ROUNDABOUTS AT THE LARRY UTECK INTERCHANGE IN HALIFAX

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1.0 INTRODUCTION

Three multi-lane roundabouts are being implemented along Larry Uteck Boulevard in Halifax, Nova Scotia. Two are at the Highway 102 interchange, and a third is to the east at Nine Mile Drive/Starboard Drive. The use of roundabouts at highway interchanges is becoming common in many areas of the United States and in some Canadian provinces. The Nova Scotia Department of Transportation and Infrastructure Renewal (TIR) is constructing a series of roundabout interchanges, and the one at Larry Uteck Boulevard will represent the busiest and most ambitious to date in the province.

Ourston Roundabout Engineering Canada developed the horizontal geometry of the roundabouts, and assisted with establishing signage plans and sightline envelopes, while CBCL Limited, a local consulting engineering firm, undertook detailed design.

This paper discusses the capacity analysis and design process associated with developing the preliminary designs. This included determining appropriate lane configurations for the forecast traffic flows, recommending optimal locations for the roundabouts, deciding on the most appropriate right-turn treatments, optimizing the conceptual designs in terms of capacity, safety and cost (property impacts) and finalizing the horizontal geometry of the roundabouts.

2.0 ROUNDABOUTS IN NOVA SCOTIA

2.1 BACKGROUND

As in other areas of Canada and the United States, circular intersections have been in use in the Maritime Provinces since as early as the 1950s. The three that remain, the, Armdale Pictou, and Port Hastings rotaries, are well-known to many residents of Nova Scotia and to motorists that have travelled in the Maritimes.

The rotaries were originally designed for merge-on-entry operation. That is to say, motorists travelling around the circle and those approaching were intended to have similar speeds. That meant the rotaries were large, with high speeds, ambiguous right-of-way rules, and relatively poor safety histories. In 2003, TIR struck an implementation committee to bring modern roundabouts to Nova Scotia. Through the efforts of this committee the legislation pertaining to rotaries was changed to allow for a yield-on-entry priority rule, to be consistent with roundabouts.

This change in priority operation, and an acceptance of the capacity, safety and environmental benefits associated with roundabouts, has led to their assessment at a number of candidate intersections across the province. At the time of writing this paper three roundabouts have been constructed in Nova Scotia since 2005, but many more are in the planning, design and construction stages.

2.2 PLANNED ROUNDABOUTS

Nova Scotia is currently in the midst of an extensive program of highway expansion. Sections of Highways 101 and 102, Highway 104 near Antigonish, and Highway 125 in Cape Breton are being expanded from predominantly two-lane undivided facilities to four-lane divided facilities with diamond interchanges at the major intersecting roads.

The majority of the roundabouts planned in Nova Scotia are for installation at the ramp terminals associated with these diamond interchanges, and at nearby major intersections. The following locations are receiving this treatment:

- Highway 101 – Exit 2A Margeson Drive.
- Highway 102 – Exit 2B Larry Uteck Boulevard.
- Highway 102 – Exit 9 Milford.
- Highway 104 – Exit 27 School Road.
- Highway 104 – Exit 31 Addington Forks.
- Highway 104 – Exit 32 Trunk 7.
- Highway 104 – Exit 33 Beech Hill Road.
- Highway 125 – Exit 8 George Street.

Other locations in the province are also being considered for the installation of roundabouts including additional intersections on the Margeson Drive and Larry Uteck Boulevard projects. A total of 17 roundabouts are planned for construction over the next year. Refer to Figure 2.1.

Figure 2.1
Roundabouts in Nova Scotia

Source: Province of Nova Scotia

2.3 PUBLIC EDUCATION

Public education is of primary importance with respect to the introduction of roundabouts as a traffic control device, particularly in areas where residents grew up with rotaries or traffic circles that operated under different priority rules and operating conditions. Any public education campaign should inform motorists and other users that roundabouts are different, and educate them on their use.

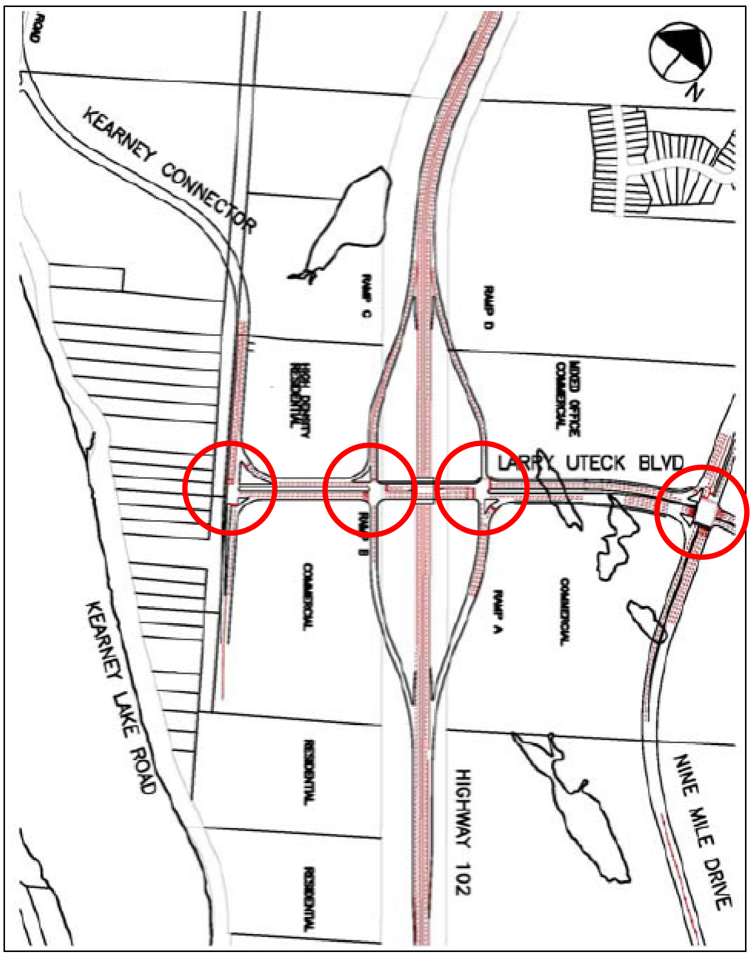
In Nova Scotia, current efforts are aimed at delivering a set of basic operational messages: Slow Down, Yield on Entry, Take a Safe Gap, and Proceed Around the Roundabout to Your Chosen Exit. These messages are being delivered through various forms of media, including the internet, radio and print.

3.0 THE LARRY UTECK INTERCHANGE

3.1 BACKGROUND

The Larry Uteck Boulevard project involves the construction of a new arterial road to serve existing and proposed developments in Halifax. The site context is shown in Figure 3.1. Funding for the project was shared between the Federal Government, the Province of Nova Scotia, and Halifax Regional Municipality.

Figure 3.1
Interchange Site Context



Source: CBCL Limited

The original project concept for the interchange ramp terminals, as well as the Kearney Connector to the west and Nine Mile Drive/Starboard Drive to the east, was for four signalized intersections. However an assessment was undertaken in 2008 to investigate the feasibility of roundabouts. Roundabouts typically have the following advantages compared to signalized intersections:

- Greater traffic capacity for the same number of lanes, with less queuing.

- Improved safety. A major study in the United States found that motorists are about 40% less likely to be involved in a collision, and 75% less likely to be involved in an injury collision, at a roundabout.[1]
- Environmental benefits such as reduced noise, fuel consumption and emissions.

A main disadvantage of roundabouts is that they typically cost more to construct. However, this is not always the case at highway interchanges and other closely-spaced systems of intersections. In this case it was estimated that significant savings could be realized (in excess of $2 million) if roundabouts are constructed because:

- Fewer traffic lanes will be needed along the corridor. Larry Uteck Boulevard will require a 6-lane cross section with traffic signals at the intersections (and up to 8 lanes at Nine Mile Drive), compared to a 4-lane cross section with roundabouts. This is due to the deceleration and storage requirements of left turn lanes at signalized intersections, which often are of such length that it costs little more to widen the entire road section.
- Fewer traffic lanes will be needed between the ramp terminals. Six lanes will be needed across the highway overpass structure with traffic signals, compared to 4 lanes with roundabouts. The narrower overpass structure with roundabouts will be considerably less expensive.
- Fewer traffic lanes will be needed on the highway ramps. The off-ramps will need 2 lanes and lengthy turn lanes with traffic signals to ensure that queues from the signals do not spill back onto Highway 102. Both off-ramps will need fewer lanes to achieve sufficient capacity with roundabouts. The on-ramps can be 1 lane because motorists exiting a roundabout can merge over a shorter distance due to lower operating speeds.

3.2 ROUNDABOUT ASSESSMENT

3.2.1 Initial Roundabout Analysis

Peak hour traffic forecasts for the 2018 and 2028 horizon years were provided by CBCL Limited. They were input into the computer programs Rodel 1.7 and Arcady 6.1 so that a capacity analysis could be conducted to determine entry lane widths and lane configurations for the four roundabouts.[2]

The analysis was first done in Rodel because it has the ability to model varying confidence levels. A 50th percentile confidence level represents the most likely estimate of capacity, and is inherent in other capacity analysis programs such as HCS or Synchro. An 85th percentile confidence level was also modelled to account for a more pessimistic estimate of capacity, in case the traffic volumes are higher than forecast or the roundabouts exhibit lower capacity than expected.[3] This allows for more conservative designs.

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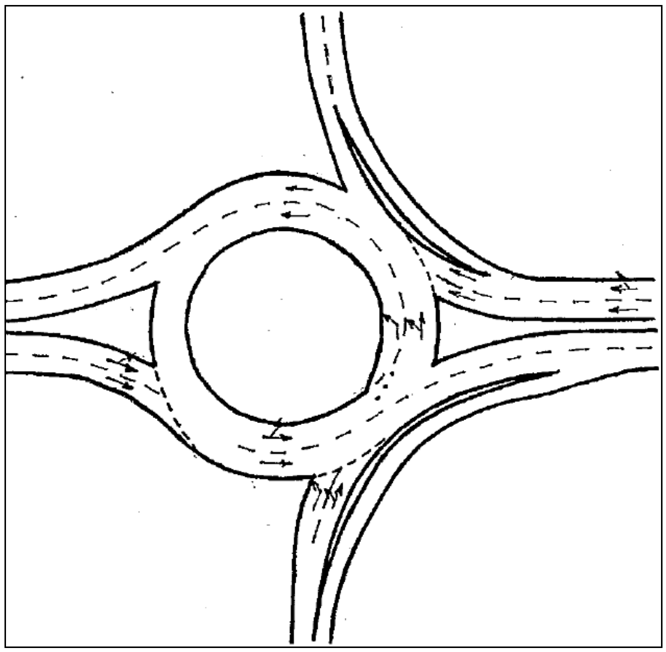
[1] *Roundabouts in the United States*, NCHRP Report 572, National Cooperative Highway Research Program, Transportation Research Board, 2007. This data is from 55 roundabouts in the U.S. in a variety of settings and previous intersection control.

[2] Both Rodel and Arcady are based on the same roundabout capacity research in the United Kingdom, and will basically give the same results.

[3] The latest version of Arcady, Arcady 7.0, has even further capabilities in this regard, including the ability to calibrate to local conditions.

Based on the analysis and lane-by-lane modelling, by 2028 all four roundabouts will need to have at least one two-lane entry, a channelized right turn, and a double left turn. The double left turn requires spiral circulatory road markings so that motorists making a left turn from the previous entry are not forced into making an unsafe lane change inside the roundabout in order to exit. The lane configuration for the easterly interchange roundabout, as an example, is illustrated schematically in Figure 3.2.

Figure 3.2
Lane Configuration of the Easterly Interchange Roundabout



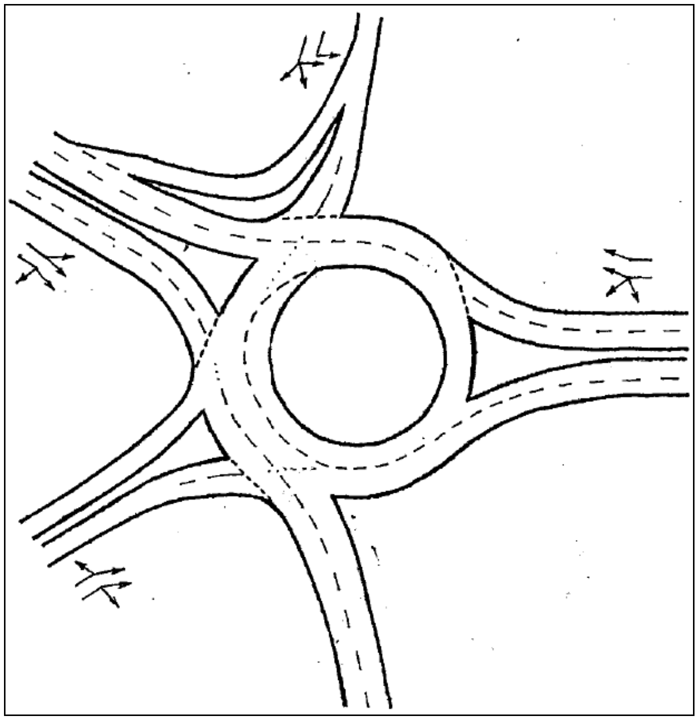
All four roundabouts were predicted to operate at overall peak hour level of service (LOS) ‘A’ to ‘B’ by 2028 at the most-likely 50th percentile confidence level. The critical entry is the northbound Highway 102 ramp terminal, predicted to have a residual capacity of 12% and a 95th percentile queue length in the order of 85 metres.

3.2.2 Westerly Interchange Roundabout

Subsequent to the initial assessment, a proposal was brought forward for a combined roundabout to replace the two roundabouts originally proposed at Kearney Connector and at the Highway 102 southbound ramp terminal. Based on the Rodel and Arcady analyses, this roundabout would require two-lane entries, a channelized right turn, and consecutive double “left” turns. As before the double “left” turn requires spiral circulatory road markings. The lane configuration for this roundabout is illustrated schematically in Figure 3.3.

The roundabout was predicted to operate at overall peak hour level of service (LOS) ‘A’ by 2028 at the most likely 50th percentile confidence level. The critical entry is from Kearney Connector eastbound (or southbound), predicted to have a residual capacity of 12% and a 95th percentile queue length in the order of 44 metres. This is based on a total entering volume of 4,250 vehicles per hour by 2028.

Figure 3.3
Lane Configuration of the Westerly Interchange Roundabout



There is certainly a cost advantage associated with combining the two roundabouts at Kearney Connector and at Highway 102 into one roundabout. But there are trade-offs as well. Potential disadvantages of a combined roundabout:

- Possibly less familiar layout to motorists because of lack of right angles at Kearney Connector.
- More complex lane configuration at the roundabout consisting of consecutive double "left" turns and a section of circulatory road three lanes wide.
- Approximately the same delays and queues under the scenarios tested, but about half the residual capacity of two individual roundabouts. (The actual worst-case residual capacity of 12% is the same as for the ramp terminal at the northbound Highway 102 off-ramp.)

Potential advantages of a combined roundabout:

- Likely to be considerably less expensive (approximately $1 million).
- Reportedly better resulting lot pattern, property access and development yield because of an existing wetland.
- Should be lower overall emissions and fuel consumption because of less distance travelled for the higher-volume movements (although the difference will be minor compared to the use of roundabouts instead of signalized intersections).
- There is precedent for more complex roundabouts in the area (namely the Armdale Roundabout in Halifax).

3.2.3 Conclusions

Based on the assessment it was decided to proceed with a combined roundabout on the west side of Highway 102, and roundabouts at the northbound ramp terminal and Nine Mile Drive/Starboard Drive.

Compared to signalized intersections, roundabouts in this context will offer equivalent or better traffic operations, and better safety for all users (pedestrians, cyclists and motorists). Roundabouts may ultimately be less expensive to construct because they will require fewer overall traffic lanes, particularly across the highway overpass structure. They will almost certainly be less expensive when life cycle costs, including the societal costs of reduced injury collisions, are taken into account.

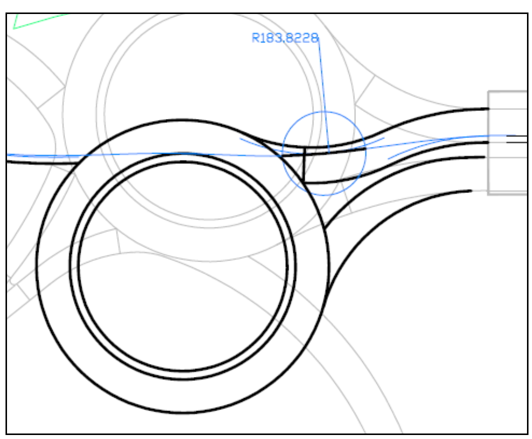
3.3 CONCEPTUAL DESIGN

3.3.1 Westerly Interchange Roundabout

Much of the conceptual design process involved determining the optimal location of the combined roundabout. Initially the proposed realigned Kearney Connector required that the circle be located too far west. This made it difficult to develop good sight to the left for motorists entering the roundabout from the southbound off-ramp. The circle was therefore shifted east, closer to Highway 102.

Several options were then explored for locating the roundabout northward or southward. Initially the preferred location was south of the Larry Uteck Boulevard centreline. This would have hidden the central island from motorists entering the roundabout from the east. It also made it difficult to develop good entry path curvature from east, an alignment fixed by the overpass structure at Highway 102.[4] Finally, it created a condition where there would be a series of reverse curves from the east entry. Refer to Figure 3.4.

Figure 3.4
Initial Location for the Westerly Interchange Roundabout



[4] Entry path curvature (or deflection) is the creation of speed control through the design of the roundabout entry. This speed control is critical in roundabout design, as it has a direct relationship with yield potential and overall safety for all users.

A series of reverse curves has been identified elsewhere as a condition that increases the potential for truck load shedding or rollover.[5] The two reverse curves on the entry can set up a harmonic in a truck suspension or load. If the third such curve is a left turn, a load shed or rollover can result on the far side of the roundabout. One solution is to introduce a tangent section between the two entry curves. Unfortunately in this case a tangent would have shifted the roundabout back to the west. The final location of the westerly interchange roundabout was therefore established further northward.

A change was also made from the lane configurations set out through the capacity analysis. Although a two-lane entry was deemed to be sufficient from Kearney Connector eastbound (or southbound), this set up some ambiguity as to which of the three circulating lanes motorists would direct themselves. A third entry lane solved this problem by moving the lane choice decision to a safer location upstream of the entry.

With the circle location and lane configurations established, work continued with completing the conceptual design of the westerly roundabout.

3.3.2 Easterly Interchange Roundabout

Compared to the westerly roundabout, the conceptual design of the easterly interchange roundabout was relatively straightforward. Initially the preferred location was on the Larry Uteck Boulevard centreline. The circle was shifted south to increase entry path curvature from the west, as fixed by the overpass structure. No changes were made from the lane configurations established through the capacity analysis.

3.3.3 Nine Mile Drive/Starboard Drive Roundabout

As with the easterly roundabout, the conceptual design of the Nine Mile Drive roundabout was also relatively straightforward. One change made from the lane configurations set out through the capacity analysis was that the southbound channelized right turn was replaced with a second entry lane.

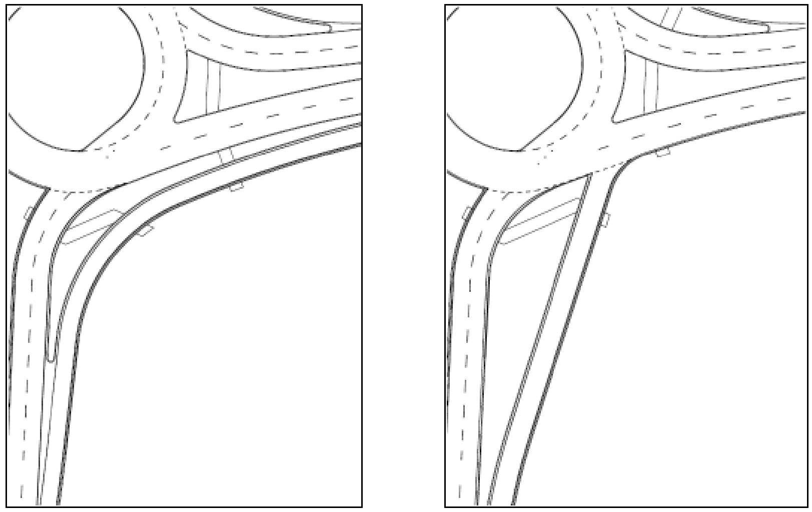
3.4 PRELIMINARY DESIGN

3.4.1 Evaluation of Right-Turn Treatments

At the preliminary design stage, an evaluation was undertaken to determine the preferred type of exclusive right-turn treatment at the off-ramps for the two interchange roundabouts. Fully-channelized right-turn lanes with acceleration lanes were contemplated initially. Such a treatment would have been difficult to design at the westerly roundabout because of the small angle between the off-ramp and the exit to Kearny Connector. An alternative is a yield-controlled right-turn lane. This treatment historically results in a low angle between traffic on the right-turn lane and through traffic, and poor sight to the left. However, more recent designs at roundabouts (and signalized intersections) elsewhere have a higher angle, providing more emphatic direction for motorists to yield and better sight to the left. A comparison of the two treatments is shown in Figure 3.5.

[5] Gingrich, Michael and Ed Waddell, *Accommodating Trucks on Single and Multilane Roundabouts*, Transportation Research Board, National Roundabout Conference, Kansas City, MO, 2008.

Figure 3.5
Fully-Channelized and Yield-Controlled Right-Turn Lanes



A yield-controlled right-turn lane (at least, one with a high angle of intersection) is a lower-speed design that is considered safer for pedestrians and cyclists. It tends to require less land on the downstream end because it eliminates the need for an acceleration lane. It may require more land on the upstream end because of the need to obtain a high angle yet have the terminus “snagged” by the opposite roundabout splitter island. It also has less traffic capacity due to yield, rather than merge, control. Lane-by-lane modelling in Rodel was undertaken to confirm the yield-controlled right-turn lanes will have sufficient capacity, and establish queue storage requirements along the off-ramps.

A fully-channelized right-turn lane was retained for the westbound movement from Larry Uteck Boulevard to the Highway 102 northbound on-ramp. As the on-ramp required two lanes for traffic capacity, right-turn traffic could enter the ramp in its own lane.

3.4.2 Optimization of Conceptual Designs

The initial capacity assessment was revisited by way of a full origin-destination analysis with detailed lane-by-lane modelling in Rodel and Arcady to determine the most effective lane configurations at and between the roundabouts. This was necessary to ensure the three roundabouts act effectively as a system.

Preliminary design then involved optimizing the conceptual designs in terms of capacity, safety and cost (property impacts) and finalizing the horizontal geometry of the roundabouts. The optimization had to do with the following:

- Accommodating the WB-21 design vehicle for all movements, particularly the yield-controlled right-turn lanes from the Highway 102 off-ramps.
- Adjusting entry path curvature values in response to anticipated approach speeds and the distribution between entering and circulating traffic.
- Ensuring that circulating and exit path curvature values result in minimal differences between entering and circulating speeds.

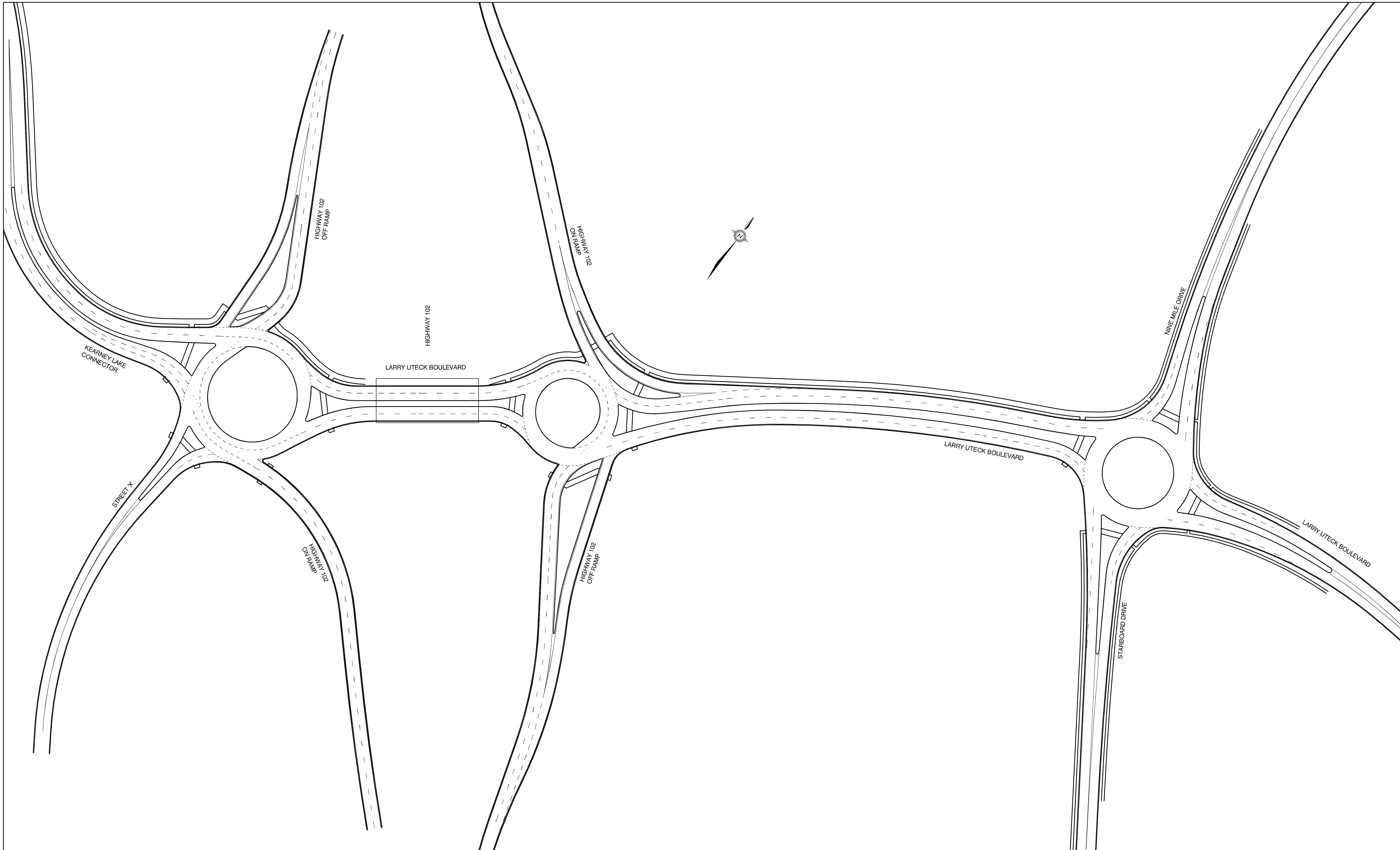
- Creating entries and exits that promote natural driving paths on the two-lane or three-lane sections that minimize the potential for vehicle path overlap as motorists enter, circulate and exit the roundabouts side-by-side.
- Paying attention to the conflict angle between entering and circulating traffic to ensure good sight to the left for entering motorists.
- Maintaining minimum widths for pedestrian refuge areas on the splitter islands and channelized right-turn lanes.

The final horizontal geometry and pavement markings for the roundabouts are illustrated in Figures 3.6 and 3.7.

3.5 DETAILED DESIGN

Detailed design involved working with the TIR to establish a signing and pavement marking plan, and specifying sightline envelopes and landscaping restrictions in the vicinity of the roundabouts.

It also required working with the lead consultant, CBCL Limited, to determine logical points at which the transition was made between, for instance, a roundabout and an interchange ramp, or a roundabout and a connector road. And detailed design for the roundabouts included reviewing documents pertaining to the vertical design (road profiles, typical cross-sections and pavement elevations), landscaping, illumination design, contract drawings, and construction staging as provided by the lead consultant. CBCL Limited is responsible for the majority of detailed design for the project including quantities, cost estimates and draft tender documents.



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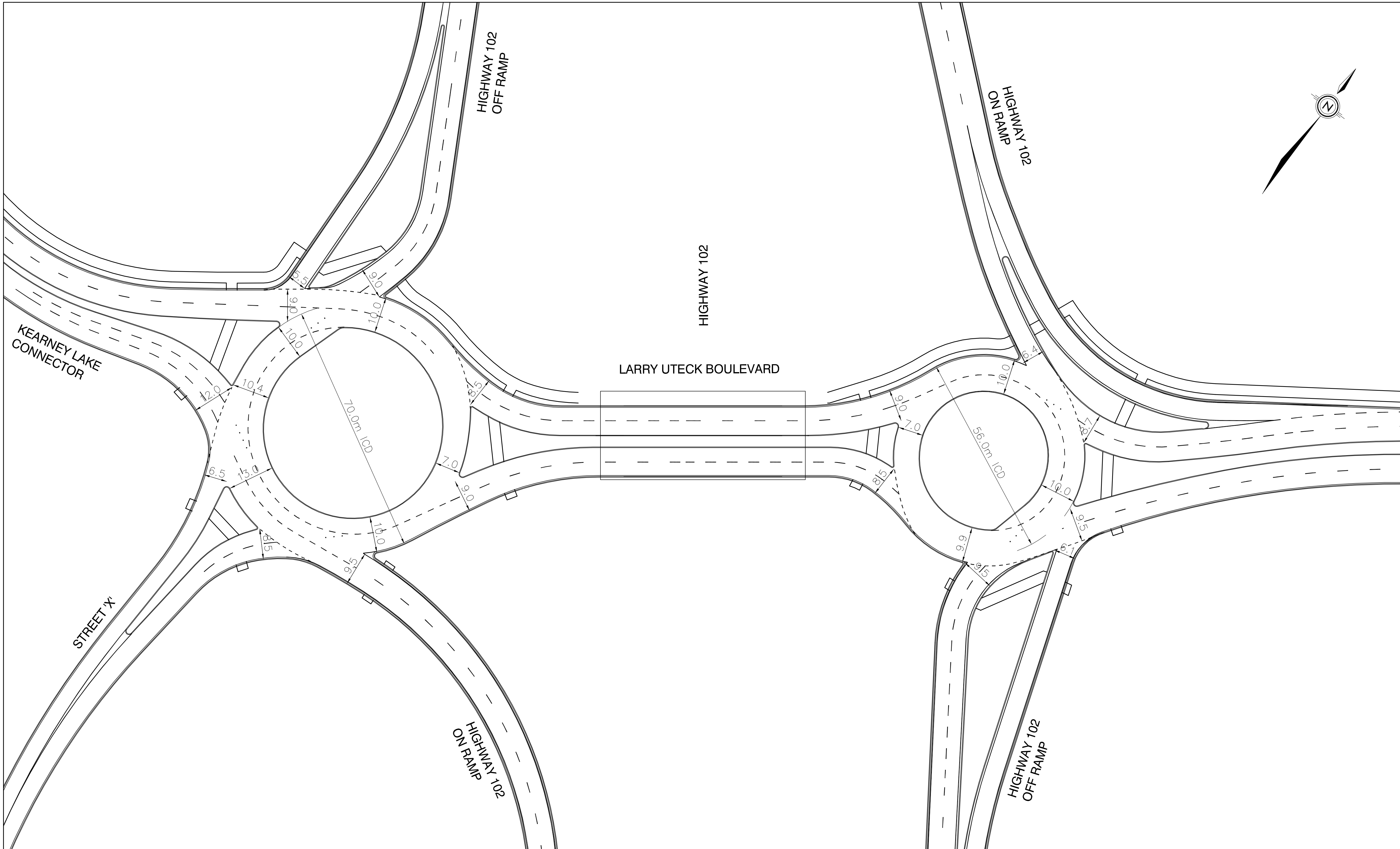
HORIZONTAL GEOMETRY – ALL 3 ROUNDABOUTS
LARRY UTECK BOULEVARD
HALIFAX, NOVA SCOTIA

DATE	PROJECT NO.
MAY, 2010	09012
SCALE	DRAWING NO.
1:2000	FIG. 3.6

R/P Date – MAY. 06, 2010 File: 09012-CR9-Figures.dwg



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HORIZONTAL GEOMETRY – INTERCHANGE ROUNDABOUTS
LARRY UTECK BOULEVARD
HALIFAX, NOVA SCOTIA

DATE	PROJECT NO.
MAY, 2010	09012
SCALE	DRAWING NO.
1:1000	FIG. 3.7

R/P Date – MAY. 06, 2010 File: 09012-CR9-Figures.dwg

4.0 CONCLUSIONS

The three roundabouts along Larry Uteck Boulevard will represent the largest such project to date and the busiest roundabout interchange in the province. The westerly interchange roundabout will be the second-busiest and second-most complex individual roundabout in Nova Scotia, after the Armdale Roundabout in Halifax, with an entering volume forecast to be approximately 40,000 vehicles per day by 2028.

Compared to signalized intersections the roundabouts are expected to exhibit better safety performance for all users (pedestrians, cyclists and motorists), provide higher capacity and less delay for the same number of lanes, and result in environmental benefits such as less pavement area and reduced emissions and fuel consumption.

At the time of writing this paper construction for the roundabouts is nearing completion. The three roundabouts are expected to be operating by the fall of 2010.