Metrolinx Trenchless Utility Works Design and Construction Guidelines on Metrolinx Right-of-Way (Heavy Rail)

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Preface

This is the first revision of the Metrolinx Design and Construction Guidelines for Trenchless Utility Works located within Metrolinx Right-of-Way – Heavy Rail document launched in October 2019. The first revision introduces new requirements related to recommended utility crossing angle, backfill material for Subsurface Utility Investigation Level “A”, abandonment of existing underground utilities and/or unsuccessful bore paths, Ground Penetrating Radar scans, continuous monitoring, operational safety risk assessment for different trenchless installation methods, as well as minor wording changes.

The contents herein serve only as a guideline to facilitate the process of choosing the most appropriate trenchless technology method, where applicable, for either Metrolinx-owned or private third-party utility sub-surface installation within Metrolinx Right-of-Way (ROW). The purpose of this document is to provide insight and reference the regulations that shall be followed. This document provides general guidelines and does not supplant or take responsibility for the judgement of the final decision made by the designer / third party applicant / or any other party for a specific project. All trenchless technology construction practices should follow the general requirements and specifications provided in the project contract documents.

For third-party trenchless utility placement and the application process, the Applicant shall refer to this document which is part of the latest version of the "Metrolinx Third Party Project Protocol for Heavy Rail Corridors".

For all types of Metrolinx Capital Projects Group (CPG) projects, this document can be referenced, when applicable, for the need to place Metrolinx-owned utility assets below ground on Metrolinx railway property utilizing trenchless technologies.

Note

The Metrolinx Guidelines for Trenchless Utility works on Metrolinx Railway ROW is intended for use by suitably qualified professionals with the necessary years of experience in the design and construction of trenchless technology. It is not a substitute for coordination and compliance with all applicable codes, standards, manuals, and approvals for fire protection, life safety, and security measures that are part of the planning, design and implementation of a railway.

The document does not cover all aerial utility works, nor does the document cover open trench cut-and-cover utility placement techniques.

The Metrolinx Guidelines for Trenchless Utility works on Metrolinx Railway ROW is intended to be followed as per industry best practices. Conflicts with requirements from any standard have to be reviewed by Metrolinx on a case-by-case basis.

Suggestions for revisions and improvement:

Suggestions for revision(s) or improvement can be sent to Metrolinx Engineering and Asset Management, Attention; Director, Engineering - Track who will introduce and coordinate the management of the proposed change(s) within Metrolinx. Be sure to include a description of the proposed change(s), complete with appropriate background information and any other useful rationale or justification. Also, be sure to include your name, company affiliation (if applicable), email address, and phone number.

A biannual review of this document can be performed for revisions to reflect changes within the standards and best industry practices covering trenchless utility work.

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1. Scope

The **Design and Construction Guidelines for Trenchless Utility Works within Metrolinx ROW** intends to provide general guidance to the design and construction of buried utilities incorporating trenchless technologies in various ground conditions. This guideline provides general specifications and references that shall be followed in the design and construction of a trenchless project.

2. Definitions

Agreement: Document executed between Metrolinx and a general contractor or a third party Applicant for any aspect of a utility crossing. The third-party agreement usually includes rates to be charged for the utility crossing within the Metrolinx ROW, responsibilities for the payment of the installation and costs for future maintenance and responsibilities for damages.

Applicant: the third party and can be, road authorities, public and private utility companies or landowners, who submit an application to construct a utility trenchless crossing within the Metrolinx Right-of-Way.

Ballast Fouling: The addition of fine particles, drilling fluid, or slurry to existing track crushed rock ballast or granular sub-ballast, causing a detrimental effect on the materials.

Blasting: Is a process in which explosives are used to excavate rock or soil. Blasting is prohibited on Metrolinx ROW as a form of trenchless technology.

Contractor: Depending on the Project contractual set up, can be working directly with the Applicant, or, directly with Metrolinx either as the constructor or as the constructor's sub-contractor who is undertaking the trenchless utility construction.

Designer: The party which completes the collaborative design of the proposed trenchless utility Project(s) with the Geotechnical Engineer. Is a Professional Engineer in good standing, licensed in the Province of Ontario with at least ten (10) years of experience in trenchless utility projects of comparable complexity and scope.

Drilling Fluid: A mixture of water and additives, including bentonite, polymers, soda ash, surfactants, or other materials, to enhance stability and excavation. Some additives may increase the effectiveness of the drilling fluid and reduce the adhesion of the spoils (cuttings).

Drilling Fluid Fracture or Frac-Out: A condition where the drilling fluid's pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Fill: Man-made mixture of previously placed/handled materials such as clay, silt, sand, gravel, broken rock, sometimes containing organic and/or other deleterious materials.

Geotechnical Data Report (GDR): Report that contains descriptions of the investigation methods and factual data collected during the field investigations completed by the Geotechnical Engineer. This report is prepared as a data report only and does not include any interpretation of the subsurface conditions.

Geotechnical Interpretive Report (GIR): Report that takes the site investigation data and the laboratory results to prepare and provide the analysis required during the geotechnical engineering design and the construction recommendations.

Geotechnical Baseline Report (GBR): Report that may be required in projects involving relatively high risk, high costs, or high complexity. The intention of the GBR is to set the range of adverse physical ground conditions that ought to be provided for and included in the contract price.

Geotechnical Engineer: A Professional Engineer in good standing, licensed in the Province of Ontario with at least ten (10) years of experience in trenchless utility projects of comparable complexity and scope.

Ground Penetrating Radar (GPR): GPR is a geophysical method that uses radar pulses to image the subsurface. It is a non-intrusive method of surveying the sub-surface to investigate the presence of sink holes and voids. The data collected shall be analyzed utilizing imaging software for the purpose of presenting in 2D a colour coded map outlining the severity and extent of subsurface voids for both pre and post-trenchless works.

Hazardous gas or liquid: As defined by Transport Canada TC-E 10, and differentiated from the flammable gas or liquid, a hazardous gas or liquid shall be considered a non-flammable gas or liquid products which, from their nature or pressure, might cause damage or endanger the lives, well-being and health of people, or the environment, if escaping on or in the vicinity of railway property. Samples of such are compressed gas, liquefied gas, pressurized cryogenic gas, compressed gas in solution and oxidizing gas.

Horizontal Direction Drilling (HDD): Directional or guided boring.

Jack and Bore or Horizontal Auger Boring: A method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead a casing and rotating a cutter head, followed by removal of material from inside the bore and casing.

Micro-Tunneling: Method of trenchless construction that use a small-scale, unmanned Micro-tunnel Boring Machine (MTBM), directed by remote control. The system simultaneously installs pipe as the ground is excavated and removed. Personnel entry is not required for routine operation.

Pipe Bursting: Is a method for installing a casing pipe or carrier pipe by forcing a larger pipe through a smaller existing pipe. This trenchless technology is prohibited on Metrolinx ROW.

Pipe Jacking: A method for installing steel casing or concrete pipe utilizing hydraulically operated jacks of adequate number and capacity, to ensure smooth and uniform advancement without overstressing the carrier pipe or liner.

Pipe Ramming: A method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached to the front end of the casing.

Project: Proposed planned work or activity to install a utility within Metrolinx ROW utilizing a trenchless technology method.

Railway Infrastructure: Any physical infrastructure that supports Metrolinx rail operations, including but not limited to, track beds, bridges, culverts, signalling and communication cables, bungalows and cases, signal bridge structures, road crossing warning systems, electrification infrastructure, and Railway communication towers and their associated building infrastructure.

Right-of-Way (ROW): Refers to the Metrolinx railway lands comprising of mainline track that is shared with freight railways and other passenger trains like VIA Rail and AMTRAK, as well as Metrolinx rail equipment layover yards and rail equipment maintenance facilities, unless otherwise specified.

Rock: Natural beds or massive fragments, or the hard, stable cemented part of the earth’s crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 metres in diameter or greater.

Slurry: A mixture of soil and/or rock cuttings and drilling fluid.

Soil: All material except those defined as rock, and excludes stone masonry, concrete, wood, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 metres in diameter.

SPMDD: Refers to Standard Proctor Maximum Dry Density as determined by MTO laboratory test method LS-706.

Third Party: Any person or entity performing works on GO Property that does not have a legal contract for work with GO or any of GO's Contractors and is anticipated to visit the site more than once to accomplish their work. Third-Party personnel will be expected to meet all the requirements of a Contractor under this program. A one-time visit by a Third Party would be managed as a visitor.

Transport Canada Standards Respecting Pipeline Crossings Under Railways TC E-10, section 5.3: Other important structures shall include all train control signal bridges and masts, road crossing warning systems, railway communication towers, railway electrification systems and the overhead catenary infrastructure.

Water Jetting: A drilling method which primarily relies on the use of a pressurized jet of fluid and extensive circulation to cut and/or excavate soil or rock. This trenchless technology is prohibited on Metrolinx ROW.

3. Trenchless Utility Design Requirements

3.1 Applicable Regulations, Standards and Design Guidelines

The most current or latest addition of the listed applicable regulations, standards and design guidelines shall be used as well as other references in the document.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE-OF-WAY ASSOCIATION - AREMA Manual for Railway Engineering (2018), Volume 1, Chapter 1 Roadway and Ballast, Part 5 -Utilities.

American Society of Mechanical Engineers - ASME Standards:

a) B31.4 Pipeline Transportation Systems for Liquids and Slurries

b) B31.3 and B31.8 Gas Transmission and Distribution Piping Systems

ASCE/CI 36-15, Standard Design and Construction Guidelines for Microtunneling

AEIC CS9-06, Specification for Extruded Insulation Power Cables and Their Accessories Rated above 46kV through 345 kV ac.

Canadian Association of Petroleum Producers (2004) Guideline - Planning Horizontal Direction Drilling For Pipeline Construction. CAPP Publication 2004-0022.

Center for Underground Infrastructure Research and Education, Michigan State University (2004) Horizontal Auger Boring Projects, ASCE Manuals and Reports on Engineering Practice, No. 106.

GO Transit Track Standards - GTTS, RC-0506-02TRK (2018)

Guidelines for Pipe Ramming, Trenchless Technology Center – Prepared for: U.S. Army Corps of Engineers, Engineering Research and Development Center, Vicksburg, MS. Simicevic, J., Sterling, R.L. (2001)

Metrolinx General Guidelines for Design of Railway Bridges and Structures, RC-0506-04STR Latest version

Metrolinx Rail Corridor Raceway Requirements MX-ELEC-RCWY-2018-REV0

North American Society for Trenchless Technology - NASTT's Horizontal Directional Drilling Good Practices Guidelines, 4th Ed., Bennett, D., Ariaratnam, S. (2017), Cleveland, OH.

Performance Specifications for Electric Traction Enabling Works. Capital Project Group MX-ELEC TRAC EW-SPEC-2016. Latest Revision

Transport Canada, TC E-05 - Standards Respecting Railway Clearance

Transport Canada, TC E-10 - Standards Respecting Pipeline Crossings Under Railways

a) CSA Z662-15 Oil and Gas Pipeline Systems

Transport Canada, TC E-11 - Wire Crossings and Proximities

a) CSA 22.3. No.7-15 Underground Systems

Transport Canada, TC E-12 – Guideline on Requesting Approval to Undertake Certain Railway Works.

Ontario Provincial Standard Specifications (OPSS) 450 - Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling

Ontario Provincial Standard Specifications (OPSS) 415 - Construction Specification for Pipeline Installation by Tunneling

Ontario Provincial Standard Specifications (OPSS) 416 - Construction Specification for Pipeline and Utility Installation by Jacking and Boring

3.2 All Trenchless Works

3.2.1 General Requirements

Unless stipulated in the Metrolinx contract documents any utility trenchless installation shall have detailed design plans and specifications covering but not limited to, design of carrier and casing pipe materials, trenchless method, ROW rail operations and property, including acceptable provincial and municipal environmental impact mitigation methods.

The following information is required on all trenchless works:

a) Detailed design drawings:

   1) Design drawings signed and sealed by a qualified Designer that must be to scale or have all dimensions shown;

   2) Site plan showing the location of crossing in relation to the legal description or road allowance or Metrolinx railway mileage, and width of ROW, and the number of tracks and the angle of crossing;

   3) Direction of flow, location of shut off valve closest to the ROW;

   4) Type, wall thickness and pressures (operating and maximum test) of carrier and casing pipes, ensure wall thickness of carrier and casing pipes meet TC E-10 requirements, CSA Z662-15, CSA 22.3 No. 7-15 and other applicable standards (See table 1 of this document);

   5) Type of exterior protective coating on casing or carrier pipe (if used);

   6) Type of cathodic protection (if used);

   7) Contact name, address and phone number of utility owner on plan or cover letter;

   8) Revised drawings must be marked as revised and reason for revision stated;

   9) Separations requirements shall be met as per applicable utility standards;

   10) Separation requirements from signal & communication structures shall: not be within five meters of railway signal bungalows/cases or within one meter of the zone of influence of the foundations of signal and communication railway infrastructure or railway signal cables. Deviation to these separation requirements shall be highlighted on submitted detail design drawing(s) for review, acceptance and approval by Metrolinx.

   11) Existing and proposed facilities must be clearly marked;

   12) GO Transit Track Standard document “Appendix W - Temporary Excavation Limits for Intrusive Works Adjacent to a Railway” on plan and cross-section-profile views, or the bridge loading influence zone on a plan and cross-section-profile views, as applicable;

      i) Approved shoring protection, designed, stamped, dated, and signed by a professional engineer, will be required for any excavation within the railway loading influence zones as per Appendix W referenced above, and / or the bridge loading influence zone. Also, see item j of this section

b) Detailed installation and material specifications, including information related to existing sub-surface utilities (clearance, location, size, quantity and depth) when available. Should additional information be required, non-intrusive methodology is the preferable approach.

c) For all trenchless and excavation works adjacent to Railway Infrastructure, a geotechnical report is required regardless of bore size and trenchless method of construction. In the GIR, the Geotechnical Engineer shall include recommendations to be implemented to limit movements of existing Railway Infrastructure and ensure structural stability during construction.

d) Submittal of a subsurface utility engineering (SUE) investigation that meets industry standard quality levels D, C and B, complete with the copies of the appropriate work permit and flagging protection documents issued by Metrolinx or Metrolinx representative. Quality level A (SUE) may be required under certain circumstances, and Metrolinx may request the proof of acceptance and or waiver exemption from a SUE investigation quality level A, in writing, from all existing subsurface private, public and Metrolinx railway utilities and signal and communication management groups.

    i) On Metrolinx railway ROW, all level A SUE investigations shall be backfilled with non-shrinkable grout or lean concrete with a 28-day compressive strength of 5MPa, or backfilled with either compacted OPSS 1010 granular A or granular B type II material that meets a field tested 98% SPMDD compaction value.

e) The Designer and Geotechnical Engineer shall provide evidence supporting the proposed trenchless construction method for the proposed casing or carrier pipe diameter, proposed trenchless overall length, construction materials, site access points, and overall degree of the trenchless project complexity as either low, moderate or high.

f) A detailed work plan methodology (WPM) on the prescribed Metrolinx form, including the proposed construction methods, the management plan for all cuttings, muck, or excavated material, and the method of dewatering.

g) The ground movement (settlement/ heave) monitoring plan shall be stamped, signed and dated by a Geotechnical Engineer registered in the Province of Ontario.

h) A contingency plan for the emergency repair and reinstatement of any track deficiencies.

i) Environmental protection plan / Environmental assessment, including a contingency plan in case of trenchless HDD frac-outs.

j) Track boring should be located at a minimum of 13.7 metres (45 ft.) from the nearest railway bridge, railway operating signal structure, building or other major structure. Any deviation from this offset requires a special design by the Applicant's Geotechnical Engineer and carrier pipe Designer and submitted for review and acceptance by Metrolinx. Any trenchless or excavation works adjacent to Railway Infrastructure shall be outside the Metrolinx load influence line, starting from the edge of footing with a downward slope of 2 horizontal:1 vertical. For track-bed excavation works also refer to sections 20 and 22 in the GTTS document.

k) Pits are not typically permitted to be constructed on the Metrolinx ROW or less than 9.14 metres (30 ft.) from the track centerline of the nearest track. See Figure 1.

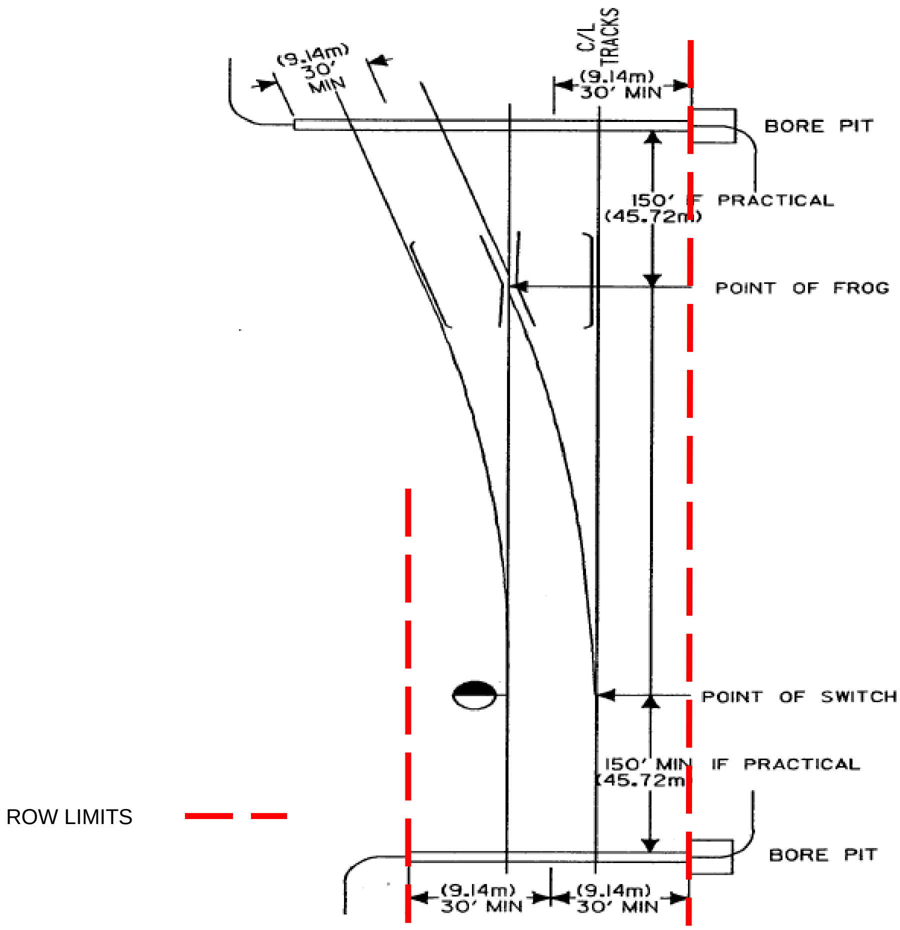

Figure 1 - Distance to Nearest Track Switch

Source: Figure 1-5-12 Standard Turnout – AREMA Chapter 1 Part 5

l) Track bores should be as far as possible from any track turnout and rail-to-rail crossing, typically at a minimum distance of 45.72 metres (150 ft.) from the nearest track turnout. See Figure 1. For any excavation within 40 metres (131 feet), the Contractor must be prepared to rebuild that turnout;

m) Shoring (or Trench Box) shall be designed by a professional engineer licensed in the Province of Ontario. When applicable the submittal of shoring drawings sealed and signed by a professional engineer for review by the Metrolinx representative prior to commencement of any excavation. Refer to Metrolinx General Guidelines for Design of Railway Bridges and Structures, RC-0506-04STR Latest version, Part 6 for all applicable Metrolinx shoring details;

n) Casing pipe and joints on the ROW and under tracks shall be of leak-proof construction, such as butt welded or interlocking joints, capable of withstanding railway loading (Cooper E-80 Loading);

o) The inside diameter of the casing pipe shall be at least 2 inches (50.80 millimetres) greater than the largest outside diameter of the carrier pipe, joints or couplings, for carrier pipe less than 6 inches (152.39 millimetres) in diameter; and at least 4 inches (101.60 millimetres) greater for carrier pipe 6 inch (152.39 millimetres) and over in diameter. The casing pipe shall, in all cases, have an inside diameter great enough to allow the carrier pipe to be removed without disturbing the casing pipe or track infrastructure. This requirement may not be applicable to power and fibre installations, conditional upon design parameters.

p) "The Contractor shall submit 'As-Built' drawing(s) no later than 30 days after completion of construction";

q) All pipelines shall be able to withstand railway Cooper E80 Live Load.

r) Least Nominal Wall Thickness Requirements.

Table 1 values (see below) are copied from CSA 22.3 No. 7-15 and CSA Z662-15 with the amendments from TC E-10 and values from AREMA.

The casing and carrier pipe thickness requirements provided by TC E-10 and the CSA standard are limited to 1524mm for the outside pipe diameter. Table 1 expands the least nominal casing and carrier pipe thickness for up to 1828.8mm (72 inches) diameter pipe.

It is further noted that the nominal wall thickness presented in table 1 is subject to design requirements for additional thickness, especially in the case of the pipe ramming trenchless technology method where the casing pipe wall will need to resist installation forces.

s) Where the casing and/or carrier pipe utilizes cathodic protection, other railway structures and facilities shall be adequately protected from the cathodic current complete with test reports submitted to the Metrolinx technical representative for review and acceptance.

t) Positive protection (flagging) will be required for all affected tracks regardless of bore size or trenchless method of construction. Within the USRC the existing signal system and interlocking operating rules restrict the number of track(s) that can be temporarily taken out of service. During initial trenchless work design services, the Metrolinx railway corridor access group shall be consulted, and restrictions on trenchless work shifts established, including the need for around the clock work shifts on pre-approved weekends or pre-approved long weekends.

u) Trenchless utilities are recommended to cross the Metrolinx ROW from 45 to 90 degrees. Trenchless utilities located within the public road allowance and cross the Metrolinx ROW are also acceptable. Trenchless utility works that cross the Metrolinx ROW at an angle less than 45 degrees shall require written approval from Metrolinx. Regardless of crossing angle, a completed comprehensive Risk Assessment is required prior to construction works and must be reviewed and approved by the Professional Engineer who is accountable for the work.

v) On Metrolinx railway ROW, the abandonment of existing buried pipelines or unsuccessful trenchless bore paths shall require that the carrier pipe and the casing pipe or the unsuccessful bore path be filled with non-shrinkable grout and the ends mechanically sealed. Grouting operation shall be carried out as per Metrolinx General Guidelines for Design of Railway Bridges and Structures, RC-0506-04STR, latest version, Part 6, Sub-part 13 Ground and Track Movement Monitoring.

Table 1 - Least Nominal wall thickness for steel casing pipe in casing crossings and carrier pipe in uncased crossings

Pipe Outside Diameter, (mm)	Least nominal wall thickness, (mm) Railways, when coated or cathodically protected
0 – 323.9	4.8
355.9 – 406.4	5.6
457	6.4
508	7.1
559	7.9
610	8.7
660	9.5
711 – 762	10.3
813	11.1
864 – 914	11.9
965 – 1067	12.7
1118	14.3
1168 – 1270	15.9
1321 – 1422	19.1
1524 – 1575	20.6
1626	21.4
1676 – 1727	22.2
1778	23.0
1829	23.8

Source: From CSA Z662-15 with the amendments from TC E-10 & comments from AREMA – with variations

Notes:

1) When a steel casing pipe or carrier pipe is installed on the ROW without the benefit of a protective coating or is not cathodically protected, the least nominal wall thickness shown in Table 1 shall be increased by a minimum of 1.6mm (Transport Canada TC E-10).

2) Steel casing or carrier pipe installed on the ROW shall have a specified minimum yield strength of 241,317 kPa (≈242 Mpa) or greater.

3) For pipe outside diameters greater than 1524 mm, values have been presented in accordance with AREMA Volume 1 Chapter 1 Part 5 section 5.1.1 Casing Pipe Table 1-5-1 “Minimum Wall Thickness for Steel Casing Pipe for E80 Loading”

3.3 Geotechnical Inputs

Within the trenchless industry, it has been well documented that the success or failure of a trenchless project is intricately tied to matching equipment, tooling, and trenchless method with the crossing site subsurface conditions, topography, and site access constraints.

Adequate subsurface information, as deemed by the geotechnical and design engineers, should be available along the alignment of the proposed trenchless crossing to facilitate the design and to identify subsurface risks. Generally, this information is obtained from a geotechnical investigation and presented in a Geotechnical Data Report (GDR), or an equivalent report.

On the Metrolinx-owned Lakeshore West corridor ROW, the predominant sub-surface material consists of silty and sandy-silt soil whose properties have contributed to the presence of voids and sinkholes in the ROW. Therefore, on the Metrolinx Lakeshore West corridor the Geotechnical Engineer shall carry out a GPR survey both pre and post trenchless works. The timeline for completing the GPR survey post trenchless works shall be specified by the Geotechnical Engineer in the Geotechnical Report based on the soil condition. The GPR coverage area should at least mimic the track and ground settlement monitoring grid. The analysis of the field data shall include utilizing imaging software to produce a 2D colour-coded map and comment on the severity of the underground voids adjacent to and along the bore path. The GPR field work and reports shall be supervised, sealed and signed by the proponent's Geotechnical Engineer or Geologist. The post-trenchless work GPR report shall include recommendations on any necessary corrective mitigation works to resolve the increased presence of underground voids associated with the trenchless works.

The above requirements should also be considered for other Metrolinx railway ROW trenchless works whose geotechnical borehole data indicate similar subsurface soil properties as the Lakeshore West corridor.

Based on the GDR, geotechnical design and construction recommendations would typically be provided in a Geotechnical Interpretive Report (GIR), or an equivalent report. In situations involving relatively high risk, high costs, or high complexity a Geotechnical Baseline Report (GBR) may be prepared to form a basis of any contracts required for construction. A GBR is intended to define and establish the geotechnical risk at the crossing site for the benefit of Metrolinx, the Applicant, the general Contractor and the trenchless contractor, and is not a stand-alone design document.

The GDR, GIR, and GBR, shall all be stamped, signed and dated by a Geotechnical professional engineer registered in the Province of Ontario. All geotechnical engineering recommendations must follow AREMA guidelines as modified within this document, as well as the GO Transit Track Standards document. In addition, all geotechnical engineering recommendations, for a particular project, must follow any and all applicable regulations, codes, and industry best practices.

The majority of geotechnical investigations are typically performed by advancing boreholes and/or test holes, digging test pits, and installing monitoring wells while collecting samples and performing in situ testing. Geophysical surveys may also be performed to supplement these methods. A minimum of 2 boreholes are suggested for any Project with at least one borehole on either side of the proposed trenchless crossing. The maximum depth of planned boreholes should follow best industry practices and shall be based upon the depth at which the utility will be installed and also on the depth of maximum excavation. When completed, all boreholes shall be backfilled in accordance with Ontario regulation (O Reg.) 903, latest edition. A geotechnical investigation shall also include a soil management plan that shall ensure adherence with current and applicable environmental provincial regulations.

Ultimately, in collaboration with the Geotechnical Engineer, it is the responsibility of the utility crossing Designer to ensure that adequate geotechnical information is available to support their proposed crossing design and construction of the proposed trenchless crossing. Including recommendations that shall be implemented to limit movements of existing structures and ensure structural stability during construction.

In all cases, completed Geotechnical Reports shall be submitted to Metrolinx for review. Any questions or comments shall be addressed within an updated report to the satisfaction of Metrolinx.

Based on the available subsurface information, GIR for a project with a moderate to high degree of complexity or perceived risk shall include, at a minimum, the following:

a) Factual sub-surface information
b) The composition, depth, and density of all soil or fill materials underlying tracks or other sensitive railway infrastructure at the proposed trenchless crossing.
c) The anticipated groundwater level within the proposed trenchless alignment (Un-stabilized and stabilized)
d) A continuous stratigraphic profile of all soils or rock expected within the proposed trenchless alignment. The subsurface information should extend to a depth below the proposed carrier or casing pipe invert elevation of no less than the maximum of 1.5 times the carrier pipe or casing diameter or 3.0 metres whichever provides the greater depth. The stratigraphic profile should provide, at a minimum, descriptions of each soil type as per applicable codes and standards, and if bedrock is encountered, a description of the rock type and quality.
e) Assessments and recommendations:
    1) Recommendations regarding the appropriate trenchless technology / construction method. All associated soil parameters required to support the design and construction of the recommended trenchless construction method.
    2) Construction considerations.
    3) Requirement for documented part time geotechnical support services on site as well as emergency 7/24 on call services.
    4) A settlement monitoring plan as detailed in section 3.4 of this document and in the Metrolinx General Guidelines for Design of Railway Bridges and Structures, RC-0506-04STR, latest version, Part 6, Sub-part 13 Ground and Track Movement Monitoring, including an estimate of the maximum anticipated track displacement due to the proposed trenchless construction method.
    5) Recommendations regarding the requirements for dewatering.
    6) Recommendations regarding excavations, as per OHSA regulations, and the design and construction of any temporary shoring elements required.
    7) The soil chemical compatibility and corrosion potential with the proposed carrier or casing pipe materials.
    8) The maximum permitted drilling fluid pressure (if applicable) to avoid frac-out.
    9) Recommendations shall be provided assessing the suitability of the chosen trenchless technology method under live railway traffic.

Table 2 below outlines subsurface information that may be required from the GDR / GIR to facilitate the trenchless technology design and construction. Please note that the required information will vary with the subsurface conditions, the proposed construction methods, and the project requirements.

Table 2 - Potential Minimum Required Geotechnical Input Parameters

Ground Component	Parameter
Soils – Descriptions and Characteristics (Observed)	Soil Identification and Classification Natural Water Content Particle Size Distribution Atterberg Limits Compactness Condition or Consistency Presence of Boulders, Cobbles, Coarse Gravel, or Known Obstructions Ground Water Level, including any construction constraints. Soil Characterization and waste management
Soils – Engineering Properties (Measured or Inferred)	Hydraulic Conductivity or Permeability Density or Unit Weight Undrained Shear Strength Effective Internal Friction Angle Effective Cohesion Stiffness (various definitions) Poisson’s Ratio Compression / Recompression Index Pre-consolidation Pressure or Over consolidation Ratio (OCR) Coefficient of Consolidation
Rock – Descriptions and Characteristics (Observed)	Rock Identification and Classification Weathering Grain Size Structure Bedding Colour Solid Core Recovery Total Core Recovery Rock Quality Designation (RQD) Fracture Index Core Photo Logs
Rock – Engineering Properties (Measure or Inferred)	Unconfined Compressive Strength Rock Mass Hydraulic Conductivity Durability (Slake Durability Index) Hardness Swell Potential

3.4 Monitoring Guidelines

The monitoring requirements are for one (1) utility crossing. For more than one (1) utility crossing, the monitoring requirements are subject to change (i.e. monitoring points shall monitor all utility installations).

Metrolinx will accept a continuous monitoring method to complement traditional total station survey methods. For deep in-ground monitoring points, a traditional survey method must be used.

3.4.1 General requirements for all monitoring plans

Below is a general guidance for what is expected for ground movement monitoring in the vicinity of Metrolinx ROW for underground crossings:

a) The ground movement (settlement / heave) monitoring must be performed by a qualified and competent 'third party'. In-ground monitoring points shall have florescent markers with blunt tops to protect track workers from injury. Additionally, a sign board on side of the tracks outside of Transport Canada's Clearance Envelope shall be installed with the following information on the board:

   1) Metrolinx Project or Metrolinx Third Party Project (whichever is applicable);

   2) Project Name;

   3) Contact information of the company and / or contractor responsible for the monitoring points;

   4) Metrolinx contact;

   5) Metrolinx consultant contact;

b) A reference drawing showing location and general arrangement of the ground movement monitoring points is required for Metrolinx review and acceptance;

c) A baseline is required to be established by taking at-least three (3) readings prior to construction, taken on three (3) separate days;

d) The following notes should be included:

   1) Metrolinx shall have the right to request additional monitoring and to the satisfaction of Metrolinx regarding the frequency and accuracy of monitoring;

   2) Metrolinx project manager or representatives of Metrolinx are to be copied on all correspondence regarding the readings taken for ground movement monitoring within 24 hours of readings. Metrolinx project manager or representatives of Metrolinx and the flag person on duty shall be notified immediately if the observed readings appear to deviate from baseline readings. If required, the flag person and Rail Corridor Infrastructure Track & Structures will request emergency protection, to ensure the safety of rail traffic.

e) The following movement monitoring reading frequencies shall be followed:

   1) Visual monitoring of the track, ground, any shoring work and existing structures shall be performed a minimum of twice daily (i.e. before morning rush hour trains and prior to afternoon rush hour trains) during construction / boring / tunneling activities and when any ROW excavation is in an open condition

   2) Track movement monitoring, via surveying of in-ground monitoring points and rail surface monitoring points shall be performed once per day during construction/boring/tunnelling activities and when any ROW excavation is in an open condition.

f) After the crossing / construction has been completed, a set of readings shall be taken at each ground movement monitoring point for:

1) Once a day for 14 days;
2) Then twice weekly for the next 30 days (i.e. month);
3) Then once monthly for the next three months;
4) The above frequency may change depending on site conditions and the monitoring may continue up to one year.
5) At the conclusion of the trenchless monitoring plan tasks, all monitoring points and any monitoring information sign boards shall be removed from Metrolinx ROW and or adjacent property.

g) The Geotechnical Instrumentation Monitoring Plan (GIMP) shall be designed, sealed, signed and dated by a Geotechnical Engineer licensed in the Province of Ontario.

3.4.2 Ground and Track Monitoring plan

Additional information required for ground movement monitoring in the vicinity of Metrolinx ROW for underground crossings:

a) Rail surface monitoring points shall be installed on the webs of each rail at 4.0 metres centre to centre (13'0") intervals for at least 12.0 metres (40 ft.) on either side of the proposed installation / crossing;

b) In-ground monitoring points are to be installed along the tracks at 4.0 metres centre to centre (13'0") interval for at least 12 metres on either side of the proposed installation / crossing, on both sides (approximately 0.15 metres from outside edge of the tie and equally spaced – if more than one track, the points can be equally spaced between tracks or can be installed along the centreline of each track. In-ground points shall extend 1.2 metres below ground surface. In-ground monitoring points shall not create a tripping hazard to workers and shall be fitted with a high visibility reflective rubber end caps;

c) Deep-in-ground movement monitoring points are to be installed along the alignment of the proposed casing placement / utility within the ROW (maximum of 4.0 metres (13ft)) intervals and approximately at a depth of 1 metre above the proposed utility alignment);

   1) The deep monitoring points are to be located outside the track structure (i.e. ties, ballast, etc.);

d) 'Alert levels' with actions to be taken, are required. The alert levels shall be as indicated in Table 3:

   1) Allowable Limits: The Contractor will review the available data and provide comments on any potential ground movement concerns and implications to railway operations. The ground movement monitoring reports shall be forwarded to Metrolinx or Metrolinx representative within 24 hours of readings;

   2) Review Limits: The Contractor will immediately notify all parties involved. Monitoring frequency shall be increased to determine if any additional ground movement is occurring. Monitoring frequency shall remain increased until there is stabilization of the ground movement. The contractor shall plan for remedial works within seven (7) days. The work may continue;

   3) Alarm Limit: The Contractor will immediately notify all parties involved. The work will immediately cease until an assessment of the observed ground movement is conducted and inspected by a qualified and competent Geotechnical Engineer. The Contractor shall arrange

for immediate repairs to the track. The findings with a proposed action plan will be reviewed by Metrolinx or Metrolinx representative. No construction work shall take place until instructed by a qualified and competent Geotechnical Engineer and Metrolinx or Metrolinx representative subsequent to the following conditions being satisfied:

i) The cause of ground movement has been identified;

ii) A corrective / preventive plan is established and adopted;

iii) Any corrective and / or preventive measure deemed necessary is implemented;

Table 3 - Ground and Track Movement Monitoring - Allowable, Review & Alarm Limits

<table>
<tr><th rowspan="2">Class of Track</th><th colspan="2">Allowable Limits (mm)</th><th colspan="2">Review Limits (mm)</th><th colspan="2">Alarm Limits (mm)</th></tr>
<tr><th>Horiz.</th><th>Elev.</th><th>Horiz.</th><th>Elev.</th><th>Horiz.</th><th>Elev.</th></tr>
<tr><td>1 / yard</td><td rowspan="2">0 to < 10</td><td rowspan="2">0 to < 12</td><td rowspan="2">10 to < 15</td><td rowspan="2">12 to < 20</td><td rowspan="2">>15</td><td rowspan="2">>20</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="3">0 to < 4</td><td rowspan="3">0 to < 4</td><td rowspan="3">4 to < 9</td><td rowspan="3">4 to < 12</td><td rowspan="3">>9</td><td rowspan="3">>12</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
</table>

3.4.3 Bridge Movement Monitoring Plan

When the installation of utilities is under railway carrying structures and the railway bridge's components' zone of influence, the Designer shall submit a ground movement monitoring plan for movements of the railway structures as well as structures in the vicinity of ROW and their zone of influence. The bridge movement monitoring plan, which is part of the GIMP, is to be stamped, signed and dated by the Geotechnical Engineer.

Additional information required for bridge movement monitoring in the vicinity of Metrolinx ROW for underground utility crossings, including any associated excavations:

a) The monitoring points are to be installed on the exposed face of all bridge elements affected by the excavation and/or trenchless works (i.e. abutments, piers, wingwalls, retaining walls, etc.), from the top to the bottom of the vertical face, arranged in a grid system spaced at 3 metres (maximum) vertically and horizontally. The monitoring plan may include other monitoring instrumentation deemed necessary by the Geotechnical Engineer based on their sub-surface investigation;

b) Additional points at the track level may be required depending on the site condition(s). If required, the points shall be installed as per Section 3.3 and/or Metrolinx General Guidelines for Design of Railway Bridges and Structures, RC-0506-04STR, latest version, Part 6, Sub-part 13 Ground and Track Movement Monitoring requirements;

c) 'Review and Alert limits' with actions to be taken, are required. The allowable, review and alarm limits shall be as indicated in Table 4:

   1) Review Limits: The Contractor will immediately notify all parties involved. Monitoring frequency shall be increased to determine if any additional ground movement (settlement /

heave) is occurring. Monitoring frequency shall remain increased until there is stabilization of the ground movement (settlement / heave). The contractor shall plan for remedial works within seven (7) days. The work may continue;

2) Alarm Limit: The Contractor will immediately notify all parties involved. The work will immediately cease until an assessment of the observed movement (settlement / heave) is conducted and inspected by a qualified and competent Geotechnical / Structural / Bridge Engineer. The Contractor shall arrange for immediate repairs to the track. The findings with a proposed action plan will be reviewed by Metrolinx / their representative. No construction shall take place until instructed by a qualified and competent Geotechnical / Structural / Bridge Engineer and Metrolinx or Metrolinx representative subsequent to the following conditions being satisfied:

    i) The cause of the settlement / heave has been identified;

    ii) A corrective / preventive plan is established and adopted;

    iii) Any corrective and / or preventive measure deemed necessary is implemented;

Table 4 - Bridge Movement Monitoring – Allowable, Review & Alarm Limits

Class of Tracks	Allowable Limits (mm)		Review Limits (mm)		Alarm Limits (mm)	
	Horiz.	Elev.	Horiz.	Elev.	Horiz.	Elev.
Any	0 to <2	0 to <2	2 to <3	2 to <3	≥3	≥3

3.5 Trenchless Design Requirements Specific to each type of Utility

The following are design requirements for each specific type of underground utility. Whether they cross under the tracks, are placed longitudinally to the tracks or at other locations on the ROW, and are conveying flammable substances, non-flammable substances, power lines, or communication cables.

For general requirements refer to section 3.2.1 of this document.

3.5.1 Underground Pipelines Conveying Flammable Substances

All underground Gas / Oil Pipe Line Crossing / flammable substance shall comply with TC E-10 requirements for separation from important railway structures, latest revision of applicable CSA Standards (i.e. CSA Z662-15), when applicable consulting AREMA Volume 1 Chapter 1, Part 5 Utilities, Sections 5.1 and 5.2, latest revision; GO Transit Track Standards, latest version, Section 20 Drilling and Excavating Around and Under Tracks and, by exception, a special design to the satisfaction of Metrolinx technical representative, and other applicable railway or material standards

The following sections provide the requirements for the type of pipeline, but do not comment on other design elements that must be considered by the Designer. For instance, the design for these pipelines shall be able to withstand railway Cooper E80 Live Load.

3.5.1.1 Steel Carrier Pipe

Pipelines carrying oil, liquefied petroleum gas and other flammable liquid products shall be of steel and conform to the requirements of the current ASME B31.4 Pipeline Transportation Systems for Liquids and Slurries, and other applicable ASME codes, except that the maximum allowable stresses for design of steel pipe shall not exceed the following percentages of the specified minimum yield strength (multiplied by longitudinal joint factor) of the pipe as defined in the above codes.

Requisites for steel carrier line pipe under Metrolinx tracks shall apply for a minimum distance of:

a) 50 feet (15.24 metres (measured at right angles) from centerline of outside tracks or
b) 2 feet (0.61 metres) beyond toe of slope or
c) 25 feet (7.62 metres) beyond the ends of casing (when casing is required), whichever is greater.

3.5.1.1.1 Allowable Hoop Stress Due to Internal Pressure

With Casing Pipe

The following percentages apply to hoop stress in steel pipe within a casing under Metrolinx tracks and ROW:

a) Seventy-two percent on oil pipelines.
b) Fifty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and other liquid petroleum products.
c) Sixty percent for gas pipelines.

Without Casing Pipe

The following percentages apply to hoop stress in steel pipe without a casing under Metrolinx rail equipment layover yards / maintenance facilities and with approval of Metrolinx technical representative:

a) Sixty percent for oil pipelines.
b) Forty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and other liquid petroleum products.
c) For uncased gas pipelines design requirements, the Designer shall consult AREMA section 5.2, and applicable ASME standards.

Longitudinally on Metrolinx ROW

The following percentages apply to hoop stress in steel pipe laid longitudinally on the ROW:

a) Sixty percent for oil pipelines.
b) Forty percent for pipelines carrying condensate, natural gasoline, natural gas liquids, liquefied petroleum gas, and other liquid petroleum products.
c) For gas pipelines the Designer shall consult AREMA Section 5.2, and applicable ASME standards.

3.5.1.2 Additional Flammable Design Requirements for Cased Pipes

For general requirements, refer to section 3.2.1 of this document.

Where the casing is cathodically protected, other railway structures and facilities shall be adequately protected from the cathodic current applicable test reports shall be submitted confirming adequate protection has been provided to Metrolinx for review and acceptance.

The casing pipe length shall extend to the greatest of the following distances (measured at right angles to the centerline of the track(s) :

a) the full width of the ROW;

b) 0.61 metres beyond toe of slope.

c) 0.91 metres beyond ditch line or area that can be affected by normal ditch cleaning operations;

d) A minimum distance of 9.14 metres each side from centerline of outside track when casing is sealed at both ends.

e) A minimum distance of 13.72 metres each side from centerline of outside track when casing is open at both ends.

Plastic carrier pipe conveying flammable substances shall be encased the entire limits of the ROW.

Profile showing depth of burial from base of rail and ditch bottom to top of pipe;

Pipelines and casing pipe shall be suitably insulated from underground conduits carrying electric wires on the ROW.

Every carrier pipe having a diameter of 76mm (3”) or more shall be held clear of the casing pipe by properly designed supports, insulators or centering devices, installed so that no external loads will be transmitted to the carrier pipe. Grouting of the space between the carrier and casing will not be permitted. A cross-section shall be provided showing (with note stating) how carrier pipe will be held clear of casing pipe by supports;

The casing pipe shall be constructed as to prevent leakage of any substance from the casing throughout its length. The casing shall be so installed as to prevent the formation of a waterway on the ROW and under the tracks, with an even bearing throughout its length, and shall slope to one end. The ends of the casing pipe must not be sealed by any load transferring material (i.e. grout). The ends of the steel casing are to be sealed with rubber gaskets.

Casing pipe shall be properly vented. Vent pipes shall be of sufficient diameter, but in no case less than 2 inches (50.8 millimetres) in diameter, shall be attached near end of casing and project through ground surface at ROW lines or not less than 45 feet (13.72 metres) (measured at right angles) from centerline of nearest track. Vent pipe, or pipes, shall extend not less than 4 feet (1.22 metres) above ground surface. Top of vent pipe shall be fitted with down-turned elbow properly screened, or a relief valve. Vents in locations subject to high water shall be extended above the maximum elevation of high water and shall be supported and protected in a manner that meets the approval of the engineer. Vent pipes shall be no closer than 4 feet (1.22 metres) (vertically) from aerial electric wires.

For the use of polyethylene carrier pipes, the requirements are laid out in TC E-10 Section 5.6. It is noted in TC E-10 Section 5.7 that aluminum pipe is not acceptable for pipeline crossings under railways.

Oil and gas pipeline crossings shall be prominently identified where pipelines enter and exit Metrolinx ROW,

For oil and gas pipelines, accessible emergency shutoff valves shall be located each side of the railway.

The Contractor is required to backfill the pits and trenches used for the installation. Those pits inside the theoretical railway loading influence zone and / or the bridge loading influence zone shall be compacted to 98% SPMDD at 150mm to 200mm loose lifts of granular material acceptable to the Designer and Geotechnical Engineer

Install warning markers at each edge of the ROW;

Location of the proposed trenchless access points, jacking and receiving pits, in relation to the nearest rail shall be identified on a drawing;

Pits are not typically permitted to be constructed on the ROW or less than 9.14 metres from the track centerline whichever is greater;

If practical, track bores should be as far as possible from any track switch, typically at a minimum distance of 45.72 metres (150 feet) from the nearest track switch;

Location of nearest excavation from nearest rail to be identified on drawing;

Manholes should be located off the ROW;

Pipelines carrying flammable or hazardous gas or liquids on the ROW shall not be placed within a culvert, under Metrolinx railway bridges nor closer than 13.7 metres (45 feet) to any portion of any railway bridge, building or other important structure on Metrolinx ROW;

Pipelines carrying flammable substance shall, where practicable, cross any railway where tracks are carried on an embankment;

Pipelines and casing pipes shall be suitably insulated from underground conduits carrying electric wires on the ROW. Pipeline must be able to electronically located;

For other requirements, please refer to TC E – 10, CSA Z662-15 and AREMA section 5.1;

3.5.1.3 Notes required on Detailed Design drawings

In addition to the general requirements outlined in section 3.2.1, the following notes are necessary on the detail design drawings / plans:

a) The Contractor is required to submit the following for review and acceptance by Metrolinx or Metrolinx technical representative prior to construction:
    i. Detailed WPM for the proposed trenchless installation;
    ii. Methodology for any temporary excavation, if required;
    iii. Any de-watering schemes on or adjacent to the ROW;
    iv. Environmental and ROW impact mitigation requirements for the proposed trenchless installation
b) "In case of ground movement beyond the 'Alert Level', at the expense of the Contractor, track work may be required by the Contractor to restore the ROW to pre-existing conditions or better';
c) Note stating method of trenchless installation;
d) Contact name, address and phone number of pipeline owner on plan or cover letter;
e) Caption stating "Installation and Maintenance to be in accordance with Transport Canada Standards Respecting Pipeline Crossings Under Railways, TC E-10, AREMA and latest edition of the applicable CSA Standards";

3.5.1.4 Minimum Cover and Clearance Requirements

Table 5 presents the minimum cover required for pipelines conveying flammable substances.

Additional requirements (TC E-10 amends to CSA Standard Z662-99 or latest release and AREMA): Pipelines shall be located to cross tracks at approximately right angles and preferable not less than 45 degrees.

Pipelines carrying flammable or hazardous gas or liquids under railways shall not be placed within a culvert, under railway bridges nor closer than 13.75 metres to any portion of any railway bridge, building or other important structure on Metrolinx ROW, except in special cases and then by special design as approved by the Designer and to the satisfaction of Metrolinx.

Pipelines shall cross any railway where tracks are carried on an embankment.

Longitudinal pipelines should not be located within 7.62 metres from the center of any track.

Table 5 - Minimum Cover for buried pipelines conveying flammable or hazardous substances, mm (measured to top of carrier or casing pipe, as applicable)

Location	Type of Pipeline	Class Location	Normal excavation mm (ft)	Rock excavation or removal by comparable means mm (ft)
Crossings of ROW: below base of rail[1] All ROW tracks:				
Cased	Flammable or hazardous gas[2] or liquid	All	1680 mm (5.5ft)	1680 mm (5.5ft)
Uncased	Flammable or hazardous gas or liquid	All	3048 mm (10.0ft)	3048 mm (10.0ft)
Crossing of ROW: below bottom of ditches or ground surface[3]				
Cased	Flammable or hazardous gas or liquid	All	1000 mm (3.0ft)	1000 mm (3.0ft)
Uncased	Flammable or hazardous gas or liquid	All	1830 mm (6.0ft)	1830 mm (6.0ft)
ROW for cased or uncase buried longitudinal pipelines[3]				
Between 7620 mm and 15240 mm from the centre-line of nearest track	Flammable or hazardous gas or liquid	All	1830 mm (6.0ft)	1830 mm (6.0ft)
Greater than 15240 mm from centre-line of nearest track	Flammable or hazardous gas or liquid	All	1524 mm (5.0ft)	1524 mm (5.0ft)

Source: Transport Canada E-10 - with variations

Table 5 References 1 to 3 inclusive:

[1]Extend to full width of the right of way, measured at right angles to the centre-line of the track

[2] Non-flammable gas or liquid products which, from their nature or pressure, might cause damage or endanger the lives, well-being and health of people, or the environment, if escaping on or in the vicinity of the ROW.

[3] On portions of the ROW where carrier or casing pipe is not directly beneath any track, and shall require the approval of Metrolinx during the **initial** design review process.

3.5.1.5 Least Nominal Wall Thickness Requirements

Please refer to section 3.2.1 of this document for general requirements applicable to all utilities and to

Table 1 within section 3.2.1 for thickness requirements. The table is copied from CSA Z662-15 with the amendments from TC E-10 & values from AREMA.

It is further noted that the nominal wall thickness presented in the Table 1 are subject to design requirements for additional thickness, especially in the case of the pipe ramming trenchless technology method where the casing pipe wall will need to resist installation forces.

3.5.1.6 Requirement for Uncased Gas Pipelines

For Uncased Gas Pipelines, the requirements are available in CSA Z662 2015 or latest version, Section 4.12.3.2, and AREMA Section 5.2. The designer shall follow the most stringent requirements.

The pipe nominal wall thickness shall not less than the applicable least nominal wall thickness given in Table 1 of this document, table 4.5 of CSA Z662 Section 4.3.11.2 or the applicable least nominal wall thickness for steel carrier pipe specified in AREMA Chapter 1 Part 5 Section 5.2 Table 1-5-3, whichever is the greater.

CSA Z662 Requirement

Uncased steel pipelines may be installed under railways, provided that the following requirements are met:

a) The pipe has been designed to sustain the loads at the crossing as specified in Clause 4.3.
b) For steel pipe with a joint factor of less than 1.00, the hoop stress in the carrier pipe does not exceed
   1) 50% of its specified minimum yield strength, if such pipe crosses secondary or industry tracks; and
   2) 30% of its specified minimum yield strength, if such pipe crosses tracks that are other than secondary or industry tracks.
c) The D/t ratio shall not be greater than the applicable maximum D/t ratio specified in Table 4.11.
d) All circumferential joints within Metrolinx ROW are non-destructively inspected as specified in Clause 7.

AREMA Requirements

Pipelines carrying oil, liquefied petroleum gas and other flammable liquid products shall be of steel and conform to the requirements of the current ASME B 31.4 Pipeline Transportation Systems for Liquids and Slurries, and other applicable ASME codes, except that the maximum allowable stresses for design of steel pipe shall not exceed the following percentages of the specified minimum yield strength (multiplied by longitudinal joint factor) of the pipe as defined in the above codes.

The pipe shall be laid with sufficient slack so that it is not in tension.

For steel carrier pipes, the Designer shall use Table 1 of this document, as well as the most restrictive of the following four design criteria. These design criteria consider:

a) The maximum allowable hoop stress due to internal pressure as specified in regulatory codes;
b) The maximum combined multiaxial stress due to external and internal loads;
c) Fatigue in girth welds due to external live loads;
d) Fatigue in longitudinal seam welds due to external live loads.

Examples of wall thickness values for various pipe diameters, several pipe specified minimum yield strengths and maximum allowable operating pressures are available in AREMA Chapter 1 Part 5

Section 5.2 Table 1-5-3. The Designer shall note that the table values are based on a specific track vertical clearance, two mainline tracks, the location of the pipe girth weld, construction consideration regarding the bore size, specific engineering soil properties and other applicable design criteria

3.5.2 Underground Pipelines Conveying Non-Flammable Substances

The following sections provide the requirements for pipelines conveying Non-flammable substances. The design for these pipelines shall follow TC E-10, unless otherwise specified, and shall be able to withstand railway Cooper E80 Live Load.

Please refer to section 3.2.1 of this document for general requirements applicable to all utilities.

3.5.2.1 Additional design requirements for Non-flammable substances

Where the casing and / or carrier pipe is cathodically protected, other railway structures and facilities shall be adequately protected from the cathodic current. Any applicable reports shall follow and be submitted to Metrolinx (or Metrolinx representative).

The casing pipe length shall be the greatest of the following distances (measured at right angles to the centerline of the track):

a) the full width of Metrolinx ROW;

b) 0.61 metres beyond toe of slope;

c) 0.91 metres beyond ditch line or area that can be affected by normal ditch cleaning operations;

d) A minimum distance of 9.14 metres from centerline of outside track when end of casing is below ground.

Profile showing depth of burial from base of rail (minimum 1.68 metres or below frost line) and ditch bottom to top of pipe (below frost line);

Cross-section showing (with note stating) carrier pipe will be held clear of casing pipe by supports;

The percent (%) slope for the casing pipe on profile view;

Every carrier pipe having a diameter of 76mm (3”) or more shall be held clear of the casing pipe by properly designed supports, insulators or centering devices, installed so that no external loads will be transmitted to the carrier pipe. Grouting of the space between the carrier and casing is not permitted.

The casing pipe shall be constructed as to prevent leakage of any substance from the casing throughout its length. The casing shall be installed as to prevent the formation of a waterway under the Railway, with an even bearing throughout its length, and shall slope to one end. The ends of the steel casing are to be sealed with rubber gaskets. The ends of the casing pipe must not be sealed by any load transferring material (i.e. grout).

3.5.2.2 Notes required on Detailed Design drawings

The following notes are required on the detail design drawings / plans, in addition to the information required in section 3.5.1.3 of this document:

a) “Pipelines carrying steam, water (including oilfield steam and water), sewer and other non-flammable or non-hazardous substances under railways, shall not be placed within culverts nor under railway bridges where there is likelihood of restricting the area required for the purposes for which the culverts or bridges were built, or of endangering the foundations;

b) For other requirements, please see Transport Canada TC E-10 and AREMA Volume 1 Chapter 1 Part 5 Section 5.3;

3.5.2.3 Minimum Cover and Clearance Requirements

Table 6 has been extracted from TC E-10 Section 6.2 Minimum Cover and Clearance Requirements with additional comments.

Table 6 - Minimum cover for buried pipelines conveying non-flammable substances, mm (measured to top of carrier or casing pipe, as applicable)

Location	Type of Pipeline	Class Location	Normal Excavation mm (ft)	Rock excavation or removal by comparable means mm (ft)
Crossings of railway ROW: below the base of rail[1] Main Tracks Cased and Rail Equipment Layover yards Cased AND Rail Equipment Maintenance Facilities Cased / Uncased				
Cased	Water, sewer, steam or non-flammable or non-hazardous[2] substance	All	The greater of 1680 mm (5.5ft) or below frost line	The greater of 1680 mm (5.5ft) or below frost line
Uncased		All	The greater of 1371 mm (4.5ft) or below frost line	The greater of 1371 mm (4.5ft) or below frost line
Crossings of railway ROW: below the bottom of ditches or ground surface[3]				
Cased		All	The greater of 1000 mm (3.0ft) or below frost line	The greater of 1000 mm (3.0ft) or below frost line
Uncased		All	The greater of 1000 mm (3.0ft) or below frost line	The greater of 1000 mm (3.0ft) or below frost line
Railway ROW for cased or uncased buried longitudinal pipelines[3]				
Between 7620mm and 15240mm from the centre-line of the nearest track	Water, sewer, steam or non-flammable or non-hazardous substance	All	The greater of 1219 mm (4.0ft) or below frost line	The greater of 1219 mm (4.0ft) or below frost line
Greater than 15240mm from the centre-line of the nearest track	Water, sewer, steam or non-flammable or non-hazardous substance	All	The greater of 1000 mm (3.0ft) or below frost line	The greater of 1000 mm (3.0ft) or below frost line

Note: Carrier pipes shall be encased with some exceptions in accordance with applicable CSA requirements, and with the acceptance of Metrolinx:

a) Under Rail Equipment Maintenance Facilities tracks as approved by Metrolinx and provided maximum operating pressure in the carrier pipe does not exceed 700 kPa.

b) For non-pressure sewer crossings where the strength of the pipe and its joints are capable of withstanding railway loading, as approved by Metrolinx.

Table 6 References 1 to 3 inclusive:

1As per section 3.5.2.1, measured at right angles to the centre-line of the track

2 Non-flammable gas or liquid products which, from their nature or pressure, might cause damage or endanger the lives, well-being and health of people, or the environment, if escaping on or in the vicinity of the ROW.
3 On portions of the ROW where carrier or casing pipe is not directly beneath any track, and shall require the approval of Metrolinx during the initial design review process.

3.5.2.4 Least Nominal Wall Thickness Requirements

The least nominal wall thickness requirement for underground pipelines conveying non-flammable substances are outlined in Section 3.2.1 Table 1 of this document.

3.5.3 Underground Power Line and Communication Cable Crossings

Wirelines shall follow TC E-11 Wire Crossings and Proximities Regulations, which references CSA 22.3 No 1-1970, which has been updated to CSA 22.3 No 7-15 Underground Systems for the underground wirelines. Underground wirelines shall be able to withstand railway Cooper E80 Live Load.

Wirelines for this section are defined as electric power and communication utility systems including, but not limited to, all associated conductors, cables, support systems, and equipment. Examples would be electrical transmission lines, local electrical services, fiber optic telecommunications, highway traffic signaling, and cable television service.

This section does not apply to railway electrical, traction power, signals and communications infrastructure.

It is noted that supply transmission cables greater than or over 69kV are not addressed in this CSA 22.3 No 7-15.

Cables shall be encased within steel conduits with some casing pipe material exceptions (see below).

Design of supply transmission cables shall incorporate measures to eliminate electromagnetic interference to any railway infrastructure using appropriate mechanical protection.

Casing pipe material

a) If constructed of steel, casing pipe shall have nominal wall thickness in accordance with Table 1 of this document. Steel casing pipe shall comply with either
    1) ASTM A53/A53M, grade B or better; or
    2) CSA Z245.1, grade 241 or better.

b) Where constructed of materials other than steel, casing pipe shall
    1) be resistant to the chemicals with which it is likely to come into contact;
    2) have a maximum deflection of 5% of the diameter from external loading (E80 railway live loading); and
    3) be designed to take into account
        i) differential settlement of attachments;
        ii) longitudinal bending shear (horizontal shear) loadings due to uneven settlement of pipe bedding;
        iii) temperature-induced stresses;
        iv) ground movement due to seasonal variations in moisture content;
        v) seismic ground movement;
        vi) the potential for ground cover surface erosion; and
        vii) the crushing/impact strength of the material.

Multiple Casing Pipes

Where multiple casing pipes are installed, the minimum separation between casing pipes shall be twice the outside diameter of the largest casing pipe.

3.5.3.1 Underground Power Cables Design Drawing

Please refer to section 3.2.1 of this document for general requirements applicable to all utilities.

The casing pipe shall be constructed to prevent leakage throughout its length; the space between the carrier pipe and casing pipe shall be sealed at the casing ends to prevent the entry of water and to prevent the formation of a waterway under the track. The ends of the steel casing are to be sealed with rubber gaskets;

Pipelines and casing pipe shall be suitably insulated from underground conduits carrying electric wires on the ROW.

Pipeline must be able to be electronically located.

Supply cables must be protected for the full width of the ROW;

If cables are mechanically protected with pipe or duct, it must extend the full width of the ROW and the space between the carrier and the casing shall be sealed at the pipe ends to prevent the entry of water and foreign objects;

Profile showing depth of burial from base of rail (minimum 1.68 metres or below frost line) and ditch bottoms to top of utility (below frost line);

Neither permanent nor temporary wirelines shall be placed within railway culverts or under railway bridges.

At at-grade railway road crossings, the wireline should be located within the street right-of-way limits while maintaining the maximum distance as practical and outside the load zone of influence for the railway infrastructure such as signal bungalows, crossing gates and support foundations, and to the satisfaction of Metrolinx.

For other requirements, please see CSA C22.3 No. 7-15.

3.5.3.1.1 Notes required on Detailed Design drawings

The following notes are required on the detail design drawings / plans, in addition to the information required in section 3.5.1.3 of this document:

a) Add caption stating “Construction, maintenance and operation of the line shall be in accordance with the latest Transport Canada General Orders E-11 and E-12 and the latest Canadian Standards Association C22.3 No. 7-15, AREMA Volume 1 Part 5 Utilities and Metrolinx Electrification Requirements as applicable.”;

b) Note specifying type and details of cable and mechanical protection;

c) Indicate horizontal and vertical separation between wires and cables.

d) Supply cables must be protected for the full width of the ROW;

e) Profile showing depth of burial from the base of rail and ditch bottoms to top of utility (below frost line);

f) Identify the method of trenchless installation;

g) Location of nearest excavation from nearest rail to be identified on a drawing;

h) For other horizontal clearances requirements refer to table 7 of this document.

Table 7 is based on the Table 6 of the CSA 22.3 No 7-15 Underground Systems for underground electrical lines, modified with some clearance requirements from AREMA manual Volume 1, Chapter 1 Part 5 Utilities:

Table 7 - Minimum cover and Clearance Requirements for cable crossings

Type of Installation	Horizontal Separation (m)	Vertical Separation Main Line	Vertical Separation Rail Equipment Layover yards AND Rail Equipment maintenance facilities
Cable crossing in casing pipe, ducts, and duct banks	End of the casing pipe shall be the **greater distance** of 0.6 metres from the toe of the slope of the rail roadbed or 1.0 metre beyond the ditch or 15 metres from the centerline of the nearest existing or future track(s), measured perpendicular to the centerline of the track or the entire width of ROW for power lines carrying more than 750 Volts	1680 mm[1] 3700 mm for non-metallic casings	1371 mm[1]
Cable duct system installed longitudinally on railway ROW	7.5 metres from the entreline of tracks[2]	1200mm[3]	1200mm[3]
Direct-buried cable system	7.5 metres from the entreline of tracks[4]	-	-

Notes:

a) The drainage of the ROW should not be compromised
b) The symbol (-) indicates that no value is specified.
c) Subsurface chambers and Manholes, for any new utility sub-surface installation, are to take place outside of Metrolinx ROW. Any exception will need to be reviewed by Metrolinx on a case by case basis during the **initial** design review process.
d) For crossings within through streets which cross under railway bridges and at-grade crossings:
   i) To facilitate road and sidewalk lighting the wireline and fixtures may be attached to the railway bridge pier or abutment

Source: Table 6 of the CSA 22.3 No 7-15 Underground Systems for underground electrical lines, modified with some clearance requirements from AREMA.

Table 7 References 1 to 4 inclusive:

1 Maybe reduced upon agreement of the parties concerned

2 See Clause 11.5.1 in CSA 22.3 No. 7-15, which references ducts laid longitudinally on railway ROW and in all cases shall require the approval of Metrolinx during the initial design review process.

3 Besides railway ROW E-80 loading requirements other portions of the ROW shall be treated as subject to road traffic due to the use of railway operating vehicles.

4 See Clause 11.5.2 in CSA 22.3 No.7-15, which references direct-buried, longitudinal cable installations on railway ROW and in all cases shall require the approval of Metrolinx during the initial design review process

3.5.3.1.2 Least Nominal Wall Thickness Requirements

Refer to Table 1 of this document.

3.5.3.1.3 Underground Wireline Crossings (More than 69kv)

Currently, there are no general standards for underground high-voltage power distribution systems. Supply transmission cables greater than 69kV are not addressed in CSA 22.3 No 7-15.

For the installation of underground transmission cables carrying over 69kV, each design shall be considered on a case by case basis. The Designer shall present a detailed design in compliance with the local hydro utility's specific standards, AEIC CS9 Standards, International Electrotechnical

Commission - IEC Standards (including but not limited to IEC 840, IEC 60287, IEC 60949, IEC 60853, IEC 60228, IEC 60853), AREMA specifications, the latest Metrolinx Electrification requirements and other case-specific applicable standards.

The Applicant or Designer shall contact the appropriate utility and apply the latest requirements for underground crossings for transmission cables over 69kV. Most experienced utilities and supplier companies have established practices based on field workforce experience.

The Designer shall provide a comprehensive report containing the following information:

a) Design of supply transmission cables shall incorporate measures to eliminate electromagnetic interference to any railway infrastructure using appropriate mechanical protection.
b) Supply cables shall be installed at the appropriate calculated depth, with a suitable foundation, placed in crushed limestone, or similar adequate material, and when applicable backfilled trench with excavated native soil. Soil must be tested for soil resistivity to provide appropriate mechanical insulation to avoid cable overheating due to improper design of the thermal resistivity of the cables.
c) Retain a suitable supplier, approved by the hydro utility company, with enough specialized high voltage cable knowledge, experience and equipment to create an individualized solution.

3.5.3.2 Underground Communication Cable

Underground communication cable crossings must meet TC E-11 and TC E-12, the latest revision of CSA C22.3 No. 1-15 and/or CSA C22.3 No. 7-15. All crossings shall meet Metrolinx Electrification Requirements.

3.5.3.2.1 Design requirements for Communication Cables

The casing pipe shall extend to be the greatest of the following distances (measured at right angles to the centerline of the track):

a) the full width of the ROW;

b) 7.5 metres beyond each side from the centerline of the outside track;

c) 0.6 metres beyond the toe of slope; and

d) 1 metre beyond the ditch line or area that can be affected by normal ditch cleaning operations;

Fiber optic cables shall adhere to the railway infrastructure separation requirements in the General Requirements section of this document, if practical, shall run near the outer limits of Metrolinx's ROW.

Fiber optic cable must not be installed within 5 feet (1.52 metres) of underground power lines, unless suitably insulated.

Fiber optic cables shall run on the field side and outside the foundation zone of influence for all railway structures, including bridges, signal facilities, buildings and platforms.

Fiber optic running line shall be kept as straight as possible while maintaining a consistent distance from the track centerline.

If the fiber optic cables shall be placed under an existing signal or communication cables a one meter (3'-3") separation is required and during construction daylighting of the existing cables is required to ensure the trenchless works maintains this one meter separation.

If the fiber system is designed within 30 feet (9.14 metres) of a track centerline or structure of any type, excavations within this area may require shoring designed to include train or structure surcharges. In such cases, stamped shoring plans shall be submitted with calculations, to Metrolinx for review prior to construction.

Design the fiber system to be installed a minimum of 42 inches (1.07 metres) below natural ground, except as noted herein. In the event local ground conditions prohibit the placement of the fiber system at a depth of at least 42 inches (1.07 metres), the fiber system must be encased.

Design the fiber system to be buried a minimum of 60 inches (1.52 metres) below the bottom of all culverts on the ROW, or around the end of the culvert (field side) and 60 inches (1.52 metres) below the bottom of the flow line. This minimum depth must be maintained a minimum of 20 feet (6.10 metres) each side of the culvert centerline.

Locate and identify buried utilities and other potential obstructions.

Do not attach the fiber system to railway bridges without acceptance from Metrolinx during the initial design review process. Trenchless works to cross under waterways, along roads or highways are Metrolinx's preferred options.

3.5.3.2.2 Notes required on Detailed Design drawings

The following notes are required on the detail design drawings / plans, in addition to the information required in section 3.5.1.3 of this document:

a) Indicate crossing is for a communication cable or show circuit voltage;
b) Caption stating "Construction, maintenance and operation of the line shall be in accordance with the latest Transport Canada General Orders E-11 and E-12 and the latest Canadian Standards Association C22.3 No. 7-15, and Metrolinx Electrification Requirements as applicable.";
c) Type and details of cable and mechanical protection;
d) Profile showing depth of burial from base of rail (minimum 1.68 metres or below frost line) and ditch bottoms to top of utility (below frost line);
e) Identify the method of trenchless installation;
f) Location of nearest excavation from nearest rail to be identified on a drawing;
g) Indicate horizontal and vertical separation between wires and cables.

3.5.3.2.3 Minimum Cover and Clearance Requirements

Please refer to Table 7 of this document.

3.5.3.2.4 Least Nominal Wall Thickness Requirements

Please refer to Table 1 of this document.

3.5.3.3 Longitudinal Powerline & Communication Cable Installations in ROW

If a powerline electrical distribution cable or communication cable is proposed to be laid within the ROW but does not cross under the tracks, including associated support infrastructure systems, shall in all situations require the approval of Metrolinx during the **initial** design review process.
Generally, Metrolinx ROW is narrow and contains existing subsurface utilities and is primarily reserved for future railway Infrastructure to support Metrolinx rail operations.

As part of the Metrolinx design review process, the Applicant or Designer must prove to Metrolinx that the electrical distribution cable could not be located off of the Metrolinx ROW as well as other requirements deemed necessary by Metrolinx. In the majority of cases the Applicant can anticipate a rejection on their proposed longitudinal cable installation in the ROW.

If and when approval is granted by Metrolinx section 11.5 "Longitudinal Cable Installations on railway ROW" from CSA 22.3 No 7-15 shall be followed and section 5.5.3 from AREMA Volume 1, Chapter 1, Part 5:

Horizontal Clearance Requirements:

Refer to table 7 of this document

Vertical Clearance Requirements:

The wireline should be located a minimum of 4 feet (1.2 metres) above or below any existing drainage structure and a vertical clearance of 8 feet (2.4 metres) is required if beyond the downstream end of the drainage structure.

3.6 High Risk Utility Trenchless Projects

For projects that may be considered to have a higher geotechnical risk or a higher overall complexity, additional considerations may be required (Appendix A outlines different risk levels). At a minimum, the following list of drawings/documents/reports would typically be required for moderate to high risk utility trenchless projects within Metrolinx ROW:

a) A Geotechnical Baseline Report.

b) Design documents with the following information shall be clearly provided:

  1) Design brief demonstrating methods applied based upon a recognized trenchless technology technical organization (CATT, NASTT, USACE). Areas addressed shall include, but not limited to:

     i) Load-bearing capacity of the casing based upon installation method, permanent and live loads

     ii) Dimensional characteristics of the casing and carrier combination

  2) An elevation drawing of the proposed trenchless alignment should be superimposed over the subsurface information. The subsurface stratigraphic profile, prepared based on geotechnical investigation, should extend to a depth of no less than 3.0 metres below the casing or carrier pipe invert elevation.

  3) Records of all boreholes, test holes, test pits, monitoring wells, or geophysical surveys that are referenced in the submission.

  4) The anticipated groundwater level and hydrostatic head along the proposed alignment.

5) The minimum setback distance from all existing railway infrastructure.

6) Thickness and details of the liner and/or carrier pipe, sealed by the Designer.

7) The location and details of the entrance and exit points, including any temporary structures, sealed by Designer.

8) If a permit to take water is required by the project, a copy of the permit application should also be provided.

3.7 Corrosion control

Corrosion control shall be considered in the design of underground installations. Methods for corrosion control include material selection, coatings, and cathodic protection (Refer to CSA 22.3 No. 4-15 Control of Electrochemical Corrosion of Underground Metallic Structures).

A common application of the cathodic protection systems is in galvanized steel, in which a sacrificial coating of zinc on steel parts protects them from rust. Cathodic protection can, in some cases, prevent stress corrosion cracking.

Other corrosion controls may be considered, such as epoxy-based corrosion protection coatings that may be required to be supplemented with cathodic protection.

When recommending cathodic protection, Applicants and crossing Designers must consider Metrolinx's future rail line electrification programs, and the application must satisfy the requirements of the Metrolinx Capital Projects Group - Performance Specifications for Electric Traction Enabling Works document.

All crossings shall meet Metrolinx Electrification Requirements.

4. Trenchless Construction Methods

4.1 Common Construction Methods

Four common trenchless construction methods are considered in this document. Other construction methods, excluding those mentioned in Section 4.3, may be considered based on project requirements or at the sole discretion of Metrolinx.

a) Horizontal Directional Drilling (HDD)

b) Jack and Bore, Horizontal Auger Drilling

c) Pipe Ramming

d) Microtunnelling

Important considerations:

Bored or jacked installations shall have a bored hole diameter essentially the same as the outside diameter of the pipe plus the thickness of the protective coating. If voids should develop or if the bored hole diameter is greater than the outside diameter of the pipe (including coating) by more than approximately 1 inch (25.4 millimetres), remedial measures as approved by the Designer shall be taken. Boring operations shall not be stopped if such stoppage would be detrimental to Metrolinx rail operations.

Tunnelling operations shall be conducted as approved by the Designer. If voids are caused by the tunnelling operations, they shall be filled by pressure grouting or by other approved methods which will provide proper support.

4.1.1 Horizontal Directional Drilling (HDD)

A steerable drilling system used to install pipes, conduits, or cables in a shallow arc using a surface-launched drill rig. It can be characterized as a two-stage process. First a pilot bore is created along the planned alignment, using the thrust of the drill rig for steering and rotation of the drill rods and cutter bit to advance in the desired direction. Once the pilot bore is completed, the back reamer drill excavates using multiple passes that increase in size until the desired diameter is achieved.

In the second stage, a back-reamer is attached to the end of the drill string, followed by the desired flexible or semi-flexible utility product pipe. The pipe is then pulled through the tunnel along a pathway that is lubricated with bentonite slurry. This process requires a moderate overcut in order to create a large enough annular space between the pipe and surround soil that the pipe or cable can be pulled through. In order to facilitate this process, the overcut can be as large as 30% of the pipe's outer diameter.

Horizontal Directional Drilling is completed from the ground surface, and therefore may not require a trench or shaft. Additionally, construction is generally completed quickly. These benefits offer a low-cost tunnelling method, however a large laydown area is required to store materials and operate equipment.

The Contractor shall provide as part of the Work Plan Methodology WPM: frac-out contingency plans, planned protection and planned clean-up of the ROW for Metrolinx's review and acceptance.

Risks:

Horizontal Directional Drilling requires a substantial overcut, which can lead to significant surface settlement. There is also potential for ground heave, soil ravelling, or cave-in, particularly if used below the groundwater table. The steering precision is limited (plus or minus one meter accuracy), and this method is not recommended to be used in close proximity to buried utilities or underground structures. The drill may also have difficulty advancing if cobbles, boulders or other obstructions are encountered, in which case it may be necessary to fill the tunnel and re-drill at a different alignment.

Typical Diameter: 50mm to 1400mm
Typical Drive Length: Varies, up to 1.8 kilometres depending on diameter

4.1.2 Jack and Bore, Horizontal Auger Boring

A trenchless technique is used to install a prefabricated utility pipe along a fixed alignment from drive shaft to receiving shaft, such that the pipe forms a continuous string in the ground. Typically, the pipe is advanced in segments using a hydraulic jacking system reacting against a rigid support. The driven end of the pipe may consist of a continuous flight auger, a cutter head, or a face shield to allow for hand mining. This technique is typically used in horizontal or near-horizontal applications. Jack and bore offers a cost-effective solution for tunnels for drives up to 100 metres in length, where ground conditions are suitable.

Risks:

Boring can become obstructed by cobbles or boulders and a contingency plan shall be in place. The risk of settlement is low to moderate, depending on the size of overcut and ground conditions. Dewatering is necessary if shafts or tunnel is below the water table, which can cause additional settlement.

Typical Diameter: 100 mm to 1800 mm
Typical Drive Length: Up to 250 m

4.1.3 Pipe Ramming

A technique for installing steel casing from a drive shaft to a receiving shaft using dynamic energy from a percussion hammer attached to the end of the pipe. Continuous casing support is provided, eliminating risks associated with cave-in and surface settlement due to over-excavation, however there is a risk of ground heave. The steel casing is designed to resist driving forces as well as the overburden earth pressures and live loads. Using this method, cobbles and boulders may be crushed or displaced and may not hinder pipe ramming advancement. The driven end of the pipe is generally open but may be closed, and soil inside the pipe is typically removed after pipe installation. Pipe ramming is typically used in horizontal or near horizontal applications.

Control is achieved through careful attention to alignment prior to driving and proper evaluation of geotechnical conditions. Modern variations on the technique incorporating a pilot drive can be used to reduce the risk of uncontrolled drifting of the larger diameter main casing.

Noise mitigation and monitoring plan shall be developed to address the noise generated from the percussion hammer and submitted for Metrolinx review.

Risks:

Pipe ramming is a soil displacement technique (e.g. soil is pushed aside rather than removed), which can pose a significant risk of surface ground heave. This method is not generally used beneath sensitive surface infrastructure, but may be used as a contingency for removing rocks or boulders if the risk of heave is deemed to be acceptable. It should be noted that pipe ramming is noisy and can cause ground vibration.

Typical Diameter: 100 mm to 1800 mm
Typical Drive Length: Up to 100 m

4.1.4 Microtunnelling

A trenchless tunnelling method is used to install concrete or steel pipelines using a guided and remote-controlled micro-tunnel boring machine (MTBM). As the MTBM advances, pipe sections are jacked behind the machine, providing continuous support of the excavation and eliminating water infiltration. Annular space between the excavation and pipe is temporarily filled with bentonite lubricant, until the drive is completed and grout can be injected.

Various types of MTBM exist, and it is necessary to select the correct type of machine for the ground conditions. Slurry MTBM systems use a drilling fluid at the cutting face to balance earth and groundwater pressures, as well as to remove spoil. Earth Pressure Balance (EPB) MTBM systems remove spoil mechanically by auger as the machine advances. The MTBM is typically advanced using hydraulic pressure applied to either a reaction point or the pipe casing. When using a pressure balanced cutter head, this approach is suitable for a wide range of ground conditions.

Although Micro-tunnelling is often a more costly option, it offers many advantages including decreased risks of surface settlement and ground heave, and the use of sealed construction techniques, eliminating the need for dewatering. Additionally, MTBM guidance systems offer a high degree of precision, with the ability to maintain alignment within a tolerance of 25 millimetres. These benefits make micro-tunnelling an ideal method when tunnelling near or below sensitive infrastructure or ecosystems.

Risks:

An appropriate type and size of MTBM and jacking pipe should be selected for the given ground conditions. Obstructions or large cobbles, boulders, and buried infrastructure can block MTBM advancement, requiring an emergency shaft. It is recommended that the Contractor select an MTBM capable of boring through cobbles and boulders when tunnelling below sensitive infrastructure, such as railway crossings.

Typical Diameter: 900 mm to 3500 mm
Typical Drive Length: can exceed 1.1 kilometres

4.2 Trenchless Method Summary

Table 8 shows the typical dimeter and drive length for trenchless tunnelling methods. This table is intended as a quick reference only and each proposed project shall be reviewed on a case-by-case basis. The Designer may wish to retain a specialist tunnel engineer licensed in the province of Ontario for a peer review of the proposed trenchless crossing design in order to evaluate the feasibility, geotechnical considerations, and risks specific to the design. As technology for trenchless tunnelling improves, the data below is subject to change.

Table 8 - Typical Values for Trenchless Tunneling Methods

Method	Typical Pipe Diameter (m)	Maximum Drive Length(m)	Accuracy (mm)
Horizontal Directional Drilling	0.05 to 1.4	180 to 1800 depending on diameter	± 1000
Jack and Bore	0.1 to 1.8	250	± 25
Pipe Ramming	0.1 to 1.8	100	1% of bore length
Microtunnelling	0.9 to 3.5	1100 +	± 25

4.3 Other Trenchless Construction Methods

The below methods are NOT acceptable trenchless technologies on Metrolinx ROW:

a) Pipe Bursting

b) Water Jetting

c) Blasting

4.4 Contractor and Design Considerations

Please note that there may be additional risks present which are not listed above. This document is intended as a guideline only, and does not relieve the Designer or Contractor of the responsibility to assess and mitigate risks. A thorough risk assessment should be conducted for each project, and appropriate controls put in place to manage risks.

4.5 Choosing a Trenchless Technique – Geotechnical Risk Considerations

The construction method must ultimately be selected based on the project requirements, encountered subsurface conditions, available expertise and experience, and the anticipated geotechnical risks. The selection of the trenchless construction method must consider any and all risks including the ones that may affect the environment, safe train operations on the ROW, protection of workers and the public, and damage to nearby properties or utilities. At a minimum, the following potential outcome should be considered in the risk assessment:

a) Ground displacement thresholds at the location of railway infrastructure
b) Fouling of ballast or sub-ballast.
c) Worker health and safety.
d) Damage to any adjacent structures or utilities due to ground movement, vibrations, or induced earth pressures.
e) Damage to the existing foundations within the load zone of influence.
f) Frac-out.
g) Encountering obstructions, such as boulders, waste materials, general debris, and abandoned structures.
h) Environmental Impacts and considerations, including a soil management plan.

Appendix A outlines a preliminary guideline for assessing the suitability of the four trenchless technologies mentioned in Section 4.1.

Appendix C outlines a series of hazards to be mitigated for each of the four acceptable trenchless methods. The completed mitigated controls to manage the risk for each hazard along with the re-evaluated residual risk values provide input to the proponent's Canadian Method for Risk Evaluation and Assessment (CMREA) document submittal.

4.6 Review of Chosen Methodology

All proposed trenchless technologies shall be required to submit a detailed WPM on a prescribed Metrolinx form. Proposed methodology is subject to review by Metrolinx. All questions or comments shall be addressed in the work plan to the satisfaction of Metrolinx.

4.7 Sample Construction Specification Outline

The construction specifications, prepared either by the Applicant, Designer or Metrolinx, which will be project specific, will broadly follow the below sample construction specification outline and that these specifics may be separated into several specifications, including, but not limited to:

a) Tunneling specification – may identify the preferred methodology
b) Tunnel Muck Process, Drilling Fluid and Slurry Disposal
c) Grout requirements
d) Tunnelling Shafts (if applicable)

<u>Outline:</u>

Part 1 General:

a) General
b) Related Sections
c) References
d) Scope of Work

e) Definitions

f) Submittals

g) Quality Control/Assurance

h) Surface and Subsurface Settlement Monitoring

i) Inflow Through Entrance and Exits

j) Allowable Alignment Deviations and Return to Line and/or Grade

k) Surveys

l) Design Criteria

   1) Project Co.'s, or Metrolinx, or General Contractor, Design Engineer, Geotechnical Engineer

m) Coordination Documentation

n) Site Conditions

o) Work Area Preparation, including but not limited to: Staging areas, vegetation removals, access points, locates, sediment and erosion controls.

p) Emergency Contact List

   1) Network Operations Control Centre – 416-601-2174

   2) Maintenance Delivery Signal & Communications – 416-202-4899

   3) Maintenance Delivery Track & Structures – 416-202-4666

   4) Engineering and Asset Management – Track – 416-202-7823

When calling the above Metrolinx Operation numbers do not leave a voice mail, repeat the call until an individual answers. Provide that person with the relevant detailed information to protect train movements, and to dispatch railway personnel to the site to assess railway asset conditions.

Part 2: Products

a) Materials

b) Water

c) Backfill Grout for Two Pass Installation of Pipe

Part 3: Execution

a) Construction

   1) Launching and Receiving

   2) Work Area Preparation and Maintenance

   3) Equipment

   4) Storage, Processing, Site Transport, and Off-Haul

   5) Excavation and Backfill

   6) Traffic Management Plan

7) Proposed detailed schedule, including all phases (pre and post) with durations.

b) Installation

1) Noise Monitoring and Abatement. Vibration Monitoring is necessary if pipe ramming is used or shafts are constructed within 100 metres proximity to residential area

2) Disposal of Muck and Excess Material including Environmental protection

3) Environmental emergency response: Spill response plan, excess soil management, contingency plans, etc.

4) Water Management and Sediment Control Plan

5) Site Cleanup and Restoration

6) Field Inspection

4.8 Before installation starts:

a) Locates must be obtained prior to all disturbances to the ground or a horizontal structure (Metrolinx Railway signals, Canadian National (CN) Railway fibre optic cables (where applicable), and other private or public utilities. The Contractor or Applicant shall provide a report indicating any potential impact(s) to existing utilities. Report must be sealed by the crossing Designer.

b) With respect to buried railway signal cables refer to Section 3.2.1 item “d” General Requirements for SUE investigation requirements and the process for obtaining daylighted SUE level A waivers as well as Section 3.2.1 d)(i) for SUE level A daylighting backfill requirements.

c) No work will be performed within the ROW without approval and railway track protection. Railway track protection must be arranged through the Metrolinx representative.

d) Metrolinx rail operations clearances shall be respected during construction at all times, in accordance with the GO Transit Track Standard document section 19 Track Construction, sub-section 19.3 Track Clearances and Centres, as well as the clearance drawings listed in Appendix X GO Transit Heavy Rail Clearance Envelopes.

e) For the work, all procedures and employees involved need to comply with all relevant regulatory health and safety standards and regulations. All contractors and their employees must follow Metrolinx’s Safety program, including acquiring certification on successful completion of the Metrolinx Personal Track Safety course.

4.9 Considerations during Construction

Once a submitted WPM, on the prescribed Metrolinx form, is approved by Metrolinx, the following are some more construction considerations:

a) Unless noted in the approved WPM form, Metrolinx requires that the Contractor contact the Rail Corridor Access and Control department, providing significant lead time, to obtain railway track protection services for the Contractor’s ROW works.

b) Based on the complexity of the installation or the type of methodology to be used, a track or railway field specialist may be assigned by Metrolinx during installation, to assess the operating track condition levels on a regular basis. They may determine the need of track resurfacing.

c) The track(s) shall be kept free of obstructions and open to rail traffic <u>at all times</u> during the work. Geotechnical engineer to confirm that works can be undertaken under live traffic. Otherwise ceasing the trenchless operation to allow the passage of all trains will be directed by the Metrolinx representative.

d) Construction equipment like but not limited to scrapers, bulldozers, trucks, barrows or other mechanical equipment shall not cross Metrolinx tracks at-grade or operate straddling the track rails. Hi-rail vehicles shall be considered. When this is not feasible, construction equipment may cross the track utilizing an approved Metrolinx temporary construction crossing. Approved Metrolinx temporary construction crossings shall be built and maintained in accordance with applicable sections of the GO Transit track standards document and applicable GO Transit track standard plans. The temporary crossing shall be constructed, maintained, and removed by a Metrolinx pre-approved track contractor, unless contract documents state otherwise. Access to the temporary construction crossing shall be under the direct supervision of a Metrolinx approved track protection foreman and/or sub-foreman.

e) All equipment shall stop working upon the approach of any train when equipment is in the vicinity of the track(s) and the work task(s), in the opinion of Metrolinx assigned track protection personnel or Representative, may be exposed to, or interfere with, the safe operations of all trains.

f) The ROW must remain clear for Metrolinx use at all times. Unless written approval has been previously granted by Metrolinx, the ROW shall not be used for the storage of materials or equipment. Construction materials and/or equipment may not be positioned to block Metrolinx access roads, the track area, or any other part of the ROW.

g) Prior to undertaking the work, Metrolinx may require that the work area shall be delineated from the rail line with construction fencing. The exact location and placement shall be determined through coordination with the Metrolinx representative and the required work incorporated into the submitted and approved WPM.

h) The colour red shall not be used for safety helmets, safety vests or survey markers on or adjacent to the ROW in order to avoid conflict with railway operational practices.

i) A construction zone of influence must be established and adequate clearances, based on applicable standards, shall be maintained from existing structures within the ROW.

j) If adequate clearance cannot be maintained from a structure within the zone of influence, temporary protection shall be provided, to the satisfaction of and not at the expense of Metrolinx.

k) Consideration should be given to the presence of a geotechnical engineer, or a person acting under supervision of a geotechnical engineer, at the site during trenchless construction activities.

l) A soil management plan has to be prepared. This soil management plan shall, at a minimum, consist of handling and disposal procedures of excess soils at the site. Contaminated soils shall be removed from site and disposed of at a licensed facility.

m) Unless covered in the approved WPM, any and all damage to Metrolinx property or railway infrastructure shall be repaired, to the satisfaction of and not at the expense of Metrolinx.

n) Metrolinx shall always reserve the right to restrict the trenchless technologies and associated work activities in any way that Metrolinx may deem necessary to ensure normal safe train operations.

o) Applicant and Contractor shall ensure that all persons obey all instructions from the assigned Metrolinx railway track protection personnel.

4.10 Final Records

4.10.1 As-Built Drawings

Once installation is completed, 'As-Built' drawing(s) shall be submitted no later than 30 days.

As-built drawings should include clear location of utility (path), clearances and depth, material specifications, size and any other critical information:

a) Record location (coordinates) and elevation along route of initial pilot bore start and both casing/carrier pipe ends.

b) Record elevation of existing base of rail at centerline of bore.

c) Record location (coordinates), surface elevation and bore depth along bore at:

    1) Right of Way, both sides of track

    2) Ditch flowline or low spots, both sides of track

    3) Toe of ballast, both sides of track

    4) At track centerline.

d) Measure distance to nearest milepost from intersection of track centerline and bore centerline.

e) Develop an as-built plan exhibit.

f) Create a cross section exhibit.

g) Measure distance along track centerline from bore centerline to nearest bridge or at-grade crossing if in the vicinity of bore.

h) Record elevation of track base of rail, elevation at top of casing pipe ends, and a horizontal distance from track centerline to ends of casing pipe at right angles to track centerline, if applicable.

i) Copy of bore pit backfill compaction test results showing the backfill has been placed and compacted in accordance with the projects bore pit backfill compaction specifications, if applicable.

4.10.2 Hand-Over

Stakeholder hand-over protocol documents and / or end of job submittals as stipulated in the contract documents, including, but not limited to, test reports, material records, installation verification records that may include CCTV interior footage of completed casing or carrier pipes.

Appendix A - Preliminary Assessment Table

Subsurface Conditions	Settlement Risk	Micro-Tunneling / TBM	Jack and Bore / Horizontal Auger Drilling	Pipe Rammin g	Horizontal Directional Drilling
Cohesive Soil - Clay, Silt, and Organics *Very soft to soft*	High	Y[1]	M	Y	M[1]
Cohesive Soil - Clay and Silt *firm to very stiff*	Medium	Y[1]	Y	Y	Y[1]
Cohesive Soil - Clay and Silt *hard*	Low	Y[1]	Y	M	Y[1]
Non-Cohesive Soil - Above The Water Table *very loose to loose*	High	Y	M	M	M[4]
Non-Cohesive Soil - Above The Water Table *compact to very dense*	Low	Y	Y	Y	Y[4]
Non-Cohesive Soil - Below The Water Table *very loose to loose*	High	Y	N	M[3]	M[4]
Non-Cohesive Soil - Below The Water Table *compact to very dense*	Low	Y	N	M[3]	Y[4]
Coarse Gravel and Cobbles *less than 100mm*	Low	Y	Y	Y	M[4]
Cobbles and Boulders *greater than 100mm*	Medium	M	N	M	N
Glacial Till *hard or very dense*	Low	M	M	M	M
Highly Weathered Rock and Residual Soils *Extremely weak, hard, or very dense*	Low	Y	M	M	Y
Soft Rock - shale, siltstone, mudstone, etc. *All qualities*	Low	Y	M	N	Y[2]
Hard Rock - limestone, dolostone, etc. *All qualities*	Low	Y	N	N	Y[2]
Mixed face conditions	Medium	M	N	M	M

Additional Notes
1. High plasticity clay soils may present a challenge due to clogging of the cutter head or swelling after drilling.
2. Highly jointed or fractured rock may present challenges.
3. Closed-face required.
4. Soils with a high gravel fraction may present challenges.

Y - Generally suitable when installed by an experienced contractor with adequate experience.
M - Difficulties may occur; some modifications of equipment or procedures may be required.
N - Substantial problems will likely occur if this method is used; generally unsuitable or unintended for these conditions.

The above table presents comparative analysis taking into account Settlement Risk only. Additional risks due to fractured rock, rock strength, tunneling speed, ground cover, and any other site specific factors must be taken into account before finalizing the tunneling method. This table is intended for preliminary planning and assessment purposes only.

The consistency (very soft, soft, stiff, very stiff and hard) condition presented above for Cohesive Soils is based on N-values obtained during drilling (Canadian Foundation Engineering Manual, 4th Ed.).

Appendix B – Trenchless Utility Data Sheet

Railway Mileage & Subdivision ....
Municipal Descriptions of Adjoining Properties ....
Name of Pipeline Owner ....

	Carrier Pipe	Casing Pipe
Contents to be handled	....	....
Outside Diameter	....	....
Pipe Material	....	....
Specification and grade	....	....
Wall thickness	....	....
Maximum Operating Pressure	....	....
Maximum Surge & Test Pressure	....	....
Maximum Operating Temperature	....	....
Minimum Operating Temperature	....	....
Type of joint	....	....
Coating	....	....
Method of installation	....	....

Vents: Number .... Size.......... Height above ground ....

Seals: .... Both ends......... Type.................

Bury: Base of rail to top of casing .... m
Bury: (Not beneath tracks) .... m
Bury: (Roadway ditches) .... m
Extent of casing measured perpendicular to centre-line of track .... m
Type, size and spacing of insulators or supports ....
Distance C.L. track to face of jacking/receiving pits .... m
Bury: Base of rail to bottom jacking/receiving pits .... m
Cathodic Protection : yes.......... no..........
Geotechnical Boreholes: yes.......... no..........
Soil Type ....
Base of Rail to ground water ....m

Appendix C – Operational Safety Risk Assessment Worksheet

HAZARD TABLE – JACK AND BORE

STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
				Risk Potential				Risk Potential			
Hazard No.	Hazard	Risk/Threat	Consequence	Impact	Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Impact	Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
Example x	*Stop Sign – Surface Fading*	*Approaching driver does not recognize faded sign. – Expected Bright Red - Stop.*	*Driver maintains speed at posted limit and enters intersection having collision with another vehicle.*	3	2	6 **Medium**	*Implement annual road sign maintenance program to ensure all control signage is in a state off good repair.* *Review paint currently used on stop signs and explore options with proven greater life span.*	3	1	3 **Low**	*No existing controls were identified for how signage is inspected. Currently signs are only being replaced when complaints are received from the community. Implementation of controls will bring risk within acceptable levels.*
1.	Environmental Compliance	The specified environmental measures are not in place throughout installation (i.e. dust, noise, vibration controls).	There may be public complaints leading to schedule delay.	5	2	10 Medium		#	#	Total	.
2.	Worker and Operator Qualifications	Operator should meet all requirements specified in the contract and follow applicable standards. All personnel working within or adjacent to the Metrolinx Right-of-Way	Failure to meet the requirements could lead to operational delay.	5	1	5 Medium		#	#	Total	

HAZARD TABLE – JACK AND BORE												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
		or Metrolinx assets should have completed a Personal Track Safety (PTS) training.									
3.	Selection of Trenchless Utility Installation Method	The contractor is responsible for selecting an appropriate installation method based on the geotechnical report and site conditions.	Selection of inappropriate method may result in additional costs, delays, or environmental impact.	5	1	5 Medium		#	#	Total	
4.	Subsurface Conditions	The encountered subsurface conditions are not considered during the construction planning stage	There may be schedule delay or increased costs.	5	3	15 Elevated		#	#	Total	
5.	Work in Confined Space	Working in confined space may result in injury to workers if adequate monitoring and ventilation systems have not been provided.	This injury has potential to cause operational delay and stop work order.	3	1	3 Low		#	#	Total	

HAZARD TABLE – JACK AND BORE												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
6.	Working at Heights	Working at heights may result in injury to a worker when safe ingress and access systems have not been installed (i.e. guard rails and protection). Potential slippery conditions during winter may also lead to worker injury.	This injury has potential to cause operational delay and stop work order.	3	1	3 Low		#	#	Total	
7.	Unauthorized Access	Inadequate or unclear signage and deficient fencing may lead to unauthorized personnel entering site and accessing construction equipment.	If the temporary fences and/or barricades are not secured adequately, unauthorized personnel can access the corridor and cause major safety concerns. This may lead to operational delay.	4	2	8 Medium		#	#	Total	

HAZARD TABLE – JACK AND BORE											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
8.	Traffic Impact	Inadequate or unclear signage and deficient fencing for traffic control may lead to interruption of daily traffic flow during delivery of equipment to site. Installations that occur near level crossings may require temporary lane closures affecting vehicular traffic and obstruction of railway signal sightlines.	This may lead to operational delay.	4	3	12 Medium		#	#	Total	
9.	On Site Flooding due to Rain/Snow Events	Flooding due to rain or snow events has potential to infiltrate construction areas.	Flooding on site may result in schedule delay.	5	2	10 Medium		#	#	Total	
10.	Seepage and Water Infiltration	Seepage has potential to infiltrate construction areas.	Water infiltration may result in schedule delay.	5	2	10 Medium		#	#	Total	
11.	Misalignment	Misalignment due to improper setup of the equipment and/or due to guidance system.	Misalignment can result in elevation loss causing schedule delay.	5	1	5 Medium		#	#	Total	

HAZARD TABLE – JACK AND BORE

STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
				Risk Potential				Risk Potential			
Hazard No.	Hazard	Risk/Threat	Consequence	Impact	Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Impact	Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
12.	Ground Collapse	Improper selection of ground support system and/or installation method may result in ground collapse.	Ground collapse may lead to operational delays and safety issues.	5	1	5 Medium		#	#	Total	
13.	Excessive Ground Settlement or Heave	Excessive ground settlement or heave as a result of trenchless installation.	This may lead to equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
14.	Settlement of Adjacent Structures	Excessive settlement to adjacent buildings and/or structures (bungalows, bridges, signal bridges, embankment, etc.) as a result of trenchless installation.	This may lead to structural damage and/or equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
15.	Metrolinx Track Monitoring	Improper installation of monitoring instruments and missing or inaccurate readings.	Can lead to potential equipment/railway operational delay.	5	1	5 Medium		#	#	Total	
16.	Obstructions (Boulders and Cobbles)	Oversized cobbles and boulders causing obstruction to installation.	Obstructions may result in equipment operational delay	5	2	10 Medium		#	#	Total	

HAZARD TABLE – JACK AND BORE											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
				Risk Potential				Risk Potential			
Hazard No.	Hazard	Risk/Threat	Consequence	Impact	Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Impact	Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
17.	Obstructions (Concrete Blocks, Construction Materials, etc.)	Encountering obstructions such as unidentified concrete blocks, construction debris and other materials.	Obstructions may result in equipment operational delay	5	1	10 Medium		#	#	Total	
18.	Unidentified Underground Utilities	Encountering unidentified utilities (during SUE investigation).	Can result in equipment operational delay	5	2	10 Medium		#	#	Total	
19.	Contamination of Soil	Inadequate waste management or leakage of draining fluids can cause soil contamination during installation.	Contamination of soil may lead to delays and environmental consequences.	4	2	8 Medium		#	#	Total	
20.	Artesian Conditions	Encountering unexpected artesian conditions may lead to more dewatering efforts which could result in excessive ground settlement.	It may also involve environmental regulatory agencies. This might result in equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
21.	Equipment Failure	Potential equipment failure due to improper selection or irregular/inadequate maintenance schedule.	Can result in schedule delay.	5	2	10 Medium		#	#	Total	

HAZARD TABLE – MICRO TUNNELING												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential		Risk Index	Mitigating Solutions and Risk Controls	Risk Potential		Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
				Impact	Likelihood			Impact	Likelihood		
Example x	*Stop Sign – Surface Fading*	*Approaching driver does not recognize faded sign. – Expected Bright Red - Stop.*	*Driver maintains speed at posted limit and enters intersection having collision with another vehicle.*	3	2	6 **Medium**	*Implement annual road sign maintenance program to ensure all control signage is in a state off good repair.* *Review paint currently used on stop signs and explore options with proven greater life span.*	3	1	3 **Low**	*No existing controls were identified for how signage is inspected. Currently signs are only being replaced when complaints are received from the community. Implementation of controls will bring risk within acceptable levels.*
1.	Environmental Compliance	The specified environmental measures are not in place throughout installation (i.e. dust, noise, vibration controls).	There may be public complaints leading to schedule delay.	5	2	10 Medium		#	#	Total	
2.	Worker and Operator Qualifications	Operator should meet all requirements specified in the contract and follow applicable standards. All personnel working within or adjacent to the Metrolinx Right-of-Way or Metrolinx assets should have completed a Personal Track Safety (PTS) training.	Failure to meet the requirements could lead to operational delay.	5	1	5 Medium		#	#	Total	

HAZARD TABLE – MICRO TUNNELING												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
				Risk Potential				Risk Potential			
Hazard No.	Hazard	Risk/Threat	Consequence	Impact	Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Impact	Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
3.	Selection of Trenchless Utility Installation Method	The contractor is responsible for selecting an appropriate installation method based on the geotechnical report and site conditions.	Selection of inappropriate method may result in additional costs, delays, or environmental impact.	5	1	5 Medium		#	#	Total	
4.	Subsurface Conditions	The encountered subsurface conditions are not considered during the construction planning stage	There may be schedule delay or increased costs.	5	3	15 Elevated		#	#	Total	
5.	Work in Confined Space	Working in confined space may result in injury to workers if adequate monitoring and ventilation systems have not been provided.	This injury has potential to cause operational delay and stop work order.	3	2	6 Medium		#	#	Total	
6.	Working at Heights	Working at heights may result in injury to a worker when safe ingress and access systems have not been installed (i.e. guard rails and protection). Potential slippery conditions during winter may also lead to worker injury.	This injury has potential to cause operational delay and stop work order.	3	2	6 Medium		#	#	Total	

HAZARD TABLE – MICRO TUNNELING											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
7.	Unauthorized Access	Inadequate or unclear signage and deficient fencing may lead to unauthorized personnel entering site and accessing construction equipment.	If the temporary fences and/or barricades are not secured adequately, unauthorized personnel can access the corridor and cause major safety concerns. This may lead to operational delay.	4	2	8 Medium		#	#	Total	
8.	Traffic Impact	Inadequate or unclear signage and deficient fencing for traffic control may lead to interruption of daily traffic flow during delivery of equipment to site. Installations that occur near level crossings may require temporary lane closures affecting vehicular traffic and obstruction of railway signal sightlines.	This may lead to operational delay.	4	3	12 Medium		#	#	Total	

HAZARD TABLE – MICRO TUNNELING

STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
				Risk Potential				Risk Potential			Existing Controls and Points of Discussion Residual Risk Tolerance Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Impact	Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Impact	Likelihood	Risk Index	
9.	On Site Flooding due to Rain/Snow Events	Flooding due to rain or snow events has potential to infiltrate construction areas.	Flooding on site may result in schedule delay.	5	2	10 Medium		#	#	Total	
10.	Seepage and Water Infiltration	Seepage has potential to infiltrate construction areas.	Water infiltration may result in schedule delay.	5	1	5 Medium		#	#	Total	
11.	Misalignment	Misalignment due to improper setup of the equipment and/or due to guidance system.	Misalignment can result in elevation loss causing schedule delay.	5	1	5 Medium		#	#	Total	
12.	Ground Collapse	Improper selection of ground support system and/or installation method may result in ground collapse.	Ground collapse may lead to operational delays and safety issues.	5	1	5 Medium		#	#	Total	
13.	Excessive Ground Settlement or Heave	Excessive ground settlement or heave as a result of trenchless installation.	This may lead to equipment/railway operations delay.	5	1	5 Medium		#	#	Total	
14.	Settlement of Adjacent Structures	Excessive settlement to adjacent buildings and/or structures (bungalows, bridges, signal bridges, embankment, etc.) as a result of trenchless	This may lead to structural damage and/or equipment/railway operations delay.	5	1	5 Medium		#	#	Total	

HAZARD TABLE – MICRO TUNNELING											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
		installation.									
15.	Metrolinx Track Monitoring	Improper installation of monitoring instruments and missing or inaccurate readings.	Can lead to potential equipment/railway operational delay.	5	1	5 Medium		#	#	Total	
16.	Obstructions (Boulders and Cobbles)	Oversized cobbles and boulders causing obstruction to installation.	Obstructions may result in equipment operational delay	5	2	10 Medium		#	#	Total	
17.	Obstructions (Concrete Blocks, Construction Materials, etc.)	Encountering obstructions such as unidentified concrete blocks, construction debris and other materials.	Obstructions may result in equipment operational delay	4	1	4 Low		#	#	Total	
18.	Unidentified Underground Utilities	Encountering unidentified utilities (during SUE investigation).	Can result in equipment operational delay	5	2	10 Medium		#	#	Total	
19.	Contamination of Soil	Inadequate waste management or leakage of draining fluids can cause soil contamination during installation.	Contamination of soil may lead to delays and environmental consequences.	4	2	8 Medium		#	#	Total	

HAZARD TABLE – MICRO TUNNELING												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential Impact	Risk Potential Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential Impact	Risk Potential Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
20.	Frac out Potential	Due to improperly controlled pressure, slurry used in trenchless installation method may leak into surrounding environment.	Leaks may result in environmental issues and equipment operational delay	4	1	4 Low		#	#	Total	
21.	Artesian Conditions	Encountering unexpected artesian conditions may lead to more dewatering efforts which could result in excessive ground settlement.	It may also involve environmental regulatory agencies. This might result in equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
22.	Equipment Failure	Potential equipment failure due to improper selection or irregular/inadequate maintenance schedule.	Can result in schedule delay.	5	2	10 Medium		#	#	Total	

HAZARD TABLE – HORIZONTAL DIRECTIONAL DRILLING											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential		Risk Index	Mitigating Solutions and Risk Controls	Risk Potential		Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
				Impact	Likelihood			Impact	Likelihood		
Example x	*Stop Sign – Surface Fading*	*Approaching driver does not recognize faded sign. – Expected Bright Red - Stop.*	*Driver maintains speed at posted limit and enters intersection having collision with another vehicle.*	3	2	6 **Medium**	*Implement annual road sign maintenance program to ensure all control signage is in a state off good repair.* *Review paint currently used on stop signs and explore options with proven greater life span.*	3	1	3 **Low**	*No existing controls were identified for how signage is inspected. Currently signs are only being replaced when complaints are received from the community. Implementation of controls will bring risk within acceptable levels.*
1.	Environmental Compliance	The specified environmental measures are not in place throughout installation (i.e. dust, noise, vibration controls).	There may be public complaints leading to schedule delay.	5	1	5 Medium		#	#	Total	
2.	Worker and Operator Qualifications	Operator should meet all requirements specified in the contract and follow applicable standards. All personnel working within or adjacent to the Metrolinx Right-of-Way or Metrolinx assets should have completed a Personal Track Safety (PTS) training.	Failure to meet the requirements could lead to operational delay.	5	1	5 Medium		#	#	Total	

HAZARD TABLE – HORIZONTAL DIRECTIONAL DRILLING											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential		Risk Index	Mitigating Solutions and Risk Controls	Risk Potential		Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
				Impact	Likelihood			Impact	Likelihood		
3.	Selection of Trenchless Utility Installation Method	The contractor is responsible for selecting an appropriate installation method based on the geotechnical report and site conditions.	Selection of inappropriate method may result in additional costs, delays, or environmental impact.	5	1	5 Medium		#	#	Total	
4.	Subsurface Conditions	The encountered subsurface conditions are not considered during the construction planning stage	There may be schedule delay or increased costs.	5	3	15 Elevated		#	#	Total	
5.	Unauthorized Access	Inadequate or unclear signage and deficient fencing may lead to unauthorized personnel entering site and accessing construction equipment.	If the temporary fences and/or barricades are not secured adequately, unauthorized personnel can access the corridor and cause major safety concerns. This may lead to operational delay.	4	2	8 Medium		#	#	Total	
6.	Traffic Impact	Inadequate or unclear signage and deficient fencing for traffic control may lead to interruption of daily traffic flow during delivery of	This may lead to operational delay.	4	3	12 Medium		#	#	Total	

HAZARD TABLE – HORIZONTAL DIRECTIONAL DRILLING												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
		equipment to site. Installations that occur near level crossings may require temporary lane closures affecting vehicular traffic and obstruction of railway signal sightlines.									
7.	Misalignment	Misalignment due to improper setup of the equipment and/or due to guidance system.	Misalignment can result in elevation loss causing schedule delay.	5	1	5 Medium		#	#	Total	
8.	Ground Collapse	Improper selection of ground support system and/or installation method may result in ground collapse.	Ground collapse may lead to operational delays and safety issues.	5	2	10 Medium		#	#	Total	
9.	Excessive Ground Settlement or Heave	Excessive ground settlement or heave as a result of trenchless installation.	This may lead to equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
10.	Settlement of Adjacent Structures	Excessive settlement to adjacent buildings and/or structures (bungalows, bridges, signal bridges, embankment, etc.) as a result of trenchless	This may lead to structural damage and/or equipment/railway operations delay.	5	2	10 Medium		#	#	Total	

HAZARD TABLE – HORIZONTAL DIRECTIONAL DRILLING											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
		installation.									
11.	Metrolinx Track Monitoring	Improper installation of monitoring instruments and missing or inaccurate readings.	Can lead to potential equipment/railway operational delay.	5	1	5 Medium		#	#	Total	
12.	Obstructions (Boulders and Cobbles)	Oversized cobbles and boulders causing obstruction to installation.	Obstructions may result in equipment operational delay	5	2	10 Medium		#	#	Total	
13.	Obstructions (Concrete Blocks, Construction Materials, etc.)	Encountering obstructions such as unidentified concrete blocks, construction debris and other materials.	Obstructions may result in equipment operational delay	5	1	5 Medium		#	#	Total	
14.	Unidentified Underground Utilities	Encountering unidentified utilities (during SUE investigation).	Can result in equipment operational delay	5	2	10 Medium		#	#	Total	
15.	Contamination of Soil	Inadequate waste management or leakage of draining fluids can cause soil contamination during installation.	Contamination of soil may lead to delays and environmental consequences.	5	2	10 Medium		#	#	Total	

HAZARD TABLE – HORIZONTAL DIRECTIONAL DRILLING												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential		Risk Index	Mitigating Solutions and Risk Controls	Risk Potential		Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
				Impact	Likelihood			Impact	Likelihood		
16.	Frac out Potential	Due to improperly controlled pressure, slurry used in trenchless installation method may leak into surrounding environment.	Leaks may result in environmental issues and equipment operational delay	5	2	10 Medium		#	#	Total	
17.	Artesian Conditions	Encountering unexpected artesian conditions may lead to more dewatering efforts which could result in excessive ground settlement.	It may also involve environmental regulatory agencies. This might result in equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
18.	Equipment Failure	Potential equipment failure due to improper selection or irregular/inadequate maintenance schedule.	Can result in schedule delay.	5	2	10 Medium		#	#	Total	

HAZARD TABLE – PIPE RAMMING											
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential		Risk Index	Mitigating Solutions and Risk Controls	Risk Potential		Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
				Impact	Likelihood			Impact	Likelihood		
Example x	*Stop Sign – Surface Fading*	*Approaching driver does not recognize faded sign. – Expected Bright Red - Stop.*	*Driver maintains speed at posted limit and enters intersection having collision with another vehicle.*	3	2	6 **Medium**	*Implement annual road sign maintenance program to ensure all control signage is in a state off good repair.* *Review paint currently used on stop signs and explore options with proven greater life span.*	3	1	3 **Low**	*No existing controls were identified for how signage is inspected. Currently signs are only being replaced when complaints are received from the community. Implementation of controls will bring risk within acceptable levels.*
1.	Environmental Compliance	The specified environmental measures are not in place throughout installation (i.e. dust, noise, vibration controls).	There may be public complaints leading to schedule delay.	5	3	15 Elevated		#	#	Total	
2.	Worker and Operator Qualifications	Operator should meet all requirements specified in the contract and follow applicable standards. All personnel working within or adjacent to the Metrolinx Right-of-Way or Metrolinx assets should have completed a Personal Track Safety (PTS) training.	Failure to meet the requirements could lead to operational delay.	5	1	5 Medium		#	#	Total	

HAZARD TABLE – PIPE RAMMING

STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
				Risk Potential				Risk Potential			
Hazard No.	Hazard	Risk/Threat	Consequence	Impact	Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Impact	Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
3.	Selection of Trenchless Utility Installation Method	The contractor is responsible for selecting an appropriate installation method based on the geotechnical report and site conditions.	Selection of inappropriate method may result in additional costs, delays, or environmental impact.	5	1	5 Medium		#	#	Total	
4.	Subsurface Conditions	The encountered subsurface conditions are not considered during the construction planning stage	There may be schedule delay or increased costs.	5	3	15 Elevated		#	#	Total	
5.	Work in Confined Space	Working in confined space may result in injury to workers if adequate monitoring and ventilation systems have not been provided.	This injury has potential to cause operational delay and stop work order.	3	1	3 Low		#	#	Total	
6.	Working at Heights	Working at heights may result in injury to a worker when safe ingress and access systems have not been installed (i.e. guard rails and protection). Potential slippery conditions during winter may also lead to worker injury.	This injury has potential to cause operational delay and stop work order.	3	1	3 Low		#	#	Total	
7.	Unauthorized Access	Inadequate or unclear signage and deficient fencing may lead to unauthorized personnel entering site and accessing construction	If the temporary fences and/or barricades are not secured adequately, unauthorized	4	2	8 Medium		#	#	Total	

HAZARD TABLE – PIPE RAMMING												
STEP 5 – Identify the Risk				**STEP 6** – Evaluate			**STEP 7** – Mitigate and Control	**STEP 8** – Re-evaluate			**STEP 9** - Conclusion
Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Risk Potential: Impact	Risk Potential: Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
		equipment.	personnel can access the corridor and cause major safety concerns. This may lead to operational delay.								
8.	Traffic Impact	Inadequate or unclear signage and deficient fencing for traffic control may lead to interruption of daily traffic flow during delivery of equipment to site. Installations that occur near level crossings may require temporary lane closures affecting vehicular traffic and obstruction of railway signal sightlines.	This may lead to operational delay.	4	3	12 Medium		#	#	Total	
9.	On Site Flooding due to Rain/Snow Events	Flooding due to rain or snow events has potential to infiltrate construction areas.	Flooding on site may result in schedule delay.	5	2	10 Medium		#	#	Total	
10.	Seepage and Water Infiltration	Seepage has potential to infiltrate construction areas.	Water infiltration may result in schedule delay.	5	2	10 Medium		#	#	Total	

HAZARD TABLE – PIPE RAMMING

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Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
				Risk Potential				Risk Potential			
Hazard No.	Hazard	Risk/Threat	Consequence	Impact	Likelihood	Risk Index	Mitigating Solutions and Risk Controls	Impact	Likelihood	Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
11.	Misalignment	Misalignment due to improper setup of the equipment and/or due to guidance system.	Misalignment can result in elevation loss causing schedule delay.	5	2	10 Medium		#	#	Total	
12.	Ground Collapse	Improper selection of ground support system and/or installation method may result in ground collapse.	Ground collapse may lead to operational delays and safety issues.	5	1	5 Medium		#	#	Total	
13.	Excessive Ground Settlement or Heave	Excessive ground settlement or heave as a result of trenchless installation.	This may lead to equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
14.	Settlement of Adjacent Structures	Excessive settlement to adjacent buildings and/or structures (bungalows, bridges, signal bridges, embankment, etc.) as a result of trenchless installation.	This may lead to structural damage and/or equipment/railway operations delay.	5	2	10 Medium		#	#	Total	
15.	Metrolinx Track Monitoring	Improper installation of monitoring instruments and missing or inaccurate readings.	Can lead to potential equipment/railway operational delay.	5	1	5 Medium		#	#	Total	
16.	Obstructions (Boulders and Cobbles)	Oversized cobbles and boulders causing obstruction to installation.	Obstructions may result in equipment operational delay	4	2	8 Medium		#	#	Total	

HAZARD TABLE – PIPE RAMMING												
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Risk Scenario				Risk Assessment			Manage the Risk	Residual Risk			Comments and Notes
Hazard No.	Hazard	Risk/Threat	Consequence	Risk Potential		Risk Index	Mitigating Solutions and Risk Controls	Risk Potential		Risk Index	Existing Controls and Points of Discussion Residual Risk Tolerance Notes
				Impact	Likelihood			Impact	Likelihood		
17.	Obstructions (Concrete Blocks, Construction Materials, etc.)	Encountering obstructions such as unidentified concrete blocks, construction debris and other materials.	Obstructions may result in equipment operational delay	4	1	4 Low		#	#	Total	
18.	Unidentified Underground Utilities	Encountering unidentified utilities (during SUE investigation).	Can result in equipment operational delay	5	2	10 Medium		#	#	Total	
19.	Contamination of Soil	Inadequate waste management or leakage of draining fluids can cause soil contamination during installation.	Contamination of soil may lead to delays and environmental consequences.	4	2	8 Medium		#	#	Total	
20.	Artesian Conditions	Encountering unexpected artesian conditions may lead to more dewatering efforts which could result in excessive ground settlement.	It may also involve environmental regulatory agencies. This might result in equipment/railway operations delay.	5	1	5 Medium		#	#	Total	
21.	Equipment Failure	Potential equipment failure due to improper selection or irregular/inadequate maintenance schedule.	Can result in schedule delay.	5	2	10 Medium		#	#	Total	