Design & Implementation of Channelized Right Turn Improvements in the City of Edmonton

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Abstract

The City of Edmonton has committed to the long term goal of zero traffic fatalities and serious injuries. Moving towards that goal, the City of Edmonton has allocated funding for a multi-year traffic safety improvement program. One of the applications of the program is to apply engineering improvements to existing right turn geometries to increase visibility and reduce rear-end collisions. These enhancements have had positive, proven results for roadway users. This paper discusses the planning, geometric design, and construction of various right-turn improvements in the City of Edmonton over the past 5 years, and examines the results of each treatment.

The City of Edmonton identified intersections with high right-turn collision frequencies and reviewed potential changes to reduce collisions. Three core design options have been adopted in the City's design standards: simple radius, high-entry angle, and low-exit angle/free flow. A detailed review of the locations and intersections was conducted, including overall collision and operational data. Projected intersection traffic data was reviewed to ensure acceptable level of service for the right turn movement after the improvement is implemented. Project constraints include existing land/road use, utilities, existing intersection geometrics, traffic/truck volumes, right-of-way, traffic control devices (signals), sight-lines, and constructability. Balance with other roadway users (pedestrians) and driver expectation and familiarity was also considered. An evaluation matrix was used to weigh the constraints and then engineering judgement was applied to determine the most applicable improvement for each location.

The intent of this paper is to present several case-studies and explain the lessons learned through all phases of design and implementation of various right-turn improvements in the City of Edmonton. Project successes and challenges will be discussed. The City of Edmonton's future strategies for right-turn improvements, including data collection and monitoring, will be presented.

1.0 Introduction

The City of Edmonton has committed to the long term goal of zero traffic fatalities and serious injuries. Moving towards that goal, the City of Edmonton has allocated funding for a multi-year traffic safety improvement program. One of the applications of the program is to apply engineering improvements to existing right turn geometries to increase visibility and reduce rear-end collisions. These enhancements have had positive, proven results for roadway users. This paper discusses the planning, geometric design, and construction of various right-turn improvements in the City of Edmonton over the past several years, and examines the results of each treatment.

2.0 History of Alternate Right Turn Designs

The City of Edmonton has developed and progressed through various standard right turn geometries for intersections. Up until approximately 15 years ago, the City used two design standards for arterial road intersections. This first standard featured a dedicated right-hand turning lane, with a three centered curve, large island separating the through lane and right turning lane, and no acceleration lane (taper) for the right turning traffic. The second standard involved a simple radius right turn with a compound radius for larger turning vehicles.

After concerns were raised due to high numbers of rear-end collisions for right turning vehicles using the three centered curve standard, an in-depth review was undertaken to determine if this standard was still appropriate for the City, and if alternate right turn designs would be advantageous to adapt (Shaheen, 2004). Geometric alternatives were developed, along with a design matrix to determine appropriate uses. The recommended geometric alternatives are discussed below.

2.1 Simple Right

This unchannelized right turn option features no island and is often referred to as a “no-island design”. Features of this design are the following (City of Edmonton, *Volume 2, Drawing #3120*):

- Forced/dedicated parallel turning lane
- A single radius is used at the majority of local, collector and neighbourhood intersections in the City of Edmonton
- A two centered corner radius, with typical radii of 15m and 40m is required for intersections used by large trucks and buses
- No vehicle departure/merge taper
- Turning lane is stop/red light controlled

This design option reduces the conflict points for pedestrians, as there are less crossing points. It eliminates the common issues with island designs, as the movement is traffic signal controlled and is less complex. No subjective yielding is required. Visibility for the turning movement (in an unskewed intersection) is high. The simple right is appropriate as a low speed design.

Drawbacks of this option are the decreased traffic volume that can be accommodated. The use of dual-right turn movements is discussed later in the report. When the “right-on-red” movement is warranted to be banned, the level of service of the entire intersection decreases. When this option is used in conjunction with different right turn geometries at an intersection, it can create relatively long, skewed pedestrian crosswalks.

2.2 High Entry Angle Right

This right turn, often referred to as an “Aussie” design, has the following features (City of Edmonton, *Volume 2, Drawing #3100*):

- Dedicated parallel turning lane
- Corner island, triangle shape
- Two centered corner radius, with typical radii of 110m and 22m
- Turn lane is Yield controlled (unsignalized)
- No departure taper

This option, developed and adapted from the Road Construction Authority in Victoria, Australia, is relatively new to the City of Edmonton. The design option follows TAC’s Geometric Design Guide For Canadian Roads (1999), Section 2.3.6.2 closely, including this clause: “*Where the channelization provides for a yield condition, the intersection angle at the yield should be at least 60° to ensure that the driver is not required to look back more than 120° to check the approaching traffic*.” The high entry angle standard design creates an angle of 70°, which significantly reduces the angle drivers must look back to merge into approaching traffic. **Figure 1** displays the standard design and typical dimensions. The absence of a departure taper is an important aspect of the design but is not always achieved in implementation, and is discussed below. Pedestrian visibility is also higher with this design, as the crosswalk position is in a more direct sightline for approaching vehicles. It has become the preferred option for new, greenfield construction in the City of Edmonton, and is being used in retrofit situations where appropriate.

2.3 Low Entry Angle Right

This right turn option is used in free flow right turning situations, where an auxiliary lane is available. Features include (City of Edmonton, *Volume 2, Drawing #3110*):

- Dedicated parallel turning lane
- Two centered corner radius, with typical radii of 30m and 100m
- Corner island with parallel shape to 30m curve
- Turn lane is “free flow” (unsignalized)
- No departure taper

This option is primarily used on high speed roadways, as drivers are able to maintain speed throughout the movement. The availability of an auxiliary receiving lane is important to this design, as it limits merge conflicts with approaching traffic. The intersection angle is significantly less than the TAC recommended 60°, but the lack of a yield condition makes this right turn

design acceptable. Access management within the auxiliary lane becomes an issue when implementing this design. Also, pedestrian movements with this design must be reviewed carefully to ensure crosswalk placement is safe and sightlines are maintained.

2.4 Legacy Design Right

This design is not within City of Edmonton standards currently, but is discussed because it is encountered in the City, especially in mature areas. The design is often referred to as the "three centered curve design" because of it's radii. Design features are:

- Dedicated parallel turning lane
- Three centered outside corner radius, with typical radii of 60m-35m-60m
- Corner island with parallel shape to 35m curve
- Turn lane is yield controlled (unsignalized)
- Departure tapers were often used in this design (acceleration lanes)

This option was implemented widespread and was the design standard for most arterial/arterial intersections within the City. Concerns were raised after it was noted that right turn collision numbers within the City were quite high. Also, this design was implemented without consideration of surrounding land uses, different roadway users, and various traffic volumes. The intersection angle for drivers at the yield is approximately 27°, which is considerably less than the TAC suggested 60° for a yield condition. Consequently, this creates a situation where a driver must turn their head 153° in order to check approaching traffic for an acceptable position to complete the right turn. Again, this is a considerable deviation from the TAC suggested maximum of 120°. It's understood that this is the major factor in causing right turn vehicle collisions within the City of Edmonton. Although this design is no longer within standards and is not built in greenfield situations, it still has merits in some retrofit situations.

2.5 Right Turn Design Matrix

To assist in the design of right turn alternatives, the City, in conjunction with ISL Engineering and Land Services, developed a right turn matrix encompassing the following factors:

- Traffic characteristics
    - Right turning volumes
    - Cross street volumes
    - Truck route designation
    - Projected traffic volumes
- Road characteristics
    - Downstream conditions - bus stops, accesses
    - Receiving roadway standard - freeway, arterial, collector
- Pedestrian user characteristics
    - Crossing volume
    - Land use - schools, seniors' residences, shopping/commercial, industrial, office

Options within the design matrix are divided between “some encroachment” and “no-encroachment”. This mainly applies to areas of higher truck/bus volumes, as it is not usually practical to design a right turn option without encroachment for those vehicles.

The development of the decision matrix won’t be discussed in detail, but it is worth noting that the factors used in making a decision can’t be considered independently, and that operation of other legs of the intersection must be considered when deciding on a treatment to implement. A significant amount of engineering judgment must be used and applied. An understanding of the overall history of an intersection/area is also useful to determine if the operation of the intersection has changed over time.

3.0 Current Implementation Strategies

Through collision data, intersections and right turns are identified and studied for the potential implementation of a right turn improvement. The rankings of intersections must be balanced with cost-benefit of the improvement. Often when completing the concept design of the improvement, it it noted that the costs of implementation can be very high. Consideration must be taken into the fact that funding for the program is composite, and funding is shared over all locations.

The City of Edmonton also delivers an Arterial Roadway Renewal program, that replaces roadway infrastructure on the basis of infrastructure condition. Often, legacy right turn designs are encountered and warrant replacement due to poor condition. At this point, the right turn must be reviewed in detail to determine if it’s warranted to be replaced with a new design, or if it’s is functioning acceptably in it’s current design. Often replacing with a new design is more costly than replacing existing.

After careful review of an intersection, if a right turn improvement is warranted at a location, geometric design solutions are evaluated and an improvement is designed. In some instances the option of “doing nothing” is ultimately chosen if the design engineer does not feel a geometric design change is appropriate for the intersection. This situation can occur for numerous reasons such as physical constraints, available right-of-way, or existing utilities that can not be easily relocated. In some cases an existing right turn design that doesn’t follow current standards is deemed to be functioning in a safe manner.

In addition to reviewing the right turn treatment itself, alternate safety improvements are also reviewed and considered, including pavement marking changes, access management in proximity to the right turn, signal re-phasing, and signal improvements/additions.

Maintaining level of service at the intersection is considered and accommodated where possible, but often minor decreases in level of service can be expected, especially with the no-island, dual-right turn design. This decrease is due to banning of double right turns on red lights, where deemed necessary. The acceptance of a lower level of service with the expectation of a safety improvement is consistent with the City’s adoption of Vision Zero.

4.0 Case Studies

4.1 Yellowhead Trail off-ramp & Victoria Trail - 2010

The location was the first right turn improvement formally implemented by the City. This project involved the westbound off-ramp of Yellowhead Trail, a major east-west highway in Edmonton, and the northbound movement on Victoria Trail. The right turn treatment was changed from a three centered curve to a no-island, one lane, simple right design. The curve radii used was 12m followed by 20m. The middle lane was converted from a through left movement to an all-directional movement, essentially creating a double right turning movement. Right turns on red were banned at this location. Utility issues with this project were minimal, with one streetlight, a traffic signal pole base, and a traffic signal cabinet requiring relocation. **Figure 2** shows the right turn improvement after implementation. Victoria Trail, the receiving roadway, is not a designated truck route, so a lower than standard turn radius could be used. Collisions were reduced from an average 35.3 per year before implementation to 0.3 per year after implementation (99% reduction).

4.2 87 Avenue & 170 Street - 2010

This right turn improvement project was completed with the arterial road rehabilitation of 87 Avenue and 170 Street. Located next to West Edmonton Mall and a hospital, this large intersection experiences high traffic volumes. Also, this portion of 170 Street is designated as part of Edmonton's inner ring road. All 4 legs of the intersection were converted from the City's legacy design to the high entry angle design (Aussie design). The radii used for the new right turn curves was 100m-12m-35m. The deviation from the two radii standard was done to accommodate the inside lane encroachment of trucks during the turning movement. Right turn bays were developed at 3 legs of the intersections, as part of the rehabilitation. The islands were constructed approximately 15m long and 7m wide, considerably smaller than the islands that were removed. The high pedestrian volumes at this intersection are better integrated with shorter crossing distances. **Figure 3** shows the design of the intersection with the right turn improvements at the four corners. Collisions were reduced from an average 16.7 per year before implementation to 5.7 per year after implementation (66% reduction).

4.3 137 Avenue & St. Albert Trail - 2010

This right turn improvement project was completed with the arterial road rehabilitation of 137 Avenue and St. Albert Trail. This large intersection is prominently skewed at approximately 65°, which required non-standard geometry to accommodate right turn improvements. See **Figure 4** for the intersection design. Re-aligning the intersection was not possible due to existing land use. The 2 acute corners of the intersection were changed from three centered curve islands to modified high entry angle right turn designs. The curve radii used was 100m followed by 20m.

The shape of the island was not the standard high entry angle “triangle shape”. A compound curve of 105m followed by 40m was used on the island, parallel to the outside curve. This non-standard shape was used for truck movements within the skewed intersection. To keep the design intent of decreasing drivers looking backwards to opposing traffic, a painted island adjacent to the outside curb line was designed for truck tracking. The intent is that the majority of vehicles approach the movement at the standard high angle, and that large trucks utilize the painted (restricted) island for their rear tracking. An unintended use of the painted island is a departure taper for vehicles to accelerate and merge onto 137 Avenue. It was clear that the standard high entry angle island design would cause significant lane encroachment for trucks, and the modifications created minor, acceptable encroachment for trucks.

At the other 2 corners of the skewed intersection (the obtuse corners), one legacy design was replaced with a low-angle entry island, while the other was replaced as a simple right.
An auxiliary receiving lane was constructed to create a free-flow condition at the low-angle corner, with a radius of 30m followed by 120m. The simple right was designed and constructed as a single 25m radius, due to the skewed corner. Right turn collisions dropped 85% percent from 18.1 per year to 2.7 at the intersection after improvements were implemented.

4.4 Whitemud Drive & 91 Street - 2015

This location was previously a three centered curve right turn curve, located on the eastbound off-ramp of Whitemud Drive and 91 Street. 91 Street consists of a rural cross section, with ditching along both sides, and a speed limit of 70 km/hr. The off-ramp speed limit is 60 km/hr. The improvement at this corner involved the design of a low entry angle right turn design (**Figure 5)**. The associated auxiliary lane was constructed from a portion of the shoulder on 91 Street. This auxiliary lane was constructed with curb and gutter, and the roadway drainage was routed back to the adjacent ditch. The outside radii used for the low entry angle design was 30m followed by 100m. The auxiliary lane and associated curb and gutter was terminated at an access approximately 200m from the off-ramp. The termination of the auxiliary lane is well signed, allowing drivers enough time and space to reach the speed limit of 70 km/hr on 91 Street and merge appropriately (**Figure 6)**. Because of this lane construction, utility relocates were more extensive than a typical right turn improvement, including multiple streetlights. Collisions at this right turn dropped from an average 18 per year to 3 per year, an 83% reduction.

4.5 Terwillegar Drive & 23 Avenue - 2016

23 Avenue and Terwillegar Drive is an intersection that previously featured a skewed three centered curve and large departure taper for merging vehicles. The right turn improvement implemented was a high entry angle design, with the standard radii of 110m followed by 22m. A short section of 60m radius curb and gutter was used at the end to make up for the intersection skew, but this curve is located past the turning movement of most vehicles. Large truck encroachment was evaluated as acceptable in this location, due to low truck volume at peak

hours (**Figure 7**). This location is located near high pedestrian activity areas (schools and recreation centres), and the high entry angle design option limits pedestrian crossing distance. Data is not available on post-improvement collisions, but it is expected that collisions will be reduced from 14.7 to 4.4 per year.

4.6 50 Street and 101 Avenue - 2016

This right turn under consideration at this intersection is shown in **Figure 8.** The existing right turn island from eastbound 101 Avenue to southbound 50 Street is relatively small. Initially a candidate for a high entry angle island, after review and consideration, it was decided to keep the island as existing, as an improvement couldn't be properly implemented. There are road right-of-way constraints at the adjacent property. Relocating the large power pole within the island was explored, but the relocation became cost-prohibitive. Right turn collisions at this island existed, but weren't high enough to warrant a complete reconfiguration. It was decided the funding could be applied to locations where geometric conditions were more flexible. As both adjacent roadways recently went through rehabilitation, it is unlikely this right turn will be re-reviewed in the future.

5.0 Lessons Learned

Throughout the City of Edmonton's design and implementation of right turn improvements at intersections, trends and opportunities for future improvement have been identified.

5.1 Pavement Markings

The high entry angle right turn design option is designed with the intention of very little pavement marking offset. An offset of 0.5m, tapering to 0m is shown on the design standard. The intention is that drivers follow the curb and gutter on the island while making their right turn movement. If deviation is made with pavement markings at different offsets, it has been observed that drivers will follow the pavement markings as opposed to the island geometry. As engineering design and theory has been put into the geometry of these islands, it is very important that the adjacent pavement markings reflect this, to ensure the intent of the right turn improvement is achieved. If pavement markings are placed in traditional positions at the exit of the island at low angles, drivers will follow this as opposed to the island geometry. As discussed above, at the skewed intersection of St. Albert Trail and 137 Avenue, painted restrictive islands intended for truck movements can be easily misused by standard vehicles, especially when covered with snow or when the pavement marking deteriorates. A possible solution for these areas would be a reinforced concrete apron, which would be avoided by most vehicles but still utilized by large truck turning movements. The pavement marking design of the island and intersecting roadway must be considered during design and correctly installed.

5.2 Shared Use Path Alignment Within High Entry Angle Islands

The City of Edmonton utilizes a 3.0m wide shared use path adjacent to arterial roadways, designated for cyclists and pedestrians. When a shared use path crosses onto a high entry angle island, there are difficulties in ensuring the complete 3.0m path width can adequately fit on the island. With the prescribed right turn crossing location, the path must make two turns to reach the crosswalk of the island in a relatively small area. Compared to the right turn islands previously constructed in the City, the high entry angle island is small and narrow. Exceptions have been made to construct 2.5m paths within these islands. It is worth reviewing on high volume pedestrian/bicycle routes if the movements of the shared use path within the island is safe. Although the right turning vehicle crosswalk location is considered safer (due to higher visibility, more direct sightlines, and lower vehicle speeds), the maneuverability within the island is lowered.

5.3 Accommodating Within Larger Road Rehabilitation Projects

During design and construction of right turn improvements, the City has discovered that it is generally easier to implement an improvement within a larger road project, as opposed to a singular local improvement. When designing as part of a road rehabilitation, tie in points are more flexible. There is the opportunity to realign intersections/lanes, and right turn designs can be better implemented. There is more flexibility to use the ideal radii in a right turn treatment, instead of being fixed to project limit. Also, the ability to implement improvements at multiple legs of an intersection helps increase driver familiarity.

5.4 Freeway Off-ramps

The collision data collected by the City shows that in addition to locations with high right turning volumes, freeway (high speed roadways) off-ramps demonstrate higher than average right turn collisions. A possible explanation for this is that drivers aren't correctly anticipating the transition from a high speed roadway onto a lower speed arterial roadway. When an improvement is warranted at these locations, jurisdictional issues may be encountered, as different municipalities and road authorities may not have consistent right turn treatments. Within Edmonton city limits, some high speed freeways are under control of Alberta Transportation, which uses different right turn standards than the City of Edmonton.

5.5 Right Turn Capacity Growth

During the concept design of a right turn improvement, there are opportunities for traffic volumes to be reviewed. If the intersection is not performing at an acceptable level, and a future traffic model shows similar issues, there is an opportunity to implement growth of the right turn capacity, coupled with a safety improvement. The operation of a double right, high entry angle design is not ideal and can potentially cause more collisions due to inadequate sightlines. This

causes the selection of a simple double right turn (no-island) to replace legacy right turns in many situations with high current and expected future traffic volumes. The right turn bay length can be extended appropriately as part of the right turn improvement.

5.6 Constructability Issues

With the conversion of a traditional right turn island to a simple right turn, there are many constructability and staging issues. The main issue is the position of the new traffic signal pole, where the new signal base is most likely positioned in the existing right turn travel lane. Working in retrofit situations, this creates many traffic detouring issues, as existing traffic signals cannot be removed until new signals are installed. Other construction issues with right turn improvement projects include detouring traffic around existing right turn islands, and forcing drivers to make 90° right turns around a very small corner radius. Any lane encroachment with this turn may conflict with opposing left turning vehicles. Signage and temporary flagging may be required in some conversion situations, and should be considered in advance of construction.

5.7 Double Right Turn Operational Issues

At an intersection where a traditional right turn island is changed to a double right movement, the entire operation of the intersection is altered. As mentioned above, the City of Edmonton's current policy is to ban dual-right turning vehicles during the red light phase. Instead of right turning vehicles yielding to find a gap in cross-traffic, vehicles are now turning on a protected "green arrow" movement, where they possess the "right of way". This is a change to the opposite leg of the intersection, where left turning vehicles must now yield to the right turning vehicles. The opportunity for protecting the associated left turning movement can be explored, but it will most likely increase intersection cycle time and lower the intersection level of service. Overall, driver familiarity is reduced. Signage regarding operational changes after the right turn improvement is constructed may be appropriate.

6.0 Conclusion

The City of Edmonton has committed to funding right turn channel improvements within the current budget cycle, and it is expected the funding will continue into the future. With each improvement, there is an expectation of a 75% collision reduction (City of Edmonton, Traffic Safety Engineering). Larger reductions have been observed at locations with initial abnormally high collision numbers.

The City and associated stakeholders are beginning to develop a knowledge base of strategies and available options to implement at problem right turn movements. Lessons learned with each right turn improvement project are valuable and have been used to create efficiencies with design and construction. This information is transferable and applicable within most urban communities. The roadway improvements benefit drivers, as well as pedestrians and cyclists. This is a major factor in the success of the program, as different transportation modes become

more prevalent and important in the City. The geometric design of each right turn must be considered carefully. The roadway design standards developed are an important guide, but within retrofit situations, alterations are often necessary. Roadway designers must consider multiple options and their consequences when considering a right turn improvement. Although one corner of an intersection is changed, impacts are often felt on other legs of the intersection. An ongoing collection and review of traffic and collision information has provided an important databank where trends and corrective actions can be studied. The right turn improvement program aims to anticipate potential driver errors through better road design, and statistics have shown a significant reduction in collisions.

References

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Figures

Figure 1: High Entry Angle Design (City of Edmonton, Volume 2)

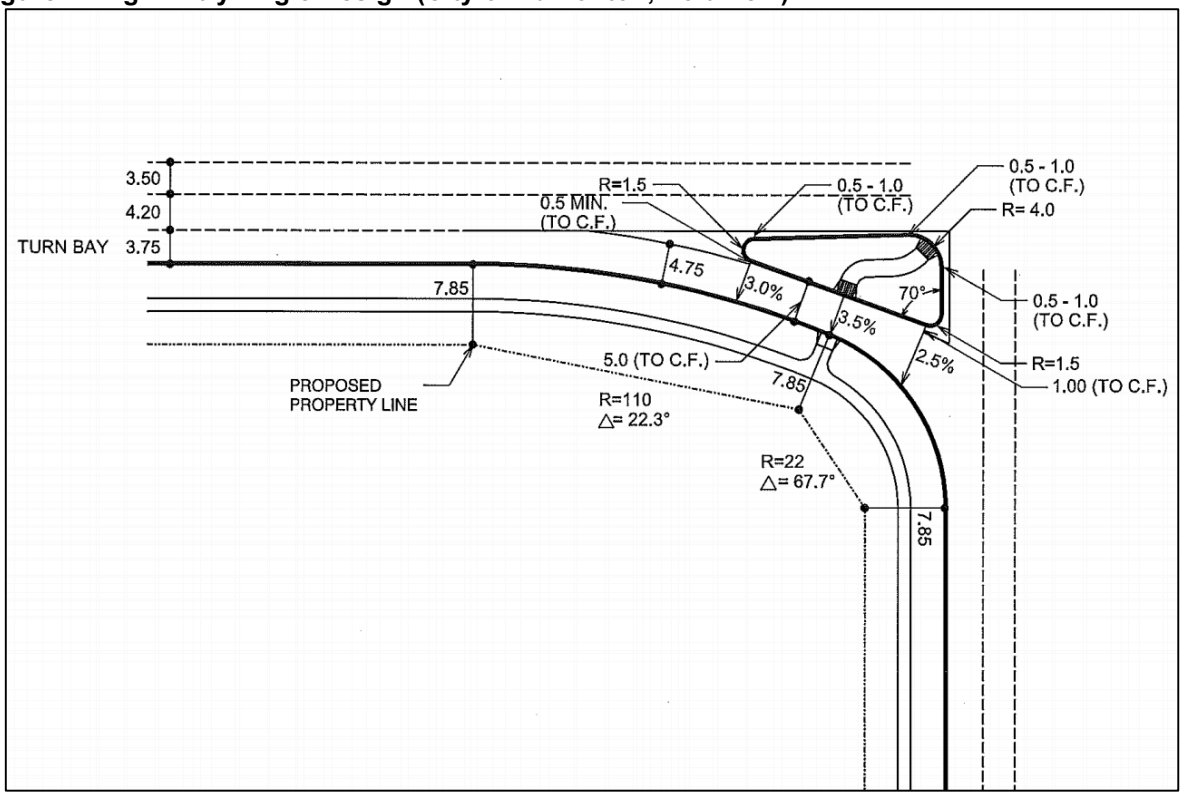

Figure 2: Yellowhead Trail & Victoria Trail Improvement (Google Maps, 2016)

Figure 3: 87 Avenue & 170 Street Intersection (City of Edmonton, Stantec, 2010)

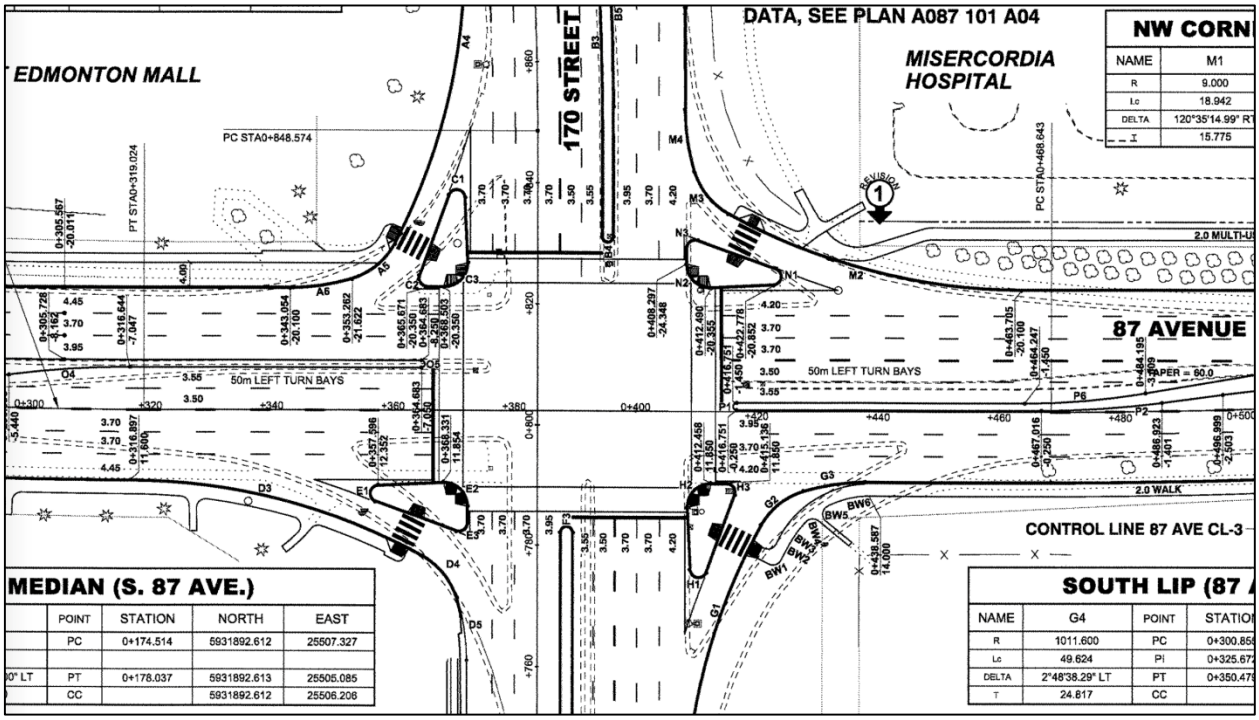

Figure 4: St Albert Trail & 137 Ave (City of Edmonton, Aecom, 2010)

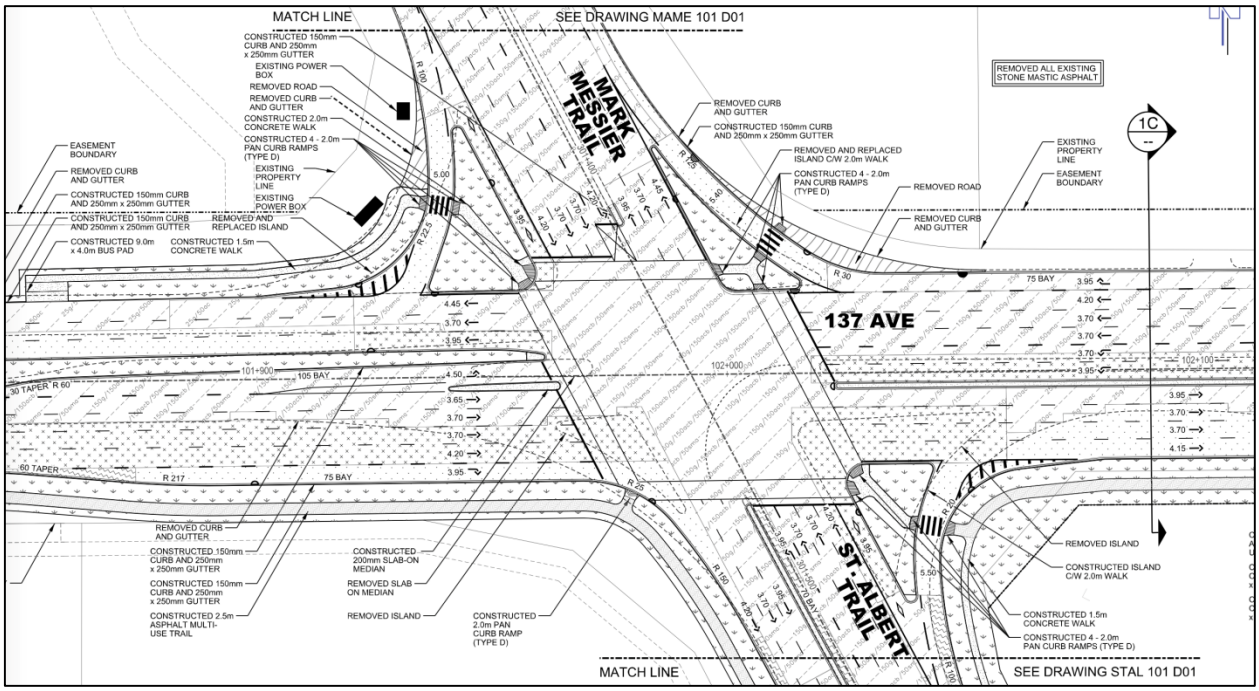

Figure 5: Whitemud Drive & 91 Street (Google Maps, 2016)

Figure 6: Whitemud Drive & 91 Street Signage and Pavement Markings (City of Edmonton, MMM Group, 2015)

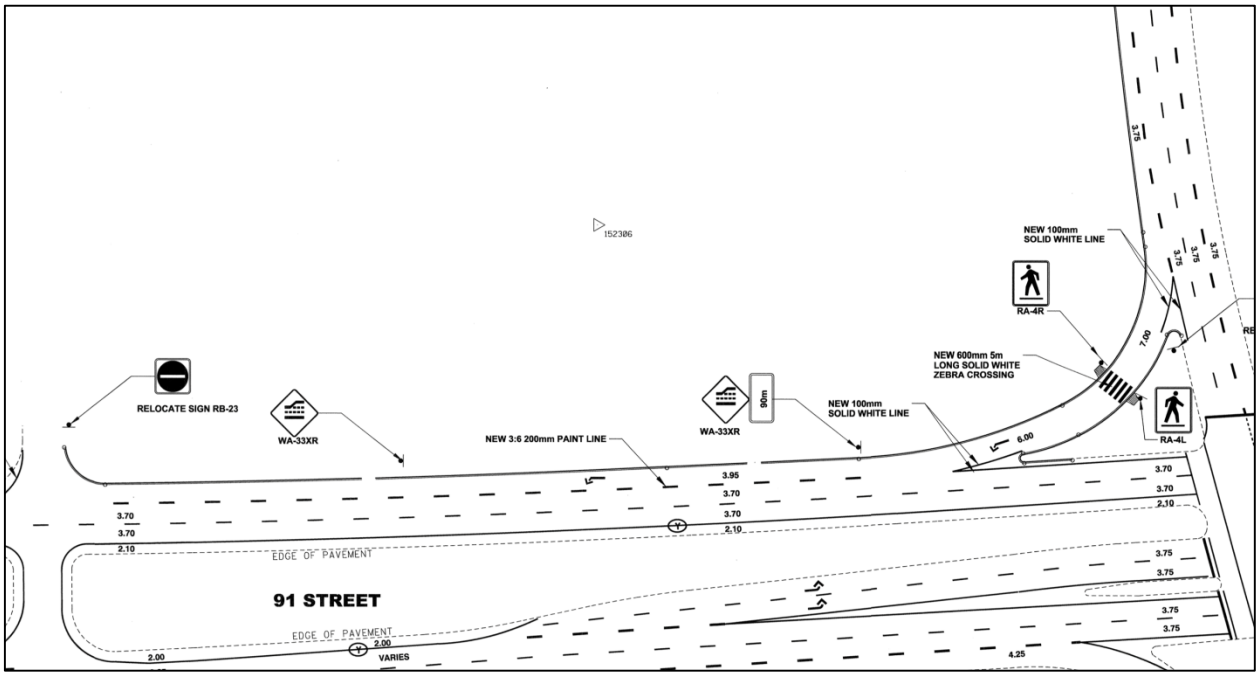

Figure 7: 23 Avenue & Terwillegar Drive (City of Edmonton, ISL Engineering and Land Services)

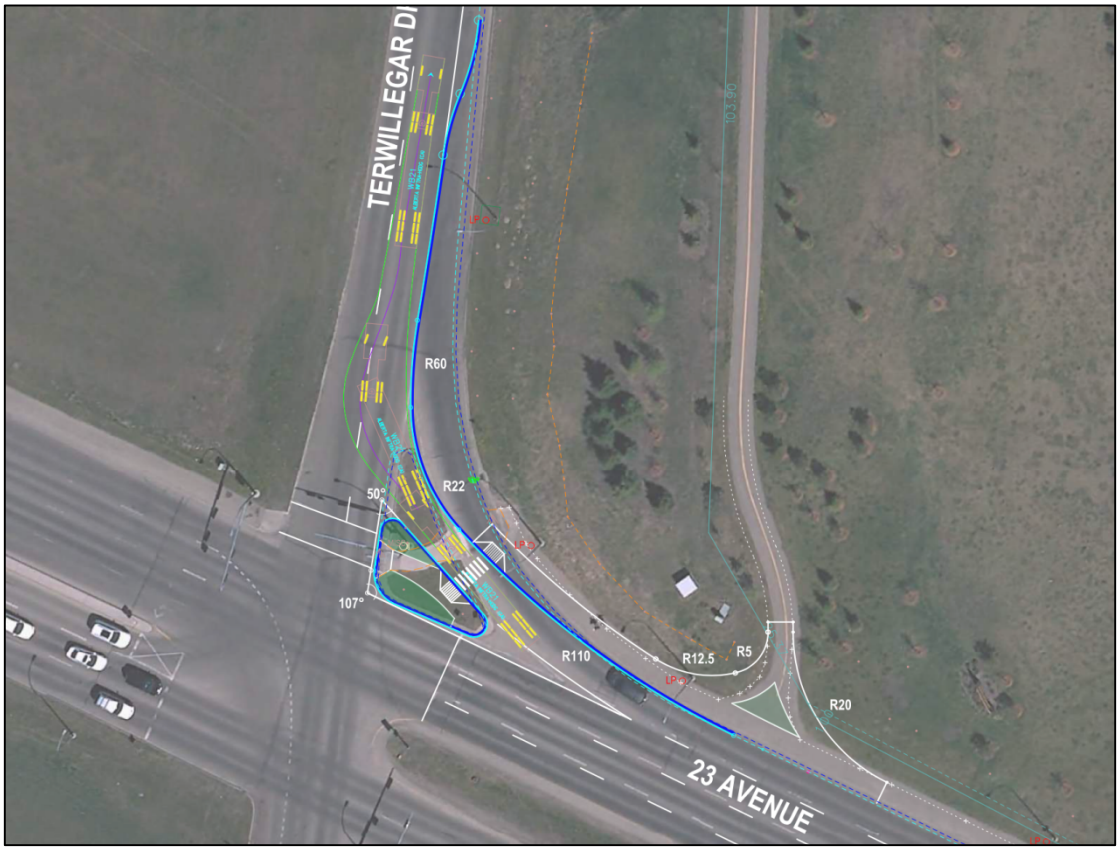

Figure 8: 50 Street & 101 Avenue (Google Maps, 2015)