1. Introduction

The purpose of the Roadside Design Manual (RDM) is to provide MTO staff and engineering consultants with updated cost beneficial policies, standards, and guidelines for design of the roadside environment adjacent to the roadway within provincial highway Right-of-Ways (ROW) as shown in Figure 1-1. A comprehensive literature review was carried out during the preparation of the RDM, relying extensively on the American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide, United States Federal Highway Administration (FHWA) Memoranda, National Cooperative Highway Research Program (NCHRP) Reports, Midwest States Pooled Fund Program Research Reports, Texas Transportation Institute Roadside Safety Pooled Fund Research Reports, and roadside safety hardware manufacturers, distributors and installers.

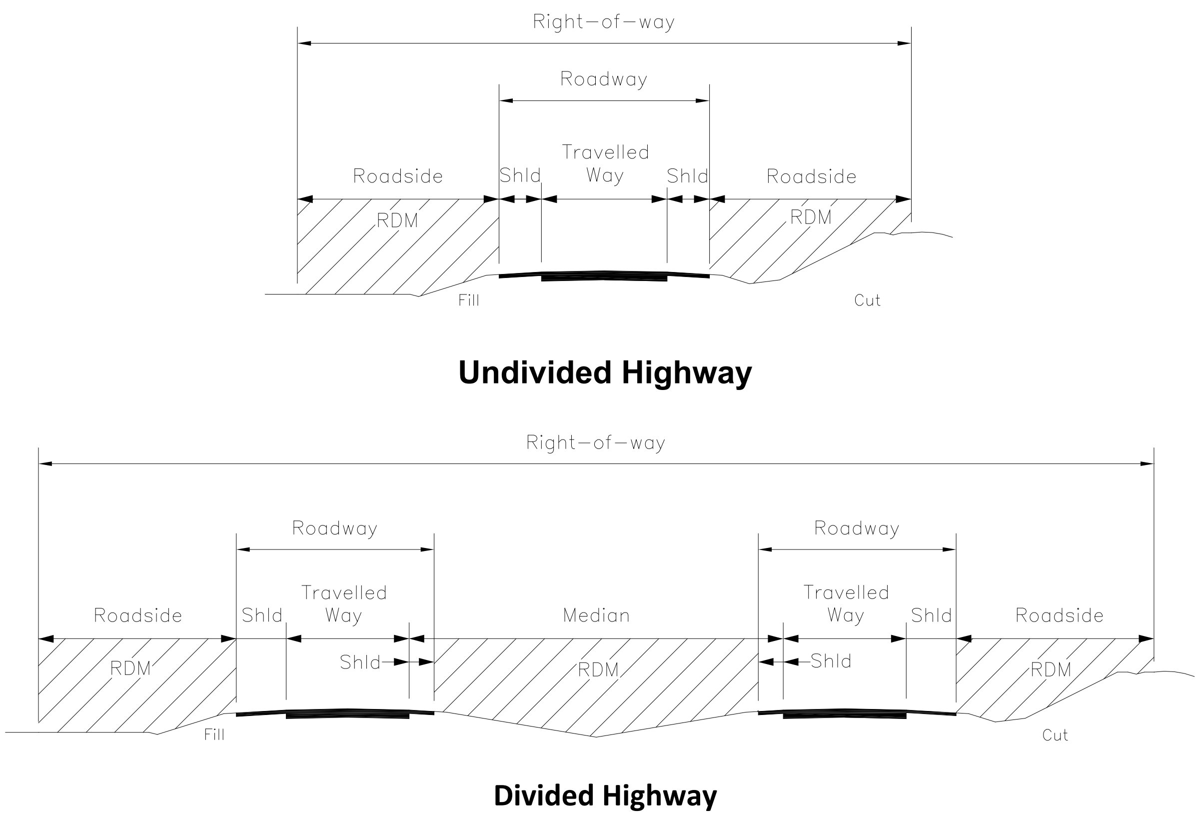

Figure 1-1 – Provincial Highway Right-of-Way Components

Although the RDM is issued primarily for the direction and guidance of MTO staff and engineering consultants for design of provincial highway projects, it may also be used as a design guideline by other road authorities in Ontario. On provincial highway projects, deviations from policies contained in Chapter 2 of the RDM shall be justified and documented in the applicable design report(s) for the project.

Desirable values are provided for various features within the roadside environment in the RDM, which should be used for design of new highways and expansion (widening) of existing provincial highways. For major capital rehabilitation or major capital reconstruction of existing highways, desirable values should be considered and explicitly evaluated during design to select cost beneficial treatments within the roadside environment that can be achieved with available funding and other constraints. In addition, as design guidelines, standards and best practices continue to evolve over time, existing highways that were originally constructed according to previous design policies, guidelines and standards, and have acceptable operational and collision histories, should not require reconfiguration or improvements based on desirable values in the RDM. This is further described in Chapter 2.

Designers should achieve a balance between competing objectives and constraints when determining how the roadside environment will be configured. In some cases, engineering judgement is required to assess trade-offs. The choices made to achieve this balance will be influenced by the:

- Functional classification;
- Design speed;
- Operating speed;
- Posted speed;
- Traffic volumes and composition;
- Drainage considerations;
- Pavement design considerations;
- Right-of-way (ROW) constraints (such as property limits, environmental)
- Other ROW user expectations (such as utility companies);
- Access requirements (such as entrances);
- Constructability considerations;
- Maintenance considerations;
- Funding considerations; and
- Other constraints (such as social, political, technological).

Common highway design objectives include:

- Maximizing road user throughput (the number of road users served for a given time period);
- Maximizing road user safety;
- Ensuring an appropriate level of access (Corridor Management Policies and Regulations);
- Minimizing impacts on the natural and socio-economic environments; and
- Minimizing the overall life cycle cost of the facility.

The RDM does not address:

- Drainage design;
- Geotechnical design;
- Maintenance;
- Property management and acquisition;
- Property access;
- Signage (other than sign-supports);
- Utilities (other than poles and boxes); and
- Shared use of ROW (Active Transportation Paths, Recreational Trails, etc.)

1.1 Key Terms Used in Manual

Roadside design, like other areas of highway design, uses many unique terms to define specific physical or operational aspects of the highway or the design process. While the Glossary presents many definitions, it is important for the designer to understand the following key terms:

Area of Concern: An obstacle or area within the roadside environment and within the desirable clear zone that has a higher severity index than a barrier system.

Barrier System: A system which provides a physical limitation through which an errant vehicle would not normally penetrate or vault over. It is intended to contain or redirect an errant design vehicle of a particular size range, at a given speed and angle of impact.

Clear Zone (CZ): The unobstructed, traversable area provided beyond the edge of the through travelled way available for use by errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes. The clear zone also includes recoverable slopes, and non-recoverable slopes with a clear run-out area. The selected clear zone width for a project is dependent upon traffic volumes and design speed, and roadside geometry.

Crash Cushion: An energy attenuating system which provides a physical limitation through which an errant vehicle would not normally penetrate. It is intended to contain or redirect or stop an errant design vehicle of a particular size range, at a given speed and angle of impact.

Desirable Value: The value at the top of a range of values in a design standard, or the discreet value when a range is not given in a design standard.

Dynamic Deflection: The maximum distance that the barrier system is expected to deflect laterally under a specified design impact, measured from the traffic face of the system.

Energy Attenuator: Has the same meaning as crash cushion.

Foreslope: A slope parallel to the roadway in a cut (frontslope) or fill (sideslope) section, between the edge of shoulder rounding and bottom of slope. It includes earth or rock, and granular base and sub-base.

Guide Rail: Has the same meaning as barrier system.

Highway: The entire right-of-way comprising of a common or public thoroughfare, including a highway, road, street, bridge, and any incidental thereto.

High Speed Roadways: Roadways with posted speeds of 70 km/h or higher.

Minimum Value: The value at the bottom of a range of values in a design standard.

Obstacle: Any non-breakaway and non-traversable feature within the roadside environment greater than 100mm in height that can increase the potential for personal injury and vehicle damage when struck by an errant vehicle leaving the roadway.

Right-of-Way (ROW): The area of land acquired for or designated to the provision of a highway.

Road: Has the same meaning as Highway.

Roadside Environment: The portion of the ROW beyond the roadway, including medians, not designed for vehicular use. The roadside environment may include a variety of surfaces, slopes, obstacles, and natural features (such as water bodies, vegetation, etc).

Roadway: The portion of the highway, including shoulders, designed for vehicular use.

Severity Index: A number from zero to ten used to categorize the potential severity of an encroachment or impact by an errant vehicle for a range of design speeds over a variety of surfaces and slopes, fixed objects and natural features within the roadside environment. The number is used for evaluating alternative safety treatments.

Shall: A mandatory obligation.

Should: A recommendation that is not a mandatory obligation

Terminal: A crashworthy end treatment or crashworthy anchor used at the end of a barrier system.

Working Width: Distance between the traffic face of a barrier system before a vehicular impact during a specified crash test, and the maximum lateral distance position of any major part of the system or vehicle after impact.

1.2 The Importance of Roadside Design

Collisions that occur within the roadside environment typically involve a vehicle departing the roadway and subsequently impacting an obstacle, or encountering a situation or feature that result in the rollover of the vehicle. These are referred to as run-off-the-road (RoR) collisions.

The 2011 AASHTO Roadside Design Guide indicates that in the United States "about thirty percent, or almost one in every three fatalities, are the result of a single vehicle run-off-the-road crash". According to the Insurance Institute for Highway Safety and Highway Loss Data Institute, in the United States "20 percent of motor vehicle crash deaths result from a vehicle leaving the roadway and hitting a fixed object alongside the road. Trees, utility poles, and traffic barriers are the most common objects struck. Almost half of the deaths in fixed object crashes occur at night. Alcohol is a frequent contributing factor. Motorists also run off the road because of excessive speeds, falling asleep, inattention or poor visibility. Efforts to reduce these driver errors are only somewhat effective, so it's important to remove fixed objects or avoid putting them along roads in the first place if feasible, especially on roads where vehicles are more likely to leave the pavement. Less preferred options include using breakaway objects, shielding objects and increasing the visibility of objects."

The Ontario Road Safety Annual Report (ORSAR) published by MTO states that in 2019 there were 221,793 reportable collisions on all roads across the province. These reportable collisions for all roads in 2019 consisted of 545 fatal collisions, resulting in 584 persons killed, and there were 33,602 personal injury collisions and 187,646 property damage collisions. For provincial highways, the reportable collisions in 2019 consisted of 142 fatal collisions, 5,771 personal injury collisions, and 37,421 property damage collisions. ORSAR is updated and published annually by the ministry and is available on the ministry's web site at: http://www.mto.gov.on.ca/english/publications/ontario-road-safety-annual-report.shtml

Although ORSAR does not specify how many of the collisions occurred within the roadside environment, it is likely that Ontario's experience with RoR collisions is similar to that experienced in the United States. The Insurance Institute for Highway Safety and Highway Loss Data Institute published a pie chart showing percentage distribution of fatal crashes by obstacle struck in the United States for the year 2015, which is reproduced in Figure 1-2.

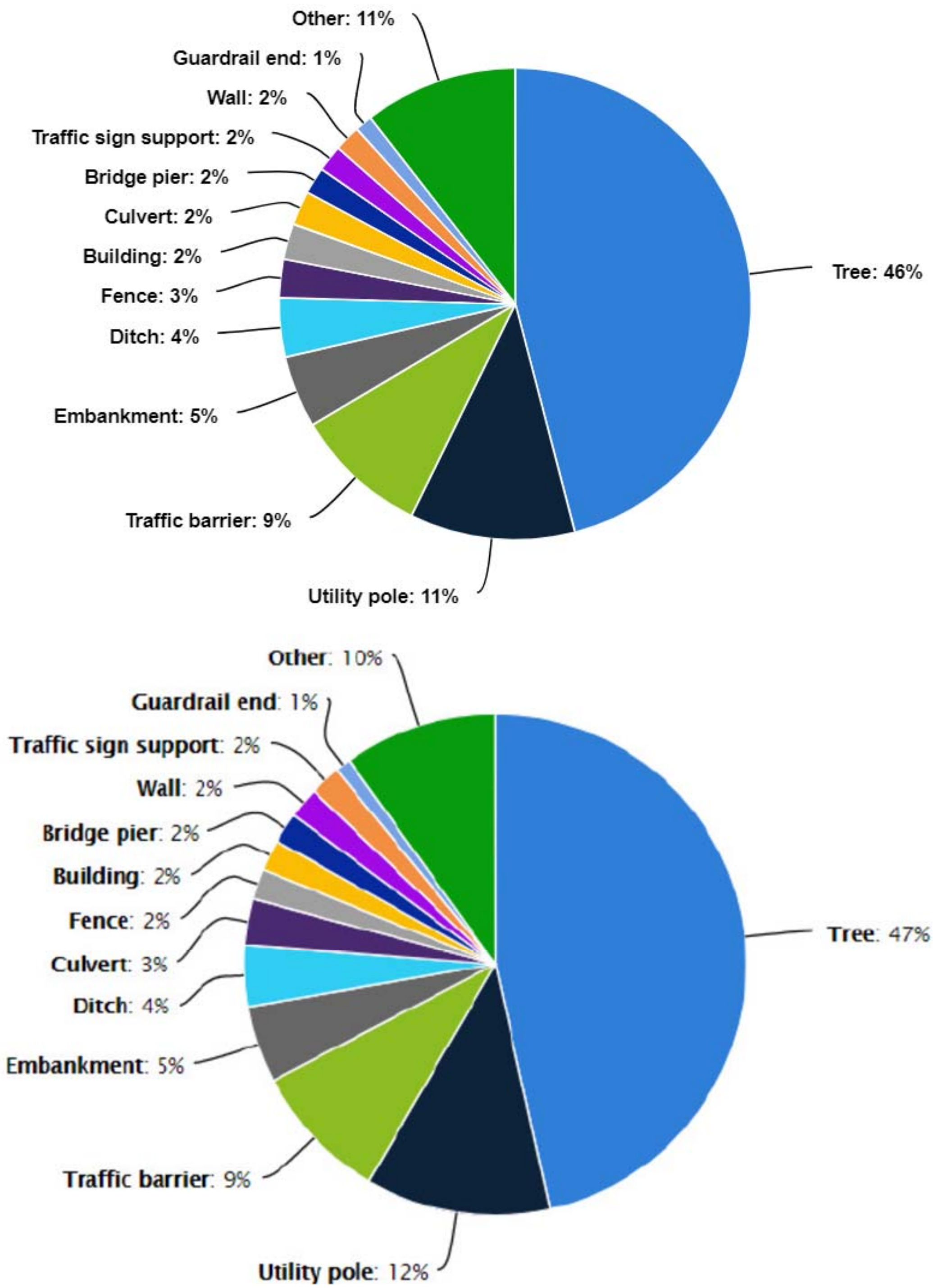

Figure 1-2 – Percent Distribution of Fatal Crashes by Obstacle Struck in US, 2020 *

* Pie Chart from Insurance Institute for Highway Safety and Highway Loss Data Institute, Washington, DC, 2020: http://www.iihs.org/iihs/topics/t/roadway-and-environment/fatalityfacts/fixed-object-crashes

1.3 Historical Perspective

The emphasis on roadside safety design emerged in North America during the 1960s. Designers came to realize that some motorists, regardless of the improvements made, may run off the roadway. It also became clear that serious collisions within the roadside environment could be reduced if a traversable recovery area was provided.

Many studies have been done to gain a better understanding of the path and stability of errant vehicles when they encroach onto the roadside environment. The vehicle behaviour depends largely on the nature of the roadside, vehicle speed, the circumstances that caused the roadside encroachment, and the characteristics of the vehicle. On traversable roadside terrain, the driver may be able to regain some control of the vehicle after the vehicle has left the travelled way, and either bring the vehicle to a stop or return to the roadway.

Test track experience and full scale testing at the GM Proving Grounds in the 1950s established a basic understanding of encroachment distance relationship and geometry of the roadside. The standard cross-section implemented at the GM Proving Ground test tracks in 1958 included 3 m (10 foot) shoulders, 6H:1V or flatter foreslopes and backslopes, and a roadside clear of obstacles for a minimum distance of 30m (100 feet) on each side of the travelled way. Field studies conducted in the mid-1960s and 1970s enhanced the understanding of the encroachment distance relationship for RoR collisions. This encroachment distance relationship is illustrated in Figure 1-3. While this encroachment relationship was first established almost 60 years ago, it is still relevant today.

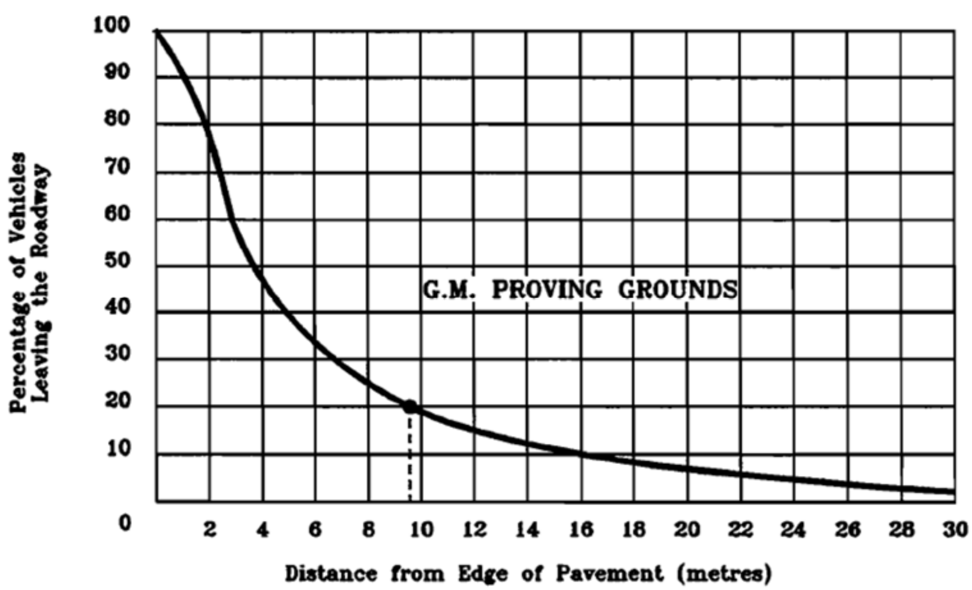

Figure 1-3 – GM Proving Ground Encroachment Relationship

As an example, Figure 1-3 indicates that on high speed roadways, a traversable, flat, obstacle free area adjacent to the travelled way results in about 80% of errant vehicles departing the travelled way to recover or stop before encroaching more than 9.1 m (30 feet) beyond the edge of travelled way. Conversely, about 20% of errant vehicles leaving the travelled way are expected to encroach more than 9.1 m (30 feet) from the travelled way. Where this area slopes downward away from the roadway, out of control vehicles will likely encroach further away from the travelled way. Conversely where this area slopes upward away from the roadway, encroachment distances should be less.

Roadside safety design treatments have also evolved over time. Roadway embankments were initially constructed using similar principles to those used for construction of railway embankments. Steep foreslopes were used to minimize the amount of materials and grading required. The steepness of the slope was typically governed by the loading requirements to support the roadway and to limit erosion. Construction through rock necessitated almost vertical walls due to cost. Early construction practices would usually result in very rough or jagged rock faces. It is now understood that providing flatter wider areas adjacent to the roadway can reduce the lateral extent and severity of encroachments within the roadside environment.

1.4 Contents of the Manual

The RDM provides cost beneficial design guidelines, standards and policies for design of the roadside environment and features on provincial highway projects.

Chapter 1 provides an introduction, historical perspective, and the general philosophy and principles of design of the roadside environment. Key terms from the glossary that are used extensively throughout the RDM are also defined.

Chapter 2 provides the ministry's policies, standards, and guidelines for design of the roadside environment on provincial highway projects.

Chapter 3 provides design processes for selection of appropriate design treatments within the roadside environment on provincial highway projects. A set of decision charts is included to guide the designer through the design process toward the selection of the most appropriate and cost beneficial design treatment for the situation and feature under consideration.

Chapter 4 provides the performance characteristics and design details for new roadside safety hardware to be used on provincial highway projects including barrier systems, terminals, crash cushions and small signs.

Chapter 5 provides the performance characteristics and design details for roadside safety hardware to be used within work zones on provincial highway projects including temporary barrier systems and temporary crash cushions.

Appendix A provides the MTO Severity Index Tables for many roadside features for a range of design speeds from 50 km/h to 120 km/h including various foreslope and backslope configurations, drainage ditches, and various obstacles such as trees, poles, piers, barrier systems, terminals, and culvert treatments. These tables are to be used for explicit benefit cost evaluations of alternative safety treatments during design of provincial highway projects.

Appendix B provides a glossary of terms common to the RDM and the MTO Design Supplement for the TAC Geometric Design Guide for Canadian Roads, June 2017.

1.5 Safety Sensitive Design

Significant improvements in safety are not automatic by-products of highway projects. In some cases, collision data may not be available or collision experience may not highlight the need to make a safety improvement, or to take advantage of a potential opportunity to improve safety. The designer should deliberately and systematically consider potential opportunities within each project to apply sound safety and traffic engineering principles.

At the beginning of the project the designer should assess the existing physical and operational conditions affecting safety by using collision data, site inspections and existing design and traffic characteristics. Consideration should be given to locations where the consequences of a collision may be severe.

1.6 Risk Mitigation and Treatment

It is recognized that it is not practical or cost beneficial to incorporate all possible safety improvements into every major capital works project on the provincial highway system due to physical, environmental, and/or funding priorities and constraints. However, the designer is encouraged to be proactive in improving safety where practical and cost beneficial. The intent of providing a clear zone adjacent to the travelled way is to minimize the probability of collisions with obstacles in the roadside environment by errant vehicles departing the roadway.

Ideally, the designer should strive towards providing the widest clear zone that can be reasonably afforded, fully considering physical, environmental, and funding constraints. However, this is not always practical. In such circumstances, the roadside mitigation treatments listed below in order of preference, should be considered and evaluated to determine the appropriate cost beneficial design alternative treatment to reduce the probability and/or severity of collisions with a roadside obstacle or area of concern.

Roadside Mitigation Treatment in Order of Preference:

1. Remove the obstacle;
2. Relocate the obstacle to a location to reduce the probability of it being impacted
3. Redesign the obstacle so that it can be safely traversed;
4. Reduce the impact severity of the obstacle by using an appropriate breakaway design;
5. Shield the obstacle with a barrier system or crash cushion;
6. Delineate the obstacle, if the above mitigation measures are not appropriate; and
7. Reduce the posted speed.

As noted above, the most preferred treatment is to remove or relocate the obstacle, provided that other considerations such as cost and environmental impact make its removal or relocation practical. Alternatively, the severity (e.g. severity index) of the obstacle may be reduced by other means, such as making it traversable by using an appropriate breakaway design, or by flattening slopes and culvert ends. These treatments are preferable to shielding them with a barrier system or crash cushion. Although barrier systems and crash cushions are designed and crash tested to minimize the severity of injuries to occupants in passenger vehicles from collisions with roadside obstacles dependent on the type of impact, significant vehicle damage can occur including injury to occupants under certain conditions. Once a barrier system or crash cushion comes into use, the crash is already in progress. The purpose of a barrier system or crash cushion is therefore not to prevent a crash, but rather to minimize the severity of the crash.

1.7 Relationship to Other Design Documents

The Roadside Design Manual should be used and read in conjunction with other guidelines, manuals, standards and codes such as:

- Canadian Highway Bridge Design Code (CHBDC);
- MTO Bikeway Design Manual
- MTO Contract Design Estimating and Documentation Manual (CDED);
- MTO Contract Preparation System (CPS);
- MTO Drainage Design Standards;
- MTO Drawings (MTOD);
- MTO Design Standards Section Drawings (DSSD);
- MTO Electrical Engineering Manual;
- MTO Design Supplement to the TAC Geometric Design Guide for Canadian Roads;
- MTO Maintenance Manual;
- MTO Provincial Engineering Memorandums;
- MTO Sign Support Manual;
- MTO Standard Special Provisions;
- Ontario Provincial Standard Drawings (OPSD);
- Ontario Provincial Standard Specifications (OPSS),
- Ontario Traffic Manuals (OTM), and;
- TAC Geometric Design Guide for Canadian Roads (as referenced in MTO Geometric Design Supplement to the TAC Geometric Design Guide for Canadian Roads).