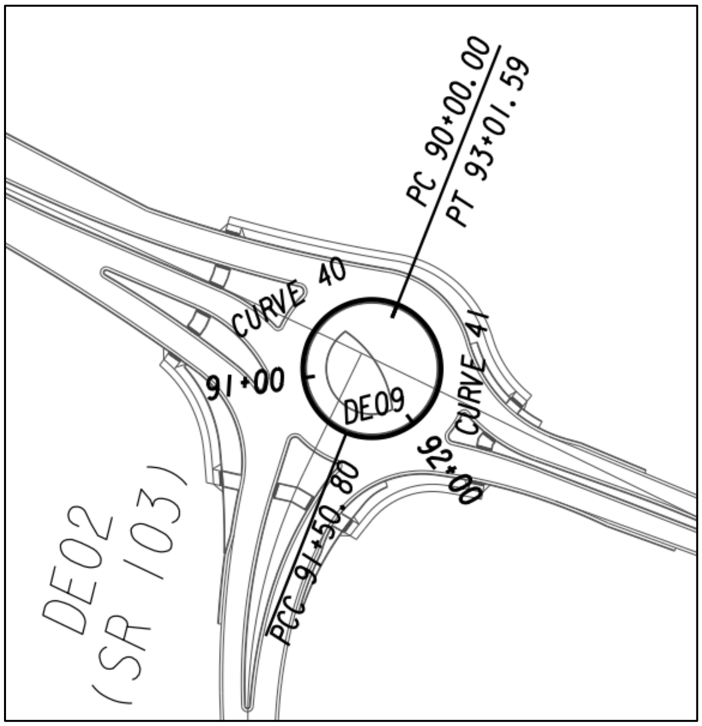
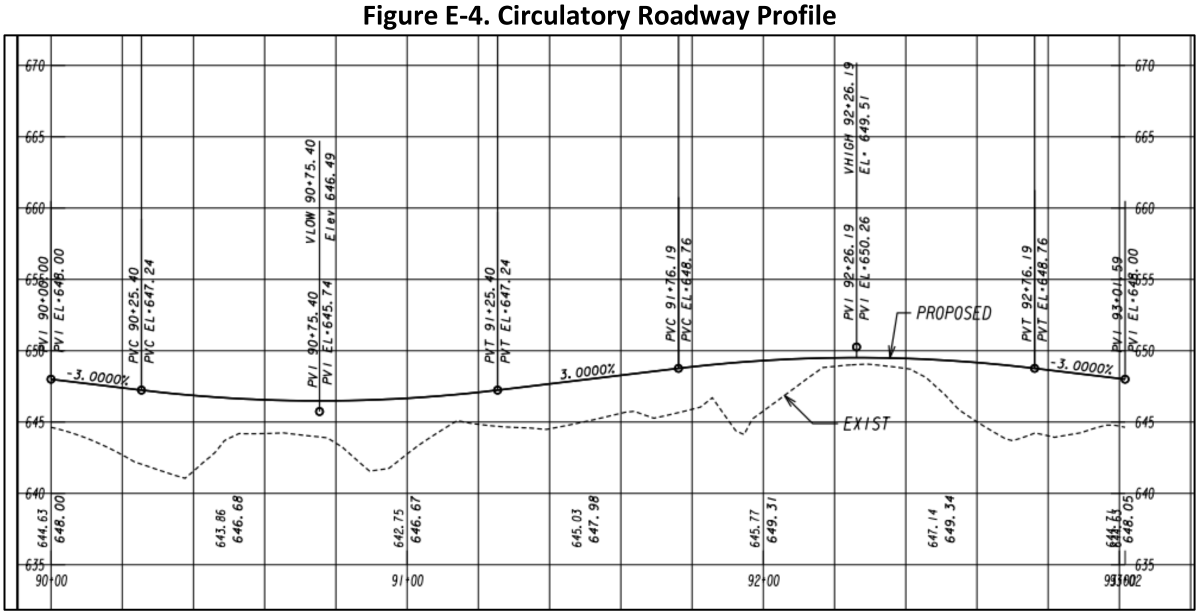


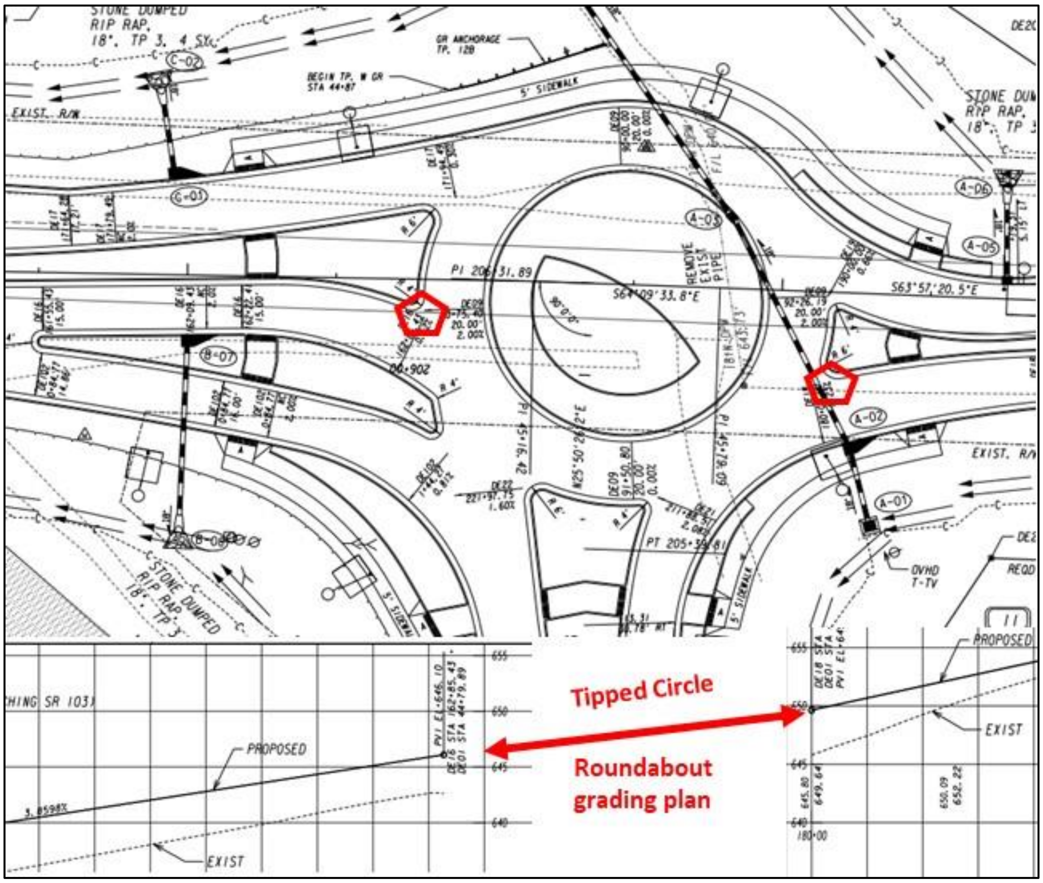
Figure E-4. Circulatory Roadway Profile



3. Develop a profile for each of the splitter island alignments to tie in to the outside edge of pavement of the circulatory roadway. The elevations of these tie-in points can be determined from the circulatory roadway's profile and its cross-slope(s). The circulatory roadway profile can be adjusted as necessary during this process to ensure optimal tie-in with regard to maintaining comfortable break-overs between the entry/exit lane and the circulatory roadway (See Figure E-5).

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

Figure E-5. Splitter Island Profiles

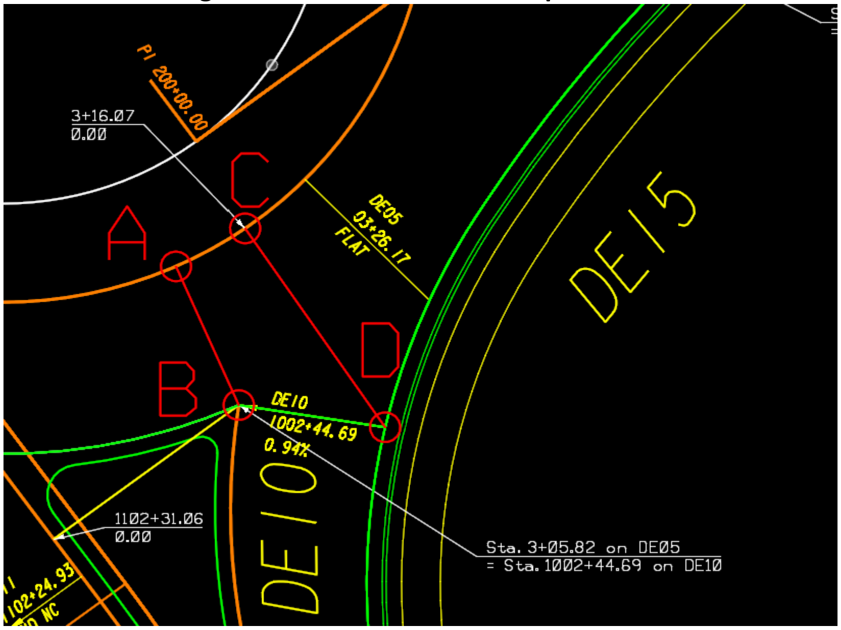


E.3 Grading Design

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

With a uniform rate of transition, it is simple to calculate the x-slope at any given point along the apron's alignment, for example, the x-slope from point A to B or from point C to D in Figure E-6. Elevations at points B and D can then be calculated to determine the x-slope from point B to D, which is the necessary x-slope to tie the entry into the circle.

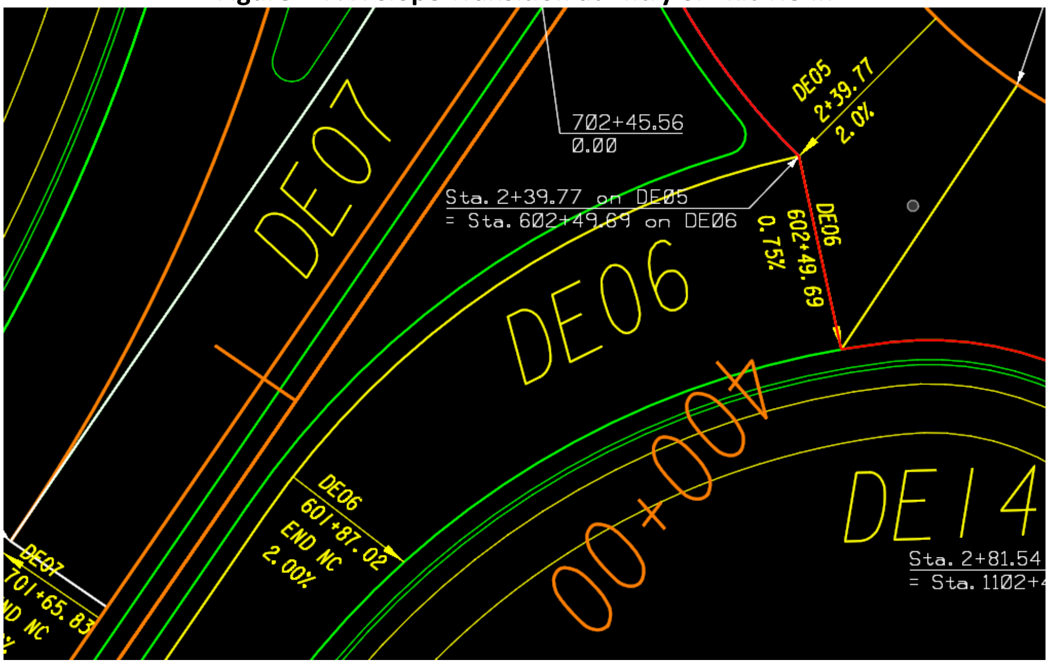
Figure E-6. Points of Station Equivalents



This tie-in x-slope is then transitioned back to Normal Crown at a rate of 0.02%/ft and up to 0.04%/ft (Figure E-7).

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

Figure E-7. X-slope Transition at Entry or Exit Tie-in



Check the outside EOP profiles (produced from the proposed DTM surface) and make adjustments if there are local low points along the gutter that shouldn't be there. Adjustments can be made through either manipulation of the outside EOP profile or the x-slopes. In either case, x-slopes should be maintained under 4%, and x-slope transition at 0.04%/ft max.

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

Figure E-8. Seamless Surface