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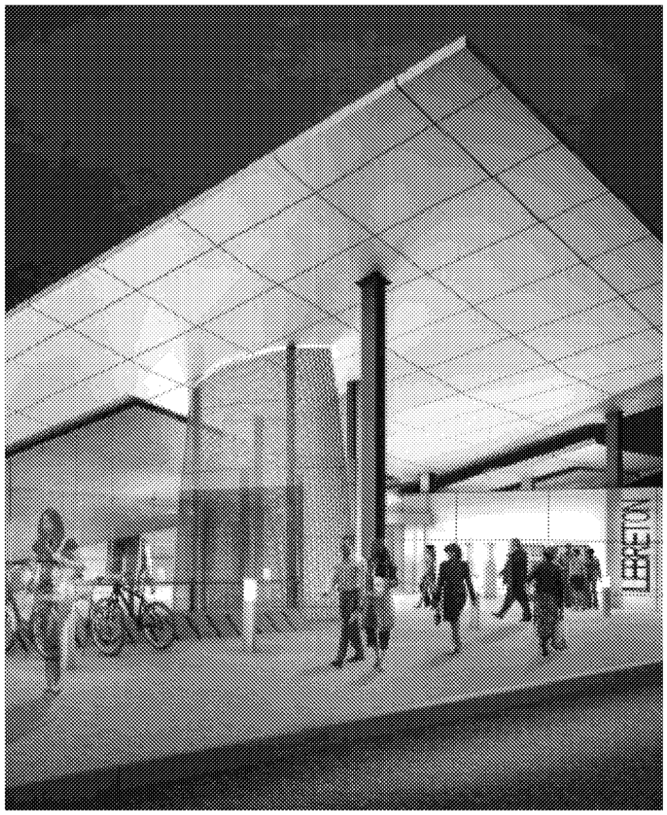
Package B2 - Design suBmission Part 1

ottawa Light raiL transit Pro ect

Response to Request for Proposals

RFP No. OILC-11-00-P006 | September 10, 2012



Submitted to:
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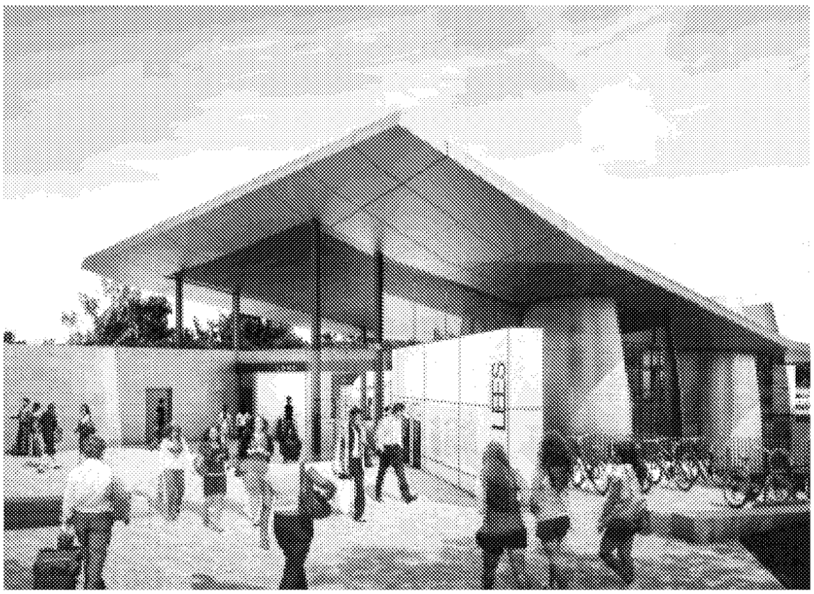
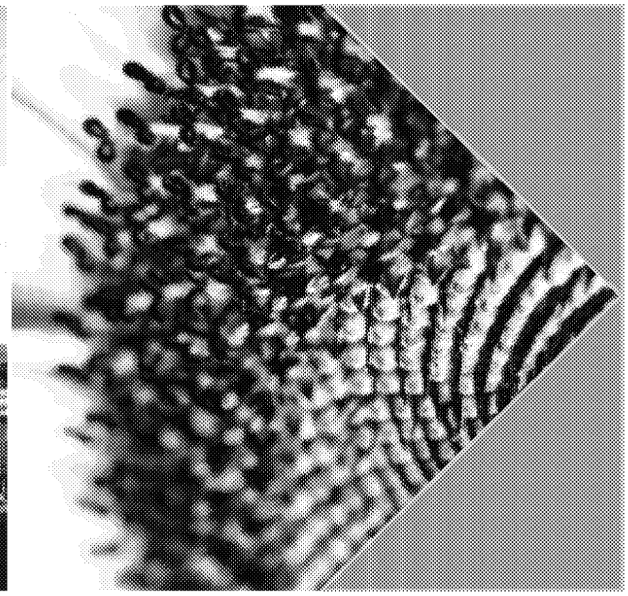
RIDEAU TRANSIT GROUP RT

5.0 design submission

5.1 Utilities, Geotechnical, Drainage, Urban Design Landscape Architecture, Artwork, Safety Management, Certification and Regulatory Mat





5.1 UTILITIES, GEOTECHNICAL, DRAINAGE, URBAN DESIGN, LANDSCAPE ARCHITECTURE, ARTWORK & SAFETY MANAGEMENT & CERTIFICATION & REGULATORY MATTERS

Over the past nine months, Rideau Transit Group (RTG) has carefully considered all City of Ottawa (the City) needs and requirements with respect to developing the Ottawa Light Rail Transit (OLRT) System. Our design solution takes into account the City's objectives as follows:

- Preventing disturbance to the City as a whole
- Minimizing disruption to the downtown
- Respecting the City's role as Canada's capital and as a venue for high-profile events

Our tunneling and station design as well as our construction methods will minimize disruption to the City and to local businesses. From our underground tunnel and station design experience in built-up cities like Barcelona, Seville and Vancouver, we know that cut-and-cover construction methods can be extremely disruptive to Stakeholders and companies, even going so far as to put some out of business. By contrast, RTG's totally mined (TMS) tunneling solution for tunnels and station caverns will achieve the following three benefits for the City:

- Minimizing construction disruption to the downtown, preserving access to buildings and businesses, and preserving historic resources
- Reducing schedule risk related to utility relocations
- Reducing schedule risk by adopting a multiple-front construction methodology of roadheader construction as opposed to a single construction-face solution such as a bored tunnel solution

As described in **Section 1.2**, an integrated design-build joint venture (DBJV) will lead RTG's Design-Build Team, which includes specialty consultants selected for their Project-specific expertise in tunnels, stations and urban design, geotechnical, structural, and fire and life safety. This organization offers the City the best of both worlds: clear accountability and management control through the DBJV contracting mechanism, and the depth of expertise that only specialists can bring to a project of this magnitude and importance.

Section 5 as a whole reflects how we will draw on our combined experience to partner with the City to deliver an outstanding Project. Throughout **Section 5.1** we have highlighted how our approach meets or exceeds the City's objectives for the OLRT Project, as specified in the Project Agreement (PA) and amplified throughout the Design Review process, in the areas of utilities, geotechnical design, investigation and monitoring, urban design and landscape architecture, management and certification, and regulatory matters.

5.1.1 UTILITIES

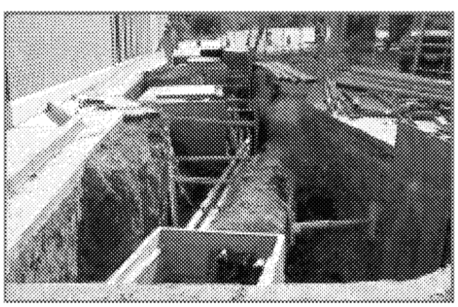
Utilities are a sensitive schedule item for OLRT construction for two reasons:

- **Critical path** - Many locations must be surveyed and relocated before construction; and some of these relocations require long-lead times for third-party design, qualification of subcontractors for construction and procurement of special materials (e.g. transformers, fibre optic cable, large-diameter pipes).
- **High-profile** – Clients like major banks and the Department of National Defence, among others, have utility agreements that preclude any disruption to their service connections. Given the essential nature of the connections between these clients in an urban area, it is the highest priority to maintain uninterrupted operations for them.

To minimize utility schedule and performance impacts, therefore, RTG has elected a mined tunnel and mined station approach for the downtown tunnel. This will eliminate full road closures downtown and minimize the number of temporary lane closures and extent of excavation by limiting construction impact to the areas around vertical shafts and service entrances. To minimize the impact on existing utilities, ventilation shafts will be located and configured optimally. Minor trenching will be required to connect Station services and this will be dealt with case by case in collaboration with detailed Station design. RTG's mining approach will reduce surface disruptions so that most utility connections remain connected and require little suspension or relocation compared to cut-and-cover construction. Outside the downtown core, a similar strategy will minimize the extent of utility impacts and risk of disruptions, thereby optimizing Project design and associated construction requirements.

5.1.1.1 Approach to Identification of Existing Utilities

Through the RFP process RTG has complemented our local knowledge of existing conditions with thorough examination of available utility information: City base mapping, existing condition reports, as-built drawings, and utility mark-ups. In most cases these information sources tend to agree; however, further information and clarification is required for a comprehensive detailed design. Prior to commencement of detail design, as part of the densification survey, RTG will confirm actual field locations (i.e. horizontal and vertical coordinates, sizes and connections) as required for all affected and adjacent utilities and verify that actual locations coincide with the proposed design. Some design adjustments may be required, which can be incorporated along with input from utility owners to optimize the ultimate configuration for all parties involved.



5.1.1.2 Utility Relocation Including Protection

The OLRT has utility protection and relocation requirements throughout the corridor extent: relatively minor ones such as relocating one catch basin, and large ones such as relocating 120 m of a crucial 1220 mm backbone watermain. Many of the largest and most critical are at tunnel portals, at the three Downtown Stations and at the Maintenance Storage Facility (MSF) entrance track. Highlights of the major utility relocation and protection requirements in RTG's design are listed in **Section 5.1.1.6. Package B2 – Design Submission Part 2 – Volume 1 (of 4)** provides the required utility relocation drawings. RTG has reviewed and analyzed available data to evaluate all components, helping to ensure that safe and predictable schedules may be adhered to during required utility protection and relocation work. To protect nearby utilities, CCTV inspections of storm and sanitary sewers within the Right of Way will be done to satisfy PA requirements.

The philosophy for utility protections and relocations in RTG's Utility Relocation Plan includes building on existing MOUs that the City has coordinated with many utility providers, as well as continued coordination and advancing agreements and relationships with utility providers that own infrastructure affected by OLRT construction. Early and effective communication throughout the design-build process will facilitate delivery of these services. Once underground utility construction is completed, RTG will replace any surface and sub-surface features affected by construction.

In addition to the original scope of work, other utility works have been incorporated into RTG's responsibilities to facilitate the OLRT Project. They allow a smoother delivery by avoiding space and scheduling conflicts with other City contracts that overlap with the OLRT. Through addenda issued during the RFP phase, RTG will now be responsible for utility relocations on Albert and Queen Streets. The additional work will be administered through a Cash Allowance, and includes construction of designs provided by the City for the watermain and utility work between Preston and Bronson Streets, a two-part contract along Queen Street consisting of sewer separation from Bronson to Lyon Street and replacing a 140-year-old watermain from Bronson to Elgin Street. For these works, the City will provide RTG with a complete design and RTG will perform the civil work and reinstate the roadways upon completion.

Since most utility infrastructure touched by this Project will be handed back to the original owner, work must adhere to normal guidelines and requirements. RTG will strive to adhere to all applicable standards and requirements for the utility infrastructure that it designs, installs or protects, as summarized in **Table 5.1-1**.

Table 5.1-1 | Utility Design Guidelines

Utility	Design Guideline
Water	City of Ottawa – Water Design Guideline
Storm Sewer	City of Ottawa – Sewer Design Guidelines
Sanitary Sewer	City of Ottawa – Sewer Design Guidelines
Gas	Third Party Requirements in the Vicinity of Natural Gas Facilities
Telecommunication	Respective Provider's Guidelines
Hydro	CSA/HOL Guidelines
Pipeline Crossing Railways	Transport Canada: Standard Respecting Pipeline Crossings Under Railways

5.1.1.3 Communication & Coordination with Utility Companies & Operational Constraints

Based on the size of this Project and to account for multiple active construction sites around the City simultaneously, RTG will employ a full-time Utility Coordinator. To facilitate communication, this dedicated position will be the node linking RTG, the City, the Utility Companies and/or other Stakeholders. This single point-of-contact will streamline communication. Through regular meetings the Coordinator will establish early identification of issues and constraints encountered through the design and construction process and relay them to all affected parties. To expedite delivery, the Utility Coordinator will also help track the design circulation, permitting and approvals process.

5.1.1.4 Communication & Coordination with Other Stakeholders including Business & Property Owners

Stakeholders include commercial, industrial and residential property owners, road users, Emergency Services, OC Transpo, STO and the Federal Government. In accordance with our Integrated Communication and Consultation Plan, we will notify Stakeholders of proposed road closure locations and schedules: coordinating with Emergency Services to maintain response times, maintaining access for City Maintenance staff, notifying OC Transpo and STO of proposed bus route changes, and informing the Federal Government of closures that could affect motorcade routing. In addition, as our Nation's Capital, Ottawa has many large cultural events including Canada Day which draws many tourists and pedestrian to the downtown core. Close coordination with organizers will minimize disruption of these events. This Response includes a Traffic & Transit Management Plan (TTMP) which describes our approach to managing long-term road closures along the entire Project alignment, including the downtown area. Short-term impacts to access and unscheduled lane restrictions/closures will be addressed case-by-case. All temporary conditions will be conducted according to Ontario Traffic Manual (OTM) Book 7.

5.1.1.5 Management of Service Interruption to Property Owners

The most severe road closures and service interruptions are avoided by the mined station approach downtown. It will be possible to reduce surface disruption of traffic and allow better access to local streets during construction. Through careful planning and design, service interruptions of all types will be minimized. Selecting a mined solution and extending the western end of the downtown tunnel also allows RTG to avoid relocating the 1500 mm watermain along Commissioner Street. Careful planning and construction staging approach minimizes the magnitude and duration of impacts, especially at important utility infrastructure relocations such as the large diameter watermains at Tremblay Road, and the University of Ottawa utility tunnel. Although external forces beyond RTG's control may still interrupt services, the PSOS stipulates that RTG provide access for utility providers to enter sites on short notice so they can provide service continuity in accordance with binding service contracts with their customers. Whenever feasible, utility service interruptions will be minimized absolutely and a high level of service continuity will be provided to customers. To achieve this goal, RTG will ensure prompt access to all vaults and connections within the OLRT construction zone to enable utility technicians to maintain connections and service to their customers. RTG will coordinate the specific access requirements with each utility after the start-up meeting, since each provider has slightly different requirements (e.g. equipment access, foot access, service vehicles). RTG design approach, construction means and methods and scheduling strategy, all combine together to minimize and mitigate disruptions. RTG's plan achieves a high level of service and will give sufficient notice when planned disruptions are necessary.

5.1.1.6 Early Identification & Mitigation of Impacts to Critical Utilities

RTG will work closely with every utility provider to accurately and efficiently progress design, and to identify and resolve conflicts. RTG's approach is to maintain utility service by avoiding when possible, supporting and protecting when necessary, and relocating only when unavoidable. This will ensure the most reliable service to all Utility customers that rely on these connections, and those in the connected branches. It is RTG's understanding that at Contract Award, Hydro Ottawa Limited (HOL), among others, will have started or completed installation of enabling works such as those outlined in the HOL planning report. But for those utilities which still need relocation and which likely have lengthy design, review and material procurement times, RTG may elect to pre-order selected long-lead items to maintain required delivery dates.

Hydro Ottawa has already drafted a temporary and permanent Hydro relocation report that will allow more flexibility for construction and more reliability for hanging lines by replacing its current circuits with flexible rubber lines which can be more easily manoeuvred and supported than the existing ducts. There are crucial watermain connections in the path of the proposed OLRT alignment. A 1500 mm watermain supplying nearly one-third of Ottawa's population crosses at the West Portal. Impacts to this critical backbone are avoided by locating the mining entrance of the tunnel to the west of Commissioner Street and mining through rock under the watermain. Of three watermains connected to the Hurdman pumping station, a 1220 mm watermain must have its valve relocated and be protected under the railway. At the MSF entrance track a 1220 mm watermain will require relocation underneath the access tunnel, and a 1050 mm watermain must be routed alongside that same tunnel. This critical intersection of Belfast and Tremblay has been the subject of a detailed staging design (see **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**). Several other watermains require relocation and protection, such as the 400 mm diameter watermain relocated around LeBreton Station, a 400 mm watermain deepened at Campus Station, and a 600 mm watermain relocation at Blair to make way for the additional bus layby area. All other watermain and gas plant will also be protected where they cross the guideway along the alignment.

Many duct banks with multiple ducts carry Hydro Ottawa and telecommunications running along and across Queen and Rideau Streets. In almost all cases, these connections are trunk lines that have far-reaching implications should they be disconnected. These connections are critical: much of Canada's banking, national defence and federal communication links are proximal to RTG's proposed work. Vital water-supply backbones and crucial service connections have been identified for protection and must be maintained. This risk must be managed by closely working with utility providers, and effectively protecting adjacent utility infrastructure. The construction schedule will consider the client notification requirements of each utility provider as it relates to service interruptions and/or switch-overs.

RTG is responsible for all major and minor utility relocation/protection. The following non-exhaustive list represents RTG's understanding of major utility conflicts to be addressed in completing OLRT construction work:

- **Protect:**
  - Twin 3800 mm x 2400 mm box storm sewer under existing Transitway from Tunney's Pasture Station to Merton Street (including transverse joint replacement)
  - 2x1220 mm and 1x1524 mm watermains at Hurdman Pumping station
  - Bell and Atria telecom East of Hurdman
  - OC Transpo Communication duct west and east of Cyrville Station
  - 400 mm gas on St. Laurent Bridge (for clearance and stray current)
  - 600 mm watermain; underside of St. Laurent Blvd. bridge deck
  - 115 kV Hydro crossing at Belfast Rd.
- **Relocate:**
  - 750 mm to 1800 mm storm sewers and drainage structures (manhole, catch basin) at Merton Street
  - 250 mm to 450 mm storm sewers and drainage structures (manhole, catch basin) at and west of Bayview Station
  - Various utilities at Booth Street/LeBreton Station (Watermain, storm and sanitary sewer, gas and hydro) ; coordination required with the Albert Street Cash Allowance work noted in the PA
  - Existing manholes along OLRT Guideway (some may remain in place at the City's discretion)
  - 300 mm storm sewer, manholes and watermain at and east of Campus Station
  - 300 mm to 600 mm storm sewer and drainage structures at and west of Lees Station
  - Bell telecom duct at Hurdman Station
  - Various utilities at Belfast-Tremblay intersection (water, storm, sanitary, hydro, gas)
- **Avoid:**
  - Bell Line along Cyrville road
- **Cap:**
  - 1050 mm storm sewer along existing transitway between Blair Station and Cyrville drain
  - 1650 mm storm sewer west of St. Laurent station
- **Check:**
  - Cave Creek Collector between Merton Street and Bronson Avenue by CCTV – for pre-condition survey
  - 750 mm storm sewer east of Hurdman - for additional loading
  - High-voltage Hydro line crossing at 109+970 - for clearance

5.1.1.7 Obtaining Utility Permits & Approvals

Satisfactory completion of permitting and approvals is a necessary pre-condition to relocating utilities as required and to delivering the Project on schedule. For example, any work along the existing road allowance and adjacent lands will likely require a road cut permit, which will require a traffic management plan as well as an approved design. Further to the City's requirements, the Ministry of Environment requires a Certificate of Authorization (CofA) for any storm or sanitary sewer work, and for any watermain work in excess of 750 mm in diameter. Building permits for Stations and other facilities will be addressed in the Station design process. We must also apply for a Permit to Take Water, since some of operations will include taking or redirecting natural water. All efforts, therefore, will be made to expedite the approvals process so that all proper permitting (see **Table 5.1-2**) can be in place in time for construction to take place.

Table 5.1-2 | Permit Types required for OLRT Utility Construction

Permit	Issuing Authority
Road Cut Permit	City of Ottawa
Building Permit	City of Ottawa
Permit to Take Water	Ontario Ministry of Environment
Certificate of Authorization	Ontario Ministry of Environment

5.1.1.8 Supplying Utility Services to the OLRT Infrastructure & Facilities

OLRT facilities have multiple servicing requirements, the major one being electricity for traction power and ventilation along with other Station and building needs. However, the OLRT also requires connection to water, sewer, and gas and telecommunication services at various points along the corridor. These connections are used for normal operation, but are also sized to account for emergencies such as the fire flow requirements that could potentially be put on water supply and sewers in an emergency. For this reason there are redundancies built into these systems as required to help maintain service and abate emergency situations.

OLRT Project power must accommodate both temporary and permanent operations. HOL has expended significant effort with respect to this issue, with its results incorporated into RTG's design approach. This section describes how RTG's proposed design will use these HOL power supply provisions.

OLRT system construction and commissioning will require significant power. The single largest loads will be required for constructing the tunnels; however, additional power will be required for functions such as welding track and general construction power. We estimate a maximum of 24.31 MVA of power may be required; however, final load estimations will depend on exact tunnel construction methods employed. As much as possible, power supplies for temporary power will (re)utilize existing power supplies (where they exist) and be reused for permanent power (where practicable).

Temporary Power Requirements

Table 5.1-3 summarizes information from the HOL Document "Temporary Electrical Construction Power for the City of Ottawa's Proposed Light Rail System – Phase 1", revision 0-T, dated 2012-02-16.

Table 5.1-3 | Temporary Power Requirements

Location	Load (MVA)	Voltage
TPSS-01	0.20	600 V
Tunney's Pasture	0.50	600 V
Bayview	0.20	600 V
LeBreton	0.20	600 V
TPSS-02	0.20	600 V
West Portal	6.78	13.2 kV
West Jet Fans	0.20	600 V
Downtown West/East	5.20	13.2 kV
TPSS-03	0.2	600 V
Rideau	0.42	600 V
East Jet Fans	0.20	600 V

Location	Load (MVA)	Voltage
East Portal	5.68	13.2 kV
Campus Station	0.20	600 V
TPSS-04	0.20	600 V
Lees	0.20	600 V
Hurdman	0.20	600 V
TPSS-05	0.20	600 V
Train Station	0.20	600 V
TPSS-06	0.20	600 V
MSF Yard TPSS	0.50	600 V
MSF	0.83	600 V
St. Laurent	0.50	600 V
TPSS-07	0.20	600 V
Cyrville	0.20	600 V
Blair	0.50	600 V
TPSS-08	0.20	600 V
TOTALS	**24.31**	

Permanent Power Requirements

For permanent operations, the single largest power requirement is for the eight traction power substations (six on the main line, two in the MSF and yard). Four Stations also have significant loads due to tunnel ventilation fans, which also must have a backup source of power (see further description below) by code. In several cases, Station power will likely be taken from an adjacent TPSS; this will be confirmed and optimized during final design.

We estimate a maximum power requirement of 63.32 MVA; however, final load estimates will depend on final traction power load flow models, Computational Fluid Dynamics (CFD) and Subway Environment Simulation (SES) models for tunnel vent, and final station/MSF electrical loads. As much as possible, power supplies for permanent power will reutilize existing power supplies provided for temporary power.

Table 5.1-4 summarizes information from the HOL Document "Hydro Ottawa Information to Support the City of Ottawa's Proposed Light Rail System – Phase 1", revision 2-T, dated 2012-06-13.

Table 5.1-4 | Permanent Power Requirements

Location	Load (MVA)	Voltage	Notes
TPSS-01	4.80	13.2 kV	
Tunney's Pasture			Permanent power from TPSS-01
Bayview	0.40	600 V	
LeBreton			Permanent power from TPSS-02
TPSS-02	4.70	13.2 kV	Also feeds Le Breton Station
West Portal			No permanent power required as jet fans fed from Downtown West

Location	Load (MVA)	Voltage	Notes
West Jet Fans	0.80	600 V	Propose to feed from Downtown West Station
Downtown West	3.20	13.2 kV	
Downtown East	3.20	13.2 kV	No HOL service required - fed from Downtown West and Rideau
TPSS-03	4.20	13.2 kV	
Rideau	3.30	13.2 kV	Propose to co-locate TPSS-03 with Rideau Station
East Jet Fans	1.20	600 V	Propose to feed from Rideau Station
East Portal			No permanent power required as jet fans fed from Rideau
Campus Station	0.50	600 V	
TPSS-04	4.20	13.2 kV	
Lees	0.40	600 V	
Hurdman	0.23	600 V	Permanent power from TPSS-05
TPSS-05	4.50	13.2 kV	
Train Station	0.29	600 V	Permanent power from TPSS-06
TPSS-06	4.40	13.2 kV	
MSF YARD TPSS		13.2 kV	See MSF for permanent power allowance
MSF	12.60	13.2 kV	
St. Laurent	1.10	13.2 kV	Service to have a second MV feed from TPSS-07 to provide alternate source
TPSS-07	4.60	27.6 kV	Also feeds Cyrville Station and alternate supply to the St. Laurent Station
Cyrville			Permanent power from TPSS-07
Blair			Permanent power from TPSS-08
TPSS-08	4.70	27.6 kV	Also feeds Blair Station
TOTALS	**63.32**		

Two incoming feeders from HOL will feed the 13.2 kV medium voltage (MV) switchgear in the MV Switchgear Rooms for each of the Downtown West and Rideau Stations. The load will be shared between the two utility feeders with an automatic transfer scheme using a tie circuit breaker so that one feeder can supply 100 percent of the load if the other feeder fails. Downtown East Station will be fed at MV from the Downtown West and Rideau Stations and does not rely on its own HOL connection. In St. Laurent Station, we propose to provide backup power for tunnel ventilation fans by an alternate source of power fed from TPSS-07 new emergency generator. Jet fans in the downtown tunnel are proposed to be fed from their closest adjacent underground station, which allows consolidation of controls, plus a backup power source which was not accommodated in the reference design.

For Downtown West Station, RTG is proposing to locate the HOL demarcation room inside the Station, and not at the corner of Lyon and Albert Streets per the original reference design. This allows for greater future development on the existing site (currently a surface parking lot). Note that due to the relocation of Rideau Station to the east, relative to the original reference design where TPSS-03 was shown on the east bank of the Rideau Canal, RTG is proposing to construct this TPSS inside the Station, including its associated HOL demarcation room.

5.1.1.9 Utility Drawings

Table 5.1-5 lists the preliminary composite utility plans in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**, illustrating relocation/protection for West Portal, Downtown West Station, Downtown East Station, Rideau Station, East Portal, and MSF connection link.

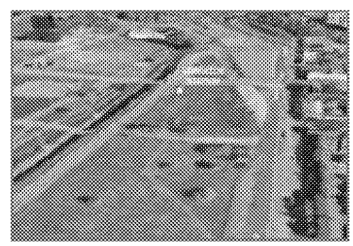
Table 5.1-5 | Preliminary Composite Utility Plans

Preliminary Composite Utility Plans	
West Portal - 1240-41DD-SW-1000-FP	Rideau Station - 1240-41DD-SW-1003-FP
Downtown West Station - 1240-41DD-SW-1001-FP	East Portal - 1240-41DD-SW-1004-FP
Downtown East Station - 1240-41DD-SW-1002-FP	MSF Access Track - 1240-41DD-SW-1005-FP, 1240-41DD-SW-1006-FP

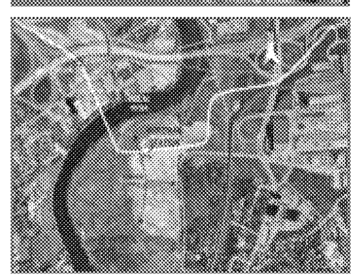
5.1.2 GEOTECHNICAL

MMM, SNC and Thurber have extensive experience in working together on major engineering projects, including several large design-build projects. They will work on this project as a closely integrated team to investigate all aspects of the geotechnical conditions and how they impact the design, maintenance and operation of the system. The senior Thurber staff nominated for the project have an excellent rapport with the design team and will work cooperatively and in an iterative fashion to help optimize the design and reduce future maintenance requirements.

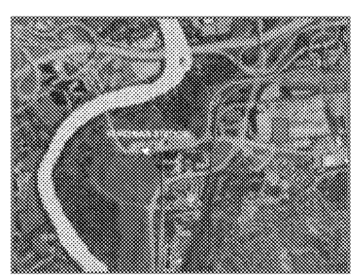
RTG recognizes the importance of sound geotechnical design in the conception, construction, operation and maintenance of an excellent transit system. This element is of even greater importance in a project such as the OLRT, with its range of complex structures, and cuts and fills constructed over challenging ground conditions which include sensitive clay, swelling shale and former landfill sites. To address these challenges, RTG has used the geotechnical data provided in the Reference Design and has developed a geotechnical investigation program to complete the identified data gaps. The major issues identified by segment below. The geotechnical for the underground is described in **Section 5.3**, however the underground hydrogeological elements are describe in **Section 5.1.2.4** herein.



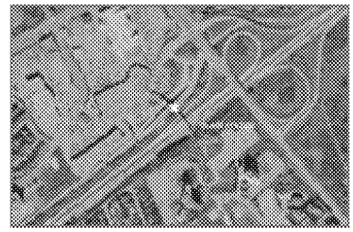
- **Segment 1 (Tunney's Pasture to LeBreton)** - In the west, geotechnical conditions range from a cut into the limestone bedrock at Tunney's Pasture to several metres of waste fill resulting from past landfilling operations in the vicinity of Bayview and LeBreton Stations. The challenges in this section will relate to constructing over the compressible and biodegradable fill and to managing possible landfill gas generation.



- **Segment 3 (Campus to East of Hurdman)** – This segment includes a relatively thick deposit of clay at Campus Station, where the grade will be raised by as much as 2 m at the platforms. Staging of construction and fill materials to be used will account for the compressible nature of the soil, and foundation design will be selected to limit settlement in the Station structure. This segment also includes Lees Station where soil and groundwater are known to be contaminated from historical land uses in the area. Also in Segment 3 are Hurdman Station and an elevated guideway which will both be constructed over a closed landfill. Design of these facilities will avoid founding on the fill and manage the risk posed by landfill gases.



- **Segment 4 (East of Hurdman to St. Laurent including MSF Access Track)** - The main geotechnical challenges relate to constructing the access tunnel to the MSF under Tremblay Road, Belfast Road and the VIA tracks. The available geotechnical information shows that the tunnel box will be partially to fully embedded in the Billings Shale, which is prone to swelling when the local groundwater regime is disturbed and the shale is exposed to oxygen. The tunnel design and construction methodology have been selected to mitigate the potential impacts from the presence of the shale.



- **Segment 5 (St. Laurent to Blair)** - Construction will be relatively straightforward with the main issue expected to be the presence of Billings Shale, which must be protected from exposure to oxygen.

5.1.2.1 Geotechnical Conditions Used in the Design Development

Geotechnical Profiles of all Major Structures

Geotechnical conditions that have been assumed for design development are those presented in the Reference Design. The available data has been used to prepare Geotechnical Profiles at the major structures that will be impacted by OLRT construction, as summarized in **Table 5.1-6**. Geotechnical profiles for these structures and Stations are in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**.

Table 5.1-6 | Major Structures: Civil and Stations

Civil Structures		Stations	
Bayview Road Bridge CPR/O-Train Bridge Booth Street Bridge Mann Avenue Bridge Rideau River Bridge Hurdman Guideway	Hurdman East Overpass Riverside Drive Bridge East VIA Loop Bridge MSF Access Tunnel Cyrville Drain	Tunney's Pasture Bayview LeBreton Campus Lees Avenue	Hurdman Train St. Laurent Cyrville Blair

5.1.2.2 Geotechnical Conditions, Constraints, Concerns & Outstanding Issues

Table 5.1-7 describes the geotechnical conditions and constraints considered in developing the design of the major structures in the at-grade sections.

Table 5.1-7 | Geotechnical Conditions

Structure	Geotechnical Conditions/Constraints
Bayview Road Bridge	There is no borehole data available at this site but original contract drawings show spread footings on bedrock. This is consistent with what is known of the local stratigraphy. Since there is no planned modification of the substructure at this bridge, there is no geotechnical constraint on the bridge. Possible geotechnical input to the identified retaining wall distress will be explored and addressed if necessary.
CPR/O-Train	Available boreholes are limited to the east approach area. These show ground conditions consisting of fill over sand and glacial till overlying limestone bedrock. The fill includes waste composed, in part, of ashes, paper, wood and plastic. The general geotechnical conditions in the area suggest that similar conditions exist at the west approach. Since the foundations of this structure will not be altered there are no geotechnical constraints for the bridge. The Reference Design mentions potentially liquefiable soils at the embankment toes. This issue will be pursued in detail design and addressed through ground improvement if necessary.
Booth Street Bridge	Conditions governing the construction of this bridge vary from fill underlain by peat over bedrock at shallow depth at the north abutment, to fill over very dense glacial till over bedrock at slightly greater depths at the south abutment. Design is complicated by the presence of two aqueducts north of the alignment, one

Structure	Geotechnical Conditions/Constraints
	covered and the other open and spanned by an historic bridge. Constraints include the presence of fill and peat overlying the founding strata and the requirement not to negatively impact existing aqueducts. Geotechnical constraints have been dealt with through embankment design and by a system of foundation elements that carries the new loads below the level of the aqueducts and avoids large open excavations near the aqueducts.
Mann Avenue Bridge	Available borehole information shows that geotechnical conditions before construction consisted of fill, including waste, overlying compact to very dense glacial till over limestone bedrock. Since the work at this bridge consists of deck rehabilitation, there is no impact from geotechnical conditions.
Rideau River Bridge	At the west abutment, the existing borehole information shows that the stratigraphy consists of waste fill over a sequence of clay, silt, sand, glacial till and shale bedrock, at Elevation 45. At the east abutment, the stratigraphy consists of peat and recent alluvium over very loose sand, very dense glacial till and shale bedrock at Elevation 47.9. There is no direct information on conditions under the river, but the original contract drawings show the bridge supported on footings bearing on bedrock. Since the work on this structure consists of deck rehabilitation, there will be no impact from the geotechnical conditions.
Hurdman Guideway	Boreholes available near the guideway indicate that before construction of the BRT the stratigraphy consisted of approximately 4 to 6 m of fill over silty clay, sand, glacial till and shale bedrock. The lower half (approximately) of the fill consists of mixed waste and the overlying material is generally mineral soil. The original BRT contract drawings show that the fill was removed and replaced in the area underlying the busway and the Station area. The fill material is considered to represent a constraint to design of the OLRT facility as it is considered unsuitable to support any foundation loads and will be subject to large settlements under embankment fill loading. The solution developed to address these geotechnical constraints is to support most of the guideway crossing the filled area on an elevated structure supported on caisson piles socketed into the shale bedrock. Between the west end of the elevated structure and Rideau River bridge, the guideway is supported on a fill embankment. Most of the embankment consists of the existing BRT embankment that has been built on an area where removal and replacement of the landfill was carried out. Where a portion of the new embankment will spill beyond the limits of the replacement, measures will be designed to reduce the potential settlement under the embankment. Additional site exploration will be carried out and, based on the findings, recommendations will be developed for replacement or for in-situ ground improvement.
Hurdman East Overpass	The stratigraphy at this bridge site consists of shallow fill and native soil over bedrock. The fill is not suitable for support of foundation loads and the structure has been founded on the shale bedrock.
Riverside Drive Overpass	There is no geotechnical information available for this bridge. Similarly, no foundation modifications are planned. If modifications become necessary in the course of detail design, investigations will be carried out and recommendations will be prepared to address this will be prepared to address this.
East VIA Loop Bridge	The geotechnical information available for this bridge site shows that shale bedrock lies at a shallow depth below the track. Founding the structure on bedrock and the RSS walls on or a small distance above the bedrock is not expected to face any geotechnical constraints.
MSF Access Tunnel	The stratigraphy at the site of the access tunnel consists of approximately 8 m of overburden, consisting of fill and native soils, overlying shale bedrock of the Billings Formation. Greater depths of overburden will be encountered where the alignment cuts into the Belfast Road embankment. The known swelling characteristics of the Billings shale comprise a geotechnical constraint on design at this site. The issue has been addressed through a design that mitigates the groundwater drawdown so that the shale is not exposed to oxygen.
Cyrville Drain	The stratigraphy identified at the Cyrville Drain site consists of shallow fill over bedrock. The bedrock formation has not been identified in the available borehole log, but geological mapping and borehole logs on the original contract drawings indicated that it is the Billings Formation. Work at this site consists of excavating around the structure to widen the footings and add counterforts. The excavation will be within the

Structure	Geotechnical Conditions/Constraints
	upper, weathered shale surface where the potential for swelling has been largely dissipated by years of exposure. To guard against remaining swelling potential, the exposed shale will be protected by a mud slab and the completed work will exclude oxygen from the shale at least as effectively as the existing conditions.
Tunney's Pasture Station	The Transitway lies in a cut in limestone bedrock at this Station. Available borehole logs show 5 m of sand and gravel fill behind the existing retaining walls and 3.7 m of fill, peat and marl overlying the bedrock beyond the area excavated for the Station. The bedrock in the vicinity of the cut is reported to have been disturbed by blasting. The undisturbed limestone bedrock will provide good support for foundations and floor slabs. Expansion of the facility will take account of the poor native soils and the previously disturbed bedrock. A twin-cell box culvert lies below the Transitway and the new foundation design will accommodate this facility.
Bayview Station	The new Station will be constructed over the O-Train track and will use existing bridge foundations. The available geotechnical information comes from boreholes drilled mostly to the east of the Station location but are believed to reflect conditions in the area. Borehole logs show several metres of fill including waste, wood, paper glass and ashes. This is underlain by a thin layer of peat and organic silt of the original ground surface, followed by sand and gravel over limestone bedrock. The fill is unsuitable for the support of new facilities and the foundations required for the new station will bear on bedrock. Any waste fill that must be removed will be managed and disposed of in an approved manner.
LeBreton Station	Ground conditions at LeBreton Station consist of 2 to 4 m of fill overlying peat, sand, silt and glacial till, all overlying limestone bedrock between elevation 48 and 52 m. The fill consists of a heterogeneous mixture of mineral soil, construction debris, ash glass and wood. The fill is unsuitable for the support of new development and foundations will be founded on the undisturbed native soil below the fill, or possibly on bedrock. Some piled foundations may be used for the Booth Street bridge, particularly where it spans the historic aqueducts.
Campus Station	Available geotechnical information indicates that ground conditions at Campus Station consist of surficial fill overlying 6 to 10 m of very stiff to stiff silty clay that, in turn, overlies a thin layer of silt, up to 6 m of glacial till and shale bedrock. The grade will be raised by as much as 2 m through the Station. This grade raise and possible groundwater lowering resulting from tunnel construction will induce consolidation settlement in the clay. The silt layer below the clay has been identified as being potentially liquefiable. The design of the grade raise and the foundations for the new Station structure will take account of these ground conditions and avoid overstressing the clay, which could lead to unacceptably large settlements.
Lees Station	At Lees Station, ground conditions are reported to consist of fill over native deposits of sand, silt and glacial till, over shale bedrock. It is anticipated that all material above elevation 52 m will consist of fill material and that bedrock will be encountered between elevation 48.4 and 49.5 m throughout the limits of the Station. All native soil below elevation 52 m was identified as being dense to very dense. The soil and groundwater at this site have been identified as contaminated with petroleum hydrocarbons and polycyclic aromatic hydrocarbons. A groundwater pump-and-treat system operates at the Station. The underlying shale bedrock is potentially expansive if exposed to oxygen. Foundations for the modified Station will consist of spread footings on native soil or H-piles driven to bedrock.
Hurdman Station	A portion of the alignment, from approximately 105+020 to 105+520, extends through a former municipal landfill site. Historical contract drawings indicate that the municipal waste was removed and replaced with engineered fill within the footprint of the existing bus station, but is still present within the proposed OLRT Station. The fill apparently consists of two fairly distinct materials: a heterogeneous mixture of largely inorganic and mainly non-cohesive soils and a layer identified as waste. The waste is assumed to be typical municipal solid waste and is described as containing components such as wood, paper, cloth, rubber, ash and metal. The fill is unsuitable for the support of new facilities and the Station and elevated guideway will be supported on piles bearing on bedrock.
Train Station	Ground conditions consist of granular fill over thin discontinuous layers of loose to compact sand, silty sand, and sandy silt over glacial till which in turn overlies shale bedrock. The glacial till was generally described as compact to very dense silty sand to sandy silt, some gravel, trace clay with cobbles and boulders. The

Structure	Geotechnical Conditions/Constraints
	surface of the bedrock was encountered between approximately elevation 55.1 and 56.4 m in boreholes within the area of the proposed Station platform. The bedrock was identified as shale of the Billings Formation. The water table at the time of the investigation ranged from 56.4 m to 56.7 m. New facilities at this Station can be supported on spread footings on the glacial till.
St. Laurent Station	Boreholes drilled in 1984 identified shale bedrock at elevations ranging from 62.2 to 65.2 m, which is 1.7 to 5.2 m above the current Transitway profile. Groundwater levels in 1984 were generally between elevation 66 and 68 m. Based on boreholes drilled in 2011, the current conditions consist of asphalt or concrete surfaces over granular fill overlying shale bedrock at approximately elevation 58.1 to 59.3 m. Any modifications to the Station will be supported on spread footings bearing on shale bedrock.
Cyrville Station	In general, ground conditions consist of granular fill over shallow shale bedrock. A thin layer of glacial till was identified directly above the shale bedrock in a few boreholes. The bedrock surface was encountered from approximately elevation 66.4 to 69.0 m. The water table in the piezometers was measured at elevations ranging from 66.7 to 68.2 m. New facilities at this Station will be supported on spread footings bearing on bedrock.
Blair Station	At Blair Station, ground conditions consist of fill overlying shallow bedrock. New facilities at this Station will be supported on spread footings bearing on bedrock.

Additional Proposed Geotechnical Investigations, Laboratory Testing & Analysis

Additional geotechnical site investigation, laboratory testing and analysis to address gaps in the Geotechnical Data Reports will be conducted to the extent necessary to satisfy RTG's design and construction requirements. The investigation will be based on sampled boreholes to determine soil characteristics and to obtain samples for classification, strength, compressibility and corrosivity analysis. Where bedrock will support new foundations, selected boreholes will be advanced into the bedrock by coring. A sufficient number of boreholes will be drilled to enable development of detailed geotechnical models at the bridges and Stations and to delineate geotechnical conditions along the guideway alignment. Reference documents identify several sites with soils that are potentially liquefiable during a seismic event. At these sites, the sampled boreholes will be supplemented by static cone penetration tests, including pore pressure dissipation measurements (CPTu).

5.1.2.3 Estimated Ground Movement as a Result of Construction Activities

Ground movements addressed in this section relate to permanent fills and cuts not related to the main tunnel. For impacts related to tunnel construction and portal approaches see **Section 5.3**.

The maximum grade raise on the main OLRT alignment is approximately 2 m and any settlement resulting from these grade raises will be contained within the OLRT right-of-way (ROW) and has been accounted for in the design. On Booth Street, there will be a grade raise of up to 5 m in the approaches to the new OLRT overhead structure that will be constructed over loose fill and buried peat. The design involves removing loose fill and peat and replacing it with compacted fill, which will remove the risk of settlement and impact on surrounding areas. Outside the main tunnel approaches, the only permanent open cuts will be the realignment at the East VIA Loop and the approaches to the MSF Access Tunnel. The East VIA loop is sufficiently remote that it will not negatively impact the VIA Rail station building.

The MSF Access track will be in a closed box structure under Tremblay, a concrete "U" structure and a tunnel under the VIA Tracks. These structures have been designed to resist the applied ground pressures and to prevent movement or impact on adjacent facilities. The temporary open excavations required for construction have been designed to protect adjacent facilities.

Approach to Ground Movement Control

Two aspects of ground movement have been identified:

- Ground movement within the Transitway ROW as a result of grade changes and loading imposed on the soil by construction of new facilities
- Ground movement that may occur beyond the ROW as a result of construction activities and that may affect third-party properties

Ground movements that occur entirely within the Transitway ROW are being managed through the design approach to have settlements and related movements completed before completion of construction of the facility.

Where there is a risk of ground movement extending beyond the ROW and affecting adjacent properties, the final design and construction methodology will be selected to reduce movement to the minimum practical value. Geotechnical monitoring will be carried out at potentially impacted properties and mitigation will be implemented if movements are found to approach unacceptable levels.

Issues Related to Ground Conditions

The principal issues related to ground conditions relative to the stations, in the at-grade sections of the alignment are as follows:

- Settlement due to loose native soils
- Settlement due to the presence of landfill materials
- Consolidation settlement of compressible clays
- Constraints imposed by the presence of sensitive clays

Various approaches will mitigate the impact of these unfavourable conditions: recompaction of loose soil, removal and replacement of poor soil, especially landfill, and in-situ ground improvement. Through Campus Station on Nicholas Street, from Sta 103+680 to 103+860, there is a grade raise of 1 to 2 m over a deposit of sensitive clay. The design in this area avoids overstressing the sensitive clay and causing a collapse of the internal structure with the attendant, substantial loss of strength and increase in consolidation settlements.

5.1.2.4 Preliminary Hydrogeological Impact Assessment & Associated Risk Assessment

Dewatering and drainage potentially introduce several risks:

- Increased potential for downward migration of contaminant sources originating in the heterogeneous fill
- Short and long-term settlement of compressible clays in response to drawdown
- Potential swelling of bedrock shales principally the Billings Formation from stress relief, exposure to oxygen and desiccation
- Acid rock drainage (ARD) potential:
    - Exposure of pyritic Billings Formation and Lindsay Formation to oxygen
    - Sulphates can attack the cement in concrete lining of tunnel
    - ARD represents a potential contaminant for effluent disposal
- Salinity issues - Saline groundwater from deep bedrock represents a potential contaminant for effluent disposal

Estimated Inflows into all Subsurface Excavation & Associated Control Measures

Approach for Preliminary Estimation of Inflow into Subsurface Excavation

Preliminary inflow estimates were based on semi-empirical and analytical methods including Heuer (1995, 2005) and Goodman (1965) and many others. Approximation methods incorporate parameters such as:

- Geometric characteristics of the excavation or tunnel (depth, cover, dimensions, etc.);

- Hydrogeologic characteristics of materials (hydraulic conductivity, storage properties, thickness, etc.); and
- Analysis assumes simple geometry and uniform materials

Estimates are based on weighted averages of values for multiple segments along the length of an excavation. Such preliminary estimates necessarily incorporate many (hidden) assumptions.

Estimated Inflow Tables

Preliminary estimates of flush (short term) and steady (long term) inflows to tunnel segments, based on simple analytical methods, are provided in **Table 5.1-8**. These preliminary estimates have been further refined by numerical modelling. The assumptions and limitations for the estimates on inflow tables are as follows:

- Estimates are prepared for:
  - Scoping purpose only
  - Identifying significant differences between alignments (for comparison)
  - Identifying critical segments based on hydrogeology
- No control measures (estimates are raw inflows):
  - Base case material properties were used
- Hydraulic properties are averaged between crest and invert along segments:
  - Extreme flows were not identified
  - Small-scale hydrogeological anomalies were ignored
- Analytical methods were applied subject to validity checks:
  - Assumptions implicit in the analytical method are satisfied
  - Averages obtained by multiple methods are consistent

Table 5.1-8 | Estimated Inflows for Subsurface Excavation with No Control Measures

Excavation	Flush Inflow (L/min)	Steady Inflow (L/min)	Approximate Segment Length (m)
Running Tunnels (excluding stations)	600	20	2000
Downtown West Station	30	1	150
Downtown East Station	15	<1	150
Rideau Station (buried valley)	1500	50	120
Rideau Station (running tunnel)	15	<1	90
East Portal	400	10	150

Dewatering & Groundwater Issues

Dewatwering the tunnel area during construction and drainage of the completed tunnel will potentially generate issues in areas where hydrostratigraphic units respond adversely to dewatering.

Short & Long-Term Settlement of Compressible Clay (Leda Clay)

- Localized problems anticipated around East Portal, Rideau buried valley and south of Downtown East Station
- Control can be exercised by limiting drawdown during construction
- Passive pressure maintenance after construction will be implemented using flow barriers as required

Shale Swelling and Acid Rock Drainage (ARD) due to Groundwater Drawdown

- Potential problem where tunnel passes through Billings or Lindsay Formation (e.g. around Downtown East Station)

- Control by limiting exposure to oxygen
- Control by limiting drawdown by avoiding dewatering during construction
- Passive pressure maintenance after construction using flow barriers
- Potential contaminant issues (ARD and salinity) for drainage water and muck disposal

Proposed Mitigation of Groundwater Control Risks

- Limit dewatering and use alternative controls, particularly for segments with compressible clay (East Portal)
- Consider the use of sulphate resistant cement for concrete lining and grouting materials in areas susceptible to ARD (e.g. Downtown East Station)
- Pre-grout where fracturing or high flows are anticipated, when settlement is not an issue
- Limit long-term settlement potential by:
  - Re-injection of groundwater for pressure-maintenance
  - Installation of flow barriers to passively resist drainage
  - Sealing (waterproofing) tunnel segments in the vicinity of the compressible clay zone (e.g. East Portal)

5.1.2.5 Geotechnical Concerns: Construction Adjacent to Existing Structures & Utilities

Geotechnical concerns related to construction of at-grade portions of the OLRT adjacent to existing structures and utilities involve ground movement toward the excavation and possible impacts of groundwater drawdown around the excavation. Ground movement can occur in open (unsupported) excavations or where support is provided by soldier piles and lagging, and some relaxation of retained soil can occur behind the lagging. These concerns can be addressed by selecting and designing appropriate support systems. Groundwater drawdown increases the effective stress in the soil, which can cause consolidation settlement in compressible soils. Where the projected magnitude of settlement is unacceptable, this issue can be addressed by preventing drawdown or by taking other steps to mitigate the impact (e.g. providing supplementary support to the facility).

The MSF Access Tunnel alignment is in conflict with watermains (1200, 1050 (2), 300), a storm sewer (900), a sanitary sewer (300) and three hydro lines. These utilities will be relocated prior to construction. The tunnel also conflicts with the end piles in the abutments of the bridge carrying Belfast Road over the VIA tracks. The abutment will be underpinned with new piles and anchors to allow safe removal of the end piles that are in conflict. Signal, communication and power lines along the VIA tracks will be protected where the tunnel passes below them.

Temporary Excavation Support

Temporary excavations in at-grade sections will be required for the construction of foundations, utility lines, including realignment or repair of existing lines and modifications to existing Stations. The most substantial in the at-grade section is the excavation required to construct the MSF access tunnel under Tremblay, Belfast Roads and under the VIA Rail tracks. Temporary excavation support will be designed and installed on a site-by-site basis.

Where temporary excavation support is required to stabilize the sides of shallow excavations for footings or utility trenches, typical support will consist of speed shores or trench boxes. At deeper excavations required to connect to below-grade access points at the Stations, temporary support will consist of soldier piles and lagging or secant pile walls. The choice will depend on the final geometry of the excavation and the proximity of other facilities, and will be determined in detail design. The design of the excavation support for the rigid frame at Tremblay and Belfast Roads will account for adjacent facilities, including residential and commercial properties, underground and surface utilities and roadways. The high-voltage Hydro towers are noted, but are far enough from the excavation not to be impacted. Soldier pile and lagging support will be provided unless detail design determines that more positive support is required, in which case secant pile walls will be used.

Geotechnical Instrumentation & Monitoring Approach

Geotechnical instrumentation and monitoring will be carried out where it is judged that planned construction activities may adversely impact adjacent facilities within the construction zone of influence. In at-grade sections, the activities that could affect existing facilities are deep excavation or pile driving. Localized excavations in the order of 1 to 2 m deep for footings or pile caps will not be included in the monitoring program.

For excavation at the MSF Access rigid frame and for Station excavations that exceed 3 m deep, monitoring will be carried out on facilities that lie within a distance from the edge of excavation that equals 3 times the depth of excavation. The instrumentation adjacent to excavations will consist of several settlement points attached to adjacent structures or settlement rods installed along sensitive utilities. These points will be monitored before construction starts to establish a baseline and then at regular intervals until construction is completed in that area. Where the excavation may draw down the groundwater and compressible soils are present, the monitoring will be extended to a distance of 50 m.

Where driven piles are used (e.g. at MSF Access/VIA bridge and possibly at some Stations including Campus and Bayview), vibration monitoring will be carried out on facilities within 30 m of the pile driving. Vibration monitoring will be achieved by attaching geophones to the facilities within the 30 m range and monitoring vibrations before construction starts and throughout the pile driving activities.

Pre-construction condition surveys will be carried out on all structures within the monitoring zones described above.

Mitigation to Protect Facilities

RTG has developed design and construction procedures that minimize impact on adjacent facilities and these will continue and be refined during detail design. Where it is not feasible to avoid all impacts to adjacent facilities, appropriate mitigation will be developed case-by-case to address specific impacts. Mitigation measures may include the following: More rigid shoring, possibly with rock anchors

- Measures to control groundwater drawdown
- Underpinning
- Relocation of facilities such as buried utilities

During construction, if the monitoring program indicates that movements or vibrations at existing facilities are approaching unacceptable values, mitigation measures will be implemented. In this situation, mitigation measures considered include modification of construction methods (e.g. a change in pile driving to reduce vibration, or installation of shoring or underpinning as described above).

5.1.3 DRAINAGE

Stormwater management forms a critical design component of the transit system to maintain the health of receiving water bodies downstream, such as area rivers and groundwater systems. In addition, the ever-evolving nature of stormwater management guidelines requires the OLRT to implement a state-of-the-art approach to managing runoff from Project areas. Four main areas will be examined in this context: Water Quantity (Flow Rate) Control, Water Quality Management, Erosion Control and Water Balance. Post-OLRT development peak flows will be consistent with pre-OLRT development peak flows (existing flows). This will avoid increasing run-off rates to the receiving infrastructure downstream. In general, this criterion is applicable to all above-ground Stations, guideways, and the MSF, except as amended by **Tables 5.1-9 to 5.1-12**. Overall, post-construction Project areas must provide a neutral or net improvement in water quality over existing conditions for all areas (except as noted in **Section 5.1.4.1**) and maintain water balance levels per project criteria. Implementation of these goals will be addressed primarily through the use of sustainable stormwater management and low impact development techniques such as bioswales or bioretention areas that focus on infiltration of runoff (at station locations) or rainwater reuse from on-site ponds (at the MSF location where water will be reused in the train wash facility). In other areas, many of the project's aspects are sufficient without further modification, such as the guideway, and additional infrastructure to address these goals will not be required.

5.1.3.1 Design Standards & Criteria

Tables 5.1-9 through 5.1-12 described design standards and criteria for OLRT Project drainage elements.

Table 5.1-9 | Storm Sewers

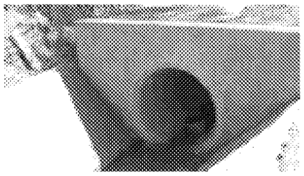
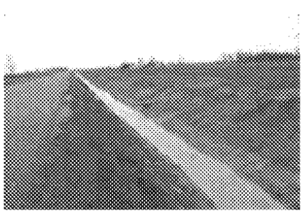
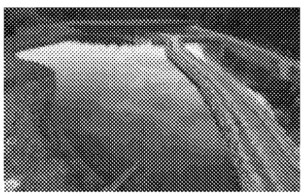
Drainage Element	Design Standards & Criteria – STORM SEWERS
General 	In all guideway areas, the existing storm sewer network will be reused where technically feasible. Areas with ballasted track will collect ballast runoff in perforated underdrains at outside edges of the guideway, directing runoff to the nearest storm sewer inlet point. Where the proposed LRT alignment deviates from the existing BRT guideway, new storm sewers configured to perform in a similar manner will connect to existing storm infrastructure with upgrades as necessary. No new river outlets are proposed. In areas of direct fixated tracks, drainage will be directed to surface catch basins with positive drainage to the existing storm sewer system.
Design Standards	Storm sewer design standards are derived from the following sources: ■ City of Ottawa Sewer Design Guidelines – First Edition (2004) ■ Interim Guidelines for the Design of Storm Sewers (MOE)
Design Criteria	■ Minimum pipe diameter will be 250 mm (City – 6.1.1.2) ■ Minimum catch basin/ditch inlet pipe diameter will be 200 mm (City – 5.6.7) ■ Catch basin/ditch inlet spacing as per MTO Drainage Manual (Chapter 4) ■ Minimum allowable velocity for smooth wall pipes (0.013) for a storm sewer will be 0.80 m/s and a trunk sewer will be 0.10 m/s (City - 6.1.2.1) ■ Design service life of mainline storm sewers (CPP) will be 50 years min. (City – 3.4.1)
Quality	Water quality is not applicable to storm sewer design.
Quantity	Storm sewers will be sized to accommodate required flows. The minor system will be designed to capture and convey the runoff from a 10-year storm event. Where no overland flow outlet exists, the sewer system will be designed to capture and convey the 100-year storm event.
Erosion Control	Erosion control is not applicable to storm sewer design. However, appropriate erosion control or energy dissipation will be provided at storm outlets.
Water Balance	Water balance is not applicable to storm sewer design.

Table 5.1-10 | Roadside Ditches

Drainage Element	Design Standards & Criteria – ROADSIDE DITCHES
General 	Roadside Ditches will be used in rural cross-sections.
Design Standards	Roadside Ditch design standards are derived from the following sources: ■ City of Ottawa Sewer Design Guidelines – First Edition (2004) ■ Interim Guidelines for the Design of Storm Sewers (MOE)

Drainage Element	Design Standards & Criteria – ROADSIDE DITCHES
Design Criteria	■ Freeboard for 10-year event; below subdrain inverts, inlet swales or top of subgrade (City 6.4.1) ■ Minimum slope 0.5% (1% desirable) (City 6.4.1)
Quality and Erosion Control	Ditches and swales inherently improve water quality by trapping sediment. However, design criteria for maximum velocity must be adhered to so that the grass lining does not fail.
Quantity Control	The roadside ditch will have sufficient capacity to ensure that the flow does not spread onto the shoulder or travelled lane for the major (100-year) storm event.
Water Balance	Typically water balance is not applicable to roadside ditch design. However, in some cases underdrains may be included to promote infiltration.

Table 5.1-11 | Stormwater Management Facilities

Drainage Element	Design Standards & Criteria – STORMWATER MANAGEMENT FACILITIES
General  	The following general stormwater management design solutions will be implemented. In each case the strategy will meet all objectives related to meeting required flow rates, improving water quality, minimizing downstream erosion potential, and reducing flood risk: ■ Stormwater management wet ponds ■ Low Impact Development techniques using natural water pathways (bio swales, rain gardens, infiltration trenches) where prescribed by the PA and where feasible ■ Enhanced vegetated swales with enhanced grass embankments draining to stormwater management dry ponds ■ Post-Project peak flow rates to receiving infrastructure to be consistent with pre-Project (existing) rates. In general, this criterion is applicable to all aboveground stations, guideways, and the MSF The stormwater management (SWM) design will meet or exceed the minimum target for water quality control for the Project, which is to achieve a net benefit to water quality improvement. All feasible opportunities to apply Low Impact Design (LID) methods will be incorporated into the drainage system designs to minimize the environmental impact of the OLRT development areas and to enhance water quality, water balances and water conservation where appropriate. Based on site-specific considerations these will be supplemented where necessary by ancillary measures such as oil/grit separators, cooling trenches and dry swales. All SWM facilities are new. There are no proposed modifications to existing facilities. Catchments in the Green's Creek watershed are required to retain runoff from the first 10 mm of rainfall, with 48-hour extended detention of the subsequent 15 mm of rainfall. These areas require "Enhanced" water quality protection, as defined by the MOE. These criteria will be implemented at Station areas inside this catchment, however, the Pinecrest-Centerpointe SWM Criteria Study (Section 5.2, subsection 3) notes that retention of 10 mm of rainfall may be difficult for the Southwest Transitway, and allows for a combination of 15 mm rainfall extended detention (provided in the track ballast) and 'overcapture' of the 10 mm shortfall in other areas, such as the Centrepointe Town Centre lands when they redevelop. Further investigation on applicable methods to achieve these goals will be provided during the Project's design phase. Catchments draining to the Ottawa River or Rideau River that are considered "Infill" development must control peak flow rates to a rate consistent with the existing condition runoff coefficient. In cases where drainage issues exist with the downstream storm sewer or outlet, peak flow rates must be controlled to the smaller of the actual runoff coefficient or a runoff coefficient of 0.5 (0.4 for combined systems).

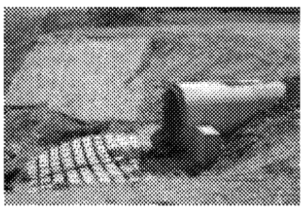
Drainage Element	Design Standards & Criteria – STORMWATER MANAGEMENT FACILITIES
	Sufficient water quality treatment is required to produce an overall net improvement in water quality, measured as a function of the site imperviousness. At Stations, on-site storage of runoff will be achieved by LID and bio-retention measures such as bio swales, rain gardens and infiltration basins, while storage in the ballast will be used in the guideways to reduce peak runoff rates.
Design Standards	For each of the measures listed above, SWM design standards are from the following sources: ■ Project Agreement, Schedule 15-2 ■ "Stormwater Management Planning & Design Manual", Ministry of the Environment, 2003 ■ "Low Impact Development Stormwater Management Planning and Design Guide, version 1.0", Toronto Region Conservation Authority, Credit Valley Conservation Authority, 2010
Design Criteria	■ Wet Ponds will provide 'enhanced' water quality treatment (as defined by the MOE) ■ Stormwater management facilities will incorporate measures to mitigate thermal impacts on receiving coldwater streams, where applicable ■ All facilities will be designed to adhere to criteria specific to reducing downstream erosion potential and flood risk ■ Access roads will be provided as required for inspection and maintenance of SWM facilities ■ SWM facilities will be designed to prevent losses of permanent pool due to infiltration and to prevent losses of active storage due to groundwater intrusion ■ SWM wet ponds will have a maximum permanent pool depth of 2.5 m, and a maximum active storage depth of an additional 2.0 m (4.5 m maximum total)
Quality and Quantity Control	Each of the proposed SWM solutions will be designed to meet water quality objectives through the removal of sediments and fines from the storm runoff and/or exposure to BMP based vegetation for excess nutrient uptake prior to discharging to a receiving body. Quantity control will be provided where required to prevent negative downstream impacts for stormwater conveyance systems, including but not limited to watercourses and existing storm sewer systems. Specific areas requiring "Enhanced" level treatment of runoff will be implemented where policy documents require them.
Erosion Control	Permanent erosion control measures related to protecting receiving waters are generally not required as all Project drainage outlets are generally existing outlets connected to stabilized infrastructure (e.g. storm sewers, viaducts) or to major watercourses (Ottawa, Rideau Rivers) insensitive to the impacts to erosive energy on the scale of this Project, except as noted in specific reports, such as the Pinecrest/Centrepointe Stormwater Management Criteria Study for the Green's Creek watershed, where special criteria have been noted (and summarized below). Erosion and sediment controls are generally limited to the protection of construction phase impacts to receiving infrastructure from non-stabilized or disturbed soil surfaces. Provision of appropriate side slopes on ditches and within the ponds, longitudinal grades that do not exceed the maximum design velocity, and grass lining the ditches and ponds will promote stability and control erosion.
Water Balance	Measures to promote infiltration of treated runoff will be incorporated into the design of SWM facilities where the need is prescribed in existing policies and documents. Retention storage coupled with contingency underdrains would be the typical measure incorporated. Generally, the addition of impervious surface areas resulting from the Project will divert captured rainfall from infiltration or evapotranspiration to runoff. Measures will be implemented at all sites to minimize any increase in runoff compared to pre-development water budgets (the proportion of incident precipitation diverted to runoff, infiltration and evapotranspiration), except as noted in the

Drainage Element	Design Standards & Criteria – STORMWATER MANAGEMENT FACILITIES
	special criteria.
Future Expansion	SWM facilities will be sized to treat runoff from their respective tributary impervious areas that will be constructed during Initial Works. Many of the basins will need to be expanded as part of any future widening or transitway construction. Sufficient details will be generated to ensure that adequate space is provided for the future expansion. Furthermore, outlets will be sized for the ultimate design.
Specific Area Criteria	Tunney's Pasture Station ■ Peak flow rates will be controlled to existing condition rates, or to a post-construction runoff coefficient of 0.5, whichever is required based on the capacity of the downstream storm sewer system ■ SWM measures using natural pathways (i.e. LID measures such as bioswales, infiltration trenches, rain gardens) will be used in the interior bus loop, the NE landscaped area and the SW landscaped area along Scott St. An Oil Grit Separator (OGS) will also be installed for treatment of other impervious areas. Bayview Station ■ Peak flow rates will be controlled to existing condition rates, or to a post-construction runoff coefficient of 0.5, whichever is required based on the capacity of the downstream storm sewer system. Quantity controls will be achieved with bio-retention methods in the landscaped areas. ■ An OGS is required for water quality treatment prior to discharge to the downstream storm sewers LeBreton Station and the West Tunnel Portal ■ Peak flow rates will be controlled to existing condition rates, or to a post-construction runoff coefficient of 0.5, whichever is required based on the capacity of the downstream storm sewer system using bio-retention methods in the landscaped areas ■ Runoff to the west tunnel portal will be conveyed in a new storm sewer up to the 10-year flow. Flows in excess of the 10-year flow will be captured in the tunnel pumping station ■ On-site water quality treatment will be provided by bio-retention sites. Drainage from Booth St. Bridge will be directed via storm sewers to the existing SWM facility on the east side of the Ottawa River Campus Station ■ Peak flow rates will be controlled to existing condition rates, or to a post-construction runoff coefficient of 0.5, whichever is required based on the capacity of the downstream storm sewer system. Runoff will be directed to existing storm sewers. ■ No water quality treatment is required at this location. However, bio-retention methods will be incorporated into the landscaped areas to provide some improvement in water quality Lees Station ■ Peak flow rates will be controlled to existing condition rates, or to a post-construction runoff coefficient of 0.5, whichever is required based on the capacity of the downstream storm sewer system. Runoff will be directed to existing storm sewers using the existing pumping stations. ■ No water quality treatment is required at this location Hurdman ■ Stormwater at Hurdman Station is collected, treated, enters the existing system, travels north and outlets to the Rideau River

Drainage Element	Design Standards & Criteria – STORMWATER MANAGEMENT FACILITIES
	■ Peak flow control to pre-development rates ■ "Enhanced" level water quality treatment at several locations (bio swales) ■ LID measures for landscaped areas in bus loop, below tracks and north of the Station prior to overflow to downstream storm sewers. Water quality treatment via an OGS required for impervious areas. <u>Train</u> ■ Stormwater at Train Station is collected and enters the existing system, travels west and outlets to the Rideau River ■ Peak flow rate control to existing condition rates, post-construction runoff coefficient of 0.5 used for allowable flow rate to downstream sewers if identified with questionable capacity issues. ■ Water quality treatment not required. Drainage to be controlled via catch basins and sewers. ■ "Enhanced" level water quality treatment north of the proposed Train Station (bio swale) ■ Additional catch basins/ditch inlets as required <u>Maintenance & Storage Facility (MSF)</u> ■ 90 l/s/ha discharge rate limit ■ Enhanced level water quality treatment ■ Extended detention facility for control of major/minor flows from site. Yard drainage via surface swales. Storm sewer collection of parking lot and roadway drainage. ■ Rainwater harvesting system ■ LEED NC 2009 "certified" status – The current certification approach for the MSF is not to rely on available SWM credits. (S.S. c6.1, S.S. c6.2) <u>St. Laurent</u> ■ Stormwater at St. Laurent is collected, enters the existing system, travels west and outlets to the Rideau River ■ Peak flow rates will be controlled to existing condition rates, or to a post-construction runoff coefficient of 0.5, whichever is required based on the capacity of the downstream storm sewer system. ■ Water quality treatment not required. Drainage to be controlled via catch basins and sewers. <u>Cyrville</u> ■ Stormwater at Cyrville Station is collected and enters the existing system, travels east to Green's Creek outlet ■ Green's Creek Special Criteria apply: 10 mm capture & retention; 48 hour detention of runoff from subsequent 15 mm of rainfall ■ Enhanced water quality treatment (bio swale) ■ LID measures for landscaped areas between tracks with overflow to proposed storm sewer to the north <u>Blair</u> ■ Stormwater at Blair Station is collected, treated, enters the existing system, travels west and outlets to a dry pond that travels to Greens Creek outlet ■ Green's Creek Special Criteria apply: 10 mm capture & retention; 48 hour detention of runoff from subsequent 15 mm of rainfall ■ SWM measures to be provided by a combination of on-site controls (e.g. Underground

Drainage Element	Design Standards & Criteria – STORMWATER MANAGEMENT FACILITIES
	storage, OGS units) and/or the downstream (existing) SWM pond to the west Guideways ■ Runoff from guideways will be captured and controlled inside guideway property. Peak flow rates will be controlled to existing condition rates. A post-construction runoff coefficient of 0.5 will be used for the allowable flow rate to downstream sewers with limited capacity. Storage of runoff within the ballast (where applicable) will be used to reduce peak runoff rates. Where appropriate, runoff from guideway areas will be controlled in conjunction with the station SWM measures. Treatment of storm water runoff is not required for guideway areas.

Table 5.1-12 | Culverts & Bridges

Drainage Element	Design Standards & Criteria – CULVERTS & BRIDGES
General 	There is one new stream culvert within Project limits. Careful consideration will be given to the design to address all quantity, quality, erosion control and water balance requirements to preserve and enhance environmental integrity within the corridor.
Design Standards	Culverts are being designed in accordance with the following standards: ■ City of Ottawa – Sewer Design Guidelines (Chapter 5) ■ MTO Drainage Manual Chapter 5
Design Criteria	The primary design criteria that govern the size of the watercourse crossings are fisheries, hydrotechnical, and geomorphology. Other issues are considered at each crossing: ■ Geotechnical design related to suitable soils for the proposed structures ■ Hydrogeology related to impacts to groundwater discharge or recharge ■ Preservation of designated natural features in ESA or PSW areas ■ Wildlife passage requirements ■ Navigation requirements in accordance with Transport Canada requirements
Quality	Fisheries Fisheries criteria are related to preserving or creating fish habitat where required and is directly related to quality issues. The design will include the following: ■ Identification of habitat requirements ■ Consideration of fish passage requirements
Quantity	Hydrotechnical Flow through culverts and bridges will achieve the following: ■ Minimize increase in upstream flood elevations for events up to the Regional storm ■ Provide sufficient clearance under the crossing between design water levels and the soffit ■ Provide sufficient freeboard to prevent road overtopping

Drainage Element	Design Standards & Criteria – CULVERTS & BRIDGES
Erosion Control	Geomorphology Geomorphology criteria is related to stream stability near crossings and will achieve the following: ■ Mitigation of potential scour and erosion ■ Management of potential channel migration
Water Balance	Water balance is not applicable to culvert and bridge design

5.1.3.2 Approach to Drainage Design

Data Requirements for Design & Decision Making

The following data requirements have been identified as necessary to ensure stormwater management measures are relevant and appropriate for the climate and locale of the various Project elements:

- City of Ottawa Intensity Duration Frequency Curves
- Rain gauge data inside Project boundaries (if available), for hydrologic model calibration
- Pinecrest/Centrepointe Stormwater Management Criteria Study, JFSA Inc., February, 2010
- Ottawa Sewer Design Guidelines
- Stormwater Management Planning and Design Manual, Ontario Ministry of the Environment, 2003

Additional Data that will Continue to be Collected & How it will be Used

Data additions may be expected based on design feedback from Regulatory Authorities and the City as designs are reviewed. Applicable and appropriate design criteria updates will be incorporated into Project design plans and subsequent reporting. In addition, updates to Project-related rain gauges will be incorporated into design criteria and compared to City Intensity Duration Frequency curves to use the most-conservative rainfall estimates for drainage and stormwater management purposes. Secondly, we will monitor pump flows from tunnel drainage points to ensure suitable pump systems are in place to service tunnel seepage drainage in line with current drainage practice, if tunnel seepage rates exceed geotechnical recommendations for design inputs. Lastly, during design of catchments in the Green's Creek watershed, adjacent development opportunities will be monitored to account for any shortfall in retention on the guideway areas (such as the 10 mm retention target).

5.1.3.3 Hydrologic & Hydraulic Models & Procedures

In general, hydrologic models are required where the cumulative effects of hydraulic features in a project area result in the need for hydrograph routing methods. Due to the nature and complexity of the drainage basins, and the outlets to the various receiving waters, the SWMHYMO hydrologic model (a model approved under the City's Sewer Design Guidelines) was selected. This model estimates pre- and post-project runoff peak flow rates and analyzes major and minor drainage systems (roadways and pipes, respectively) to ensure drainage criteria are respected, including requirements for major flow to remain below the tops of the rails. For certain Stations and the MSF (i.e. areas with sufficient controls to detain and manage flow on-site to the capacity of the minor system), the Rational Method (using spreadsheets and/or proprietary software that incorporates this method, such as the Hydrocad software suite) will be used to incorporate the effects of low-impact development measures (such as bioswales) and verified with SWMHYMO models, as necessary.

5.1.3.4 Key Drainage Issues at Different Locations

Catchments in the Green's Creek watershed are required to retain runoff from the first 10 mm of rainfall, with 48-hour extended detention of the subsequent 15 mm of rainfall. These areas require "Enhanced" water quality protection, as defined by the MOE.

Catchments draining to the Ottawa or Rideau Rivers that are considered "infill" development must control peak flow rates to a rate consistent with the existing condition runoff coefficient. In cases where drainage issues exist with the downstream storm sewer or outlet, peak flow rates must be controlled to the smaller of the actual runoff coefficient or a runoff coefficient of 0.5 (0.4 for combined systems).

The Rideau Valley Conservation Authority (RVCA) has a Level 2 agreement with DFO which authorizes it to review potential Harmful Alteration, Disturbance or Destruction (HADD) of fish habitat. This means that RVCA is authorized to review DFO authorization for mitigation of possible loss of fish habitat but not with compensation for loss of fish habitat.

To minimize the threat to receiving infrastructure, we will implement emergency protocols for areas with potential for uncontrolled or unplanned releases of deleterious substances (spills) from OLRT operations. Areas with higher OLRT traffic, such as the MSF, will benefit from on-site stormwater management or backup containment measures that provide a secondary point to address unwanted spills before materials leave the site.

With respect to large-scale flooding events, such as a repeat of Hurricane Hazel in the Ottawa area, critical OLRT system infrastructure components will be located outside the floodplain, as administered by the local Conservation Authority with jurisdiction over flooding policy, where possible. Where critical infrastructure must be placed in flood-prone regions for technical reasons, appropriate flood-proofing measures will minimize damage to critical components to the extent possible. This can mean locating the lowest opening of the building above flood levels, thus ensuring access and egress in the event of a flood. For minor flooding events, care will be exercised to ensure that OLRT-related property is graded to direct overland flows around low-lying sites and planned to ensure critical components are located outside flood vulnerable areas.

5.1.3.5 Potential Issues & Approach in Meeting Requirements from Relevant Authorities

The local Conservation Authority and City technical review departments have jurisdiction over stormwater management and drainage issues in the form of permit requirements and commenting authority for development applications. Early approaches to the Conservation Authority and City will be required after Contract Award to facilitate early buy-in and preliminary feedback on design approaches related to these issues. We anticipate requests from Regulatory Authorities to relocate certain Project aspects outside these buffer areas and to eliminate (by redesign or redirection) any deleterious effects to sensitive areas. We propose to reuse as much existing infrastructure as technically feasible to ensure that Project impacts are limited to previously disturbed areas (such as existing drainage outlets), or that impacts to buffer areas do not expand beyond current encroaching footprints. If modifications are still required to address recent policies that are incompatible with a functioning OLRT system, compensation strategies (such as additional vegetation plantings in other areas, or cash contributions to other environmental initiatives) will be advanced to authorize Project impacts.

5.1.3.6 Collection and Diversion of Drainage Runoff from the Guideway

Guideway

In general, the former BRT guideway asphalt surface will be replaced or overlain with ballasted track, or converted into direct fixation track. This conversion improves drainage capacity by introducing a flow storage and control function in the void spaces between the ballast stones which store and restrict runoff flow compared to the existing BRT surface, reducing peak flow rates on downstream sewer systems. In areas of direct fixation track, imperviousness is not affected. Therefore, additional measures to reduce peak flows further, such as additional stormwater management facilities, are not recommended in these areas. However, as the ballast material will retain runoff for a longer period, all areas will be examined and modelled as necessary to ensure all retained water elevations (up to and including the 100-year event) remain below the rail tracks to ensure rail service is not interrupted by these events. In terms of water quality, all ballast and rail material is expected to be free from deleterious material such as native hydrocarbons or soluble pollutants. Pollutants from OLRT operations (e.g. wheel grease, meltwater sediment, sand size particles, etc.) will be retained in the ballast material or spread over and adhered to the ballast material's large surface area, exposing the contaminants to oxidation or bacterial film action. In this manner, water quality impacts from guideway areas will be reduced below levels experienced with the current BRT system. Additional water quality controls in guideway areas are not recommended. In a manner similar to water quality control, overall imperviousness in guideway sections will be reduced, ensuring water budgetshifts toward increased runoff are avoided.

Stations

Proposed Station modifications and/or sites may both increase and decrease imperviousness based on the nature of the existing site configurations. Therefore, the requirements for flow control are site-specific and noted in the special criteria. Water budgets and water quality impacts will be similarly affected by changes to site imperviousness. In general, for sites that result in lower imperviousness compared to the pre-Project sites, additional stormwater management controls will not be required (except as noted in the special criteria). All sites with increased post-Project imperviousness will require sufficient controls to reduce flow rates to their respective special criteria, maintain pre-development water budgets and provide a net improvement in water quality.

5.1.4 URBAN DESIGN, LANDSCAPE ARCHITECTURE & ART WORK

5.1.4.1 Approach to the Development of the Urban Design & Landscape Plan

Through the Design Presentation Meetings (DPM) and Client Confidential Meetings (CCM) process RTG received verbal confirmation from the NCC that our designs meet the spirit of the NCC requirements and conditions. While RTG has been greatly encouraged by the endorsement received, it also respects the intent and process described in the NCC Requirements and Conditions Endorsement Letter, dated February 6th, 2012.

RTG's approach and commitment is that it will fully support and partner with the City to assist it in successfully completing the NCC's "Federal Land Use Design and Transaction Review and Approval process" (FLUA), such that all approvals and permits for the OLRT project will be obtained to the satisfaction of the key participating parties.

RTG's understanding of the FLUA process is that it dovetails into the Federal Environmental Approval (FEA), and as such there are four federally Responsible Authorities (RA's) that must provide review and approval. These include Transport Canada (acting as the coordinating RA), Public Works and Government Services of Canada (PWGSC), Parks Canada and the NCC.

To obtain the NCC Board of Director's Approvals as required by Section 12 of the National Capital Act, the Requirements of Conditions derived from the NCC's review of RTG's 60%DD submission will be incorporated into the Decisions and Mitigations provided in the FEA under the Canadian Environmental Assessment Agency (CEAA). As described in the February 6th 2012 letter, a continued review process after selection as Preferred Proponent is anticipated and will continue throughout the project. The 60% DD (Second Pre-Final DD) scope of review will be all encompassing and the following subject areas will have Conditions assigned which the Proponent will be required to address. These Conditions include General Conditions Limited to Federally Mandated Stations, Alignment, Landuse and Design, Environmental, Construction, Real Estate Transactions and Temporary Use and Land Access, Maintenance. Monitoring, and Station Specific Conditions.

Rtg Design Review and Approval Process

Refinement of the review process will be developed and clarified with the Sponsors at the Preferred Proponent stage, but at a high level RTG's process assumes the following:

1. RTG's designs as presented and submitted in this RFP, as described in the February 6th 2012 letter, conceptually represent the 60%DD (Second Pre-Final DD) submission. However, the designs as currently developed have not benefitted from a substantial dialogue with the Sponsors and the NCC, apart from receiving limited feedback through the DPM and CCM process. RTG anticipates there will be a number of urban design and landscape issues that the NCC and Sponsors will want to discuss prior to formal 60%DD submission. RTG anticipates a regular process of meetings with the NCC will be established by the City and through the early consultation process key issues that might have influence on the current designs will be discussed. RTG will prepare a First Pre-Final DD submisison

that will represent the RFP submission and any preliminary modifications agreed to with the City. The purpose of the First Pre-Final DD submission will be to act as a base-line from which discussions can be initiated.

2. The primary key milestone will be to make the Second Pre-Final Design submisison which will be equivalent to the 60%DD as decribed in the letter. As part of this submittal process, presentation of the project to NCC's Advisory Committee on Planning design and Realty (ACPDR) is assumed. As described in the February 6th letter any decisions, conditions, deletions or additions arising from the review process will be incorporated into the Decisions and Mitigations list provided in the FEA, and provided there are no serious objections, the City of Ottawa will receive NCC 60%DD Approval, which will permit RTG to start construction on any Federally Mandated Stations that are seeking a staged approval and constuction process.

   RTG recognises, the process described in the February 6th, 2012 letter assumed 60%DD Approval would be granted to the City upon providing a letter indicating the proponent's bid submission is compliant with the RFP requirements. While RTG favours the proposed streamlined process its experience on large transit projects such the OLRT is that optically, and substantially, it is important for the project to be seen to follow the due processes of the authorities having jurisdiction. In this regard RTG is prepared to make a full submission to ACPDR if overall it benefits the project, the Sponsors and stakeholders.

3. A second round of ACPDR and design submittals will be targetted and coordinated with the 90%DD (Final DD) submission. The intent will be to complete the FLUA process and for the City to obtain FLUA approval from the NCC.

4. Assumed time lines in which RTG should complete the FLUA process are provided in the Project Schedule (See the Project Schedule, in section 3.2).

5. Upon receipt of the FLUA approval, design will progress into the Construction Documents phase. On going dialogue with the City and NCC staff will continue, although the level of coordination and extent of issues will assume to have diminished. Stations will progress into construction as described in the Schedule 10 Review Procedure contained in the Project Agreement

6. Final approvals from NCC and the three other Responsible Authorities will only be achieved at the end of the project, once application for 'Substantial Completion of the Fixed Component' is ready to be submitted. The precise coordination and sequencing related to the release of permits and approvals will be finalised in discusison with the Sponsors and affected parties.

Development of the Urban Design and Landscape Plan

The RTG urban design and landscape plans have been developed to address the NCC's capital interests and objectives. Unresolved issues in the Reference Designs have largely been addressed and the designs as a whole are improved. Site furnishings have been provided to be compliant with the table of quanitities provided in Schedule 15-2 Part 1, Article 17.5, clause (b)(iii). Quantities of planting provided at each station site are listed on the station landscape drawings (see **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**). Principles of landscape and urban design as described in the PSOS have been followed. Indigenous plant lists, the use of bioswales to improve stormwater management and reduce surface run off are core strategies to the RTG design approach.

Moving forward, RTG's approach through the design coordination meetings as described above will be to enter a process of dialogue with the Sponsors and NCC to refine the urban design and landscape issues at and around each station. RTG acknowledges that through the RFP process it has not had opportunity to interact closely with the Sponsors. A broad range of key issues remains to be discussed at each station. For example:

1. **Tunneys Pasture** – Further understanding of the transition between bus loop and the anticipated TOD forms of development will likely lead to further refinement and improvement of the site plan.

2. **Bayview Station** - The pathway network serving Bayview station offers convenient connections, but does not adequately take into account the full range of CPTED issues. Individuals walkng late at night will not want to use

routes, that are out of sight and pass through remote areas because of the perceived threat. Other choices and pathway options via main streets should be explored and may need consideration.

3. **LeBreton Station** - The new configuration of Lebreton station has been optimised to improve functionality and connectivity to the multiple pathways and access points. The new station footprint is reduced in area, and returns land to the NCC. However, a deeper understanding of the TOD to station interface objectives needs to be understood. While language in the PSOS refers to overbuild of the station in future, technical requirements that would transform the station and potentially require new ventilation measures would be key considerations.

4. **Hurdman Station** – The anticipated development to the north of Hurdman station offers significant opportunity to intensify around the station. Little is know about how development to the southwest of the station might evolve, and the relationship of pathways and connections to entire station hub including the BRT bus loop, warrants further discussion

5. **Train Station** – Construction of the new train station will lead to decommissioning of the existing BRT station and re-sculpting the landscape form in the centre of the 'D" shaped circulation route. Extensive discussion regarding the final scheme will be needed.

RTG is committed to working with the City and NCC to examine the types of issues highlighted above and where agreed make refinements. RTG as a willing partner will work closely with City and NCC to effectively manage overall scope and budget to the overall benefit of the project. Any issues of scope gap that might arise will be addressed separately between RTG and the City.

5.1.4.2 Respecting the Spirit of the NCC Requirements and Conditions

As described above, RTG will comply with federal legislative and regulatory framework approval processes to ensure the OLRT project meets its obligations under the CEAA process that has already been initiated for the project. This commitment includes compliance with NCC plans and policies.

RTG's design approach is dedicated to providing a quality design solution, uniquely tailored to Ottawa's context, reflecting best practices in urban planning, architecture and landscape design. The station and urban designs described in section 5.5 Stations Design, demonstrate an approach focussed on sound transit planing, with strong linkages and connectivity with other transit modes; a commitment to creating an elevated and enhanced pasenger experience, combined with a strong urban design approach that knits stations with their communities, establishes strong passenger connections and preserves future Transit Oriented Development opportunities.

RTG's construction approach has been tailored to minimize impact to Ottawa's City Centre. This has been achieved by adopting a fully mined construction methodology, which avoids impacting the Capital's national symbols. Some use of Federal lands is required for construction staging and temporary operations, but RTG has sought to minimize its use of these lands. This minimal impact approach has been adopted to allow the natural course of Ottawa's daily business including its capital celebrations and annual events to continue as normal.

Moving forward into the next phase, RTG expects to work with the Sponsors and NCC to develop the public art program as part of the Capital's interests to enhance venue programming, intepretations and commemorations. Finalization of the Downtown East station's entrances and their relevance to the Parliament Precinct may yet be further refined, subject to the Sponsors direction. In addition, the potential of establishing a new underground connection with the NAC has been identified as a potential project objective. RTG and its design team will work closely with the Sponsors and NCC to develop cost effective and appropriate solutions.

5.1.4.3 Roles, Responsibilities & Experience of the Urban Design & Landscape Architecture Team

RTG's integrated project team comprises professionals from design, construction and maintenance. The DBJV is primarily responsible for design and construction of the project, and it has subcontracted the entire project design to a joint venture formed between SNC-Lavalin Inc and MMM (DEJV). The DEJV has retained Adamson Architects, bbb Architects, IBI Group and HMM, to perform the stations, urban, and landscape designs.

Consistent with its design presentations to the NCC and City during the RFP process the DEJV has appointed Ritchard Brisbin and Claudina Sula as the joint technical design leads of these three elements, with Claudina as Lead Architect and Ritchard Brisbin and Lead Designer. The Landscape design Lead is (Cameron Owen/MMM) who will work in collaboration with Claudina and Ritchard.

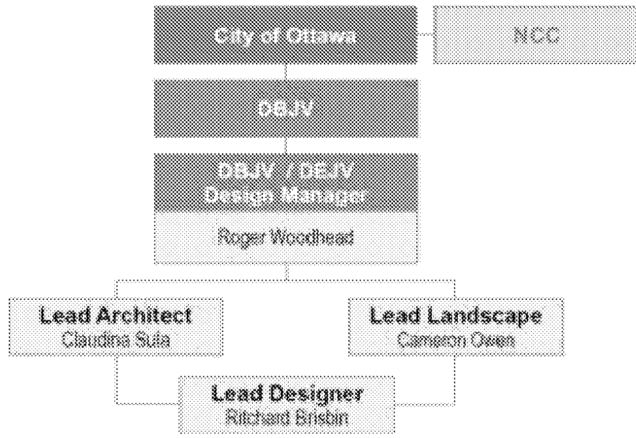


Figure 5.1-1 | Team Organization

The Technical Design Team reports to the DEJV design Manager, who has responsibility to deliver the entire design, and has control over program, technical compliance and schedule. The DEJV Design Manager reports to Design-Build Design Manager who's prime role will be to liaise with the City of Ottawa on all design matters and to ensure the DEJV is delivering the project on schedule, and in compliance with the PSOS. RTG's design team has strong credentials as summarised below:

Design Manager (Roger Woodhead) – Roger has 35 plus years experience involved in the design management of large complex projects. Roger was the Technical Director for the Canada Line responsible for all the design and engineering, and his transit project experience includes the Millennium Line in Vancouver, and Kuala Lumpurs System 2 Line.

Lead Architect (Claudina Sula) – Is a partner at Adamson Architects, and has 26 years experience in the design and design management of large multidisciplinary teams, including large social infrastructure and transit projects. Claudina is higly experienced in the Infrastructure Ontario Alternate Finance and Procument method.

Lead Designer (Ritchard Brisbin) – Ritchard lives and works in Ottawa and is the Principal in charge of bbb Architects. Ritchards recent accomplishments include design of the Ottawa International Airport and Ottawa's Convention Centre. Ritchard has extensive experience in working with the City of Ottawa and the National Capital Commission, and his in depth knowledge of Ottawa's culture, history and aspirations has provided the inspiration that has shaped and formulated RTG's stations designs.

Lead Landscape Architect (Cameron Owen) – Cameron is an IBI Group Associate and he is a Registered Landscape Architect and provisional member of the Planning Institute of BC with 13 years of professional experience. He served as Lead Landscape Architect, for preparation of RTG's Ottawa Light Rail Transit Phase 1 bid. He brings a range of international experience to IBI Group, from master planning to habitat restoration. Mr. Owen has worked both in private practice and as a municipal park planner, leading comprehensive greenway planning projects, stakeholder groups and large diverse project teams. As an example of his ability to work within complex planning processes, Mr. Owen was responsible for the production of the Vancouver 2010 Winter Games Master Planning (Non-Venue) resource management mapping project. Mr. Owen holds a Bachelor of Landscape Architecture from UBC (1998).

5.1.5 SAFETY MANAGEMENT & CERTIFICATION & REGULATORY MATTERS

RTG has closely examined the requirements for Safety Management and Certification and Regulatory Framework under which the OLRT will be designed, constructed, maintained, and operated, and proposes a similar approach to that which was successfully undertaken in Vancouver for the Canada Line project, where in accordance with the Railway Safety Act (BC), the British Columbia Safety Authority (BCSA) has the delegated authority to oversee provincial railways (including rapid transit). A similar regulatory framework will exist for the OLRT System with the Delegation Agreement passing authority from Transport Canada to the City to regulate matters covered by Parts III and IV of the Canada Transportation Act (CTA) and by the Railway Safety Act (RSA).

RTG's approach will be collaborative, and comprise all key Stakeholders from RTG and the City expected to provide adequate resources so as not to delay the schedule for the OLRT. In particular, OC Transpo will provide control operators and train Drivers so that Testing and Commissioning can commence and Trial Running can be completed on schedule. We expect that the City will be in a position to issue an Operating Certificate in a timely manner to achieve the Revenue Service date.

5.1.5.1 Safety Management & Certification

This section addresses management of the systems assurance disciplines on the OLRT Project:

- Safety management and certification requirements in RFP Schedule 2, section 14 and Schedule 3-1, section 5.1
- Systems assurance requirements in RFP Schedule 2, section 14 and Schedule 3-1, sections 5.1 and 5.4
- System security requirements in RFP Schedule 2, section 14
- Safety management plan requirements in RFP Schedule 15-2, Part 1 Article 9
- Safety and security certification requirements in RFP Schedule 15-2, Part 1 Article 10

RAMS (Reliability, Availability, Maintainability and System Safety) disciplines will be implemented and managed as part of the conceptual detailed design, construction, installation, testing and commissioning, acceptance and operation phases of the contract. The RAMS program will provide a numerical foundation for each asset's contribution to overall system performance.

System safety standards will use appropriate material from RAM studies (IEEE 497), ISO Standard (14224), CAN/CSA-0632-90 – Reliability and Maintainability Management Guidelines, CAN/CSA-0396 – Software Quality Assurance Standards, and EN 50126 – Specification and Demonstration of Management of Reliability Availability, Maintainability and Safety.

RAMS requirements will be specified for each subcontractor providing the Vehicle, the Train Control System, and the Communications Systems. These will include numerical RAM requirements, as well as the System safety requirements identified below.

Safety and Systems Assurance Management and Process

Representative samples of the signed and sealed certificates are provided on a drawing in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**. There are two separate safety disciplines in an operating railway:

- System safety is the discipline of identifying, controlling and documenting hazards associated with the operating system before revenue service. This is explained in a System Safety Plan or a System Safety Certification Plan.
- The Safety Management System is the discipline for administering safety during revenue service.

Management of systems assurance disciplines begins before design commences, and continues through Design and Construction. It also plays an important role in maintenance disciplines, and in Service Authorization and Revenue Service Demonstration. These roles are described below. Management of the systems assurance process will be described in the System Safety Certification Plan. These systems assurance disciplines are used to steer the design, and thereby optimize system safety, reliability, availability and maintainability.

System Safety Certification Plan (SSCP)

The SSCP will define the standards which apply to the Safety Certification and other systems assurance disciplines of the OLRT Project and its major subsystems, including the following:

- APTA Manual for the Development of System Safety Program Plans for Commuter Railroads
- APTA Manual for the Development of Rail Transit System Safety Program Plans
- US DOT FTA Hazard Analysis Guidelines for Transit Projects
- EN 50126 Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
- IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
- IEC 15288 Systems and Software Engineering – System Life Cycle Processes

The SSCP will also describe the specific role to be played by each standard and the specific lower-level documents which will be produced as part of the management of each systems assurance discipline, including RAM. Subcontractors providing the Vehicle, the Train Control System, and the Communications Systems will be required to provide an SSCP for their system, with similar documentation requirements.

The development process for the System Safety Case and safety management will be in accordance with the SSCP. Specific documentation requirements are described below.

Hazard Analyses

Hazard analyses will be produced by the subcontractors providing the Vehicle, the Train Control System, and the Communications Systems. Each of these subcontractors will produce a Preliminary Hazard List and Analysis, a System Hazard Analysis covering their entire scope of supply, a Subsystem Hazard Analysis covering each subsystem within their scope, and an Operating and Support Hazard Analysis, addressing hazards to which operators and maintainers may be exposed, as well as hazards which may be created by the operators and maintainers. A Fault Tree Analysis will support both the System Hazard Analysis and the Subsystem Hazard Analysis. Where complexity warrants, each Subsystem Hazard Analysis may also be supported by a Failure Modes, Effects, and Criticality Analysis.

A similar set of documents will be produced by RTG to address specific hazards at the level of the overall OLRT Project, hazards associated with subsystems where responsibility is not subcontracted (such as tunnel ventilation, trackwork, and traction power), and hazards which exist at the interfaces between OLRT systems, including Vehicle, Train Control, and Communications Systems, and between these systems and the remaining elements of the OLRT Project and/or the outside world. Each of these analyses will contain adequate information to define the conditions being analyzed, and will identify and assess the criticality of hazards.

Hazard Mitigation

Hazard analyses will suggest possible mitigations for each hazard, either to eliminate the hazard, or to reduce it to an acceptable level of safety. Forms of mitigation include design considerations, safety devices, warning devices or recommendations for adopting special procedures or training.

Hazard Tracking & Closure

All hazards, from all analyses, will be rolled up into Hazard Logs which will be used to track progress on reaching agreement with the Stakeholders regarding which forms of mitigation will be implemented. Separate Hazard Logs will be produced for the Vehicle, Train Control, and Communications Systems, and for the overall OLRT Project. Closure of hazards will be documented by signatures of the parties responsible for implementing the agreed forms of mitigation, and confirming that this has been done. This may be done either within the Hazard Logs, or as separate documents, such as Hazard Tracking Matrices or Risk Registers. The specific mitigation actions will be identified.

The SSCP will describe the process for tracking progress on each document and certificate produced under that Plan, and any subsequent action items. This process will be used to ensure that all Project participants provide required analyses in a timely manner, and that action is triggered where delinquent receipt is delaying hazard resolution. The tracking method will be available as a status report every other month. The tools for tracking these will be Microsoft Office based, either Word or Excel.

The SSCP will also define the relationship between post construction, pre-revenue safety certification and the role of other independent professionals responsible for system safety critical items such as: Civil Works, Architecture, Fire/Life Safety and Code Compliance.

Safety Certificates

The OLRT Project will be safety certified by performing the activities described in the sections above, and by documenting these in a series of certificates. The Project will be divided into certifiable elements, based on the subsystems and the individuals responsible for those subsystems, as well as the anticipated timing of the completion of activities necessary to certify each element. Examples of subsystems would be the Vehicle, Train Control, Communications Systems, Tunnel Ventilation and Traction Power. Examples of the activities which would be expected to be timed differently for these subsystems would be Design Criteria, Type Testing, Field Testing, Construction Specifications, O&M Manuals, Training, Spare Parts and Operating Procedures. Certificates will also be required for Project-wide disciplines, such as Electromagnetic Compatibility, Grounding, Corrosion Control, interfaces with the outside world (e.g. Utility Crossings, Oil and Gas Pipes), and for different types of Guideway (e.g. tunnel, elevated, at-grade).

RTG will have access to Safety Certificates produced and signed for the Canada Line to assist with the structure of certificates and the list of signatories appropriate for each signature. **Section 5.1.5.1.6** shows the list used to successfully manage the Safety Certificates for that Project; **Package B2 – Design Submission Part 2 – Volume 1 (of 4)** provides examples of certificates.

Safety Case

The Safety Case will be based on the composite of all SSCP documents, and will provide links to the disposition of all hazards, and to the status of Safety Certificates. The Safety Case will be a composite of both the Generic Safety Case and Application Specific Safety Case, as outlined in both EN 50126 and EN 50129. These include the following:

- An overview of the OLRT as a system
- A summary or reference to the safety requirements
- Evidence that the OLRT, as designed, installed and tested, meets all safety requirements
- Adequacy of compliance with the safety requirements
- A summary of the safety assessment and safety audit tasks
- A summary of the safety analysis tasks
- An overview of the safety engineering techniques employed
- A Quality Management Report, providing a summary of the quality and safety management controls adopted
- Related Safety Cases for any subsystems on which the main Safety Case depends
- A summary of any limitations or constraints, and how these may be lifted

RAM Documentation

RTG will allocate the numerical RAM requirements to the Vehicle, Train Control System, and Communications Systems, as well as to the overall Project. The following steps prepare documentation and demonstrate RAM requirements:

- Reliability - allocation, analyses and demonstration
- Availability - allocation, analyses and demonstration
- Maintainability - allocation and analyses

Safety Management System

This document will address OLRT safety and security during revenue service operation: responsibilities, policies, operating rules, procedures for risk/threat assessment and data gathering, corrective actions and audits. Non-proprietary sections of the Safety Management System now in place on the Canada Line will be the basis of this document.

Evaluation and Development of Systems Assurance Activities

Our methodology to evaluate and develop Systems Assurance requirements is described in *Safety and Systems Assurance Management and Process* above. We will stage these Systems Assurance activities as follows:

- **Conceptual Design** - The SSCP will be prepared during the Pre-Design stage. Selected portions of this document will be provided to selected sub-system contractors, which will outline numerical allocations for RAM and include a high-level definition of responsibilities for hazard mitigation, and will identify the systems assurance documents required from subcontractors, thus ensuring that RAMS requirements drive the design.
- **Design** - Each party responsible for design of a sub-system or for design of the overall OLRT system, will understand their responsibilities to produce a design that conforms to the systems assurance requirements described in the previous paragraph.
- **Construction** - Management of the safety of construction activities will be described in the Construction Safety Plan in accordance with RFP Schedule 3.1, section 1.4.
- **Maintenance** - Management of the safety of maintenance activities will be addressed in the Operating and Support Hazard Analysis and the Hazard Log.
- **Service Authorization** - Safety and Security Certification are prerequisites for Service Authorization. Safety Certification is described in *Safety and Systems Assurance Management and Process* above. Security Certification is described in *System Security and Additional Response Requirements.*
- **Revenue Service Demonstration** - Major subsystem subcontractors must meet specific numerical targets for RAM during a specific period of revenue service (e.g. 12 months). A significant milestone payment will be withheld until that subsystem meets the performance criteria for the designated duration.

Optimization of the OLRT System

Reliability, Availability and Maintainability documentation will be as outlined in *Safety and Systems Assurance Management and Process - RAM Documentation.* Operations are by OC Transpo.

Although not normally considered to be part of the systems assurance process, the following disciplines and methods will apply to the OLRT Project. These are in addition to those described in **Section 5.1.5.1** to steer the design to optimize system safety, reliability, availability and maintainability.

Service Dependability

Service dependability, safety and security must be primary considerations in the design of any transit system. The use of proven methods, materials, and systems is extremely important, as is consideration of the local climate, geography, and any other unique conditions. To provide a highly dependable system in Ottawa, RTG will draw on expertise gained through our design, construction, operation and maintenance of other modern transit systems in Vancouver, Seville, Barcelona, and Calgary. The means and methods to be employed are described throughout this Response.

With respect to Safety Management and Regulatory Matters and how safety, security, and regulatory systems influence service dependability, RTG believes that the two complement one another. Certainly service dependability will not be degraded by the regulation that RTG will participate in developing nor the Safety and Security Management Systems that will be put in place. The approach will be to implement performance-based regulation and systems, ensuring safety while delivering high levels of service dependability.

Maintainability and Lifecycle Cost

Many proponents responding to opportunities such as the OLRT comprise consortia or financial entities. The successful concessionaire then typically awards separate contracts for the design-build of the facility and for its maintenance and rehabilitation (M&R). These design-build companies and operating companies may or may not have equity participation in the overall concession company.

Not wanting their capital tied up in long-term operations, construction companies often do not seek equity participation in the concession company. They are also generally focused on minimizing construction costs, sometimes to the detriment of lifecycle outcomes. Similarly, operating companies do not want to be exposed to the risks inherent in design and construction which have not sought to minimize long-term M&R costs.

These positions can lead to conflict within the consortium: the operating entity can feel that not enough consideration is given to M&R costs and, conversely, the design-build entity can feel burdened with unnecessary cost to minimize M&R costs. RTG has achieved a balance between the long-term nature of the OLRT and the fact that some components will have design lives that extend well beyond the Project Term. This is achieved in three ways:

- RTG Team members will take and maintain an equity position in Project Co throughout the Project Term.
- RTG Team members will become the design-build contractor, assuming all the responsibilities that go along with such a position. This arrangement means that there is a genuine interest is ensuring on-time completion because of the overall corporate interests of the company in the concession.
- RTG Team members will be the system maintainer. As such, there is a corporate interest in ensuring that the design-build of the system optimizes M&R costs and in ensuring that operating performance criteria are met and that scheduled payments are not compromised through the Project Term. The M&R Team is involved in design, particularly in aspects involving maintenance, such as Station materials, MSF layout, and access to the guideway. The M&R Team involved in the bid will also carry through this role in the Detailed Design phase.

Risk Allocation and Management

Appropriate warranties in the design-build contract will ensure that suppliers assume responsibility for product performance by providing warranties for one or two years after Service Commencement (SC). In some cases this is an additional two years after installation. In addition, the design-build contract incorporates an extended warranty for critical items, an endemic defect warranty and a latent defect warranty. These design-build contract conditions impose a strong onus on the DBJV to consider the long-term operation of the system.

Optimizing Design to achieve Cost Savings and Efficiencies for life of Project

This approach was successfully implemented on the Canada Line, where design and procurement were undertaken in close cooperation with a small, dedicated team of highly experienced O&M personnel, and the design managers were experienced in considering lifecycle costs for similar infrastructure projects for governments. Design initiatives that took into account long-term O&M considerations were as follows:

- **Running rail and wheel materials** - The wheel/rail interface is a critical element of rail transit design. Early rail and wheel wear lead to early rail replacement and wheel reprofiling and contribute to increased noise and reduced ride quality. On the Canada Line, it was decided to adopt high-strength steel for both rail and wheel, thereby reducing operation impacts and minimizing maintenance costs.
- **Structures** – High-strength concrete was used for all structures to extend design life and reduce maintenance costs.
- **Station finishes** – These were selected based on maintainability, particularly ease of cleaning and graffiti removal. Recycled materials were used where possible; e.g. concrete from a building demolished along the right of way was crushed and used as subgrade materials.

- **Electrical system** - After an extensive study of stray currents, the electrical system was designed to minimize any chance of stray currents causing premature corrosion of embedded items. This included using continuously welded rail, bonding across joints, rail bond jumpers, electrical grounding of Station structures and insulated track fasteners which isolated the running rails.
- **Diagnostics** – Where possible, all major equipment was designed to be capable of self-diagnostic health analysis. In addition designs took into account access to equipment, repair and replacement procedures, tools to be used, safety, access doors, panels and hatches and sufficient space around components to allow ease of repair. Long-term power use was minimized by selecting components and equipment with energy-saving features and by optimizing lighting levels in Stations.
- **Team integration** - O&M personnel were especially involved in design reviews of the Stations, Vehicles, the O&M centre, control rooms and traction power stations. In addition, O&M personnel visited the major suppliers' facilities during manufacturing and were fully involved in testing and commissioning. Their input minimized lifecycle costs and the potential for vandalism while optimizing equipment maintenance.

RTG will implement similar measures and lessons learned on the OLRT.

Failsafe Design & Failure Management of System Operation

Failsafe design is the cornerstone of rail transit safety and is integral to our design philosophy. We have chosen proven systems for our proposed solution and teamed up with leaders in our industry. Pioneering the application of failsafe design in the CBTC field, Thales is a Canadian success story. Alstom is a world leader in LRV technology with a proven safety and reliability record. All safety-critical systems proposed for the OLRT Project have been proven in revenue service. The safety analysis process outlined above will identify any single-point failures which will then be appropriately mitigated. Failure Management will be achieved first by a high level of redundancy in mission-critical systems. Our solution emphasizes the use of self-diagnostic equipment with extensive monitoring and alarm systems to notify the M&R Team of problems which can then be addressed before they affect service.

However, RTG realizes that, however rarely, failures can and do occur. In cooperation with the City, we will develop operational procedures and training programs to provide OC Transpo controllers and Drivers with the tools to manage the failure and minimize impact to Passengers. M&R personnel will be trained to promptly return the System to full operation.

System Integration Methodology

As with any project of this magnitude, there is integration risk. RTG is committed to managing that risk to deliver a transit system that meets or exceeds performance expectations. RTG will carefully review all supplier submittals to ensure that proposed systems and equipment can perform as required in the Ottawa environment. The process of choosing our Team's Vehicle and Train Control supplier, who carry the major integration risk, included a detailed review of their proposed interfaces and interface management plan to verify that both suppliers understood the interface requirements and had the necessary knowledge and experience to implement those interfaces. We have chosen two experienced suppliers with demonstrated systems integration capability, and experience working together and working with RTG.

The responsibility to meet interface performance requirements between vehicle and train control has been allocated to both Alstom and Thales. They will be contractually required to take joint responsibility to meet performance requirements and they will be required to provide access to their key subcontractors to provide sufficient visibility to RTG that interface requirements are well understood and properly implemented. A similar approach will be taken with other major suppliers such as trackwork, OCS, power supply and communications.

RTG's LRT Systems Integration Manager will manage the design process to ensure that all interfaces are properly defined, appropriate engineering expertise is allocated to the task by each supplier, and the inevitable challenges are dealt with. A detailed system interface specification will be prepared for each major interface to define all interface details. Particular attention will be paid to brake and propulsion interfaces, and the wheel/rail interface. The Systems Integration Manager will chair meetings attended, as a minimum, by Alstom, Thales, and key subcontractors such as the brake and propulsion suppliers. All details of system interface specifications will be discussed, agreed and documented. Other subsystem suppliers such as communications, power and OCS will attend as required.

Test programs will be developed to demonstrate all aspects of the interfaces. This will include First Article Inspections, qualification tests, Factory Acceptance Tests and subsystem integration tests. Vehicle/Train Control integration tests are planned in the Maintenance and Storage Facility (MSF) early in the schedule. These tests will be a key milestone for ensuring that all vehicle-train control interfaces have been properly addressed. On-site testing will be planned in stages that demonstrate the functionality in a logical sequence and ensure that, as far as possible, only one function within one system is being tested at a time. Once multiple systems have been tested to an appropriate stage, they will be combined for integration testing. This process is shown graphically in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**.

Over the past 30 years that our Team has been successfully integrating CBTC systems, Vehicle and Train Control systems have changed dramatically. Standardization of interfaces has been driven both by supplier consolidation and by technological advances, especially in communication equipment and protocols. The application of modular design methodologies to both hardware and software engineering has simplified interface design. This progress has dramatically reduced the risks associated with Vehicle-Train Control integration. RTG believes that we can properly manage the integration risk for any major Vehicle and Train Control supplier, and provide the City with the most cost-effective system.

RTG will manage the system integration of other subsystems by applying the same principles as used for the Vehicle-Train Control interface.

Precedents

RTG will have access to the SSCP, hazard analyses, safety certificates, failure reports, reliability reports and other reports implemented by one of the partners on the Canada Line. The subcontractors providing the Vehicle, Train Control System, and Communications Systems will provide similar information from corresponding documents. Information from these sources will be combined and used to assist in preparing similar documents specific to the OLRT Project, thus ensuring a coordinated approach to RAMS. These subcontractors will also be required to advise RTG of any pattern failures which have occurred on other projects, or which become evident after award of contract, where similar equipment or software is used on the OLRT. This information will, in turn, be provided to the City, together with an assessment of its potential relevance to the OLRT Project.

Integration of Lessons Learned from Other Projects

Integration of the Canada Line project used a strategy similar to that outlined herein. The following lessons are directly applicable to the OLRT Project:

- Agree early-on which parties will authorize major steps in Project start-up, such as the following:
  - Traction Power Energization
  - First Train Movement
  - Multiple Train Movements
  - Trial Running
  - Revenue Service

  (Note that this is an example list, and not necessarily a comprehensive list for the OLRT Project.)
- Agree with each party the list of documents and other activities required in support of their signature authorizing start-up. This list to be documented in a System Activation Plan.
- Agree with each party the processes and/or standards to be used in preparing relevant documents and other activities
- Prepare and sign certificates as early as possible
- Combine items in one certificate where timing is similar and signatories match

- Prepare Revenue Service Operating procedures and training programs related to safe operations during the Testing and Commissioning (T&C) phase (e.g. train movements, traction power energization, hand signals) well in advance of the start of T&C
- Ensure that sufficient operators are trained for the start of T&C
- Ensure that system access requirements for O&M training are scheduled well in advance of the start of T&C and coordinated with testing activities on an ongoing basis
- Use experts for key Project challenges and identify latent issues based on experience on other projects

Files to be submitted

A record copy of safety certification files will be submitted to the City upon completion of the Work.

Implementation of Systems Assurance Requirements throughout the Maintenance Term

During the 30-year Maintenance Term, RAM requirements will be achieved through the ongoing procurement of spare parts and tools and the performance of the Maintenance Plans. During the initial phase of the service, Maintenance Plans will be developed driven from supplier recommendations and instructions. Concurrent with prescribed and planned maintenance activities, data will be collected on component failures as well as status and wear on serviced components. A data-driven failure management program will be developed based on trended projections and actual failures. The RAM statistics obtained will be analyzed and used to enhance the Maintenance and Asset Management Plans and ultimately allow predictive asset maintenance.

System Security and Additional Response Requirements

The approach to System Security is described below as System Security Certification Plan and in *Scope, Activities & Processes.* Additional response requirements of RFP Schedule 3-1 are discussed in order:

- Configuration control
- System integration
- Post-construction pre-revenue certification
- Safety auditing

Configuration Control: RTG will apply configuration management and change control management procedures and techniques for the OLRT Project. Where appropriate (for example, in systems with software components), these procedures and techniques will comply with internationally recognized standards

A project wide documentation control process will ensure that all changes to documents and drawings are properly recorded and distributed to ensure that the work is performed to the accepted design. These processes are discussed further below.

A Configuration Management Plan and Change Control Management Plan for the whole OLRT System including Vehicles will be prepared at the conceptual design phase and will define the methodology, procedures and management organization to perform these functions. This is detailed in Section 5.4.1.4.

During the Operations/Maintenance phase, RTG will maintain all systems plans, maintenance reports, remedial actions, instructions and procedures in an asset management system. System plans include the conformed design plans reflecting as-built conditions at final acceptance of construction. The design plans, including typical installation drawings that document installation standards, will be controlled by the Maintenance Director by implementing a configuration management process embedded in the asset management program. With the large number of interdependent and complex systems making up a modern LRT system, a system must be in place that will evaluate and control change and provide traceability of these changes. This is necessary to ensure the ongoing integrity and functionality of all software, hardware, and equipment throughout the Project Term.

A Configuration Management Committee, chaired by the Maintenance Director, will control configuration management. Safety and security personnel will have a prominent role on the Board, which will be responsible for controlling changes in system configuration, components and procedures to ensure system safety, and reliability. The Board will apply a Configuration Management (CM) process to ensure system integrity:

- **Configuration Management Committee (CMC) -** A CMC is set up with key personnel of the organization. The CMB is authorized to review and approve/disapprove the CM plan, CM procedures, selection of configuration items, configuration baselines and changes to those baselines including deviations. CMC is chaired by the Maintenance Director.
- **Configuration control -** Version control for software items will be done according to the rules of the tool implemented for the Project. Configuration control of documents will be carried out according to the internal procedures developed during the design-build phase and before pre-revenue operations. A defined configuration item can be changed only after approval from the CMC.
- **Evaluation of Change Request -** A change request is analyzed with respect to its effects on the system and operations. A detailed technical description of the solution to the intended change is compiled and the following benefit/risk criteria are examined:
    - Benefit analysis
    - Impact on safety
    - Impact on quality
    - Impact on human resource planning
    - Impact on interfaces to the entire system or to related systems
    - Impact on reliability, availability and performance

All changes in the configuration of a system or equipment will include a request, an evaluation of the change (both in terms of the system itself and any interrelated systems), an approval process, and the final recording and documentation of the change. This will be managed and recorded within RTG's asset management systems to provide traceability.

Where life-limited or serialized components are changed in any equipment, the overall impact on future maintenance and life cycle of the parent asset will be accounted for and adjusted within RTG's asset management systems

System Integration

System integration is discussed in *Optimization of the OLRT System* above.

Post-construction pre-revenue certification

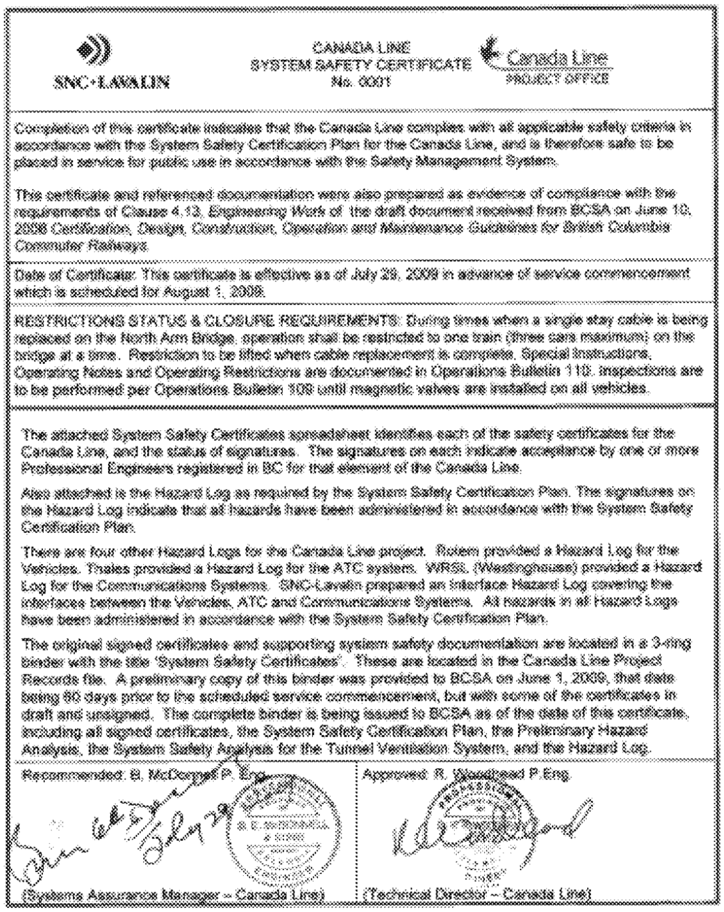
System integration is discussed in *Safety and Systems Assurance Management and Process* above.

Security Certification

System integration is discussed in *System Security and Additional Response Requirements* above.

Safety Auditing: RTG will be responsible for OLRT system maintenance. RTG will establish an annual audit of all safety-critical and safety-related maintenance activities, including checking that the forms of mitigation used to close the Hazard Log and Risk Register items are being implemented, that documented maintenance procedures are being adhered to, and that each individual involved in safety-critical work has been properly trained. The party responsible for OLRT system operation will also be required to establish a similar annual audit of all safety-critical and safety-related aspects of the operation. If variances are identified in either of the operating or M&R procedures, the audit will follow-up by documenting legitimate variances accordingly. Details of the Regulatory Working Group and its establishment of a Safety Management System are discussed in *Scope, Activities & Processes*. During the concession period, key metrics will be gathered and reported to both the Regulatory Working Group and the City. Typical metrics will include, but not be limited to the following:

- Safety incidents (potential or actual) that may involve the public
- Safety incidents (potential or actual) that may involve staff
- Maintenance failures with potential safety implications
- Issue closure rate



SNC·LAVALIN

CANADA LINE
SYSTEM SAFETY CERTIFICATE
No. 0001

Canada Line
PROJECT OFFICE

Completion of this certificate indicates that the Canada Line complies with all applicable safety criteria in accordance with the System Safety Certification Plan for the Canada Line, and is therefore safe to be placed in service for public use in accordance with the Safety Management System.

This certificate and referenced documentation were also prepared as evidence of compliance with the requirements of Clause 4.13, *Engineering Work* of the draft document received from BCSA on June 10, 2008 *Certification, Design, Construction, Operation and Maintenance Guidelines for British Columbia Commuter Railways.*

Date of Certificate: This certificate is effective as of July 29, 2009 in advance of service commencement which is scheduled for August 1, 2009.

RESTRICTIONS STATUS & CLOSURE REQUIREMENTS: During times when a single stay cable is being replaced on the North Arm Bridge, operation shall be restricted to one train (three cars maximum) on the bridge at a time. Restriction to be lifted when cable replacement is complete. Special Instructions, Operating Notes and Operating Restrictions are documented in Operations Bulletin 110. Inspections are to be performed per Operations Bulletin 109 until magnetic valves are installed on all vehicles.

The attached System Safety Certificates spreadsheet identifies each of the safety certificates for the Canada Line, and the status of signatures. The signatures on each indicate acceptance by one or more Professional Engineers registered in BC for that element of the Canada Line.

Also attached is the Hazard Log as required by the System Safety Certification Plan. The signatures on the Hazard Log indicate that all hazards have been administered in accordance with the System Safety Certification Plan.

There are four other Hazard Logs for the Canada Line project. Rotem provided a Hazard Log for the Vehicles. Thales provided a Hazard Log for the ATC system. WRSL (Westinghouse) provided a Hazard Log for the Communications Systems. SNC-Lavalin prepared an Interface Hazard Log covering the interfaces between the Vehicles, ATC and Communications Systems. All hazards in all Hazard Logs have been administered in accordance with the System Safety Certification Plan.

The original signed certificates and supporting system safety documentation are located in a 3-ring binder with the title 'System Safety Certificates'. These are located in the Canada Line Project Records file. A preliminary copy of this binder was provided to BCSA on June 1, 2009, that date being 60 days prior to the scheduled service commencement, but with some of the certificates in draft and unsigned. The complete binder is being issued to BCSA as of the date of this certificate, including all signed certificates, the System Safety Certification Plan, the Preliminary Hazard Analysis, the System Safety Analysis for the Tunnel Ventilation System, and the Hazard Log.

Recommended: B. McDonnell P. Eng.	Approved: R. Woodhead P.Eng.
(Systems Assurance Manager – Canada Line)	(Technical Director – Canada Line)

Figure 5.1-2 | Canada Line / System Safety Certificate No. 0001

SSCP: We suggest that the System Security Plan be a separate document from the System Safety Plan, since the former may require tighter distribution and control. If the City approves this separation, the System Security Certification Plan will describe the responsibilities for ensuring OLRT system security during construction, start-up and revenue service. It will address security of Passengers, staff, contractors, visitors, emergency personnel, the public and trespassers, as well as assets. It will address guideway and perimeter protection, access control, and responsibilities of security personnel. It will outline a methodology parallel to the steps in the System Safety Certification Plan (i.e. Threat Identification, Threat Mitigation, Risk Register, Security Certification and Progress Reporting). Non-proprietary sections of the Security System now in place on the Canada Line will be the basis of this plan. A record copy of security certification files will be submitted to the City upon completion of the Work. Further details on System Security are in *Scope, Activities & Processes*.

5.1.5.1.6 Precedent Certificates

Table 5.1-13 lists the Safety Certificates prepared for the Canada Line Project. A comparable list will be prepared for the OLRT Project to track progress. Representative samples of the signed and sealed certificates are provided in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**.

Table 5.1-13 | List of Safety Certificates for the Canada Line

Safety Certificate	Draft Complete	Signed	Safety Certificate	Draft Complete	Signed
0001 Overall Canada Line	●	●	0701 AC PS&D Design	●	●
0101 Vehicles Design Requirements	●	●	0702 PS&D Supporting Services	●	●
0102 Vehicles Supporting Services	●	●	0703 PS&D Inst, Inspec, & Test	●	●
0103 Vehicles Inspection & Testing	●	●	0801 DC PS&D Design	●	●
0104 Vehicles Systems Assurance	●	●	0802 Blue Light System Design	●	●
0201 ATC Design Requirements	●	●	0803 Stinger System Design	●	●

Safety Certificate	Draft Complete	Signed	Safety Certificate	Draft Complete	Signed
0202 ATC Supporting Services	●	●	0804 Emergency Stop Design	●	●
0203 ATC Inst, Inspec, & Test	●	●	0805 Grounding of Running Rails	●	●
0204 ATC Systems Assurance	●	●	0806 Guideway Lighting	●	●
0301 Comms Design Reqmts	●	●	0901 Fire Alarm Design	●	●
0302 Comms Supporting Services	●	●	0902 Fire Alarm Supporting Services	●	●
0303 Comms Inst, Inspec, & Test	●	●	0903 EMC	●	●
0304 Comms Systems Assurance	●	●	0904 Train Noise and Vibration	●	●
0401 GIDS Design	●	●			
0402 GIDS Supporting Services	●	●	0906 Oil & Gas Pipes	●	●
0403 GIDS Inst, Inspec, & Test	●	●	0907 Underground Storage Tanks	●	●
0404 GIDS Systems Assurance	●	●	0909 Utility Crossings	●	●
0405 Vulnerability to Intrusions	●	●	0911 OMC Design	●	●
0501 Alignment & Trackwork	●	●	0913 Fire Alarm Inst, Inspec, & Test	●	●
0502 Gauge Clearance	●	●	0921 Emergency Braking Rate	●	●
0503 Trackwork Supporting Services	●	●	0922 VOBC Timeouts during Low Adhesion EB Applications	●	●
0601 TVS Design	●	●	0951 Elevated Guideway	●	●
0602 TVS Supporting Services	●	●	0961 North Arm Bridge Design	●	●
0603 TVS Inst, Inspec, & Test	●	●	0971 Bored Tunnel Design	●	●
0604 TVS Systems Assurance	●	●			

5.1.5.2 Regulatory Matters

General Approach to Development of SMS, SeMS, TVA, SOPs and LRT Rules

RTG has closely examined the regulatory framework under which the OLRT will be designed, constructed, maintained, and operated, and proposes a similar approach in developing the required Regulatory Standards and Support Documentation to that which was successfully undertaken in Vancouver for the Canada Line light rail transit project. In accordance with the Railway Safety Act (BC), the British Columbia Safety Authority (BCSA) has the delegated authority to oversee provincial railways in BC (including rapid transit). Recognizing that much of the BC Railway Safety Act (which is very similar to the Federal Railway Safety Act) is not applicable to an automated LRT system, SNC-Lavalin worked with the BCSA to develop, file, and implement regulation governing Canada Line operation and maintenance. A similar regulatory framework will exist for the OLRT system with the Delegation Agreement passing authority from Transport Canada to the City to regulate matters covered by Parts III and IV of the Canada Transportation Act (CTA) and by the Railway Safety Act (RSA).

RTG's approach to developing Regulatory Standards and Support Documentation will be collaborative, and comprise all key Stakeholders from the City and RTG, which will provide adequate resources to enable effective development of the required Regulatory Standards and Support Documentation. RTG proposes that a Regulatory Working Group be established. The two principal members of the Working Group will be OC Transpo (as the future operator) and RTG (as the successful proponent and future maintenance provider). The Working Group will also include City representatives on an ongoing or as-required basis (e.g. Rail Implementation Office, By-Law and Regulatory Services, Ottawa Fire Service, Ottawa Police Service, Security and Emergency Management). This approach will be particularly important given the multi-party nature of the OLRT operation, where the system will be regulated by the City, operated by OC Transpo, and maintained by RTG. We will draw on the in-house expertise and experience from implementation of the Canada Line system as well as on outside expertise, and will contribute to the Working Group in such a way that the parties will jointly meet PA Schedule 15-4 requirements.

Regulatory Matters – Responsibilities and Organization

Responsibilities of the Parties

With the regulatory framework that will govern OLRT operation, it is important to define the responsibilities of the parties:

- The City will be the recognized authority to regulate and oversee all matters pertaining to OLRT system safety and security.
- RTG will be responsible, as a component of its work, to assist the City in developing OLRT Regulations and Support Documentation, including the following elements:
    - Safety Management System (SMS)
    - Security Management System (SeMS)
    - Threat and Vulnerability Assessment System (TVA)
    - Standard Operating Procedures (SOPs)
    - OLRT Operating Rules and Procedures
    - Monitoring and Enforcement Procedures.
- OC Transpo will be responsible for obtaining from the City, with the support of RTG, the Operating Permit for the OLRT system.
- RTG will be responsible for maintaining the OLRT system in accordance with all developed and accepted regulation and support documentation.
- Each organization will be responsible to provide adequate resources to the Regulatory Working Group. RTG will provide personnel who are knowledgeable and capable, with the expertise to develop relevant regulation, policy and procedures based on the systems to be delivered. Additionally, this Working Group will undertake the following:
    - Prepare and agree on critical timelines and maintain the schedule associated with development of all Regulation and Support Documentation.
    - Update and make any necessary revisions to the Safety and Security Management Systems, LRT Operating Rules and Procedures, and Standard Operating Procedures through the various phases of the project.
- The Working Group will continue into and through the operating period, with Working Group leadership transitioning from RTG (during the design, construction and T&C phases) to OC Transpo (during the operating phase). The Working Group will have operating responsibilities for the following:
    - Establishing an ongoing operational framework
    - Liaising with managers to ensure that all safety and security measures are addressed in accordance with the developed regulation, rules, and standard operating procedures
    - Providing direction for all safety and security activities
    - Participating in all management discussions regarding safety and security
    - Managing and coordinating safety and security audits
    - The quality and accuracy of all safety and security deliverables

RTG Organization and Key Personnel

Organization

After Contract Award, RTG will implement an organization to work with the City and OC Transpo to effectively develop OLRT Regulation and Support Documentation. A Manager of Regulatory Matters will be appointed immediately to commence work on the requirements of PA Schedule 15-4. This Manager will be a hands-on individual who will organize and mobilize the necessary resources and expertise within RTG, establish key relationships with the City and OC Transpo, and initiate the Regulatory Working Group and support the City's interface with Transport Canada, as appropriate. This position will be supported by the expertise of key RTG personnel, many of whom were involved in successfully developing the regulation, safety and security management systems, operating rules, and standard operating procedures that govern the operation of the Canada Line in Vancouver. The Manager of Regulatory Matters will report to the RTG Design Manager, who will guide the process, ensuring at a higher level that the requirements of PA Schedule 15-4 are being met and that OC Transpo will be in a position to obtain an Operating Permit in time for OLRT system service commencement.

Key Individuals

Roger Woodhead, PhD, P.Eng. – Design Manager

Roger Woodhead will have overall responsibility for ensuring that RTG effectively develops the OLRT Regulations and support documentation in partnership with the City and OC Transpo. Dr. Woodhead was Technical Director on the Canada Line Project, which successfully implemented a similar approach to obtaining an Operating Permit from the BC Safety Authority (BCSA). This document was one of the critical requirements for achieving Service Commencement, a milestone which was reached 110 days ahead of schedule and which allowed Canada Line to open well in advance of the 2010 Winter Olympics. Roger is a Lead QMS Auditor.

Brian McDonnell, M.Eng.Sc., P.Eng. – Manager of System Assurance & Regulatory Matters

Brian McDonnell will be responsible for managing Safety Certification and Regulatory Matters of the OLRT Project before revenue service. Brian wrote the Systems Assurance and Safety Certification portions of RTG's Response. Specializing in systems assurance of transit systems for the past 23 years, he was responsible for systems assurance of Toronto's Sheppard Subway and Vancouver's Canada Line and managed the Safety Certification of both projects before revenue service.

John Selke, BASc., P. Eng. – Testing & Commissioning Manager

John Selke has 30 years of experience in the specification, analysis, design, development, and commissioning of real-time automatic train control) systems for the transit and freight rail markets. His relevant experience includes application of formal system engineering process to complex software-based train control systems and system safety certification of safety-critical transit systems. As the Testing and Commissioning Manager for the Canada Line Rapid Transit Project in Vancouver, Canada, John was responsible for developing the operational safety procedures used during T&C and for ensuring that the test program supported the project safety certification process.

Grant Bailey, P.Eng. – Director of Maintenance

Grant Bailey will be deeply involved in the OLRT through Design and Construction, contributing the lifecycle perspective. He is currently Director of Engineering for PROTRANS BC Operations Ltd., a subsidiary of SNC-Lavalin and operator and maintainer of the Canada Line in Vancouver. Grant was integrally involved in developing and writing the regulations, rules and procedures governing O&M of the Canada Line.

Service Providers

In supporting the development of Regulatory Standards and Support Documentation, RTG has identified and will retain the expertise of various consultants with strong credentials and backgrounds in regulatory affairs. The expertise of these consultants will be used as an additional resource in the development of regulatory standards and support documentation.

Louis Ranger Advisory Services Inc.: Louis Ranger worked for the Government of Canada in transportation and public infrastructure for 35 years, including 7 years (from 2002 to 2009) as Deputy Minister of Transport. In that capacity, he led Transport Canada's efforts to implement Safety Management Systems in all modes of transportation under federal jurisdiction, with a particular focus on the air and rail sectors. With the Minister of Transport, he also launched a formal review of the working and efficiency of the Railway Safety Act which led to a series of recent legislative amendments (Spring 2012), including new provisions to enhance the role of Safety Management Systems.

Design and Detailing of the System to Address Safety and Security

RTG will design and detail the system to address all aspects of safety and security:

- Safety of employees, contractors and other authorized personnel on the property following service commencement as described in *Scope, Activities & Processes – Safety Management System*
- Safety of Passengers on the system after service commencement as described in *Safety and Systems Assurance Management and Process – System Safety Certification Plan*
- Safety of the general public adjacent to the site after service commencement as described in *Safety and Systems Assurance Management and Process*, System Safety Certification Plan
- Security of employees, contractors and other authorized personnel on the property after service commencement as described in *Scope,* Activities & Processes – Security Management System
- Security of Passengers on the system after service commencement as described in *Scope, Activities & Processes – Security Management System*

Means and Methods of Construction to Address Safety and Security

RTG's means and methods of construction will consider and address all aspects of safety and security:

- **Safety** of employees, contractors and other authorized personnel on the site during Construction as described in the Construction Safety Plan **Section 1.4**.
- **Security** of employees, contractors and other authorized personnel, and property on the site during Construction. This will be described in a Construction Security Plan specific to the OLRT Project. It will include threat identification and assessment, a risk register, risk mitigation, access control, locks and keys, ID badges, responsibilities of security staff, other employees and contractors, disciplinary measures, inspections, incident reporting, alarms, and liaison with local emergency response agencies. The Construction Security Plan will be a controlled document with limited distribution. The Construction Security Plan will also refer to portions of the Public Safety and Security Plan where the risks and forms of protection are the same.
- **Safety and security** of the general public adjacent to the site during Construction. RTG will implement a security and public safety program to protect work areas from inadvertent or unauthorized entry into Project areas and to ensure the public, motorists, business and the surrounding community are properly protected from the Works. This will be described in a Public Safety and Security Plan specific to the OLRT Project. Fences, gates and barriers will deter inadvertent and unauthorized entry. Additional protection will be provided if trees, stair towers or ladders provide access to high-risk areas. The Public Safety and Security Plan will describe the protection to be used at various Project areas as well as security monitoring requirements, and will dovetail with the Construction Safety Plan and traffic management plans to ensure proper containments and signage are in place. The Public Safety and Security Plan will be a controlled document with limited distribution.

Approach to Developing OLRT Rules and Regulations

Compared to traditional heavy rail systems, where regulation and industry rules and procedures have developed over the past 100 years, automated LRT systems typically operate on a much different basis and with more sophisticated systems. Features of automated LRT systems include sophisticated monitoring and alarm systems, increased redundancy, and use of self-diagnostic equipment. Thus, in many areas, the regulations, rules and operating procedures of heavy rail do not apply to LRT. Although the goals and objectives are the same—to ensure the safety of passengers, employees, the environment, and the operation in general—the development of rules and regulation for LRT systems must be specific and consider the features, reliability, and the types of systems being provided, in addition to how much human intervention is required or will be used in operating these systems.

The approach to developing OLRT Rules and Regulations will involve an analysis of the methods of operation, the features and redundancies of the systems being provided, the monitoring and alarm systems being provided, the recommendations from the designer's and supplier's O&M manuals, the amount of human involvement and intervention in operating the systems, the physical features of the line, and also the environmental conditions in the Ottawa area. A risk register will be created that will identify the risks of operating and maintaining the OLRT system, taking into account this analysis. It will also identify the potential impact of any associated failures. Rules and regulations will then be developed to mitigate and control these risks, and to ensure public, employee, and environmental safety. A similar process was undertaken on the Canada Line whereby the following rules and regulations were developed, filed for ministerial approval, and adopted well in advance of service commencement:

- Rail Operating Rules
- Safety Management System
- Train Inspection and Safety Rules
- Guideway Inspection and Maintenance Rules
- Tunnel Ventilation Inspection and Maintenance Rules
- Accident and Incident Reporting Rules
- Passenger Handling Safety Rules
- Medical Rules for Positions Critical to Safe Operations
- Rules Governing Safety Critical Positions
- Work Rest Rules for Operating Employees

RTG has full access to these rules and regulations and many can be used as base documents in establishing similar rules and regulations on the OLRT. Rules and procedures will also need to be in place before system T&C. T&C can also be a proving ground for many of the rules and procedures that will be used during the operating period. Through the Regulatory Working Group, RTG will ensure that such rules and procedures are developed and in place to facilitate OLRT T&C.

Scope, Activities & Processes

Safety Management System

RTG will lead the establishment of a Safety Management System (SMS) fully meeting regulatory and contractual requirements. The Regulatory Working Group will draft and finalize it. Before revenue service commencement, the Regulatory Working Group will be led by RTG, which will be responsible for making the application to the City. After acceptance of the submission, OC Transpo will take over SMS administration and maintenance.

RTG will lead the development of Supporting Policy and Procedures, guided by existing proven and functioning processes in full support of the Railway Safety Act. The Regulatory Working Group will draft and finalize them.

The Regulatory Working Group will establish SMS requirements to ensure agreement and common interpretation and acceptance for the system. Additionally, input will be taken from the bid submission and contract documents with roles and responsibilities associated with the drafting, acceptance, adherence to and maintenance of the SMS.

The SMS will be comprised of required policy and procedures to be implemented to provide safety assurance on an ongoing basis and allow continuous improvement.

- **Objectives** - To operate and maintain the OLRT with safety as the principal objective, the SMS will take direction from both RTG and OC Transpo's Safety Policy on how to achieve the following:
  - Meet mandatory requirements and good industry practice in maintaining a safe and healthy environment in all places that RTG works, for employees, Passengers, contractors, suppliers, members of the public and any other third party

- Ensure that a demonstrated competency system exists for all personnel to allow safe and professional job performance for all normal, abnormal and emergency circumstances
- Clarify accountabilities and responsibilities for both the RTG and OC Transpo teams
- Maintain a consultative program with employees to encourage continuing involvement and teamwork within the whole team in all safety-related matters, to further embed the safety culture. The Regulatory Working Committee will oversee safety issues and ensure the appropriate configuration controls are in place throughout the concession period.
- Ensure that all significant risks to health and safety are identified and plans exist to reduce these to acceptable levels
- Work in partnership with OC Transpo and third parties to continuously improve OLRT safety standards

- **Safety planning** - The Regulatory Working Group will conduct annual planning with clear safety goals to ensure safety direction for the OLRT. Performance will be reported and reviewed in conjunction with the City for applicable improvement actions.
- **Procedures** - The Regulatory Working Group will produce procedures detailing all work which directly or indirectly impacts the operation, maintenance and safety of Vehicles on the OLRT.
- **Training** - The Regulatory Working Group will implement an effective training program associated with all procedures and subsequent changes.
- **Performance monitoring & incident management-** The Regulatory Working Group will implement a safety data recording and analysis process to monitor OLRT safety performance. Additionally, a formal structure will be put in place for managing incidents: emergency response plans, investigation processes, cooperation processes for those investigations requiring liaison between various parties, and mandatory reporting. The Regulatory Working Group will review all emergencies and incident records to assess whether system or procedural improvements are warranted.
- **Corrective/preventive action** - The Regulatory Working Group will define and implement procedures to correct deficiencies or make improvements, manage and document all necessary changes including changing procedures, notify affected personnel, retrain if required, and follow up for monitoring.
- **Audits** - A formal process for auditing will define activities and responsibilities for the initiation, execution, reporting and follow-up of audits and the resolution of any corrective action requests. The audits will review key SMS elements.
- **Risk management** - The Regulatory Working Group will maintain a risk registry and Risk Management Process. Before OLRT operation, RTG and OC Transpo will conduct a comprehensive system-wide risk based analysis on the findings of the SSCP, the SMS, and the SeMS. This will identify risks to Passengers, employees and others; suggest appropriate mitigation for unacceptable or undesirable risks; and provide a hazard log process for tracking and managing all hazards. The systematic risk assessment is seen as core to the SMS. The Regulatory Working Group will review any significant change to the infrastructure or Vehicles or main operating procedures to understand the impact and agree on and establish appropriate controls. This process will involve all necessary parties to assess risks accurately and confirm appropriate controls. Hazard review and risk assessment methodologies will be used to minimize risks and identify appropriate controls and mitigations. The RTG system-wide risk assessment is based on US Department of Defence Standard Procedure for System Safety (Mil Std – 882C). This risk assessment process will start with documents provided by RTG during handover, most notably the Operating and Support Hazard Analysis. After handover, these documents will be kept up-to-date, and will address changes to OLRT systems, equipment or procedures. Before service commencement, RTG will lead risk assessment. During operations, the Regulatory Working Group will maintain the operating hazard log and lead periodic reviews to ensure that the risks faced during revenue service are known and addressed.
- **Stakeholder review process** - To periodically review safety and the SMS, including identified risks, recommendations, incidents and corrective actions.

While developing the SMS, we will also do initial development work on detailed courseware in parallel stages:

- Courses covering safety associated with operation and maintenance of all assets
- General safety policy and rules

TVA

The Regulatory Working Group will commission an independent Threat and Vulnerability Assessment of the entire line prior to commencement of service. Independent security specialists will provide input as to what is seen as vulnerabilities and priorities. This information will be used as a foundation for the Security and Threat Escalation Plan for the railway.

SOP

The Standard Operating Procedures will be developed to cover all aspects of the railway operation as a foundation to training. To be developed are the supporting Policy and Procedures, required for safe Operations and Maintenance of the railway. Operating Procedures will cover Normal, Abnormal and Emergency circumstances and detail responsibilities and roles of the organization in each case. Maintenance procedures will address activities not detailed as work instructions released with work orders. Activities which involved Operations and Maintenance will be identified and drafted within the Regulatory Working Group.

LRT Rules

The LRT Rules provide the high level guidance to the organizations in terms of what must be attended to. The Rules are derived from the outcome of activities in *Approach to Developing OLRT Rules and Regulations*

Pre-Revenue Safety Programs

Before revenue service, the SMS will not direct employees since applicable portions of the SMS will be implemented via appropriate training. Employees hired to participate in T&C must fully adhere to T&C Safety Rules governing this work. After initial safety training, employees will undergo on-the-job training (OJT) during which they will be given the opportunity to develop hands-on experience.

During construction, RTG will maintain demonstrated safety competency of all personnel working on any sites. The operating SMS will come into effect on commencement of service.

Testing Safety Knowledge

A key part of the SMS will be competency management and training, developed by the Regulatory Working Group and provided for all staff in one of three streams. The first stream will be for managers and this will be a strategic safety management course. All managers will attend a 'Managing Safety' course to give a good foundation in safety management principles and how to manage their teams and workload. The second stream will be for all supervisory staff, who will attend the Supervisory Safety course giving them the skills to supervise and understand their safety responsibilities. The third stream will be for all staff, who will receive safety training when joining the OLRT Project and additional safety briefings when undertaking new tasks or for any change to process, activity or legal aspect of their roles. Specific training will also be identified for individuals that must be completed before being allowed to undertake the task.

During operation, OC Transpo employees will be tested regularly to assess their knowledge in safety, which will be used by the Regulatory Working Group to provide guidance and to correct processes and behaviours. At the conclusion of all training, employees will be assessed and given the opportunity to demonstrate their new skills to ensure their competence on the safety objectives. The Regulatory Working Group will establish criteria for demonstrated competency and minimum levels of knowledge pertaining to safety. As specified in the SMS, employees will be required to take refresher training at specified intervals. Systems for monitoring training and maintaining records will be specified.

Safety Materials

Guiding safety policy and procedures will be the Railway Safety Act and its interpretation by the City. Additionally, the Occupational Health and Safety Act and Ontario Ministry of Labour regulations will underpin RTG employee and subcontractor Occupational Health and Safety policy (see Section 1.4). Extensive use will be made of safety materials provided by suppliers as appropriate. In some instances, safety materials will be developed by the Regulatory Working Group that is specific to the needs of Operations or M&R.

Safety Schedule

A preliminary timetable for developing and implementing the agreed regulations and SMS is provided at the end of this section. The safety timetable will be coordinated with the staffing plan/schedule to optimize the time for training of all hires. Additionally, the Regulatory Working Group will be formed early in the Project process to initiate and establish regulation. It will also have an ongoing role associated with Risk Management, Audits and investigations.

Safety Training

All Operations and M&R technical and procedural safety training will take place at the MSF and will be conducted by either RTG or OC Transpo staff or Vendor trainers. This training will prepare employees to undertake their duties safely. During execution of the safety training program, we will make extensive use of operations and M&R manuals, thereby ensuring that trainees become familiar with and confident in using the formats and contents of these manuals and suggested safety elements.

Safety Needs Analysis

Every OLRT job will have a defined safety classification. The Regulatory Working Group will establish a thorough needs analysis involving a study of all job descriptions, input from the managers, a review of the safety material provided by suppliers, and a review of safety training provided to employees at similar transit operations. We anticipate that several roles will be classified as safety-critical positions in accordance with the Railway Safety Act and derived regulations, requiring special recognition, training and monitoring.

Visitor and Contractor Safety Training

Before access is granted to any OLRT property, visitors must undertake basic safety training and receive an identifying badge. The Regulatory Working Group will establish safe practices and policy to ensure employee and contractor safety while working on the OLRT. Contractors expected to work on OLRT property without continual supervision will require training appropriate for their work location and activities. Managers admitting contractors and visitors will be responsible for ensuring this training occurs.

Common Safety Procedures

We propose to develop one Safety Management System, incorporating both Railway Safety Act requirements and Occupational Health and Safety Act requirements. There are safety courses that all employees will be required to take either before or shortly after service commencement. The purpose of these courses is to ensure that all employees understand their obligations under the Railway Safety Act and the Occupational Health and Safety Act for safety and Company Policy Rules and Procedures; for example:

- OLRT orientation
- General safety orientation
- Rules and procedures
- First aid
- Emergency procedures (especially fire and building evacuation)
- Workplace Hazardous Material Information System (WHMIS)

OH&S Rules to be address are identified in Table 5.1-14 below

Table 5.4-14 | OH&S Rules

Application	
Working at heights	Working in Stations (e.g. use of ladders, elevators/escalators risks, vent fans)
Working in confined spaces	Use of Engineering rail vehicles
Control of contractors	Working with electricity and lockout/tag out
Working hours and fatigue control	Air and water quality
Safety on the track	Fire (e.g. hazards, prevention, extinguishers, drills)
Use of company road vehicles	Use and maintenance of lifting equipment
Use of hand tools	Safety-critical positions

Security Management System (SeMS)

RTG recognizes the unique security challenge of operating an LRT system in the National Capital of Canada, a G8 country with world-wide influence and frequent host to many dignitaries and foreign guests. Ensuring the safety and security of the public, Passengers and employees is a key RTG objective. Additionally, other key Stakeholders require assurance that security has been addressed and that all reasonable efforts have been taken to mitigate threats.

To augment the security features designed and built into the OLRT, a comprehensive Security Management System (SeMS) covering all OLRT operations and property will be developed to provide Security Assurance. In addition, security policy and practices will be written documents and form the basis of OLRT security training. The SeMS will meet these objectives:

- Act as a principal reference for managing security activities
- Provide RTG and OC Transpo with a reference for reviewing security objectives, plans and schedule with others
- Act as a standard for Security during revenue service to protect the public, Passengers and employees
- Guide the identification and assessment of all activities affecting security

The Regulatory Working Group will have responsibility for the following:

- Ensuring that a Security Threat Assessment is conducted on the OLRT and that the outcome is addressed as a part of the SeMS
- Providing direction for security activities
- Participating in management discussions regarding security
- Managing, coordinating and scheduling security meetings
- Executing the RTG and OC Transpo SeMS and ensuring it is understood by the City to allow submission for the Operating Permit
- Revising the SeMS, its schedule and maintaining document control as necessary

SeMS requirements are derived from Transport Canada guidelines for Urban Transit Security with input from experts in transit security. The SeMS will be part of RTG and OC Transpo's means for ensuring OLRT safety and security. The SeMS is comprised of elements providing ongoing Security Assurance and allowing ongoing review and assessment of threats:

- **Security Policy** – This Policy from RTG and OC Transpo gives direction to the Regulatory Working Group for the SeMS to ensure that security is a priority. It gives the organization direction on how to do the following:
    - Be mindful of security along the entirety of the OLRT system
    - Meet mandatory requirements and good industry practice in maintaining a secure operation

- Establish a SeMS clearly allocating accountabilities and responsibilities to the Regulatory Working Group
- Maintain a consultative program with external agencies that share responsibility for security in the community
- Identify all significant risks to security and plan how to reduce these to acceptable levels
- Work in partnership with each other and third parties to continuously improve OLRT security standards

- **Security Planning** - Annual planning with reviews of OLRT security risks will focus on making risk assessment a standard practice. Additionally, special focus is placed around special City events to ensure that reasonable measures are taken in compliance with other security agencies.
- **Training** - Implementation of an effective security training program.
- **Incident management** - Implementation of a formal structure for managing incidents will include emergency response plans with review and agreement with emergency response agencies, investigation processes and cooperation processes for those investigations requiring liaison between various parties and mandatory reporting. The Regulatory Working Group will review all emergencies and incident records to assess whether system or procedural improvements are warranted.
- **Corrective/Preventive Action** - Implementation of procedures to correct deficiencies or make improvements in security, to manage and document all necessary changes including changing procedures, to notify affected personnel, to retrain if required and follow up for monitoring.
- **Audits** - A formal process for assessing security and auditing security aspects of procedures. This will apply to all audits whether conducted by RTG and OC Transpo staff or on their behalf. Audits will review all key elements of the SeMS and comply fully with the stipulated requirements of the Delegation Agreement.
- **Initial threat assessment** - Independent security specialists will conduct a comprehensive system-wide security threat assessment on the OLRT, identifying threats to Passengers, employees and others and suggesting mitigation for unacceptable or undesirable risks. The Regulatory Working Group will maintain a log of vulnerabilities and suggested mitigating actions. Systematic risk assessment is core to the SeMS. Any change to infrastructure, Vehicles or main operating procedures will require review to understand any security impact and agree on and establish appropriate controls. This process involves all necessary internal groups and external agencies to assess risks accurately and confirm appropriate mitigating actions. Threat analysis and risk assessment methodologies will be used to minimize risks and identify appropriate controls and mitigations. The system-wide risk assessment will be based on Transport Canada's guideline, "Transport Canada Rail and Urban Transit Security Threat Risk Assessment Guideline", or as deemed appropriate by the City.
- **Ongoing threat assessment** - The security threat assessment is an ongoing assessment based on known vulnerabilities and police input relative to known threats. A threat escalation process is maintained and implemented commensurate with identified need. At least one member of the Regulatory Working Group will require security clearance to receive sensitive information.
- **Review process** - Security and the SeMS will be reviewed periodically for identified risks, recommendations, incidents and corrective actions.
- **Document controls** – These will restrict SeMS access to appropriate personnel.

Security Training

The proposed competency management and training model applies to the SeMS. Security training will be provided for all staff in one of three streams. The first stream will be for general awareness associated with security on the OLRT and the obligations pertaining to all employees. The second stream will be for all OLRT employees, who will attend a course given as foundation in security management principles and their role in helping to monitor activities along the OLRT. The third stream will be for all Regulatory Working Group members involved in the Risk Management processes of RTG and OC Transpo, who will undergo additional training in their responsibilities. All staff will have security training when joining the OLRT Project and additional security briefings when undertaking new tasks or for any change to process, activity or legal aspect of their roles where security is an issue. All employees will require refresher security training at regular intervals, which will be scheduled as part of their training matrix.

Visitor and Subcontractor Training

Managers admitting visitors and subcontractors will be responsible for ensuring the following:

- Visitors receive and visibly display a badge at all times while on premises, and are escorted while on OLRT property. Visitors will be the responsibility of the person accepting them on premises.
- Subcontractors expected to work on OLRT property without continual supervision receive training appropriate for their work location and activities.

Security Materials

Security policy and procedures will be in accordance with the Railway Safety Act and its interpretation by the City as well as by policing agencies. Additionally, input will be taken from external agencies and organizations such as Transport Canada, which sets standards for railway operations. We will make extensive use of security materials provided by such groups, including training materials. In some instances, security materials may be developed by the Regulatory Working Group specific to the operational needs of employee groups.

Security at MSF

Identification Badge

RTG and OC Transpo employees must be able to produce identification (ID) issued to them as a condition of employment. This ID badge will activate a network of secure gates and doors. At the MSF, only employees with permission to enter restricted areas (e.g. electrical equipment rooms, Control Room), will have badges programmed to allow this entry. Additional security measures will be taken associated with managing employee badge loss and deactivating them.

MSF Exterior Physical Security

The perimeter will be fenced to delimit the premises and deter intrusions. The fence will be armed with intrusion-detection technology and the perimeter and yard will be monitored with cameras. Ornamental plants (e.g. bush, trees, and flowers) will be maintained in a way not to neutralize the current security system; for example, bushes will not be planted to obstruct surveillance or to prevent intrusion detection. Crime Prevention through Environmental Design (CPTED) principles will be used to assist in this function. The use of a clear zone around the perimeter of the facility will improve natural surveillance and increase the probability of detection.

Perimeter Gates

All gates will be reception controlled at entrance and with control room backup. Authorized entry to the MSF site will be made via ID badge.

Outside Detection System

An electronic detection system and additional sensors will monitor the perimeter fence and inside the fenced area to detect unauthorized entry and suspicious activity.

Video Surveillance System

Video surveillance (network video recorder, mobile cameras and fixed cameras) will monitor key areas of the MSF Building and each Station for full coverage of public areas. Images will be viewable from the Control Room and other established areas. The CCTV system used on the OLRT will be designed to monitor operation for safety and security.

Video Records

Video records are a sound evidentiary tool that can assist law enforcement and others in investigations of incidents, but remain a reactive measure to most security incidents. Guideway intrusions will trigger cameras at Stations, as will certain alarm conditions, and bring up images for Control Room personnel. The Regulatory Working Group will establish operating practices for the retention of any recorded images, consistent with regulations and operating permits.

Security Control – Main Building

To protect against internal employees having access to sensitive areas of operations, certain security protocols and equipment will be protected with secondary access restrictions.

Security Needs Analysis

Every OLRT job classification will require some level of security awareness and training. It is anticipated that assigned levels of security alert by policing agencies will change from time-to-time including during special events which may necessitate a different level of vigilance and staffing associated with security. These will be addressed via a Security Escalation Process to be developed by the Regulatory Working Group.

Access Control

The OLRT will have different levels of access restriction. As shown in **Table 5.1-15**, personnel will have screening conducted appropriate for the level of access given. The Regulatory Working Group will determine who should receive keys and access to the any parts of the line and develop a system for recording and tracking same.

Table 5.1-15 | Access Restrictions by Zone

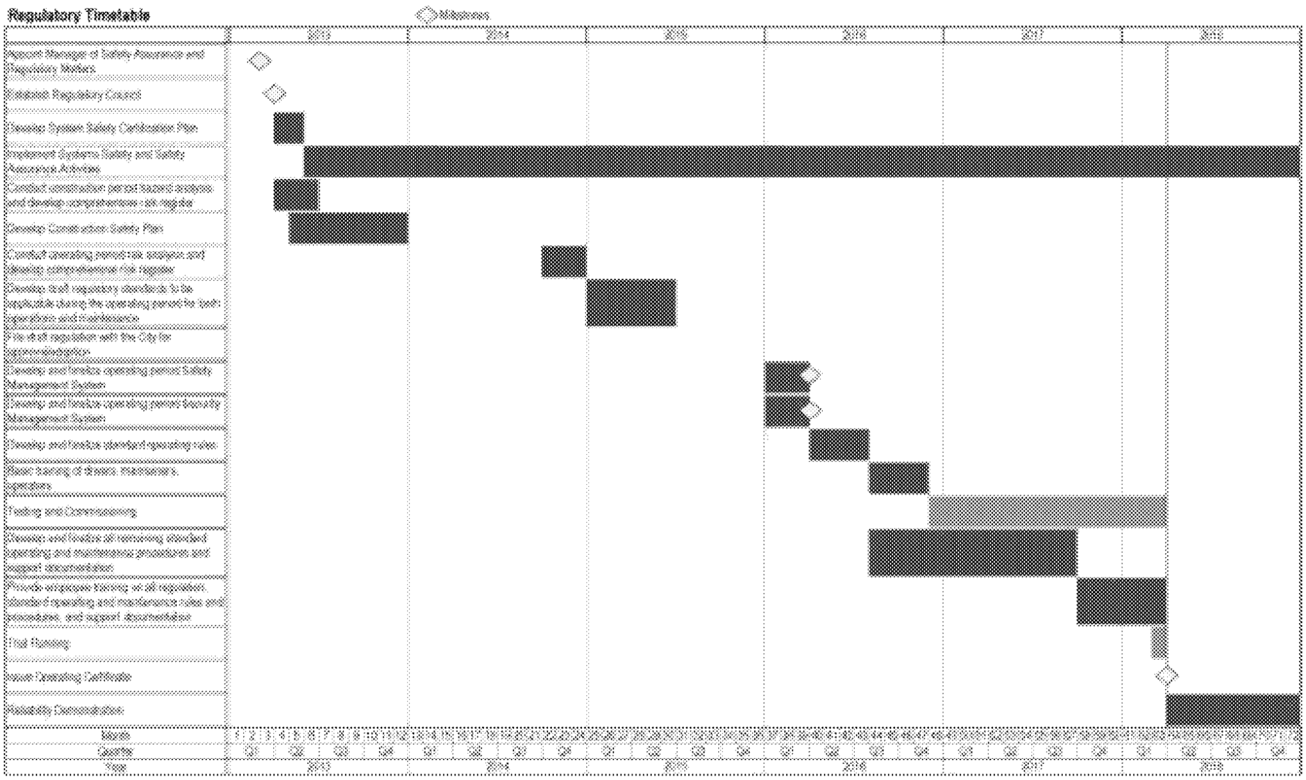
Zone	Access	By
1	To enter main compound and facility	Badge
2	Zone 1 plus Control Room	Badge
3	Zone 1 plus Common Areas of station facilities	Badge
4	Zone 1 + Zone 3 plus Ancillary Spaces	Badge
5	Security holding room at stations	Police only with Badge/key
6	All zones	Badge/keys

Preliminary Regulatory Timetable

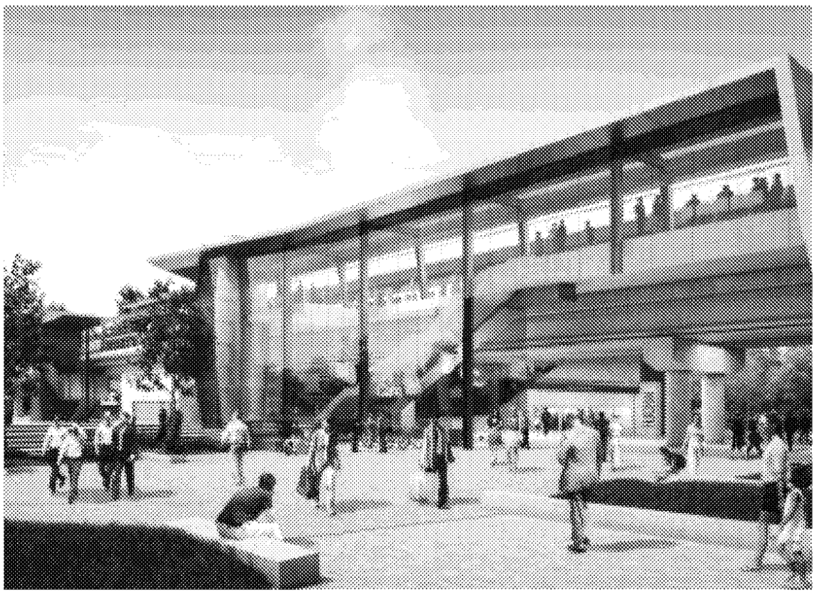
The preliminary regulatory timetable is shown in **Figure 5.1-3**.

COW0544752

Figure 5.1-3 | Preliminary Regulatory Timetable



5.2 GUiDewAy DeSiGn



5.2 GUIDEWAY DESIGN

Rideau Transit Group's (RTG) lead design team members SNC-Lavalin and MMM Group will deliver a complete guideway design solution tailored to suit the OLRT Project and to effectively integrate the structural, civil, alignment, trackwork, systems and landscape elements. Designed to optimize Vehicle performance and enhance Passenger ride comfort, the alignment offers the following features that distinguish RTG's solution:

- A solution geared to Alstom's Citadis 100% Low Floor Light Rail Vehicle, with a top operating speed of 100 km/h: the only service-proven vehicle to meet both top speed and 100 percent low-floor criteria.
- A Vehicle and alignment solution that achieves an end-to-end trip time under the 24-minute requirement (including dwell times at Stations)
- A refined Station and alignment configuration at the Blair terminus Station that supports 105-second operating headways
- An integrated alignment, Station and Vehicle solution based on operating a modular two-car 97.5 m Vehicle consist, fitted to a 90 m-long platform during operating scenarios one and two, and requiring only a 10 m Vehicle and platform extension to fully meet the Ultimate Ridership demand

RTG's integrated guideway, Stations and Vehicle design solution offers superior Passenger comfort, efficient and reliable service, improved urban integration, and reduced future system-expansion costs.

5.2.1 GEOMETRIC DESIGN BRIEF

Horizontal and vertical alignment design is based on performance, Passenger comfort, Vehicle criteria, safety, and maintenance factors. Track geometry has been designed to optimize speed, track centre spacing and curve transitions, while following design guidelines in Project Agreement (PA) Schedule 15-2, Part 2, AREMA Track Standards, and the recommendations of TCRP Report 57.

5.2.1.1 Horizontal Alignment Design

Vehicle Criteria

The horizontal alignment design is limited by the design Vehicle specifications. The following criteria are based on the selected Alstom Citadis Vehicle:

- Minimum distance from platform to horizontal curves = 15 m desirable minimum; 12 m absolute minimum based on maximum track centres
- Roll rate = 1.0 deg/sec desirable; 2.0 deg/sec maximum
- Twist = 0.0019 radians/m desirable; 0.0038 radians/m maximum
- Mainline = 150 m radius, desirable minimum; 95 m radius, absolute minimum
- MSF connecting track = 55 m radius minimum
- Yard track = 35 m radius minimum

- Turning radius of Vehicle = 25 m radius minimum

Performance

The horizontal alignment has a maximum design speed of 100 km/hr. Speed is optimized for end-to-end run time and switching at the terminal Stations, and emergency crossovers are designed and located to meet operational and single-tracking requirements. Crossovers at terminal Stations are designed and located to meet operational headways and turn-around times including the realignment of special trackwork closer to Blair Station for lower turn-around times. These design factors allow consistent and optimal Train service between Stations and throughout the system.

Passenger Comfort

Passenger comfort is based on many factors. Our horizontal alignment design meets the following comfort criteria drawn from the PA and from our own experience. Wherever possible, desirable criteria were incorporated.

- Length of fully super-elevated horizontal curve = greater of 30 m or 0.5 V desirable
- The desired and maximum actual super-elevation = 150 mm for ballasted track, direct fixation or embedded track
- The maximum unbalanced super-elevation = 75 mm desirable; 115 mm maximum
- Lateral acceleration = 0.05 g desirable; 0.075 g desirable maximum; 0.1 g absolute maximum
- Lateral jerk = 0.034 g /sec desirable; 0.05 g /sec maximum
- Roll rate = 1.145 deg/sec desirable maximum

Safety

Train speed through tangents and curves is determined by the geometric design. The selection of unbalanced super-elevation of 115 mm will ensure that the design is well within safe-speed criteria. Sight distance is not a requirement based on the Automatic Train Protection system.

Maintenance

Geometric design has a strong influence on constructability of trackwork and track maintenance. The following criteria take into account constructability, physical Train negotiation, and track maintenance:

- Tangent length beyond switch/frog for horizontal curves = 5 m ahead of switch point and beyond last long ties; 2 m beyond heel of frog under constrained conditions, minimum
- Tangent length beyond switch/frog for vertical curves = 3 m ahead of switch point and beyond last long ties; minimum
- Tangent length between back-to-back switch points = 20 m preferred; 12 m minimum based on maximum truck centres
- Transition zone between ballasted and direct fixation track for special trackwork = 50 m desirable.
- Wheel curving force considerations at special trackwork = 0.04 g lateral acceleration desirable; 0.05 g maximum.
- Curves less than or equal to 145 m will be protected by restraining rail.
    - Restraining rail in the MSF yard is not a requirement as the speed is limited to 15 km/h in non-revenue territory.

5.2.1.2 Vertical Alignment Design

Vehicle Criteria

Vehicle specifications and performance influence the design of the vertical profile of the track. The design Vehicle presents the following design criteria to vertical curves and tangents:

- Minimum distance from platform to vertical curves = 15 m desirable minimum; 12 m absolute minimum based on maximum track centres
- Vertical tangents = 12 m absolute minimum based on maximum truck centres

- Sustained unlimited length grade = 4.0 percent maximum
- Maximum sustained grade up to 750 m = 6 percent maximum

Performance

System performance is influenced by the vertical grades on which the Trains travel. For mainline and MSF connecting tracks, the desirable maximum grade is 4.5 percent and the maximum design grade is 6.0 percent. Due to geometric constraints in the MSF connection track, there is a 150 m section of track at 6.0 percent grade. The maximum grade for MSF storage tracks is 0.3 percent but the designed grade is 0.0 percent for the entire yard.

Passenger Comfort

Passenger comfort is taken into account in the design of vertical curves and follows these criteria:

- Length of crest curves = 30 A preferred minimum; 0.005 AV^2 minimum
- Length of sag curves = 30 A preferred minimum; 0.003 AV^2 minimum
- Vertical acceleration = 0.018 g desirable minimum based on AREMA Sub-Committee 8 recommendation
- Vertical tangents = greater of 0.57 V or 30 m desirable

5.2.2 APPROACH ALIGNMENT INTO THE STATIONS

Trains approaching Stations often navigate through both horizontal and vertical curves. The horizontal alignment is designed such that a minimum horizontal tangent length of 15 m is provided beyond all Station platforms to provide sufficient running clearances between the Alstom Citadis Vehicle and the platforms. Similarly, a minimum vertical tangent length of 15 m extends from each platform.

Geometric constraints such as overhead structures and underground utilities at Tunney's Pasture, St. Laurent, and Blair limit the vertical elevation the track can be designed, while transit structures and Station design requirements influence the positioning of the Station and the horizontal alignment going into Stations.

5.2.3 TRANSITION BETWEEN VARIOUS GUIDEWAY TYPES

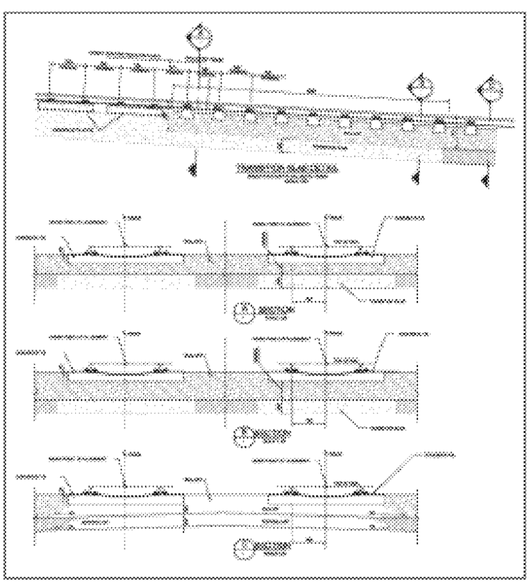


Figure 5.2-1 – Transition between Direct Fixation and Ballasted Track

Direct fixation is provided in the downtown tunnel, on the twin-cell culvert through Tunney's Pasture, through the Bayview aerial section, and on the Rideau River Bridge. Direct fixation was also used for the VIA Rail underpass on the MSF connection track. Ballast has been used everywhere else.

There are various guideway transitions, including at-grade to underground, and at-grade to aerial. The guideways transition between direct fixation (DF) track and ballasted track as shown in **Figure 5.2-1**. A reinforced concrete transition slab of 6 m minimum will be used at the end of the DF tracks to gradually transition from the relatively stiffer DF track to the relatively softer ballasted track and avoid an instantaneous change, which would cause "hammering" on the track structure and settlement of the ballast and subgrade. The concrete tie spacing will be reduced to 685 mm to provide additional stability and an increased track modulus (a measure of the vertical stiffness of the rail foundation), subject to detailed design. The track modulus for DF has been chosen to be in the same order of magnitude as ballasted track to minimize track deterioration, and ballasted track settlement is contained by using the transition slab. Periodic inspection and resurfacing will be required to avoid "pumping" track conditions during operations. The transition between track types is a proven design based on our experience in Calgary and Edmonton, where track and supporting infrastructure do not degrade prematurely at these transitions.

5.2.4 MITIGATION AGAINST SNOW, ICE BUILD-UP & VEGETATION DEBRIS

For safe and reliable operation, our track design approach uses a combination of architectural landscaping, guideway design, track geometry, track structure, and periodic maintenance of the track formation to minimize the build-up of snow, ice, and vegetation on the track and guideway.

In winter, hot-air switch blowers in the MSF will be used to maintain switch operations. A positive cross-slope of 3 percent on ballast and sub-ballast and a positive cross-slope of 2 percent on at-grade base slabs, aerial structures, and tunnel structures will carry water away from the track structure. Positive drainage along the length of the guideway and periodic inspection and maintenance of track formation and drainage outlets will ensure proper drainage. Proper drainage of ballasted track allows particles and debris to flow out of the ballast, whereas improper drainage leads to contaminating and eventual deterioration of the track structure. Plinths in DF track also help prevent accumulation of precipitation and vegetation growth. A higher track elevation relative to adjacent land will be maintained where possible and the height of rail from guideway surface will be optimized. Where there is anticipated vegetation growth or migration of fines from surrounding soils, track ballast will be separated from existing ground in open-cut areas with geotextile fabric. Leaf drop on the guideway will be minimized by providing appropriate architectural landscaping and selecting vegetation that requires minimum maintenance. Vertical grades and the length of excessive grades that are not protected from the environment will also be minimized, especially where we anticipate vegetation debris.

5.2.5 VEHICLE DYNAMIC ENVELOPE

The vehicle dynamic envelope of the Alstom Citadis Vehicle addresses all Vehicle failure modes under the worst case scenario of Vehicle failure and track conditions. The established clearance envelope included all track construction tolerances, curving effects of the Vehicle with the maximum assumed super-elevation and the vehicle running clearance. The structure gauge used by RTG to develop the track centres and clearances to structures included the clearance envelope, structure construction tolerances, as well as the required clearance to structure as established by PSOS standards.

Calculations have been performed to meet all Vehicle clearance requirements while optimizing the at-grade, underground, and aerial guideway design. The clearance envelope is the space which only the Vehicle can occupy and the structure gauge is the minimum distance between the centreline of track to a point on a structure. The formulas for calculating these are shown below, along with the calculated clearance envelopes and structure gauges based on the design Vehicle:

- **CE (Clearance Envelope) = VDE+TT+C&S+RC**, where:
  - VDE = vehicle dynamic envelope
  - TT = track construction and maintenance tolerances of 37 mm
  - C&S = vehicle curve (inswing and outswing) and super-elevation effects of 100 mm
  - RC = vehicle running clearances
- **SG (Structure Gauge) = CE+SC+ST+AA**, where:
  - CE = clearance envelope
  - SC = required clearance to wayside structure
  - ST = wayside structure construction tolerance
  - AA = acoustic allowance

By taking into account running and wayside clearances and construction tolerances, the minimum track centres can be determined. The emergency walkway is also a factor in the running clearance and is measured to the Vehicle envelope.

The walkway envelope is 610 mm wide at grade level, 760 mm wide at 1.42 m height, and 610 mm wide at 2.025 m height based on NFPA 130.

The vertical clearance from top of rail to overhead structures is 4500 mm nominal with a minimum of 4460 mm under transit structure at Tunney's Pasture. The nominal clearance from top of rail to tunnel roof is 4700 mm using rigid conductor rail.

5.2.6 MINIMIZING STRAY CURRENT

The level of stray current is determined by the linear resistance of the conductors (running rails) to which the negative return current will induce a voltage along the running rail and the resistance of running rails to ground insulation. To minimize the level of stray current, the linear resistance for the negative return current will be made as low as possible for a given rail by providing electrical bonds around moving points and other mechanical connections in special trackwork as well as by providing cross-bonding between tracks to equalize the return current between all rails. The insulation between running rails and the structure or ground will be made as high as possible by providing insulated track fasteners with sufficient and non-bridgeable surface tracking distances between charged and grounded components. Track switches are provided with insulated rods where connected to the rail.

On OCS systems, stray current can never be eliminated but must be minimized. There will always be some stray current which will leave the rail and conduct along the structure to ground. To minimize the corrosive effect of stray current in guideway structures, the metal in the structures will be provided with bonding such that it is electrically continuous along the structure. This will be done by installing continuous bonding conductors along each track, providing bonds to the rebars at most 30 m intervals as well as at any discontinuities of the structures. These measures will ensure the metallic reinforcements in the structure are electrically continuous and allow stray current to flow along the structure, thereby minimizing the stray current flowing into the ground. For ballasted track, isolation will be provided between the running rail and concrete tie. Clean placed ballast will provide additional insulation against stray current. For ballasted track on structures, an insulating membrane will be placed between ballast and structure.

For the mined tunnel, where metal reinforcements in the segments will be difficult to bond together, metallic mesh will be provided in the invert and will be bonded to the continuous bonding conductor to provide a low-resistance path for the stray current to flow, thereby minimizing stray current flow outside the structure.

Proactive and diligent maintenance is key in dealing with stray current. Insulators and fasteners will be kept clean of debris and washed regularly to prevent build-up of rail particles, salt and dirt. Guideway drainage will be designed to prevent standing water.

5.2.7 ACCOMMODATION OF SYSTEM ELEMENTS WITHIN THE GUIDEWAY

System elements including signaling, OCS, cableways, and switch heaters have been designed to fit within the guideway. Signals will be installed around special trackwork, on walls of trenched sections, and are free-standing on at-grade sections. The CBTC wayside radio infrastructure will be mounted on OCS poles or separate poles/mast. OCS poles will generally be between the tracks along the mainline; except in areas where the track diverges and in special trackwork areas. OCS supports mounted on the tunnel ceiling by elastic supports in tunnel and trench areas and underpass sections, transition to elastic supports to accommodate the low vertical clearance. Cableways vary through the system depending on the supporting guideway type. Underground ducts or cable trenches will be used in at-grade sections; cable trays are used in elevated guideway and bridge sections; and cable trenches and embedded ducts will be used along tunnel and trench sections. Electric hot-air blowers and ducts will be mounted adjacent to switch points within the mainline guideways and gas switch heaters and ducts will be installed in the MSF. The various infrastructure supporting signaling and communications equipment and electrification will be designed to effectively service systems components.

5.2.8 CONFIRMATION THAT THE ALIGNMENT IS DESIGNED WITHIN THE LANDS PROVIDED

Where feasible, retaining walls have been specified to ensure that the grading foreslopes and backslopes are contained within the ROW (lands provided). RTG confirms that the alignment is designed within the lands provided except at the locations listed below, which are also identified on the drawings in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**:

- **Grading Easements -** At certain locations along the OLRT alignment, RTG has identified grading easements for the backslope of the guideway ditch. The grading easements are located on City property and are specified to limit the extents of retaining walls and ensure proper drainage of the OLRT guideway.
- **LeBreton Station -** Additional property is required in the southwest and southeast quadrants of LeBreton Station. The additional lands being contemplated belong to the City and appear to be available. Discussions with the City on this property acquisition have been initiated.
- **MSF Access Track -** As indicated on **drawing 1200-41DD-S4-1002-FP**, additional property is required on the east side of the MSF Access Track alignment in the southeast quadrant of the Belfast Rd./Tremblay Rd. intersection. The additional lands being contemplated belong to the City and appear to be available. Discussions with the City on this property have been initiated.
- **OLRT Mainline Alignment -** As indicated on **drawing 1200-41DD-S5-1003-FP**, additional property is required on the south side of the OLRT alignment from approximately 110+160 to 110+350. The additional lands being contemplated belong to the City and appear to be available. Discussions with the City on this property acquisition have been initiated.

5.2.9 ALIGNMENT DRAWINGS

The following alignment drawings are provided in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**:

- Key plan & legend
- Vertical alignment for tunnel
- Continuous plans at no less than 1:1000 scale showing LRT alignments with curve data and locations of key features such as special track sections, turnouts, embankment grading and other key features
- Profiles at no less than 5H:1V and no less than 1:200 vertical scales
- Schematics of guideway types in plan and profile
- Typical sections at major intervals

These drawings are provided as composite drawings showing the trackwork and the guideway drawings to demonstrate coordination between these elements.

5.2.10 STRUCTURAL APPROACH

RTG's structural design approach for new civil structures, modifications to existing civil structures, and the strategy for construction/erection of the proposed structural elements will comply with the PA, with its main focus on achieving the key criteria specified in PA Schedule 15-2 Part 1, all performance criteria specified in PA Schedule 15-2, and the maintenance and turnover requirements specified in PA Schedule 15-3. The design philosophy prioritizes safety and reliability of structures to provide a safe and efficient design, in part by minimizing the required maintenance and eliminating the need for system closure for rehabilitation during the Maintenance Term.

5.2.10.1 Preliminary Design Brief

Design Approach and Criteria

RTG's Design Team understands that PA Schedule 15-2, Part 1, Article 21 represents the minimum design criteria and system requirements based on the Reference Design. Our Team has developed a System-specific set of design criteria compliant to PA Schedule 15-2, in accordance with PA Schedule 3, Part 1, Article 5.2.

This section of the Design Report describes the structural approach to design of the new structures, modification to existing structural elements and the strategy for construction/erection of structural elements. Below, the structural approach narrative demonstrates how the designs will conform to the technical submission requirements.

Design Codes and Standards

The design for new bridge structures carrying the Alstom Citadis Vehicles and the evaluation of existing structures that will carry these Vehicles will conform to the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA-S6-06, supplemented by the AREMA Manual to incorporate LRT and rail structure loading. New bridge structures not subject to Alstom Citadis Vehicle loads will be designed in conformance with CAN/CSA-S6-06 in conjunction with MTO Structural Manual for more site-specific requirements.

RTG's OLRT Bridge Structural Design Criteria will deliver these outcomes:

- Meet the requirements of PA Schedule 15-2, Part 1, Article 21
- Clarify conflicts between reference documents in PA Schedule 15-2, Part 1, Article 21.1 (a) and Article 21.2
- Clarify modifications to CAN/CSA S6 to address fatigue requirements for mass transit systems and the system-specific design
- Clarify modifications to CAN/CSA S6 to address seismic design requirements for mass transit systems and the system-specific design
- Provide the system-specific structural design loads, Live Load Vehicle, Maintenance Vehicle, and live load factors
- Provide criteria for all transient load and rail specific loading not included in CAN/CSA S6

Loads

Bridge structures carrying Alstom Citadis Vehicles will be designed for Alstom Citadis Vehicle loading in accordance with PA Schedule 15-2 and are to be checked for the highway vehicle loading of CL 625-ONT according to CAN/CSA-S6-06. Bridge structures carrying road vehicles will be designed for the highway vehicle loading of CL 625-ONT. Existing structures will be evaluated to determine that they can accommodate both the CL 625-ONT design live load and the LRT live loads. Piers of bridges carrying Alstom Citadis Vehicles that are within 3 m of an adjacent roadway will be protected by suitable barriers or be designed to withstand a static force of 1,000 kN. Bridges over the LRT guideway and the O-Train will be protected by a crash wall if they are within 6 m of the track centreline.

Dynamic Performance Requirements

The design of the proposed new structures incorporates provisions for deflections and vibration control as defined in PA Schedule 15-2. The first-mode natural frequency of flexural vibration for all new bridge structures conforms to PA limits and requirements. Review of the vibrations and deflections for existing structures has been performed based on the criteria specified in PA Schedule 15-2.

Seismic

Per PA Schedule 15-2, new bridge structures will be designed to meet the Emergency Route importance category. Existing bridge structures will be designed to meet the "other bridges" category for seismic loading per CAN/CSA-S6-06, except those listed as exception cases which will be designed to meet the Emergency Route importance category. Existing overpasses proposed to carry the OLRT will be seismically retrofitted in conformance to an Emergency Route importance category if they are not found to be structurally satisfactory for all other loading combinations.

Minor clarification and modifications to the CAN/CSA S6 are required to address seismic design requirements specific for mass transit systems and the system-specific design, including defining the Emergency Route classification and addressing the probability of the presence of live load during a seismic event.

The Emergency Route classification requires, at a minimum, the structure to be open to emergency vehicles immediately after an earthquake with a return period of 475 years. This definition is generally intended for highway structures and, therefore, the following performance criteria (per CAN/CSA S6 Section 4) will be considered in the design. Emergency-Route bridges should be predicted to withstand the major design earthquake event with moderate or less damage, where "moderate damage" is defined as: damage that does not cause collapse of a bridge and following which the bridge can be repaired to full strength without full closure and limited access to normal traffic is available within a few days.

Design Life

All guideway structures, including new and existing bridge structures, new and existing retaining walls and all portions of elevated guideway, will have a minimum Design Life to meet CAN/SCA S6-06 including Supplement No. 1, May 2010. To improve durability, concrete structures with appropriate reinforcement types will be used for new bridges. Consideration will be given to drainage, de-icing and reinforcement corrosion effects on structure design life.

Any existing structure that will support the OLRT system and that does not meet design requirements will be rehabilitated to provide adequate structural capacity, dynamic performance, seismic capacity and the required design life. The seismic retrofit of existing bridges to carry the Alstom Citadis Vehicles will conform to standard practices for rail structures. All bridge structures carrying these Vehicles will have a depressed approach slab to permit the transition between ballasted track and the DF track used on the bridge structure.

New Structures

Pedestrian Bridge Adjacent to Holland Avenue

The new Pedestrian Bridge will allow for pedestrian flow above the transitway at Tunney's Pasture Station. The bridge structure will be west of the existing Holland Avenue Bridge; will span the same distance of approximately 24 m and have a similar depth to that of the Holland Avenue Bridge. Bridge design will be closely coordinated with Station design.

Booth Street Overhead Bridge

The new Booth Street Bridge will allow road traffic to overpass the OLRT, LeBreton Station and the adjacent aqueduct. The general arrangement and structural details for the proposed structure are shown in the appended structural drawings. Key design considerations include the location of the existing subsurface covered aqueduct crossing, the existing cycling and pedestrian pathways along the aqueduct, the existing subsurface utilities crossing under Booth Street, and the integration with LeBreton Station. Structural analysis was performed to ensure the proposed structure will meet PA loading requirements. Preliminary response spectrum analysis was performed to ensure the structure will meet the seismic importance category of Emergency Route structures, as defined in CAN/CSA-S6-06. To provide structural stability and avoid conflict with the existing aqueduct and utilities below, we propose drilled caissons, socketed into bedrock, for pier foundations. To protect for future adjacent development, we propose retained soil system (RSS) walls to run the length of both the north and south bridge approaches.

Hurdman West Elevated Guideway and Hurdman Station Guideway

The Hurdman Elevated Guideway is a new structure running from the south approach to the Rideau River Crossing to the east end of Hurdman Station. The elevated guideway is immediately adjacent to Hurdman Station, a Federally Mandated Station. A context-sensitive design approach has been implemented for the guideway, considering Hurdman Station's architectural theme and surrounding features. Design features include: an open structure; low profile/slender superstructure, consistent substructure details, and open railing. The proposed design addresses the poor subsurface conditions and the potential high corrosiveness of the soils. RTG has investigated an alignment to optimize the design and cost of the elevated guideway and minimize overall impact on adjacent lands. The proposed alignment involves implementing approximately parallel alignments spaced at 4.2 m through the curved part of the Hurdman Elevated Guideway and alignments spaced at 4 m in the vicinity of Hurdman Station. The general arrangement of the proposed elevated guideway includes: a single superstructure with composite concrete deck, CPCI prestressed beams, shared substructures, ballasted track, centre-mounted catenary, deep foundations-drilled caissons to bedrock, vertical and horizontal clearances to meet the requirements for the joint use and future access road crossing below the elevated guideway.

Hurdman East Overpass

The Hurdman East Overpass is a new structure east of Hurdman Station. To reduce overall structural width and costs, our proposed guideway alignment consists of parallel alignments spaced at 4.2 m through the structure. The general arrangement for this structure includes: a precast girder structure, centre-mounted catenary, and vertical and horizontal clearances to meet access road requirements.

East VIA Loop Bridge

The East VIA Loop Bridge is a new structure east of Train Station. The proposed general arrangement for this structure includes: concrete jointless rigid frame, light pole and sidewalks on the deck to continue existing services.

MSF Access Track

The MSF line connects eastbound and westbound OLRT lines to the MSF, located south of the Via Rail line. The track profile is below existing grade and requires structures along a length of approximately 420 m.

The alignment is under and adjacent to Belfast Road and a high-voltage overhead power line runs along the alignment to the east and crosses to the west just prior to the VIA Rail grade separation. RTG's design proposes a single-cell, single-track, cut-and-cover tunnel; a two-cell, dual-track, cut-and-cover tunnel U-section founded on rock; and finally a single-cell double-track tunnel crossing under the Via Rail lines. Due to the double sump nature of the tunnel and its low relative elevation, drainage will be captured at the sumps and pumped to the sanitary sewer on Tremblay Road. The known swelling characteristics of the Billings shale comprise a geotechnical constraint on design at this site. The issue has been addressed through a design that mitigates groundwater drawdown so that the shale is not exposed to oxygen.

Modifications to Existing Structural Elements

West Transitway Twin-Cell Box Culvert

The existing West Transitway Twin-Cell Box Culvert is a reinforced-concrete box culvert constructed below the existing transitway approximately between Northwestern Avenue and Merton Street. The general arrangement and structural details for the proposed structure are shown in the appended structural drawings.

Based on both the Condition Assessment and Renewal Options Analysis Report by McCormick Rankin Corporation (2005) and the Renewal Options Report by Delcan (2010), RTG has noted the following significant issues pertaining to the existing structure:

- Damage to waterstops and foam joint filler at many expansion joints, spaced every 30 m
- Deterioration of concrete and corrosion of reinforcing steel within the haunches adjacent to many expansion joints
- Localized concrete deterioration of the interior slab soffit and walls
- Erosion of the concrete walls near the waterline in the north cell of the culvert
- Deterioration of concrete and corrosion of reinforcing steel within the slab soffit adjacent to many catch basin inlets

Structural analysis was performed to ensure the existing culvert has adequate capacity to support both highway vehicle loading and the proposed Alstom Citadis Vehicle loading. This analysis included the effects of directly fixing plinths to the existing top slab of the culvert. The culvert is structurally sufficient, but requires rehabilitation: removing and replacing the existing expansion joints, and localized partial-depth concrete removal and repair, including removing and replacing corroded reinforcing steel as deemed necessary. Additionally, the existing asphalt and waterproof membrane will be removed to allow for DF of plinths to the existing structure. Exposed concrete will be waterproofed with an epoxy base or methyl methacrylate concrete sealer or equivalent.

Bayview Road Overpass

The existing Bayview Road Overpass is a reinforced-concrete rigid-frame structure with a single span of 23 m that allows the existing West Transitway to travel over Bayview Road. Based on the Bayview Road Overpass visual inspection report produced by Capital Transit Partners, RTG has noted the following significant issues pertaining to the existing structure:

- Isolated light-to-medium spall on the west abutment at the southwest corner
- Isolated cracks in the RSS wall's precast panels
- Localized settlement on the existing approaches potentially caused by leaking catchbasin drain pipes

In addition to these defects, we anticipate localized deterioration due to aging of the reinforced-concrete deck and abutments.

Structural analysis was performed to ensure the existing structure has adequate capacity to support both highway vehicle loading and the proposed Alstom Citadis Vehicle loading. The bridge is structurally sufficient but requires rehabilitation: retrofit to the existing deck, replacement of the existing approach slabs, localized partial-depth concrete repairs where necessary, repair to the leaking catchbasin drain pipes, and repair to the segmental RSS panels.

West Transitway CPR/O-Train Overpass

The existing West Transitway CPR/O-Train Overpass is a three-span, cast-in-place, post-tensioned, voided-deck slab structure that allows the existing West Transitway to travel over the CPR and O-Train tracks. Per PA Schedule 15-2, the existing bridge is to be removed and replaced with a new Bridge structure.

Key design considerations include the vertical and horizontal clearance to existing rails found below the structure, a potential future O-Train connection with the OLRT, a potential future northerly interprovincial extension of the O-Train, a potential future double-tracked electrified light-rail line and platform which would replace the existing O-Train spur line, and integration with Bayview Station.

Structural analysis was performed to ensure the proposed structure will meet PA loading requirements. Preliminary response spectrum analysis was performed to ensure the structure will meet the seismic importance category of Emergency Route structures, as defined in CAN/CSA-S6-06. The proposed design for the new structure includes four spans, with a maximum span length of 20.25 m based on the additon of a new centre pier. The addition of the new pier allows a more efficient and cost-effective design by coordinating spacial requirements with the Station and optimizing superstructure depth. The proposed span arrangement provides adequate clearance to meet the horizontal clearance requirements of the potential future rail extensions below the structure, and is to be integrated with the Bayview Station structure.

Mann Avenue Subway

The existing Mann Avenue Subway is a steel girder structure with a single span of 26.2 m that allows the existing Transitway to overpass Mann Avenue. Based on the Mann Avenue Detailed Bridge Condition Survey and Renewal Options Report produced by Genivar (2011), RTG has noted the following significant issues pertaining to the existing structure:

- Localized coating failure with corrosion of steel girders at girder ends and light surface rust on girder coatings at various locations
- Leaking expansion joints
- Corrosion of fixed bearings at south abutment
- Localized concrete deterioration of various structure components including parapets, sidewalk, the deck underside, abutment walls and wingwalls
- Deterioration of the north approach slab

Structural analysis was performed to ensure the existing structure has adequate capacity to support both highway vehicle loading and the proposed Alstom Citadis Vehicle loading. In addition to issues listed above, it is noted that the welded plate on the bottom flange of the steel girders may be prone to fatigue. Analysis shows that fatigue is not a concern for either the highway vehicle loading or the proposed LRT Vehicle loads and their associated number of loading cycles. Overall, the bridge is structurally sufficient but requires rehabilitation: retrofit to the existing deck, replacement of expansion joints, replacement of bearings, reconfiguration of existing abutments to provide a semi-integral connection, replacement of existing approach slabs, localized blast cleaning and recoating of existing steel girders, localized partial-depth concrete repairs where necessary, and localized replacement of approach guardrails.

Rideau River Crossing

The existing Rideau River Crossing comprises a three-span, post-tensioned, concrete voided-slab structure. The longitudinal articulation is fixed at the north pier and free at the abutments and south pier. The structure currently carries two 4.0 m transit lanes and two 2.41 m pathways across the Rideau River. The pathway is separated from the transitway by concrete barriers.

To meet asset preservation requirements, an extensive rehabilitation of the existing structure is required to achieve a BCI of 90 at five years of service life. The proposed cross-section of the rehabilitated structure maintains existing pathways and light poles and replaces the barrier wall with parapet wall and chain link fence above, to separate guideway and pathways. RTG's structural review found that the structure meets ULS and SLS requirements under gravity and live load with load rating/restrictions for specialty maintenance equipment. The assessment of the first-mode natural flexural frequency indicates the structure meets vibration criteria. To meet seismic design requirements for another route classification, retrofitting of the structure is required:, including expansion joint replacement and new seismic isolation bearings.

Riverside Drive Overpass

Built in 1986, the existing Riverside Drive Overpass is a slab-on-steel girder bridge with a total deck width of 13.05 m. The reinforced-concrete deck is 225 mm thick and is supported on 8 WWF steel-plate girders. The existing cross-section includes two 4 m lanes of vehicle traffic, a 1000 mm safety curb and barrier system, a 2500 mm bikeway with a 350 mm wide curb, and a barrier system on the north side of the roadway. RTG's structural review found that the structure meets ULS and SLS requirements under gravity and live load with load rating/restrictions for specialty maintenance equipment. The assessment of the first-mode natural flexural frequency indicates the structure meets vibration criteria. The proposed seismic bridge retrofit includes conversion to semi-integral abutment, bearing replacement and construction of new keeper blocks. The proposed bridge retrofit also includes placement of rail plinths and centre-mounted catenary.

Cyrville Drain

RTG proposes a new precast culvert structure for this location, which will accommodate the placement of ballast and centre-mounted catenary.

Existing Road Bridges Over LRT Guideway

Preliminary review of structure geometry found that all existing overhead bridges have adequate clearance for the Alstom Citadis Vehicle to travel below. It is likely that the overhead catenary system can be supported on columns adjacent to these existing structures; however, the mounting of protective fencing and catenary shrouding frames on the superstructure may be required. Design will proceed based on the assumption that minor modification to these structures may be required.

5.2.10.2 Proposed Construction or Erection Strategy

The proposed structures consist of CPCI girders supported on cast-in-place piers composed for two columns and a pier cap. Each pier column will be supported by a single cast-in-place drilled caisson with the exception of Hurdman East Overpass which is supported by H-piles and the East Via Loop Underpass which is a rigid frame.

Due to the similar structural typology, the construction techniques considered could be standardized for all structures; however, the construction approach will have slight differences due to the boundary conditions.

West Transitway CPR/O-Train Overpass

The existing structure will be removed with conventional means, maintaining the abutments and pier foundations which will be extended to integrate the Station into the structure. Caisson installation for the new middle pier will be done with standard methods. The work sequence will start with conditioning the access so the caisson rig reaches the location of boring. Once the rig is in place it will drill the caisson. Once auguring is complete, the drill rig will give way to a crane that will put the rebar cage in place. The third stage is the concrete pouring, which will be achieved by direct placement or concrete pump.

Hoisting for pier and cap pier construction can use standard methods with only minor works to facilitate access. Cast-in-place concrete piers will be constructed using contemporary steel forms to provide a high level of finish and uniform appearance. The sequence will include the assembly of half of the formwork, then the rebar and lastly the second half of the formwork. Once the formwork is closed, concrete will be poured by mobile crane or concrete pump. Depending on the height of the piers this task should be accomplished by one or more stages. The pier caps will be constructed using custom steel forms which will be hoisted and secured, to be followed by rebar and concrete.

Erection of CPCI girders will be carried out with conventional mobile cranes. Minor to moderate works will be required to adapt the area to stock up the girders before their erection. Temporary bracing will be installed to secure the girders. After the girders are in place, concrete planks will be erected. After that, formwork and rebar will be assembled and the concrete will be poured with a concrete pump.

These activities will take place on the north side, keeping the O-Train in service. If required, off peak hours will be used for construction of the eastern span.

Booth Street Overhead Bridge

Caisson installation for piers and spread foundations for the abutments can use standard methods with only minor works to facilitate access. The process will be the same as described before. Construction of the foundation of north abutment and caissons for pier 1 will not affect the heritage bridge over the open aqueduct.

Caisson, columns and pier cap installation of piers 1 and 2 will take place while maintaining BRT services on the existing Transitway by maximizing security measures and using off-peak hours and flagman if required.

The sequence for cast-in-place concrete abutments will include the assembly of half of the formwork, then the rebar and lastly the second half of the formwork. After that, concrete will be poured by mobile crane or concrete pump. The same sequence will be follow for cast-in-place piers and cap piers.

Erection of CPCI girders will be carried out with conventional mobile cranes. The girders will be trucked to the site from the precast yard and lifted into place using mobile cranes; a temporary bracing will be installed to secure them. Once planks, formwork and rebar for the deck are in place, concrete will be pumped.

The construction of the middle span will take place during the night or weekend to avoid disrupting the BRT schedule.

Hurdman West Elevated Guideway and Hurdman Station Guideway

Caisson installation for the elevated guideway and the Station can use standard methods with only minor works to facilitate access.

Columns and pier cap installation and erection of CPCI girders will take place from the north side while maintaining Hurdman Station in operation.

Construction sequences for caissons, abutments, piers and deck are the same as described for West Transitway CPR/O-Train Overpass and Booth Street Overhead Bridge.

Hurdman East Overpass t

H-piles installation can use standard methods with only minor to moderate works to facilitate access. H-piles will be protected from RSS backfill material by a corrugated steel pipe filled with concrete.

Hoisting for abutments and for the erection of CPCI girders will take place from north to south, after construction of retaining walls.

Construction sequences for abutments and deck are the same as described for West Transitway CPR / O-Train Overpass and Booth Street Overhead Bridge

East Via Loop Bridge

According to the Traffic and Transit Management Plan, East Via Loop Road will be closed when construction of the structure starts. Once the earthworks team removes the existing road, spread foundations and cast-in-place concrete abutments can be done. Work sequence will be the assembly of half of the formwork, then the rebar and lastly the second half of the formwork. After that, concrete will be poured by mobile crane or concrete pump.

For the construction of the deck, the formwork will be supported by a scaffolding system. Then rebar will be placed and concrete will be poured by concrete pump.

5.2.11 STRUCTURAL DRAWINGS

Structural drawings are provided in **Package B2 – Design Submission Part 2 – Volume 1 (of 4).**

5.2.12 ROADWAY APPROACH

In conjunction with OLRT construction, the finalized product of the OLRT will require modification and reconstruction to several municipal streets.

5.2.12.1 Design Standards and Criteria

Per the PA, design standards include the Geometric Design Guide for Canadian Roads (TAC – 1999) and the Geometric Design Standard of Ontario Highways (MTO – 1985). Geometric design is based on City guidelines in concert with TAC requirements. All municipal streets outlined in **Table 5.2-4** are considered low-speed as they are posted 50 km/h, assumed design speed of 60 km/h. Cross-sections, horizontal and vertical alignment designs are based on local requirements for the road type (urban collector or arterial road) and design speed. In general, designs follow the guidance of Table 1-5.1 Design Criteria for the Roadway Improvements in OLRT Project, except as noted below.

Horizontal Alignment

The minimum radii used by RTG for roadway design meets TAC Geometric Design Guidelines. The design of the radii also considered the existing use and permitted the safe use of super-elevation rates (4.0 percent maximum) as required for urban settings. Although spiral curve transitions are not a requirement on low-speed roadways in an urban setting, their implementation will be re-evaluated at the detailed design stage to meet Driver comfort and aesthetics.

Vertical Alignment

All geometrics designed by RTG meet the minimum vertical requirements of TAC-1999. RTG's design also avoided the use of flat gradients, where applicable, to promote proper drainage. Minimum K values are based on stopping sight distance (SSD) and comfort control.

Access and Intersection Layout

Intersections (signalized and unsignalized) are designed by RTG to PA requirements: pavement markings, traffic signage, street lighting and traffic control signals as required. Sight distances are designed for sufficient approach and departure sightlines as required by Vehicle movements. Intersection operations including traffic, transit pedestrian, and cyclist movements are also incorporated into the design. The proposed intersection design has been matched to existing conditions to limit the reconstruction impacts of the intersection. Impacts to the Belfast Bridge over the BRT and, therefore does not meet all turning requirements for WB-20.

Cross Section Elements

In accordance with TAC, special-purpose lanes such as bus-dedicated lanes at Tunney's Pasture have been specifically designed to accommodate each design Vehicle. All bike lanes that are required are designed to a width of 2.0 m. In addition to the width requirements for lanes, a minimum cross-slope for normal crown is set at 2.0 percent to facilitate drainage of water from the road.

5.2.12.2 Approach to Municipal Roadway Alteration and Restoration

Table 5.2-1 outlines the municipal streets that are proposed to be affected by the construction work and how the proposed changes will integrate into the revised transportation network.

Table 5.2-1 | Proposed Roadway Alteration & Restoration

Roadway	Design Summary
Tunney's Pasture BRT Ramp	Implementation of OLRT Tunney's Pasture Station now requires that buses on the BRT facility require a new access ramp to connect the existing BRT roadway (located in a trench) to the at-grade transfer station. The two-lane connection to the southwest corner of the new BRT facility consists of 4.0 m travel lanes and a 2.5 m maintenance strip. Horizontally, it consists of two 204 m radii separated by a short tangent section. The vertical alignment has reduced the grade of the BRT ramp which allows smoother operation and better visibility.
Goldenrod Street	A south extension of Goldenrod Driveway connects Yarrow Driveway and Scott Street at the west side of Tunney's Pasture BRT with two 4.25 m bus-only lanes with paved sidewalks, spanning the lower BRT/LRT corridor. The horizontal alignment is straight and the vertical alignment is virtually flat based on the surrounding constraints. The intersection designs at Yarrow Driveway, BRT loop and Scott Street are connected on a slight skew and designed to accommodate movements and sightlines of the City's A-Bus, B-12 standard bus and the double-decker bus.
Scott Street	Scott Street will be widened (3.3 m max.) from Smirle Avenue to Bayview Road along with significant local widening at Preston Street, along Albert, just south of the new LeBreton Station to accommodate dedicated turning lanes and dedicated transit lanes. The horizontal alignment will follow the existing alignment and the vertical alignment is similar.
Booth Street	The construction of LeBreton Station requires vertical realignment of Booth Street with the construction of a bridge for the grade separation to occur. On the approaches, Booth Street has two northbound and two southbound lanes in each direction and a 3.0 m sidewalk on both sides. Because of its use as a transit hub, the cross-section has been widened on the bridge to incorporate two 3.5 m traffic lanes, a 3.0 m bike lane, a 3.5 m bus only lane and a 3.9 m sidewalk. The northbound and southbound lanes on the bridge are laid out in the same fashion. Due to the tangent alignment on the bridge; a 2.0% cross-fall is used to drain the roadway to the median barrier.
Belfast Road	MSF access is achieved through a tunnel under the existing intersection of Belfast and Tremblay Roads. Cut-and-cover construction of this tunnel will require the relocation of two large feeder watermains and a full reconstruction of the intersection. The existing approach from the east and the west (Tremblay Road) consists of through-right and a left-turn lane. The existing approach from the north side of Belfast Road has a right-turn and a through-left lane. The existing approach from the south has a through-left and a through-right lane. The reconstructed intersection will be similar to the existing lane arrangement with the exception that the through-left lane from the south approach is changed to an exclusive left-turn lane. The existing two northbound lanes on the south approach will now be one northbound lane; the other lane will be converted to a southbound left-turn lane. The new lane arrangement at this signalized intersection will provide better intersection function. The reconstruction of Belfast Road to the south will be reduced to a two-lane roadway which will consist of a sidewalk on the west side. The horizontal alignment will match the existing 250 m curve through the existing Belfast/CP Rail bridge and the existing 5% cross-fall before the Belfast/CP Rail bridge.

5.2.13 ROADWAY DRAWINGS

Package B2 – Design Submission Part 2 – Volume 1 (of 4) includes the required set of roadway drawings (including crossing drawings): geometry and general layout, grading and drainage, and roadway components of the guideway municipal roadalterations and restoration associated with the guideway.

5.2.14 TRACKWORK APPROACH

5.2.14.1 Design Methods, Standards & Supporting Design Criteria

Trackwork design is based on performance, Passenger comfort, Vehicle criteria, safety, and maintenance factors, and is in accordance with the criteria in PA Schedule 15-2, Part 2 and Part 6, AREMA Track Standards, and the recommendations of TCRP Report 57.

5.2.14.2 Approach to Installation, Testing & Commissioning of Trackwork Components

After completing factory inspection, proof testing, and routine testing during manufacture of trackwork components, the components are ready for installation and then testing and commissioning.

Site Inspection, Proof Testing and Routine Testing during Installation of Trackwork

Installation of trackwork components includes welding of rail, laying of ballast, DF track construction, and special trackwork construction.

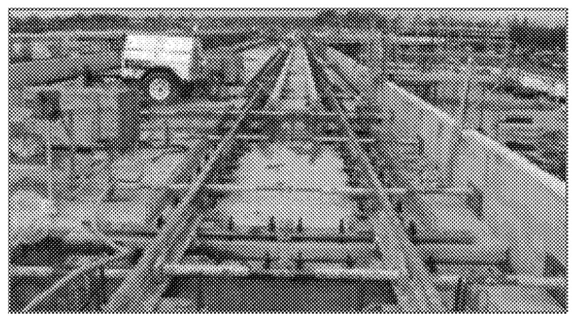


Figure 5.2-2 | Installation of Direct Fixation

Welding of rail using a flash-butt welding process includes inspection and acceptance of welding plant equipment and components, acceptance of procedures for rail handling, rail straightening, rail cutting, rail-end preparation, welding alignment; weld proof testing; and weld production testing based on acceptance criteria established for weld proof-test results.

Ballasted track will be constructed following a prescribed sequence of events: placing initial ballast, placing concrete ties, laying rail and anchoring, surfacing, and aligning. Production testing will include acceptance of the final surfacing and alignment of track including formation of ballast sections.

DF track construction will include setup and construction of base slabs (if required), plinths including placement of dowels and reinforcing steel, placement and securing of female anchor inserts, DF fastener placement, rail installation including field connections, anchoring of continuous welded rail (CWR), final surfacing, and aligning. Proof testing will include the acceptance of equipment, components, process, procedures and qualified personnel. Production testing will include acceptance of the final surfacing, track gauge and alignment of track.

Ballasted special trackwork installation will include placing initial ballast, placing concrete ties, laying special trackwork and anchoring, surfacing and aligning, and fine-tuning for final acceptance. Similarly, DF special trackwork will be constructed following a prescribed sequence of events including setup and construction of second-pour concrete, placement and securing of female-anchor inserts, laying and securing special trackwork on the second-pour concrete, securing of baseplates, surfacing and aligning, and fine-tuning for final acceptance.

Proof testing will include the acceptance of equipment, components, process, procedures, qualified personnel, and installed miscellaneous hardware. Production testing will include acceptance of the final surfacing, track gauge, and alignment of track.

Testing and Commissioning of Trackwork

Testing and commissioning (T&C) of trackwork will include the following sequence of tests and documentation:

- Post-installation commissioning (PICO) of mainline, MSF access, and yard track for track geometry, track gauge, DF fastener bearing surface, formation of ballast sections, spacing of DF fasteners, spacing of concrete ties, and critical clearances to structures and walkways.
- PICO of special trackwork for track geometry, track gauge, track centres, fastener bearing, formation of ballast sections, spacing of fasteners, spacing of concrete ties, and critical clearances to structures and walkways.
- PICO of switch machine interface and operations will also be necessary. Rail profile grinding prior to T&C will remove mill scales.
- Inspection and testing during revenue service will include following a maintenance manual for yearly, quarterly, monthly and regular inspection and maintenance activities by the M&R Team throughout the Maintenance Term.

5.2.14.3 Special Trackwork Design

Special trackwork will be designed to meet operational objectives. Crossovers at Terminal Stations and MSF access will be designed and located to meet operational headway objectives, and emergency crossovers will be designed to meet operational requirements for emergency switching and single-tracking requirements.

A minimum distance from special trackwork to Station platforms, horizontal curves, vertical curves, and transition slabs will be designed to meet geometric criteria. All special trackwork is at least 5 m from point of switch to horizontal curves, 3 m from point of switch to vertical curves, and 15 m from end of Station platforms. The minimum distances from special trackwork to curves is a minimum requirement for constructability and the distance to Station platforms ensures that horizontal clearances from the LRV to the platform are met.

On mainline track, No. 12 tangential geometry turnouts with maximum design speed of 40 km/h will be preferred where site conditions allow, and No. 8 tangential geometry turnouts with maximum design speed of 30 km/h will be used in areas where there are site constraints.

5.2.14.4 Proposed Track Structure/Rail Fastening Systems

Track Configuration

The track type has been designed such that continuous lengths of ballasted track are maximized to reduce transitions that compromise track integrity. Ballasted track will be used in at-grade sections on existing transitway, at-grade sections off existing transitway, at-grade Stations, Stations on embankment designed to carry ballasted track, aerial structures (new and retrofitted) engineered to carry ballasted track, embankment engineered to carry ballasted track, and the existing tunnel at St. Laurent Station. The ballasted track does not compromise performance, and maintenance can be achieved as required in PA Schedule 15-2, Part 2, Article 3.

DF track will be used in the downtown tunnel and Stations, existing aerial structures and Stations that cannot carry dead load of the ballasted track, and at-grade sections that are constrained by underground utilities, soil conditions, and/or overhead structures. Sections of DF track include Tunney's Pasture, where the track is on top of a twin box culvert, the aerial structure at Bayview Station, the downtown tunnel from the West Portal to East Portal, and Rideau River Bridge. DF track will also be used for the VIA Rail underpass on the MSF connection track.

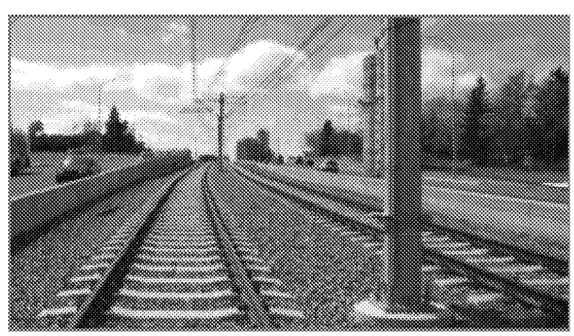


Figure 5.2-3 | Ballasted Track

Ballasted Track Design for Mainline

To ensure that ballasted track can withstand Ottawa's environmental conditions and maintain its integrity under different loads, the ballasted track design complies with the following criteria, drawn from the PSOS and our own experience in Calgary and

Edmonton with similar extreme temperature ranges:

- Ballasted sections will be designed to resist longitudinal and lateral forces based on Ottawa's environmental conditions, Vehicle loadings and thermal forces from CWR.
- Mainline ballasted track will be designed and constructed using precast-concrete cross-ties with resilient rail clips, insulators, and rubber pads.
- Ballast will conform to AREMA crushed stone ballast, class number 4A.
- Ballasted sections on asphaltic concrete (existing transitway), aerial structures, Station platforms, concrete slab, etc. will be constructed with ballast and filter fabric without additional sub-ballast; and placed on a 2 percent slope for drainage away from the track.
- Ballast mats will be installed where vibration mitigation is required on ballasted track.
- Ballasted sections on prepared sub-grade will be constructed on ballast and sub-ballast; with the prepared sub-grade at 3 percent slope for drainage away from the track.
- Ballasted sections at Station platforms will be held in position with lateral braces anchored to the Station platform structure.
- Longitudinal restraint load = 10.7 KN per tie per rail nominal
- Assumed track modulus of concrete tie ballasted track = 34 to 55 N/mm/mm
- Concrete tie spacing on tangents = 760 mm; subject to detailed design
- Concrete tie spacing on curves less than 300 m = 685 mm; subject to detailed design
- Ballast shoulder on tangent and curves greater than or equal to 300 m will be 300 mm minimum
- Ballast shoulder on curves less than 300 m will be increased to 600 mm to provide better lateral restraint to CWR forces.
- Desired load transfer to ballast = 0.45 MPa maximum
- Desired load transfer to sub-grade = 0.14 MPa maximum
- Desired load transfer to asphaltic concrete pavement to be established during detailed design.
- Minimum ballast/sub-ballast depth below tie is less than 400 mm as computed from AREMA standards.

Direct Fixation Track Design for Mainline

DF track is supported on plinths that are anchored to structural deck, tunnel invert or concrete base slab. Longitudinal and lateral forces are resisted based on Ottawa's environmental conditions, Vehicle loadings and thermal forces from CWR. The following design inputs are also used in analysis of DF track:

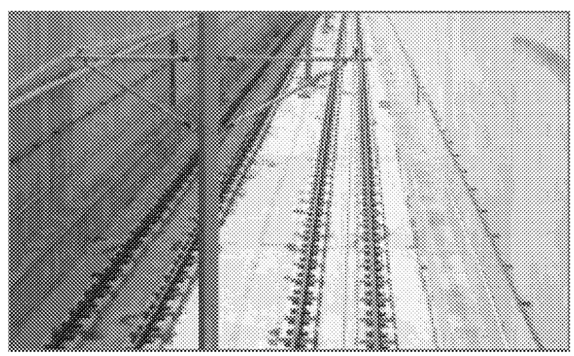


Figure 5.2-4 | Direct Fixation Track

- DF fastener slip load = 9.0 to 13 KN per fastener subject to detailed rail/structure interaction and rail break analysis.
- Vertical spring rate of standard resilient DF fastener = 17 to 22 KN/mm.
- Vertical spring rate of vibration mitigation fastener for noise and vibration control; if required = 9 to 13 kN/mm.
- Floating slab track will be installed where noise and/or vibration is required in DF track and vibration mitigation fasteners are insufficient for reducing noise and/or vibration to acceptable levels.
- Lateral DF fastener stiffness = 4.4 KN/mm, nominal.
- DF fastener spacing on tangents = 750 mm, subject to detailed design.
- DF fastener spacing on curves = 750 mm, subject to detailed design.

See Section "Rail Structure Interaction Design" for rail break analysis.

Rail

New 115RE standard rails with surface hardness of 310 HB will be used on mainline and MSF connecting tracks. Relay 115RE standard rails may also be used on yard tracks, except for rail switches and tracks within the MSF Building limits. All rails will be CWR except in shop tracks and MOW tracks and maximum and minimum rail temperatures will be 58°C and -36°C, respectively. Running rails will be canted at 1:40 slope or 1:20 slope, subject to detailed rail/wheel interface analysis, and running rails in special trackwork will be uncanted. Running rails on mainline track, MSF connecting track and MSF yard track, including special trackwork, will be electrically isolated from the ground.

Rail Structure Interaction Design

The rail structure is designed to control rail stresses due to differential movements between rail and structure and to control rail break gap and resulting loads transferred to superstructure and substructure. Rail stresses must be controlled to ensure safety and minimize maintenance of the rail system. Assuming a neutral rail temperature of 15°C to 24°C for laying tracks, axial forces due to thermal changes is given by the following:

- **$N = EA\alpha T$**, where
  - N: thermal force in the rail
  - E: modulus of elasticity of steel rail = 210,000 Newton/mm^2
  - A: area of rail section = 7258 mm^2
  - α: coefficient of thermal expansion of rail = 1.18 x 10^{-5} per °C
- T_{rise}: temperature rise = 43°C (assumed neutral temperature of 15°C)
- T_{drop}: temperature drop = 60°C (assumed neutral temperature of 24°C)
- N_{rise} (Compressive axial force) = 7.7 x 10^5 Newton
- N_{drop} (Tensile axial force) = 10.8 x 10^5 Newton
- Radial force (95 m-radius curve) = 8.2 kN/m compression; 11.4 kN/m tension.

Rail break gap is computed using:

- **$\upsilon = 2 \times (lc1 + lc2 - lc3)$**, where
  - υ = total rail gap in mm
  - lc1: total displacement if rail is unrestrained = 64 mm
  - lc2: shear deformation of the fastener = 6 mm
  - lc3: reduction in rail displacement over the distance required to develop total restraint force = 32 mm
- υ = 76 mm based on fastener spacing of 750 mm
- "Breathing" length is computed to be about 90 m measured from the free end of CWR

The unbalanced force from the broken rail is resisted by both the unbroken rails and the guideway support in proportion to their relative stiffness. Beyond the "breathing" region, the rail string does not move relative to the guideway structure below.

To meet the rail break gap of 50 mm, the rail-laying temperature will need to be in the range of 10°C, which is not a practical range for laying track during the normal construction period in Ottawa. Further, as rail stress-free temperature must be constant over transition structures, this low laying temperature would also expose ballasted track to high buckling forces in the high heat of the summer.

There is no recognized standard for evaluating the safety of a rail gap in Transit applications. In the interim, ACI Committee 358, Analysis and Design of Reinforced and Prestressed-Concrete Guideway Structures, ACI 358.1R-92, recommends a maximum gap of 50 mm for a 400 mm wheel diameter, and up to 100 mm gap for larger wheels. During detailed design, a rail gap limit will be selected based on the proposed wheel diameter of the selected LRV, which is about 630 mm.

MSF Track Design

Ballasted track design for the MSF yard is similar to mainline ballasted tracks with exceptions, as stated below:

- Vehicle loading will be based on AW0.
- Asphalt concrete paved tracks will be used on grade crossings, service aisles and cart paths.
- Ballasted track spacing will be 760 mm; subject to detailed design.
- DF track at 1000 mm spacing will be used on wash track and VCIF tracks.
- Embedded track will be used on aprons outside of building limits.
- Pedestal tracks will be used in pit areas of maintenance tracks and MOW tracks.
- Rail mounted wheel stops will be used on dead-end maintenance tracks and MOW tracks.
- Minimum ballast/sub-ballast depth below tie is less than 400 mm as computed from AREMA standards.
- No. 6 turnouts at approximately 100 m radius with maximum design speed of 25 km/h will be used on frequently-used MSF switches and No. 4 lateral turnouts at approximately 37 m radius with maximum design speed of 15 km/h will be used on storage, maintenance and MOW tracks.

Interaction with the Elevated Guideway and Existing Bridge Components

DF track will be used on elevated guideway and existing guideway structures where it is required. The CWR will be supported by DF fasteners spaced at 750 mm, subject to detailed design, which will rest on reinforced-concrete plinths that are anchored to the concrete deck with steel dowels. Due to differential expansion between the CWR and the structure, longitudinal loads will be imparted on the structure along tangent track. For curved track, both longitudinal and radial loads will be imparted on the structure. These loads will act as either tensile or compression forces in the CWR, depending on the differential expansion. Holes will be drilled for the plinth dowels to be embedded with an epoxy grout, into the concrete deck. The steel dowels are designed to transfer all longitudinal and transverse loads from the rail, through the plinths and into the superstructure. These forces will be transferred to the substructure where the superstructure is fixed to guideway piers and abutments. Structural analysis was performed to ensure the existing guideway structures can resist these rail/structure interaction loads imparted to the structure.

Mitigation for Potential Noise and Vibration

A preliminary analysis of potential noise and vibration impacts of the OLRT was performed and methods of mitigation were proposed for sections of the alignment based on PA Schedule 17.

Because the alignment runs near many residential buildings on ballasted track, several sections of the alignment require ballast mat to reduce vibration. The ballast mat is placed under the ballast to provide a resilient layer. Ballast mat will be required east of Tunney's Pasture Station, near the University of Ottawa, east of Lees Station, at the MSF connection track, and near Cyrville Station.

Resilient DF fasteners will be installed in sections of the downtown tunnel below residential buildings, hotels, and the Government Conference Centre. Resilient DF fasteners provide lower vertical stiffness than standard DF fasteners and reduce groundborne noise and vibration transferred to the surrounding environment. Floating slab track (FST) is another type of DF track used for vibration mitigation. It consists of a concrete slab supported on resilient elements such as a rubber mat. FST effectively reduces levels of groundborne vibration but it is much more expensive than using resilient fasteners. Because of the noise-sensitive operations of the Canadian Broadcasting Corporation and the National Arts Centre, floating slab will be required at these two locations.

5.2.14.5 Infrastructure Installed in Support of the Signalling & Communications Equipment & Electrification

Underground ducts and system-wide cableways will be installed with traction power feeders typically installed perpendicular to track when crossing under tracks. Maintenance holes and pull-box locations will be coordinated with drainage and track alignment and will be no more than 120 m apart. Signalling and communications cableways will be installed to reduce cross-talk and interference with running rail and power circuits.

Infrastructure for signalling will include Central Instrumentation Houses (CIH) for CBTC, which will be strategically located along the guideway.

OCS poles will have duct work and feeder cables run into the pole through the foundation, and pole foundations will be coordinated with ductbanks, drainage, trackwork, and utilities.

5.2.14.6 Proposed End of Track Devices

The proposed rail arrestor for the mainline terminal tracks is designed to engage the Vehicle coupler with a maximum force of 400 kN and a 3-car train at AW3 of 193,710 kg. Impact speed is assumed to be 25 km/h with a slide gradient of -2.0 percent and maximum deceleration of 2.5 m/sec^2. These factors result in a required buffer zone of 20 m from the face of the rail arrestor to the end of track.

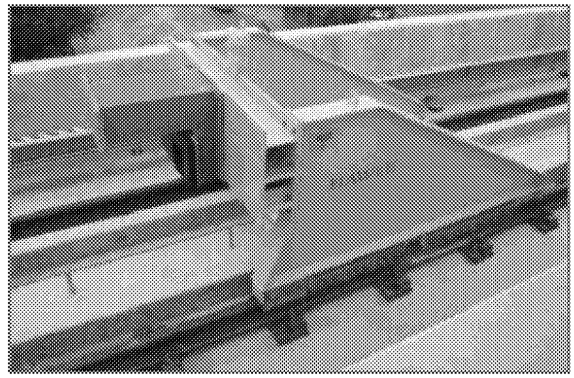


Figure 5.2-5 | Mainline Rail Arrestor

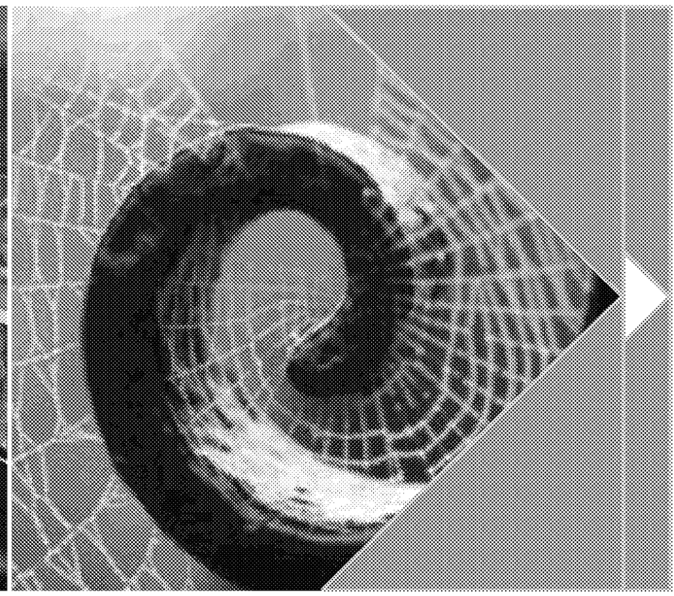
Similarly, the proposed buffer stop for stub-end yard storage tracks is designed to engage the Vehicle coupler with a maximum force of 400 kN and a 3-car train at AW0 of 141,000 kg. The impact speed is assumed to be 10 km/h with a slide gradient of 0.0 percent and maximum deceleration of 2.5 m/sec^2. These factors result in a required buffer zone of 6 m from the face of the buffer stop to the end of track.

Rail-mounted wheel stops will be installed at stub-end shop tracks to impede travel beyond the end of track.

5.2.15 TRACKWORK DRAWINGS

Trackwork drawings (1:100 scale) are provided in **Package B2 – Design Submission Part 2 – Volume 1 (of 4).**

5.3 TUnneL DeSiGn



RIDEAU TRANSIT GROUP

5.3 TUNNEL DESIGN

To execute and deliver design and construction services, Project Co will contract with an integrated design-build joint venture (DBJV) of SNC-Lavalin Constructors (Pacific) Inc., Dragados Canada Inc. (the construction arm of ACS), and EllisDon Corporation. Hatch Mott MacDonald and the Dr. G. Sauer and Partners Corporation will collaborate on the tunnel design for the OLRT Project, drawing on their Canadian and international experience.

As described throughout this Section and **Section 5.5**, Rideau Transit Group's (RTG's) construction approach is to use roadheaders to construct the running tunnel and the Stations. Based on our experience of underground tunnel and station design in built-up cities such as Barcelona, Seville and Vancouver, we know that cut-and-cover construction methods can be extremely disruptive to Stakeholders, even going so far as to put some small businesses out of business. By contrast, our totally mined solution for OLRT tunnels and Station caverns will deliver these benefits:

- Expediting schedule as no allowance has to be made for the long manufacturing and delivery period required for a large-diameter tunnel-boring machine
- Causing less disruption to subsurface utilities at the Station locations and relying less on the input of third-party utility companies
- Minimizing construction disruption to local businesses and downtown traffic and transit, and preserving access to buildings and businesses
- Reducing schedule risk by adopting a multiple-front construction methodology of roadheader construction as opposed to a single-construction-face solution such as a bored tunnel
- Minimizing dust and noise pollution at the surface

5.3.1 OVERALL APPROACH TO DESIGN & CONSTRUCTION OF TUNNELS & OTHER UNDERGROUND STRUCTURES

RTG's aim with tunnel and Station design has been to minimize the amount of surface excavation, thereby significantly reducing disruption to utilities, traffic, pedestrians, and local businesses. To achieve this aim, our Team has developed a preliminary design based on sequential excavation methods (SEM) with roadheader used for tunnel and Station cavern excavation. This Section details tunnel construction methods; **Section 5.3.5** describes tunnel design.

5.3.1.1 Construction Methods & Sequence

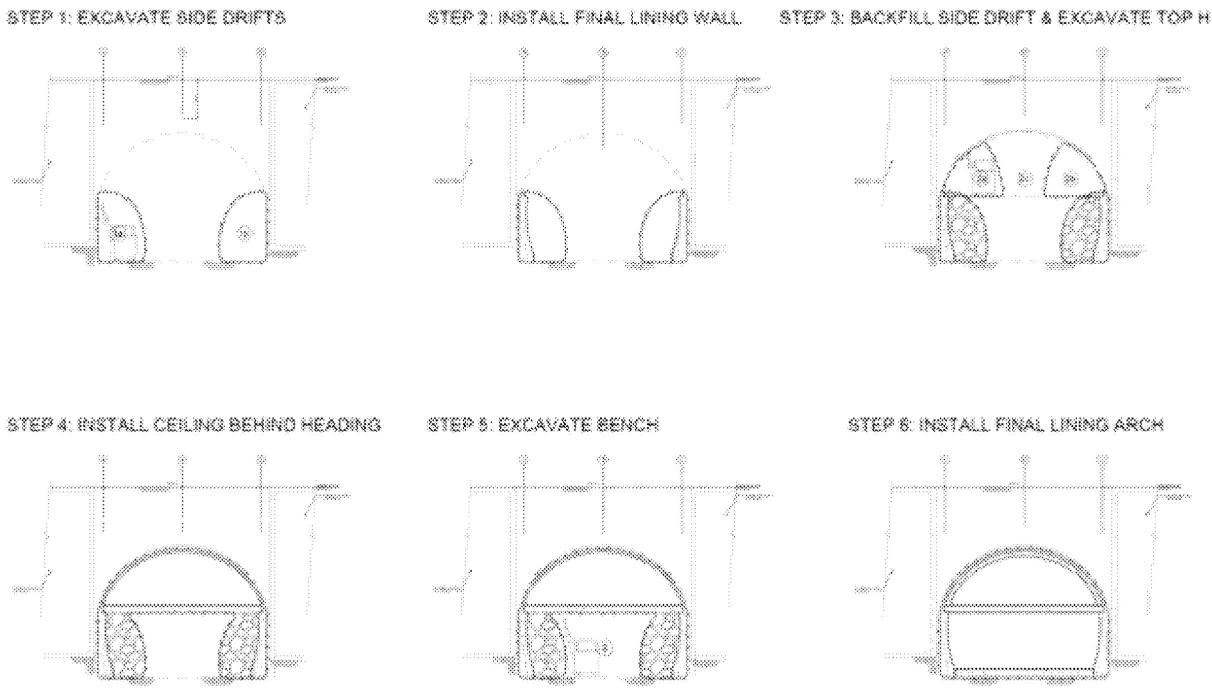
Running Tunnel

Running tunnel alignment sections located in bedrock will be excavated using roadheader equipment. To provide access and reach for the roadheader, excavation will proceed using a top heading and invert-bench sequence. For sections where the running tunnel is in soft-ground material (Rideau buried valley) the tunnel will be constructed in two side drifts using hydraulic excavators.

Station Caverns

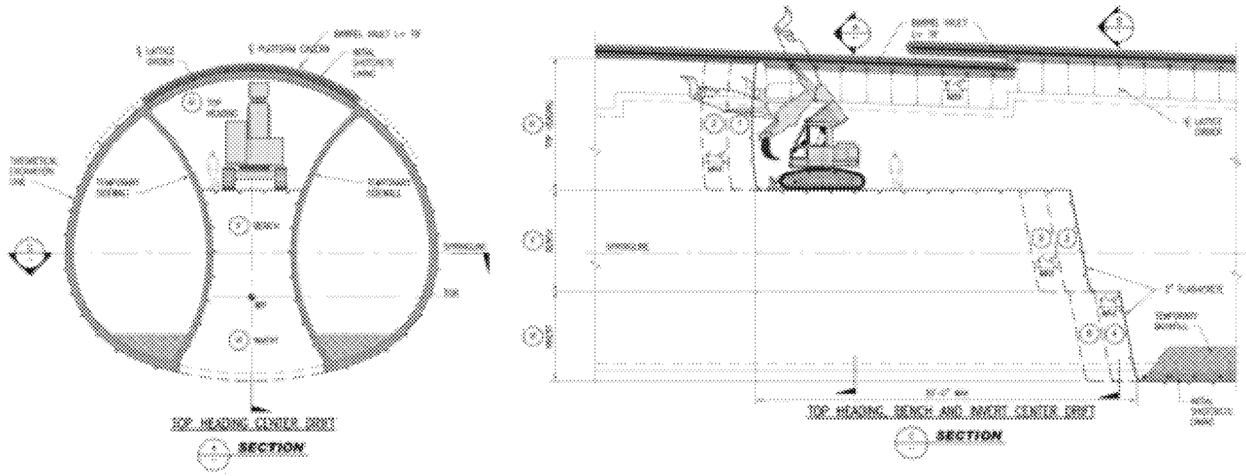
Station caverns for the Downtown East and Downtown West Stations will be constructed along Queen St. where the cavern will be close to existing deep basements. To prevent impact on adjacent structures during construction and in the long term, the initial support will be designed to support the full overburden load without relying on the adjacent building for support. To achieve this objective, we will use a multiple drift method: walls are first constructed in lower side drifts to support subsequent installation of a tied-arch arrangement. The excavation sequence for the Downtown East Station is similar. **Figure 5.3-1** shows a typical excavation sequence for these Stations.

Figure 5.3-1 | Downtown West and East Stations Excavation Sequence



As the structure is not as deep as the tunnel close to Rideau Station cavern, the protection measures noted above are only required for the Downtown West and East Stations. A similar, but somewhat more conventional, excavation and support sequence to that required at Downtown West and East Stations will be used for the section of Rideau Station cavern in rock. A portion of Rideau Station Cavern will be constructed in soft-ground conditions in the Rideau buried valley, where a double sidewall drift soft-ground excavation and pre-support method will be used with a barrel vault installed in advance of the tunnel excavation. **Figure 5.3-2** shows the Rideau Station excavation sequence in progress.

Figure 5.3-2 | Rideau Station Excavation Sequence (centre drift)



Shafts & Station Accesses

Figure 5.3.3A | Typical Secant Pile Support

Figure 5.3.3B | Typical Shaft Excavation Equipment

Although the decision to proceed with mined Stations significantly reduces the need for utility relocation and traffic management, each Station requires several large vertical shafts/accesses that extend to the surface for vertical circulation, tunnel ventilation and HVAC. Potential traffic impacts will be minimized by locating these shafts at the sides of roads or on walkways. Utilities must be relocated before and during construction, with traffic diverted around construction where necessary. Some accesses extend into other properties and careful coordination with property owners will be required before and during construction.

All shafts, with the exception of those within the buried valley at Rideau Station, will extend through overburden and into the rock below. Shaft excavations through overburden will typically be supported by temporary shoring, and preliminary details for these elements are shown on the drawings provided in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**. Typically, temporary shoring will be by tie-back, soldier or secant piles as appropriate: **Figure 5.3-2A** shows typical secant pile primary support. Excavation through rock will be by mechanical excavation: **Figure 5.3-3B** shows typical shaft excavation equipment. All shafts will be concrete lined and fully waterproofed upon completion.

The various access and ventilation shafts enter the Station caverns at different locations and elevations within the cavern roof and sidewalls. The cavern construction methodology requires that a shotcrete arch be installed in the cavern roof, and that the roof arch be tied at the concourse level to support rock and overburden loads. In general, shafts that penetrate the roof arch will be excavated and backfilled with foam concrete before excavating the Station caverns. Once mining of the caverns is complete and the permanent lining is in place, the foam concrete will be removed and the shafts lined with shotcrete or concrete as required. Horizontal access tunnels, at Downtown West and Rideau Stations, will either be mined during cavern excavation or after installation of the Station cavern permanent lining.

5.3.1.2 Construction Traffic & Staging Areas & Muck Handling for Downtown Tunnel and the MSF Connection Tunnel

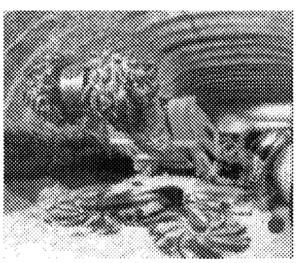
Underground construction will be carried out using roadheaders for rock excavation and hydraulic excavators for the soft ground conditions at the Rideau buried valley. Underground construction will commence from two faces at the West and East portals and from a central shaft, located in a laydown area provided by the City, between the Downtown West and Downtown East Stations. Careful planning will be undertaken to manage the spoil generated at each excavation face, considering noise levels, surface disturbance, and the cleanliness of public roads. Appropriate facilities will be procured and used to meet these low impacts to the public, even in the City centre.

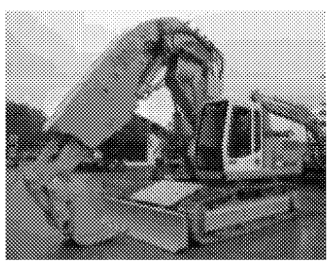
For the design of underground work, we have studied several possibilities that use areas that the City has provided near the portals and along the alignment. The main objective is to condense the surface work in certain areas. Tunnel excavation will be executed using three working faces: two main faces from the portals and an ancillary face to excavate Downtown East from a laydown area provided by the City. This approach provides increased flexibility and quality of its construction while reducing schedule delay risk by making construction of this element non-linear in its execution.

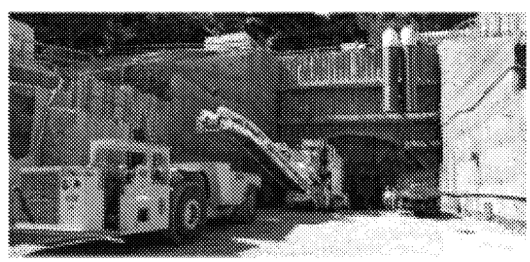
Spoil generation occurs at the excavation face. The spoil-transport cycle starts when the roadheader has excavated a pile of material that is loaded by the front panzer of the machine and transferred to its belt conveyor. By using this kind of equipment, it is possible to load the muck directly from the roadheader's belt conveyor to the trucks. There are several advantages to using this procedure, such as not requiring auxiliary machinery for the muck load, which results in more clearances in the tunnel, and improved overall excavation rates. This machinery also uses high pressured nozzles which reduce the dust generated by the excavation process.

Muck will be transported using rubber tired trucks along the tunnel, to the portals and to the shaft. There are two options for truck hauling. The first would be direct transport from the excavation face to the disposal site, when a shaft is not required, as in the West Portal. The second needs some auxiliary means to transfer the load from tunnel trucks to road trucks, through a vertical shaft; this is the case for the East Portal and Downtown Face. Typical photos of roadheader, excavators and underground trucks are shown in **Figure 5.3-4**.

Figure 5.3-4 | Roadheader, Excavator and Underground Trucks







Examples of Ottawa Disposal Sites

- Contaminated Fill:
  - BFI Waste Services (3354 Navan Road, Orleans)
  - Waste Management Dump (Carp Road & 417)
  - Springhill Landfill (7720 Springhill Rd, Metcalfe)
- Clean Fill:
  - BFI Waste Services (3354 Navan Road, Orleans)
  - Moodie Quarry (Fallowfield exit of 416, 952 Moodie Drive, Nepean)

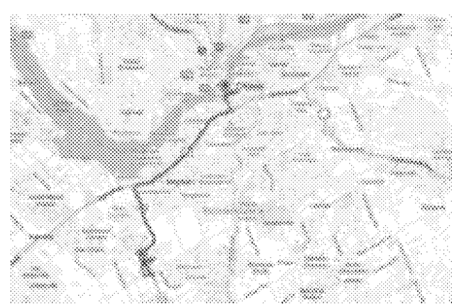


Figure 5.3-5 | Moodie Quarry

- Rock:
  - Moodie Quarry (Fallowfield exit of 416, 952 Moodie Drive, Nepean)
- Others:
  - Stittsville Quarry (635 Jinkinson Road, Stittsville)
  - Rideau Quarry (3500 Rideau Road, Gloucester)
  - Canaan Quarry (3865 Birchgrove Road, Sarsfield)
- Moodie Quarry: 25 km from West Portal
- BFI Canada Inc.: 18 km from Rideau Station Shaft
- Springhill Landfill: 20 km from West Portal

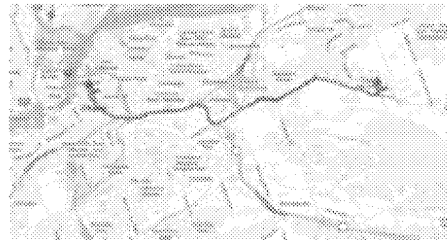


Figure 5.3-6 | BFI Canada Inc.

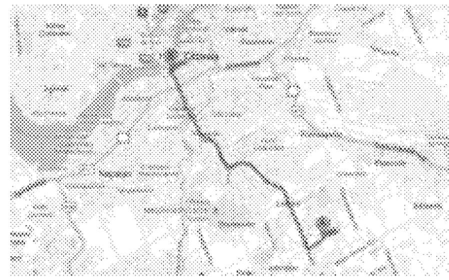


Figure 5.3-7 | Springhill Landfill

5.3.1.3 Working Drawings

Table 5.3-1 provides a summary of working drawings. Drawings are provided in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)**.

Table 5.3-1 | Working Drawings

Drawing Number	Title
1200 - 41DD - S2 – 1001	West Portal Construction Access – Plan and Section
1270 - 41DD - S2 – 1017	Running Tunnels and Stations – Overall Excavation Sequence
1270 - 41DD - S2 – 1104 & 1105	Running Tunnel - Excavation & Sequence - Sheets 1 & 2
1270 - 41DD - DW – 1001 thru 1003 & 1013	Downtown West – Overall Excavation Sequence - Sheet 1, 2, 3 & 4 of 4
1270 - 41DD - DW – 1101	Downtown West – Vent Shafts – Excavation Sequence
1270 - 41DD - DW – 1008 thru 1011	Downtown West – Cavern Excavation & Support Sequence – Sheets 1 thru 4
1270 - 41DD - DW – 1012	Downtown West – Parking Tunnel Crossing – Excavation & Support Sequence
1270 - 41DD - DE – 1001 thru 1003	Downtown East – Overall Excavation Sequence - Sheets 1, 2 & 3 of 3
1270 - 41DD - DE – 1004 thru 1007	Downtown East – Cavern Excavation & Support Sequence – Sheets 1 thru 4
1270 - 41DD - RD – 1001 thru 1003	Rideau – Overall Excavation Sequence - Sheets 1, 2 & 3 of 3
1200 - 41DD - S2 – 1002	East Portal Construction Access – Plan and Section

5.3.2 ASSESSMENT OF ANTICIPATED GROUND CONDITIONS ALONG TUNNEL ALIGNMENTS & AT MAJOR SHAFTS

5.3.2.1 Regional Geology

The Project is in the physiographic area of the Ottawa Valley Clay Plain region, which is characterized by thick deposits of sensitive clay overlying thin glacial till and glaciofluvial deposits overlying bedrock. Bedrock within the Project area consists of a series of sedimentary rocks, predominantly shale and limestone. Several major faults with vertical throws of up to 40 m cross the tunnel alignment. The groundwater table is generally near or at the bedrock surface except where existing building foundations have depressed the water level, primarily at Downtown West Station, and in bedrock buried valleys.

Two fault-induced buried glacial valleys exist along the tunnel alignment, the Rideau bedrock buried valley, between chainages 102+330 to 102+515 at the west extent of Rideau Station, and at the East Portal, south of Chainage 103+200.

5.3.2.2 Primary Geological Units

Borehole locations, relevant borehole logs, and interpreted stratigraphic profiles along the tunnel and Underground Stations are provided on drawings 1113-4GDD-S2-1000 through 1006.

Overburden

Overburden in the Project area ranges from less than 1 m thick to more than 37 m at the bedrock valley near Rideau Street and Colonel By Drive. Over the majority of the alignment the overburden consists of fill overlying deposits of sand, silt or clay. The sands and silt are often found as pockets or seams within the glacial till. The clays are found as more continuous layers overlying the glacial till. The glacial till consists of a silty sand to sandy silt matrix with varying amounts of gravel, cobbles and boulders, and is generally found overlying the bedrock. **Table 5.3-2** details the primary overburden units.

Table 5.3-2 | Primary Overburden Units

Unit	Description
Fill	▪ Man-made deposit ▪ Composition is highly variable ▪ Typically 2 – 4 m thick
Clay	▪ Silty clay to clayey silt ▪ Typically found overlying till, up to 20 m thick ▪ Highly sensitive and compressible
Silt	▪ Typically found as pockets or seams within till unit
Sand	▪ Typically found as pockets or seams within till unit
Till	▪ Matrix consists of silty sand to sandy silt ▪ Contains gravel, cobbles and boulders ▪ Typically found overlying bedrock as a thin veneer except in bedrock valley where it is up to 30 m thick

Bedrock

The bedrock in the downtown Ottawa area is made up of a series of sedimentary rocks consisting of shales, limestones, dolostones and sandstones. The formations that will be encountered by this Project from youngest to oldest are the Billings, Lindsay and Verulam Formations. **Table 5.3-3** describes the bedrock formations.

Table 5.3-3 | Bedrock Formations

Formation	Description
Billings	▪ Shale - black, very fine grained, very thin to thinly bedded
Lindsay Unit 3	▪ Interbedded Shale (50 – 90%) and Limestone (10 – 50%) ▪ Sequence of black, fine grained, thin to medium bedded shale and grey fine to medium grained, thin to medium bedded limestone
Lindsay Unit 2	▪ Limestone – medium to dark grey, fine to medium grained, thin to medium bedded ▪ Contains 5 – 10% shale
Lindsay Unit 1	▪ Limestone – dark grey, medium grained, medium to thickly bedded ▪ Contains less than 1% shale

Formation	Description
Verulam	■ Interbedded Limestone (80 – 95%) and Shale (5 – 20%) ■ Sequence of medium to dark grey, medium grained, thin to medium bedded limestone and very thin to thin beds of black shale

Faults

A series of faults cross the tunnel alignment and have been inferred from Golder's technical memorandum, "Fault Study along OLRT Tunnel Alignment" dated 24 October 2011. Widths of inferred faults are assumed to be 5 m except for faults oriented roughly parallel to the tunnel alignment. Vertical offsets at faults were inferred from boreholes.

5.3.2.3 Geotechnical Design Properties

Bedrock

The rock that will be encountered during construction of Segment 2 has been grouped by Rock Mass Type (RMT). Each RMT is expected to exhibit similar behaviour during excavation. Four RMTs were created with several subcategories:

- RMT1: Blocky Limestone
- RMT2: Very Blocky Limestone
- RMT3: Faults
- RMT4: Shale of the Billings Formation and Lindsay Unit 3

RMT1: Blocky Limestone

RMT 1 consists of limestone and limestone interbedded with less than 50 percent shale. It includes rock of the Verulam formation and the Lower Lindsay (Unit 1 and 2) formation. The rock mass is characterized by horizontal bedding and typical fracture spacing is greater than 20 cm. The rock mass is blocky, consisting of well-interlocked blocks or slabs. RMT 1 is further subdivided into RMT 1a and 1b. 1a includes rock from Lindsay Units 1 and 2 and 1b includes rock from the Verulam formation.

RMT2: Very Blocky Limestone

RMT 2 consists of limestone and limestone interbedded with less than 50 percent shale. The rock mass includes rock of the Verulam and Lower Lindsay formations (the same as RMT 1). The distinguishing feature is the closer fracture spacing and a very blocky rock mass structure. The rock mass is characterized by persistent horizontal bedding and a typical fracture spacing of less than 20 cm. The rock tends to be very blocky, consisting of partially disturbed, interlocked blocks or slabs. RMT 2 is also further subdivided into RMT 2a and 2b. 1a includes rock from Lindsay Units 1 and 2 and 2b includes rock from the Verulam formation.

RMT3: Faults

This rock mass type consists of fault zones located in both shale and limestone. A total of seven faults are inferred along the alignment with vertical offsets ranging from 4 to 40 m. The fault zones consist of broken rock with healed calcite veining and with some gouge material.

RMT4: Shale of the Billings Formation and Lindsay Unit 3

RMT 4 consists of shale and shale interbedded with less than 50 percent limestone. RMT 4 is composed of the Billings formation and Lindsay Unit 3. It consists of blocky to very blocky rock mass with dominant horizontal beds. The shales are known to swell upon stress relief and when in contact with fresh water. The shale is also anticipated to swell due to oxidation when exposed to air.

Interpreted stratigraphic profiles showing RMTs along the alignment are shown on drawings 1113-4GDD-S2-1007 through 1012.

Geotechnical parameters for design for each RMT described above and in-situ stresses in rock formations are presented in a technical memorandum dated 08 June 2012, "Bedrock Formations and Rock Mass Types – Segment 2" prepared by RTG.

Overburden in the Bedrock Buried Valley

Anticipated subsurface conditions in the bedrock buried valley east of Colonel By Drive are shown on Drawings 1113-4GDD-S2-1004 and 1113-4GDD-S2-1013 and presented in technical memorandum dated 15 June 2012, "OLRT – Ground Treatment Requirements for Tunnelling in the Rock Valley" by RTG. The mixed subsurface conditions and high groundwater table anticipated in the bedrock buried valley will result in difficult tunnelling conditions and the need for a combination of dewatering and ground treatment. **Table 5.3-4** shows the geotechnical parameters for the soils in the bedrock buried valley.

Table 5.3-4 | Preliminary Soil Parameters at the Bedrock Buried Valley

Soil Description	Unit Weight γ (kN/m³)	Hydraulic Conductivity K (cm/s)	Young's Modulus Es (MPa)	Poisson's Ratio ν	Effective Cohesion (kPa)	Undrained Shear Strength Cu (kPa) (ϕ=0)	Effective Friction Angle ϕ' (deg)	Earth Pressure Coefficient		
								In Situ (K_0)	Active (K_a)	Passive (K_p)
Silty Clay	15-17	$1x10^{-4}$ - $1x10^{-8}$	10 - 20	0.35	3 – 7	30 - 80	32 – 35	0.5 – 0.8	0.25 – 0.28	3.5 – 4
Silt	20 - 22	$1x10^{-3}$ - $1x10^{-6}$	10- 40	0.3	0	---	25 - 35	0.4 – 0.6	0.27 – 0.41	2.5 – 3.7
Glacial Till	21-24	$1x10^{-3}$ - $1x10^{-6}$	50 - 160	0.3	0 – 3	-	34 - 44	0.5 - 1.1	0.24 – 0.35	2.9 – 4.2
Sand and Gravel	20-23	1 - $1x10^{-2}$	35 - 70	0.3	0	-	30 - 38	0.5 – 1.1	0.24 – 0.35	2.9 – 4.2

5.3.2.4 Hydrogeological Conditions

Regional Hydrogeology

The nearest areas serviced by groundwater are about 10 km to the south, and the nearest local wells completed in the geological units that are likely to be encountered during tunnel construction are about 20 km to the east, based on technical memoramdum TT9, by Golder, on "Hydrogeological analysis and interpretation of the OLRT Project Ottawa, Ontario" dated 22 December 2011.

Regional groundwater flow is assumed to move northward, towards the Ottawa River, and both eastward and southward, towards the Rideau River; where it discharges. Vertical gradients from the overburden (where saturated) and between the shallow and deeper bedrock are challenging to evaluate due to the presence of service trenches and drained foundations in the downtown area, which introduce substantial variability in the water table elevation. However, downward gradients (i.e. higher head at higher elevations) are to be expected, to the depth of the tunnel. The absence of systematic time-synchronous data makes it difficult to assess groundwater flow directions and gradients.

Based on interpreted stratigraphic profiles, the elevation of the bedrock potentiometric surface is generally within 2 m to 12 m of the ground surface. At the West Portal, the potentiometric surface elevation is within the glacial deposits. At the Downtown West and East Stations, the potentiometric surface elevation is within the bedrock Lindsay Formation. At the Rideau Station, the potentiometric surface elevation traverses the Leda Clay, glacial deposits, and bedrock Lindsay

Formation. The potentiometric surface elevation is within the Leda Clay at the East Portal. Locally "perched" water tables may occur (usually at higher elevations).

The fill and the glacial deposits are the most permeable units, with the Leda Clay being the least permeable unit. The bedrock formations (Billings, Lindsay, and Verulam) are the low-permeability units, except where fracturing occurs at the bedrock/overburden interface. The bedrock units are considered poor to average in terms of available well yield. Faults are recognized as zones with potentially high hydraulic conductivities based on technical memo TT6, by Golder, on "Fault study along OLRT tunnel alignment" dated 24 October 2011.

The hydrostratigraphy at the proposed OLRT tunnel alignment is presented in **Table 5.3-5**. The overburden and bedrock hydrostratigraphic units and sub-units are listed, from the surface down (young to old). The range of regional hydraulic conductivities for each sub-unit anticipated at the site is provided.

Table 5.3-5 | Hydrostratigraphy

Unit	Sub Unit	Lithology	Regional Hydraulic Conductivity (cm/s)
OVERBURDEN	Fill	Various, mainly loose permeable materials	2 x 10-3 - 2 x 10-4
	Leda Clay	Highly compressible sensitive clay	1 x 10-6 – 1 x 10-7
	Glacial Deposits	Mainly till sandy silt to silty sand, with glacio-fluvial sands, silts and clays	2 x 10-3 – 2 x 10-5
BEDROCK	Billings Formation	Bedrock shale (pyritic)	1 x 10-4 – 5 x 10-6
	Lindsay Formation	Bedrock limestone with shale inter-beds	
	Verulam Formation	Bedrock limestone with shale inter-beds	

5.3.2.5 Hydrogeological Impact Assessment

Methodology

A three-dimensional (3D) groundwater flow model was developed to estimate groundwater inflow and drawdown related to excavation of the OLRT tunnel portion in downtown Ottawa. The projected excavations are the running tunnels, three Underground Stations (Downtown West, Downtown East and Rideau), and both the West and East Portals. **Figure 5.3-8A** shows the extent of the 3D model domain and some samples of the level of detail included in the model.

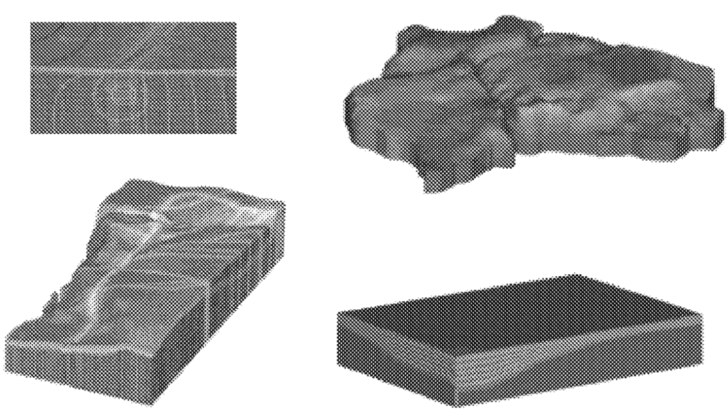


Figure 5.3-8A | Clockwise from upper left: (1) Head contours around running tunnel; (2) Colour-shaded regional heads for model domain; (3) Mesh detail for excavation alignment and faults; (4) Geologic detail for buried valley.

Simulations were performed using a 3D numerical groundwater flow model primarily based on geologic and hydrogeologic data and the tunnel alignment. Results from the model include both simulated flows and drawdowns. The 2D extent of the model domain is shown in **Figure 5.3-8B** together with the bedrock geology.

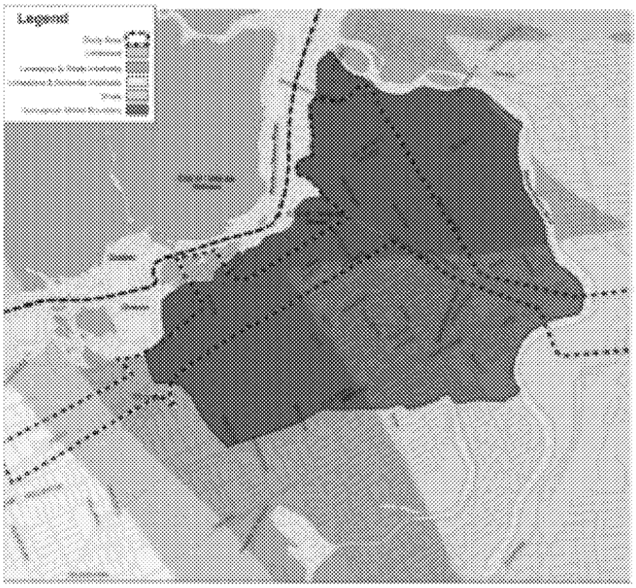


Figure 5.3-5B | Model Domain and Bedrock Geology

Simulated flows after one day are assumed to be reasonable estimates of "flush" flows but this has yet to be confirmed by more realistic modelling of the excavation sequence. Initial flow estimates will be overestimated because the excavation was assumed to occur instantaneously at the start of the simulation.

Drawdown estimates are used to assess the potential impact of dewatering on nearby sensitive marine clay soils located south of the tunnel alignment. These clay-rich soils are known to be compressible when loaded or when pore pressure in the clay decreases due to groundwater level lowering. The integrity of the foundations built on these soils could be impacted by settlement of the compressible clay caused by groundwater drawdown. The low hydraulic conductivities suggest that such settlement will occur slowly and construction practice may allow some drawdown recovery such that all potential settlement may not be realized.

Modelling Assumptions

- Preliminary modelling assumed instantaneous excavation and installation of final lining after two years. These assumptions result in very high initial flows and a two-year period of drawdown before applying any mitigation measures.
- No mitigation measures were applied in the model for the West Portal, Stations and running tunnels west of Metcalfe Street.
- Rock tunnel excavations are assumed to have drained linings to allow drainage at the bedrock/concrete interface. This drainage is assumed to be collected and removed at the bottom of the excavation. In the model, it is assumed that drained groundwater inflow is a permanent condition.
- Mitigation measures for groundwater inflow and drawdown are only applied from Metcalfe Street to the East Portal. For these excavations it was assumed that the permanent linings resist hydrostatic pressure and there is consequently no groundwater flow to the excavation after it is lined.
- Groundwater is assumed to discharge freely from the beginning of the excavation for a two-year period before the final lining becomes effective.

East Portal & Buried Valley Ground Treatment

- Scenarios were examined to investigate the effectiveness of ground treatment before excavation in critical zones to reduce potential inflows and consequential drawdowns.
- For buried valley/Rideau Station (and a further distance of approximately 50 m into the bedrock), the ground around the excavation is assumed to be pretreated by grouting, and a zone of reduced hydraulic conductivity extending to approximately 1.5 tunnel diameters was applied.
- Similar pre-treatment by grouting is assumed for the East Portal segment.

Modelling Scenarios

The model was used to predict groundwater inflow and drawdowns for three major scenarios (and four modified sub-scenarios). The drainage conditions and ground treatment applied in the model for the various scenarios are summarized in **Table 5.3-6**.

Table 5.3-6 | Summary of Modelled Scenarios

Modeled Scenarios		Time Interval	West Portal to Metcalfe St	Metcalfe St to Buried Valley / Rideau Station	Buried Valley / Rideau Station	Buried Valley / Rideau Station to East Portal	East Portal
1	Base Case	Construction	Drained	Drained			
		Post-Construction		Tanked			
2	Pre-Treatment Case	Construction	Drained	Drained	Pre-Treated	Drained	Pre-treated
		Post-Construction		Tanked			
2a		Construction	Drained	Faults treated	Pre-Treated	Drained	Pre-treated
		Post-Construction		Tanked			
2b		Construction	Drained	Faults treated	Pre-Treated	Drained	Pre-treated
		Post-Construction		Tanked			
2c		Construction	Drained	Drained	Tanked	Drained	Pre-treated
		Post-Construction		Tanked			
3	Tanked Liner Case	Construction	Drained	Drained	Tanked	Drained	Pre-treated
		Post-Construction		Tanked			
3a		Construction	Drained	Faults treated	Tanked	Drained	Pre-treated
		Post-Construction		Tanked			

- **Base Case (Scenario 1)** - All excavations are drained for an initial period of two years. After two years, the excavation between Metcalfe Street and the East Portal is given an impervious tanked liner such that hydraulic heads can recover.
- **Pre-treatment Case (Scenario 2)** - Segments through the buried valley/Rideau Station and the East Portal are surrounded with an annular zone of reduced hydraulic conductivity to simulate ground treatment. As with the base case, all excavations are drained for an initial period of two years. After two years, the excavation between Metcalfe Street and the East Portal is given an impervious tanked liner such that hydraulic heads can recover.
- **Fault Treatment (Scenario 2a)** - Critical fault-intersections west of Metcalfe Street are assigned low hydraulic conductivity to simulate grout treatment.
- **Reduced Fault Hydraulic Conductivity (Scenario 2b)** - Critical fault-intersections west of Metcalfe Street are assigned low hydraulic conductivity to simulate grout treatment. The hydraulic conductivity along all fault planes is reduced by an order of magnitude relative to the base case.
- **Reduced Hydraulic Conductivity Treatment (Scenario 2c)** - Critical fault-intersections west of Metcalfe Street are assigned low hydraulic conductivity to simulate grout treatment. The hydraulic conductivity along all fault planes is reduced by an order of magnitude relative to the base case. The hydraulic conductivity of the treatment annulus is reduced by an order of magnitude relative to the pre-treatment case.
- **Tanked Liner Case (Scenario 3)** - Segments through the buried valley/Rideau Station are given a tanked liner at the time of construction. All other excavations are drained for an initial period of two years. After two years, the unlined portion of the excavation between Metcalfe Street and the East Portal is given an impervious tanked liner such that hydraulic heads can recover.
- **Fault Treatment (Scenario 3a)** - Segments through the buried valley/Rideau Station are given an impervious liner at the time of construction. Critical fault-intersections west of Metcalfe Street are assigned low hydraulic conductivity to simulate grout treatment.

Modelling Results

Both inflows and drawdowns during construction and post-construction were simulated using the model. The model was also used to evaluate alternative ground-treatment options.

Groundwater Inflows

The modelled groundwater inflow results appear to provide reasonable flush-flow estimates consistent with various approximate analytical estimates with idealized assumptions for boundary conditions (Thiem, 1904, Goodman et. al., 1965; Heuer, 1995, Heuer, 2005). The groundwater modelling suggests that the cumulative "instantaneous" inflow rate to the entire excavation may be in the range of 15,000 L/min to 1,500 L/min.

Inflows were estimated for five tunnel segments: (1) the permanently drained bedrock running tunnel from West Portal to Metcalfe Street; (2) the bedrock running tunnel East of Metcalfe Street to the buried valley; (3) the buried valley/Rideau Station and 50 m buffer zones; (4) the bedrock running tunnel from the buried valley to the East Portal; and (5) the East Portal and 50 m buffer zone. The conclusions of this analysis are as follows:

- **Bedrock Running Tunnel Inflows** (segments 1, 2, and 4) - Inflow rates per m-run normalize flows for segment lengths and are used for the following discussion. For the bedrock Running Tunnels, predicted inflows after two years range from 0.27 to 0.06 L/min/m.
  - After two years, the highest inflows for the base case are for the Rideau Station to East Portal, segment (4). For the pre-treatment cases the highest inflows are associated with the West Portal to Metcalfe Street, segment (1). For the tanked-liner cases, the highest inflows are associated with the Metcalfe Street to Rideau Station, segment (2).
  - After four years, the simulated inflows to the permanently drained segments (1, 2) range from 0.20 to 0.03 L/min/m with the lowest values associated with the reduced fault conductivity cases.
  - Relative to the base case, inflows tend to decay more slowly for cases where the ground has been pre-treated (Scenarios 2 and Scenario 2a) as a result of slower drainage through the treated zone.
  - Relative to Scenario 2, inflows for reduced fault conductivity cases (Scenario 2b and Scenario 2c) are reduced as a result of slower drainage through the effective reduction in overall bedrock hydraulic conductivity (a consequence of reducing the effectiveness of the fault-network conduits).
  - Relative to the base case, inflows for the tanked liner cases (Scenario 3 and Scenario 3a) are reduced as a result of the reduction in the total length of the deep drained tunnel.

- **Buried Valley/Rideau Station Inflows** (segment 3): The predicted inflows after three months range from 140 L/min to 31 L/min. After two years the predicted flow range is 42 L/min to 10 L/min.
  - For the base case (Scenario 1), simulated inflows decrease from 140 L/min after three months to 42 L/min after two years.
  - For the pre-treatment case (Scenario 2), simulated inflows decrease from 65 L/min after three months to 10 L/min after two years.
  - For the pre-treatment case with fault treatment (Scenario 2a), simulated inflows decrease from 83 L/min after three months to 12 L/min after two years. These results are very similar to Scenario 2 with the slight increase attributed to the loss of the fault as a drain.
  - For the pre-treatment case with reduced fault conductivity (Scenario 2b), simulated inflows decrease from 58 L/min after three months to 31 L/min after two years. Reducing fault conductivity reduces not only the inflow but also the rate of decay of inflows.
  - For the pre-treatment case adding more effective pre-treatment (Scenario 2c), simulated inflows decrease from 31 L/min after three months to 28 L/min after two years. More effective pre-treatment reduces the inflow after two years by only a small amount, but earlier flows (after three months) are reduced by more than 50% and the total volume of drainage over the two-year period is significantly reduced.
  - The tanked liner cases (Scenario 3 and Scenario 3a) eliminate inflows at the buried valley/Rideau Station by assuming immediate lining. Simulated inflows to the buried valley/Rideau Station are, consequently, zero.

- For all cases, after two years when the permanent liner is installed, further drainage is halted.

- **East Portal Inflows** (segment 5): The predicted inflows after three months range from 34 L/min to 1.1 L/min. After two years the predicted flow range is 1.9 L/min to <0.1 L/min.
  - For the drained base case (Scenario 1), the East Portal becomes unsaturated after less than a year. Simulated inflows decrease from 34 m3/d (24 L/min) after three months to <0.1 L/min after one year.
  - For the pre-treatment cases (Scenario 2 and Scenario 2a), inflow estimates are reduced from 3.7 L/min and 5.7 L/min respectively to <0.1 L/min after two year.
  - For the reduced fault conductivity cases (Scenario 2b and Scenario 2c), small inflows between 1.1 and 2.6 L/min were simulated after three months reducing only slightly to 0.9 and 1.9 L/min after two years as a consequence of the treatment "backing-up" heads and delaying drainage.
  - For the tanked liner cases (Scenario 3 and Scenario 3a), the East Portal was simulated as pre-treated (not tanked) and the simulated inflows fell from 1.0 and 1.1 L/min respectively after three months to <0.1 L/min after two years, consistent with other pre-treatment cases (Scenario 2 and Scenario 2a).
  - For all cases, after two years when the permanent liner is installed, further drainage is halted.

- **Entire Excavation Inflows** (segments 1, 2, 3, 4, 5): The predicted inflows after three months range from 1,100 L/min to 580 L/min. After two years the predicted flow range is 530 L/min to 240 L/min and after four years 370 L/min to 100 L/min.
  - The base case simulation (Scenario 1) indicates that cumulative groundwater inflow rate to the entire excavation is expected to decrease from 1,000 L/min after three months to 350 L/min after two years and 150 L/min after four years.
  - The pre-treatment case simulation (Scenario 2) indicates that cumulative groundwater inflow rate to the entire excavation is expected to decrease from 1,100 L/min after three months to 530 L/min after two years and 370 L/min after four years. The effect of pre-treatment is to "back-up" heads and delay drainage. Local fault treatment (Scenario 2a) has little impact on total inflows to the entire excavation.
  - Reducing the conductivity of the fault network (Scenario 2b and Scenario 2c) reduced simulated inflows by approximately 45-55 percent: after three months to 580 L/min, falling to 280 L/min after two years and 230 L/min after four years.
  - For the tanked liner case, the predicted inflow rate after three months was 970 L/min falling to 240 L/min after two years and 100 L/min after four years. The reduced flows relative to the base case and pre-treatment case result from reducing the length of drained excavation and eliminating direct inflows from the buried valley. Local fault treatment (Scenario 3a) has little impact on total flows to the entire excavation.

Groundwater Drawdowns

Table 5.3-7 presents simulated drawdowns for the critical buried valley/Rideau Station and East Portal excavations. Maximum values are based on four specific boreholes for each location. **Figure 5.3-6** provides an example of contoured values.

Table 5.3-7 | Simulated Drawdowns

Modelled Scenarios		Time Interval	Maximum Simulated Drawdown (m)	
			Buried Valley / Rideau Station	East Portal
1	Base Case	2 years	25.6	9.0
		4 years	1.0	1.2
2	Pre-Treatment Case	2 years	21.6	5.5
		4 years	2.0	1.6
2a	with fault treatment	2 years	21.5	5.3

Modelled Scenarios		Time Interval	Maximum Simulated Drawdown (m)	
			Buried Valley / Rideau Station	East Portal
2b	with fault treatment and reduced fault conductivity	2 years	18.0	3.0
2c	with fault treatment and reduced fault conductivity and reduced pretreatment conductivity	2 years	13.2	2.4
3	Tanked Liner Case	2 years	7.4	4.7
3a	with fault treatment	2 years	4.2	3.6

- The maximum drawdown simulated at the overburden/bedrock interface for the base case (Scenario 1) after two years was 25.6 m near the buried valley and 9.0 m at the East Portal. Following installation of the tanked liner after a further two years, the drawdown near the buried valley recovers to less than 1 m and at the East Portal to less than 1.2 m.
- For the pre-treatment case, after two years the maximum simulated drawdown at the overburden/bedrock interface was 21.6 m near the buried valley and 5.5 m at the East Portal. Following installation of the tanked liner after a further two years, the simulated drawdown near the buried valley recovers to approximately 2.0 m and 1.6 m at the East Portal. The simulated pre-treatment was effective in reducing drawdowns at the East Portal (by 40 to 50 percent), but ineffective at the buried valley.

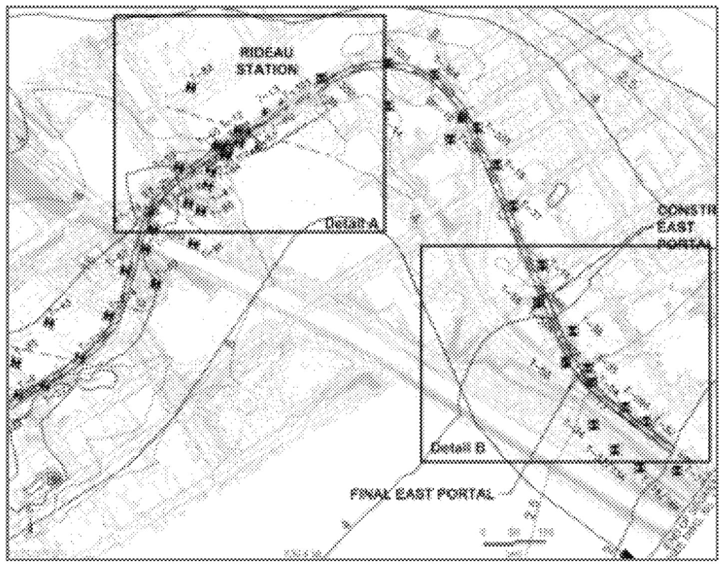


Figure 5.3-6 | Simulated Drawdown after 2 years (Scenario 3)

- The tanked liner case (Scenario 3) results in maximum simulated drawdowns of 7.4 m in the buried valley after two years (relative to 25.6 m for the base case). For the East Portal, the drawdowns were 4.7 m (compared to 9.0 m for the base case).

The limited effectiveness of the pre-treatment case in the buried valley is a consequence of two assumptions in the model: a hydraulic conductivity of 1.5×10^{-7} m/s for the treated annulus; and permeable fault zones in the bedrock, allowing low heads in the drained tunnel segment to be transferred to the buried valley. Scenarios 2a, 2b, 2c and 3a examine the sensitivity of model predictions to these specific assumptions:

- **For scenario 2a**, the simulated drawdowns after two years around the buried valley remained at 21.5 m. The simulated fault treatment was ineffective in reducing drawdown in the buried valley (although drawdowns after one year were reduced by about 10 percent).
- **Scenario 2b** reduces the fault zone hydraulic conductivity in the model by an order of magnitude. Such a reduction is consistent with testing of fault intersection and fractured bedrock. The simulated drawdowns after two years around the buried valley remained at 18.0 m. The reduction in drawdowns, relative to the base case, are approximately 30 percent. Less conductive faults result in lower drawdowns.
- **Scenario 2c** reduces the hydraulic conductivity of the treated annulus and uses a value of 1.5 x 10-8 m/s. This assumption is consistent with expected results for successful jet grouting treatment. After two years, the maximum simulated drawdown at the overburden/bedrock interface was 13.2 m near the buried valley, and less than 2.4 m at

the East Portal. The simulated pre-treatment was effective in reducing drawdowns at both the buried valley and East Portal (relative to the base case) by approximately 50 to 70 percent.

- **Scenario 3a** for the tanked liner with fault treatment results in the smallest maximum drawdowns simulated at the buried valley 4.2 m and relatively modest drawdowns at the East Portal 3.6 m. Simulated fault treatment is effective for the tanked liner case.

5.3.2.6 Tunnel Alignments

Ground conditions along the proposed tunnel alignment can be broadly categorized in four sections according to the overburden stratigraphy as follows:

- **West Portal to the bedrock valley near Rideau Street -** Overburden thickness in this section generally ranges from 2 to 5 m. It consists of fill up to 5 m thick underlain by small pockets or seams of sand and silt which, in turn, is underlain by a fairly continuous layer of till. The till layer ranges from 0 to 4 m in thickness. There are also a few discontinuous clay deposits up to 2 m thick underlying the fill and above the till. The groundwater table in this section of the alignment is generally just below the bedrock surface.

- **Bedrock buried valley near Colonel By Drive and Rideau Street** - In this area the bedrock surface dips sharply and the overburden thickness reaches a maximum of approximately 37 m. The overburden consists of 2 to 4 m of fill over 2 to 4 m of clay, which in turn overlies a reworked till material that fills the bedrock valley. The till-like material in the valley consists of a heterogeneous mixture of clay through boulder-sized material. In general, the matrix consists of silty sand to sandy silt with trace clay. Material density varies widely based on the SPT N values recorded during the GDR investigation work. The groundwater table in the valley is approximately 6 m below the ground surface.

- **East side of the bedrock valley to about 60 m north of where the alignment crosses Laurier Avenue** - In this section the overburden is typically only 4 m thick and consists of fill overlying some small isolated pockets of till which overlies bedrock. The groundwater table is generally located about 2 m below the bedrock surface.

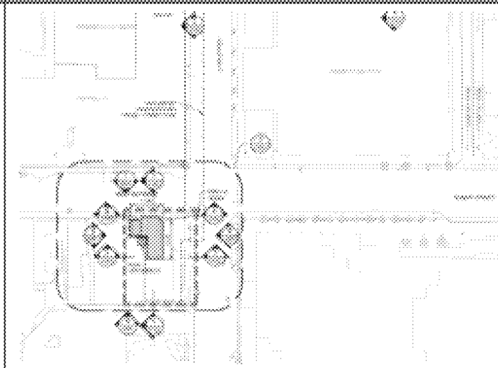
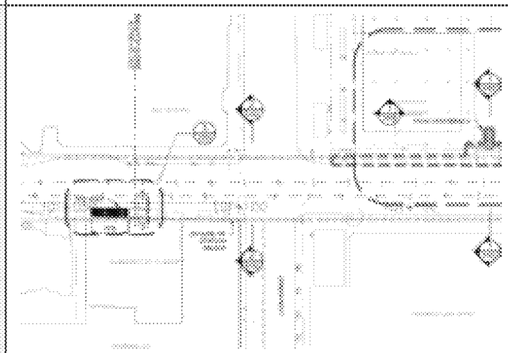
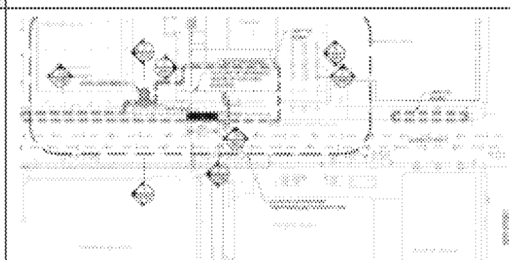
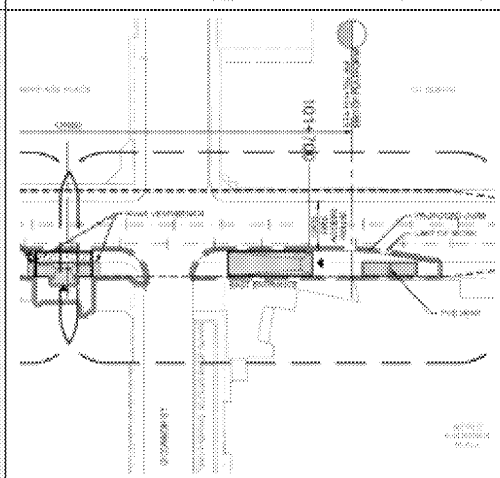
- **Approx 60 m north of Laurier Avenue to East Portal** - This section is characterized by deep clay deposits. Bedrock depths range from 4 m to a maximum of 26 m. The overburden consists of a thin layer of fill up to 2 m thick which overlies clay ranging from 3 m to 19 m in thickness. The clay generally overlies a thin layer of till which overlies bedrock. The groundwater table is located near Elevation 63 m, within the clay deposit.

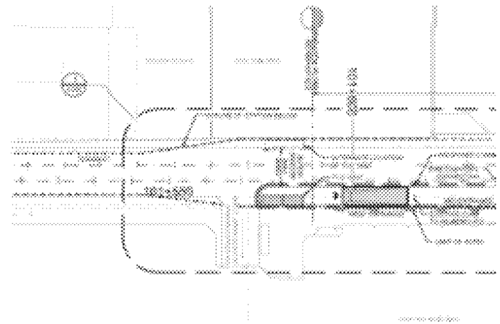
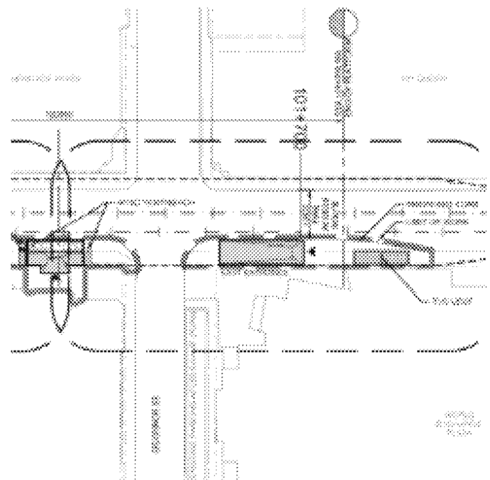
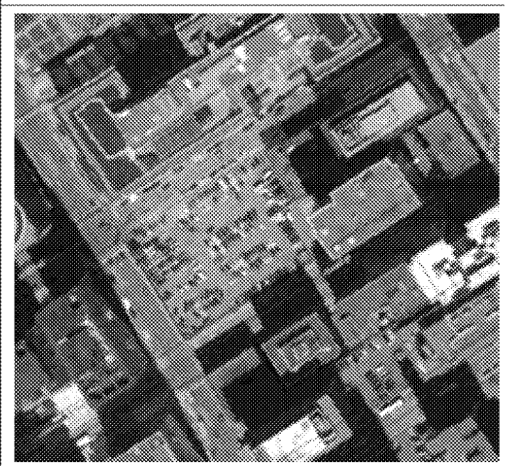
The bedrock sequence through which the tunnel will be excavated consists of the Billings, Lindsay and Verulam Formations. Most of the tunnel will be excavated within the Lindsay and Verulam Formations with the exception of a short section near the Downtown East Station which will encounter the Billings Formation.

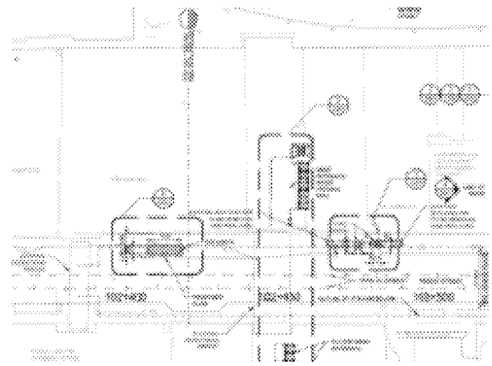
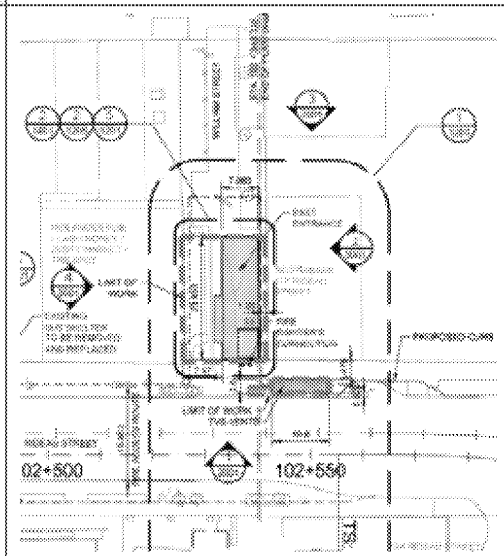
5.3.2.7 Major Shafts Larger than 3 m in Diameter

Table 5.3-8 summarizes several large shafts required for construction of the running tunnels and Station structures, and the anticipated ground conditions.

Table 5.3-8 | Large Shaft Details

Shaft Location & Purpose	Approx. Plan Dimensions	Approx. Depth (m)	Anticipated Ground Conditions	Location
Downtown West Station West Entrance	18.7 m x 30.4 m	14.2	■ Overburden – 4.5 m depth ■ Rock – 9.7 m depth ■ Water table – 5.5 m below ground level	
Downtown West Station West Vent Shaft	5.0 m x 6.7 m	12.7	■ Overburden – 2.4 m depth ■ Rock – 10.3 m depth ■ Water table – 3.5 m below ground level	
Downtown West Station East Vent Shaft	5.0 m x 6.7 m	12.7	■ Overburden – 5.5 m depth ■ Rock – 7.2 m depth ■ Water table – 10.0 m below ground level	
Downtown East Station East Vent Shaft	2.6 m x 10.7 m	16.1	■ Overburden –5.0 depth ■ Rock – 11.1 m depth ■ Water table – 6.7 m below ground level	

Shaft Location & Purpose	Approx. Plan Dimensions	Approx. Depth (m)	Anticipated Ground Conditions	Location
Downtown East Station West Vent Shaft	2.6 m x 10.7 m	16.1	■ Overburden – 4.5 m depth ■ Rock – 11.6 m depth ■ Water table – 4.0 m below ground level	
Downtown East Station Elevator Shaft	15.3 m x 5.4 m	14.8	■ Overburden – 5.0 m depth ■ Rock – 9.8 m depth ■ Water table – 6.5 m below ground level	
Downtown East Station Construction Access Shaft	15 m x 25 m	18.5		

Shaft Location & Purpose	Approx. Plan Dimensions	Approx. Depth (m)	Anticipated Ground Conditions	Location
Rideau Station East Entrance	13.6 m x 39.4 m	28.0	■ Overburden – 2.0 m depth ■ Rock – 26.0 m depth ■ Water table – 4.6 m below ground level	
Rideau Station West Entrance	11.5 m x 39.4 m	28.2	■ Overburden – 6.0 m depth ■ Rock – 22.2 m depth ■ Water table – 5.0 m below ground level	

5.3.2.8 Geotechnical Profiles

The borehole locations, relevant borehole logs and interpreted stratigraphic profiles along the tunnel and underground stations are provided on drawings 1113-4GDD-S2-1000 through 1006.

5.3.3 TEMPORARY EXCAVATION SUPPORT METHOD

5.3.3.1 Temporary Support Methods at Portals

The running tunnel daylights into the cut-and-cover and U-shape structures at both the West and East Portals to reach grade level:

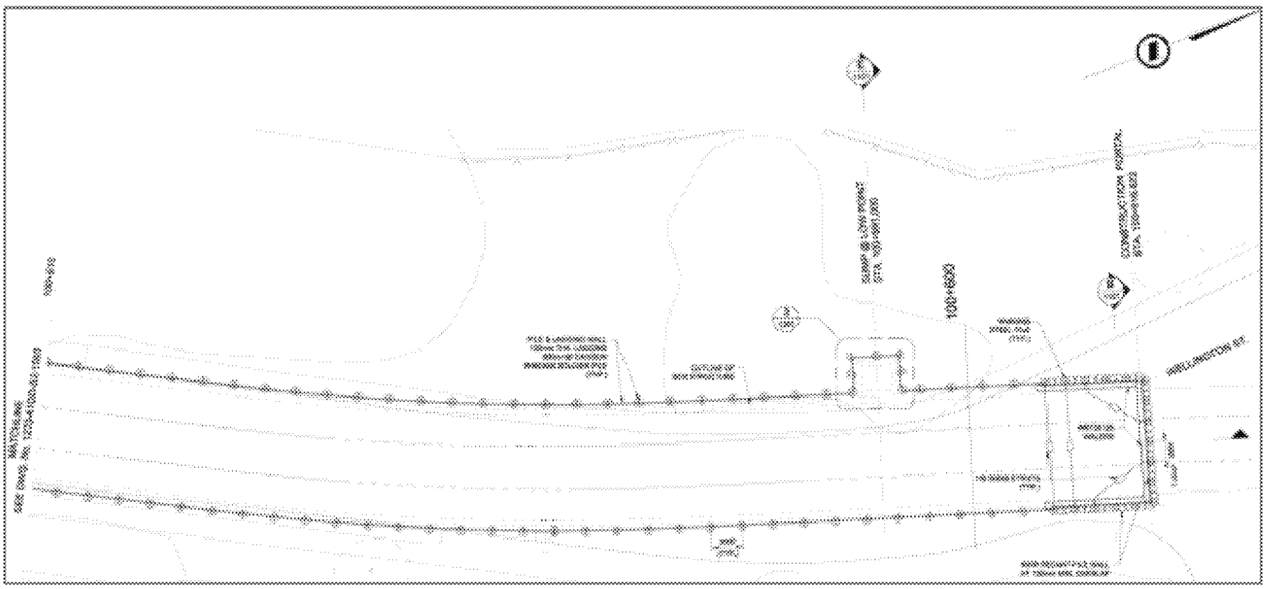
- **West Portal** – The running tunnel daylights into an approximately 200 m-long cut-and-cover section and approximately 100 m-long U-Shape structure to reach grade. The cut-and-cover section commences west of the Commissioners St. right of way. Excavation support is largely by pile and lagging walls except at the construction portal where a braced secant pile wall is used.

  Subsurface conditions at the West Portal are characterized by an escarpment with a nearly vertical rock face. Subsurface conditions along the proposed retaining wall consist of overburden soils of variable thickness underlain by sloping bedrock. The overburden soils consist of surficial fill material underlain by very dense silty sand till. The sedimentary bedrock belongs to the Verulam Formation – Unit 2. Subsurface conditions at the West Portal are shown on Drawing 1113-4GDD-S2-1001.

Temporary support of the excavation system at the West Portal will consist of soldier pile and lagging walls in the overburden, laterally supported by struts and/or rock anchors, and a combination of rock dowels and shotcrete in the bedrock. The final structure will consist of a watertight cast-in-place concrete box.

Recommendations for the design of the West Portal temporary support of excavation and cast-in-place box structure have been included in a technical memorandum dated 11 June 2012, "East and West Portals – Lateral Pressures for Support Design" by RTG. **Figure 5.3-7** shows the plan at West Portal.

Figure 5.3-7 | Plan at West Portal

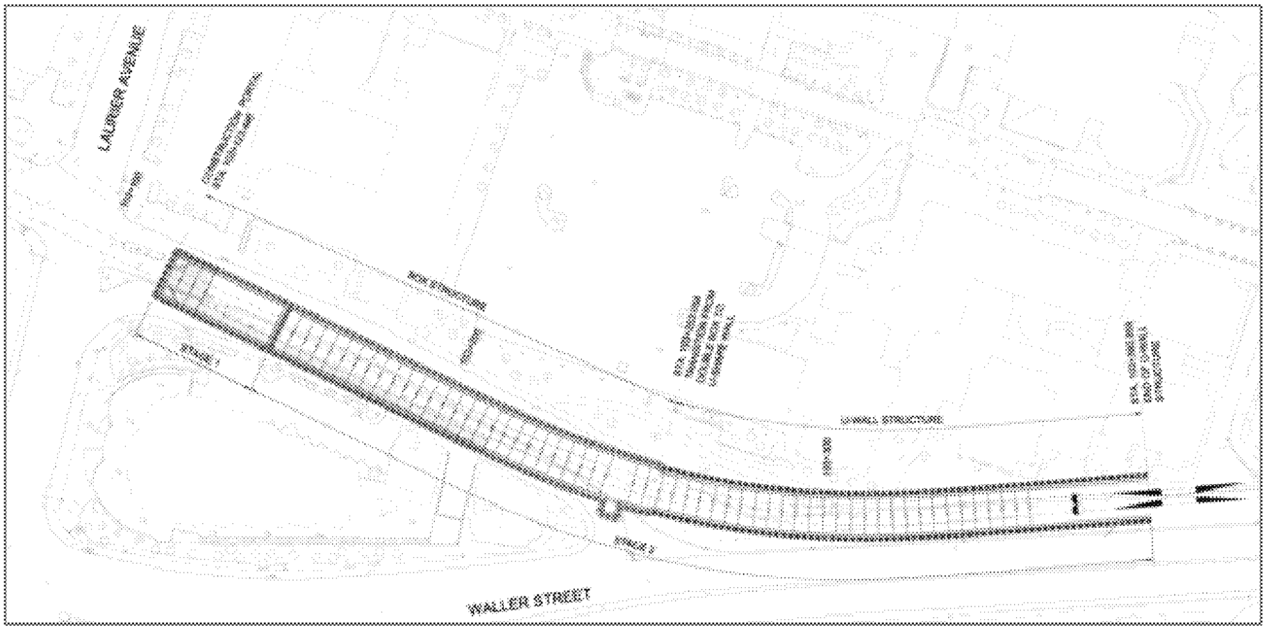


- **East Portal** - The running tunnel daylights into an approximately 130 m-long cut-and-cover section and approximately 140 m-long U-shape structure to reach grade. The cut-and-cover section commences east of the Laurier Avenue right of way. As there is a potential issue with the sensitive Leda Clay in this area which could cause excessive surface settlements under water table drawdown, support to the excavation will be provided by secant pile walls that extend to bedrock to seal the excavation from groundwater ingress during construction.

  Subsurface conditions at the East Portal are variable along the proposed retaining wall, and consist of overburden soils of variable thickness underlain by sloping bedrock at the north side of a buried valley in the bedrock. The overburden soils consist of surficial fill material underlain by silty clay and clay-like silt (Leda Clay), and silt and sandy silt till. The sedimentary bedrock belongs to the Lindsay Formation – Units 2 and 1. The subsurface conditions at the East Portal are shown on Drawings 1113-4GDD-S2-1006 and 1113-4GDD-S2-1013.

  The temporary support system at the East Portal will consist of watertight secant piles or slurry trench walls in the overburden, laterally supported by struts at ground surface elevation, and a combination of rock dowels and shotcrete in the bedrock. The final structure will consist of a watertight cast-in-place concrete box. The recommendations for design of the East Portal temporary support of excavation and cast-in-place box structure have been included in a technical memorandum dated 11 June 2012, "East and West Portals – Lateral Pressures for Support Design". **Figure 5.3-8** shows the plan at East Portal.

Figure 5.3-8 | Plan at East Portal



5.3.3.2 Temporary Support Methods at Shaft and Station Accesses

All shafts, with the exception of those within the buried valley at the Rideau Station, will extend through the overburden and into the rock. Shaft excavations through overburden will be typically be supported by temporary shoring; preliminary details for these elements are shown on the drawings. Typically temporary shoring will be by tie-back, soldier, or secant piles as appropriate. Excavation through rock will be by mechanicalmeans . Temporary support within the rock will vary from only shotcrete support for small shafts and/or good rock, to spot bolting and shotcrete, or shotcrete and pattern bolting, depending on the rock and in-situ stress conditions at each shaft location.

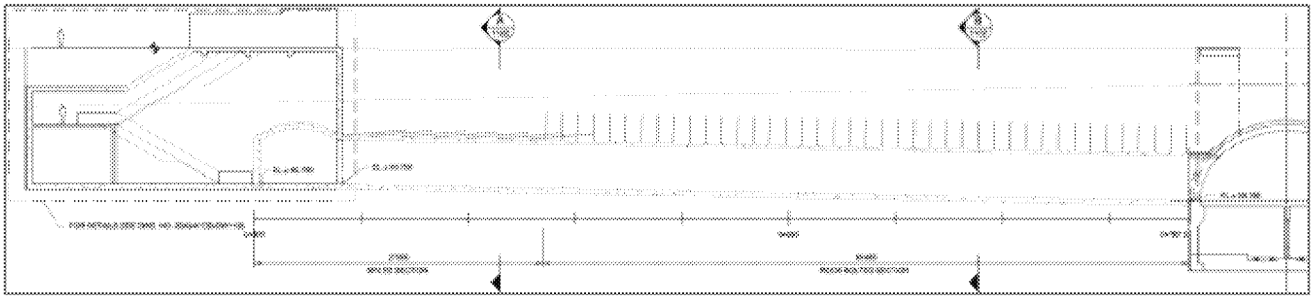
5.3.3.3 Descriptions of Shaft and Station Accesses

Downtown West

There are two accesses: the west entrance to the south of the station at Lyon St. and the east entrance at the Crehoy building on the north side of the cavern:

West entrance – The building is at Lyon and Albert Streets. A shaft of approximately 30 m by 18 m will be constructed through overburden and rock to provide access from the surface-access building. A tunnel will then run from this shaft beneath Lyon Street to the Station cavern concourse level. Excavation support will be a braced and tied pile and lagging wall through the overburden, with rock bolts to support the excavation in rock. The Lyon Street pedestrian tunnel will be excavated from the shaft under relatively low rock-cover conditions which will require spiling, lattice girders, and shotcrete for the initial length followed by pattern bolting and shotcrete for the remainder. **Figure 5.3-9** shows a cross-section at Downtown West – West Entrance.

Figure 5.3-9 | Downtown West Station – West Entrance



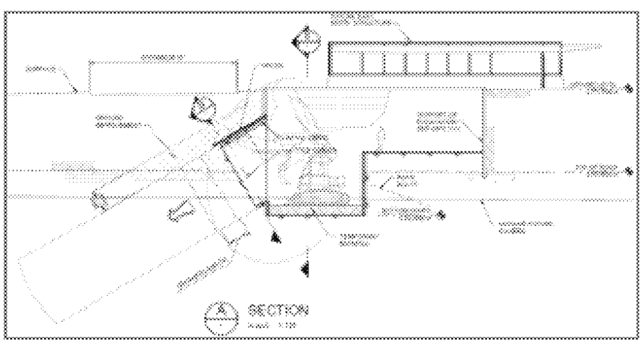
East entrance - In the first and basement floors of the Crehoy and Place DeVille buildings, the entrance will require cutting and strengthening floor slabs for vertical access perforations. The connection to the Station cavern concourse level will be via a short D-shaped tunnel excavated through the basement foundation wall to the side of the Station cavern. The tunnel will be drained type, with a waterproof membrane installed over the arch and sidewalls.

Two ventilation shafts penetrate the cavern roof at either end of the Station. The overburden sections of these will be supported by braced piles and lagging, with sections in rock supported by shotcrete and rock dowels as required to the top of the cavern. The shaft will then be filled with foam concrete and re-excavated once the Station cavern permanent lining is in place.

Downtown East

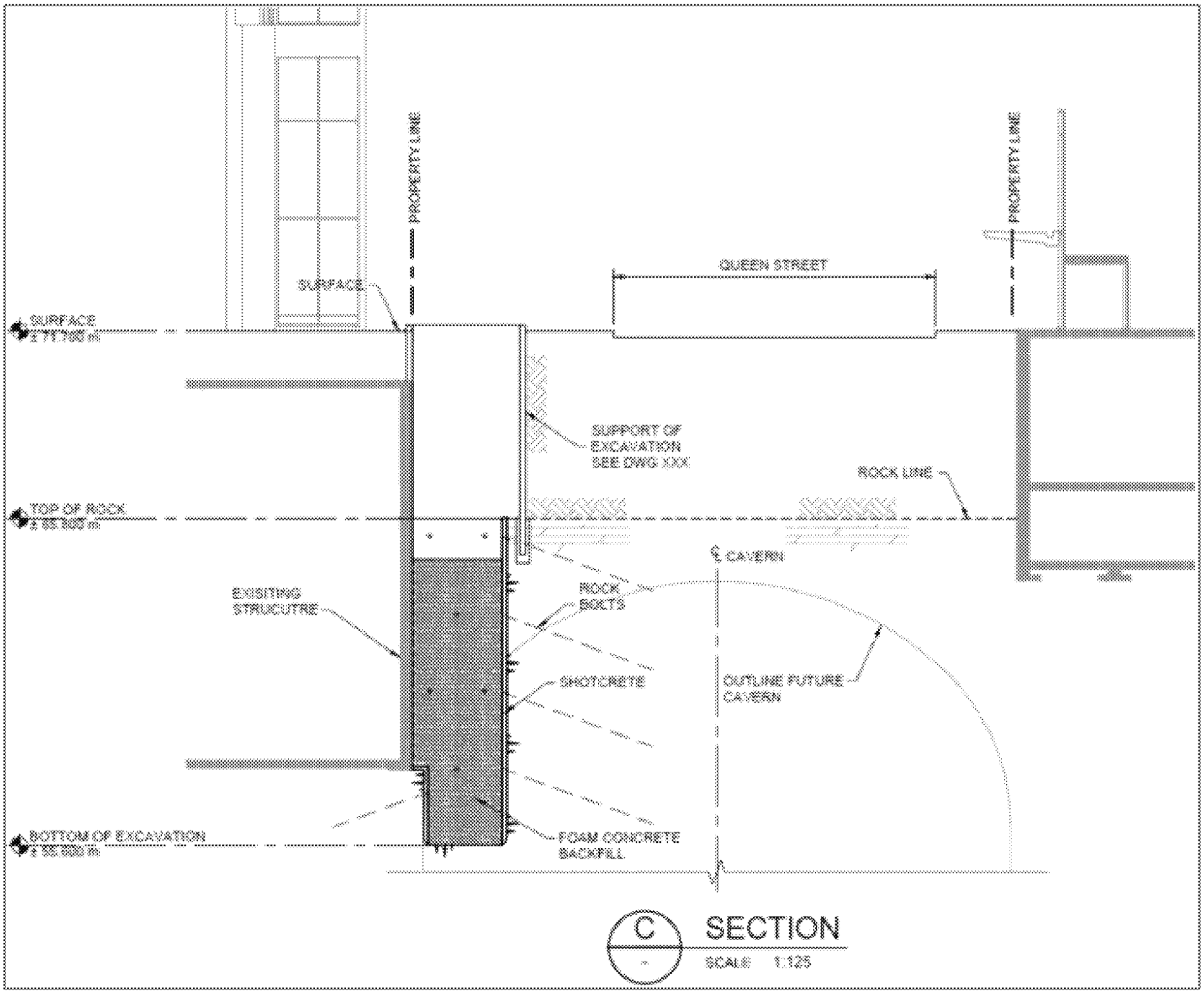
There are two escalator/stairs and an elevator access, one pair at the west end of the cavern and another pair at the east end. These accesses are to be located in the existing lanes which will be acquired for this purpose. The escalator/stair access are inclined from street level. Overburden sections will be supported by piles with the lagging tied to rock and the inclined shaft excavated. To support the rock and overburden at the start of the inclined excavation, ground improvement by jet grouting and pipe spiles will be required. A heavy shotcrete arch will then be installed. The excavation will then be backfilled with foam concrete and re-excavated once the permanent concrete lining is installed. As the excavation for the elevator shafts is vertical, excavation support will be simpler and ground improvement and spiling will not be required. **Figure 5.3-10** shows the Downtown East – East Entry Shaft proposed construction.

Figure 5.3-10 | Downtown East – East Entry Shaft Construction



Two ventilation shafts penetrate the cavern roof at either end of the Station. For these, overburden will be supported by braced piles and lagging and the shaft in rock supported by shotcrete and rock dowels as required to the top of the cavern. The shaft will then be filled with foam concrete and re-excavated once the Station cavern permanent lining is in place. The inclined and vertical shafts will then be waterproofed and permanent reinforced concrete linings installed. **Figure 5.3-11** shows the proposed ventilation shaft construction at Downtown East Station.

Figure 5.3-11 | Downtown East Station Entry Shaft Construction



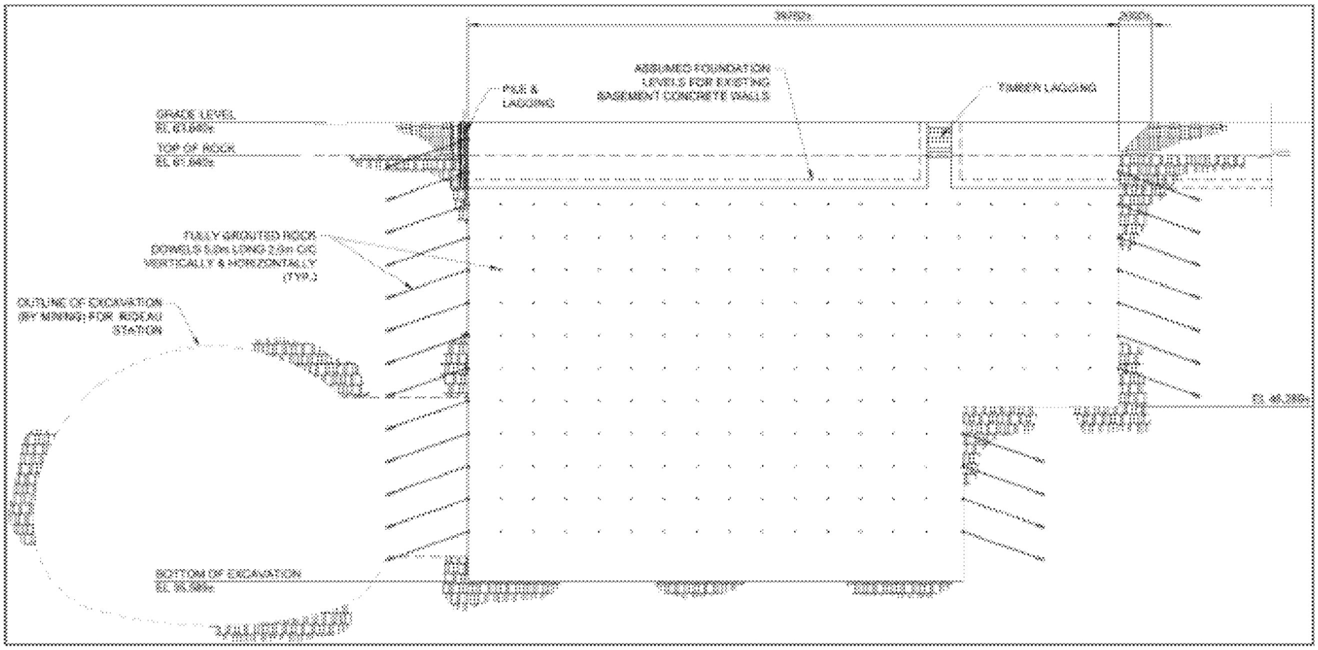
Rideau Station

Two accesses are to be initially constructed on the north side of the Station cavern: the west entrance in the Freiman Mall, and the east entrance at William Street. Facilities for two future entrances on the south side of the Station cavern are to be considered in the design.

The west entrance building in the Freiman Mall extends from the first floor to below the basement level of the building. Facility for five high-speed elevators and an emergency access stair is required. A shaft will be constructed through the existing basement level of the Freiman Building, through the overburden and into rock. The Freiman building columns are supported on footings resting on the overburden; therefore, the footing will be under-pinned using micropiling prior to excavating the overburden. The overburden will then be supported with piles and lagging, and the shaft excavated by mechanical means. In the interests of safety and constructability, we have relocated this shaft to the east to ensure that it, and the access tunnel to the Station, is located entirely in rock. However, due to the proximity of the Rideau buried valley and the potential for weathered rock, some treatment of the rock by grouting from within the excavation is anticipated. On completion of the excavation, the fully waterproofed reinforced concrete lining will be installed. This entrance will require cutting and strengthening floor slabs for vertical access perforations.

The east entrance building is located at William Street. For this entrance, a 40 m by 16 m shaft will be constructed through overburden and rock to provide access from the surface-access building. A short tunnel will then run from this shaft to the Station cavern concourse level. The excavation will be between basement foundations that are founded on rock, so no support is required on these edges through the overburden. A pile and lagging wall braced to rock will be installed for support at Rideau Street and overburden sloped back at the north side. The section of the shaft in rock will be supported by grouted rock bolts and shotcrete as required. These structures will be fully waterproofed. **Figure 5.3-12** shows the William Street Entry Shaft construction for Rideau Station.

Figure 5.3-12 | Rideau Station – William Street Entry Shaft Construction



Two ventilation shafts penetrate the cavern roof at either end of the Station. For the east shaft, the overburden will be supported by braced piles and lagging and the rock supported by shotcrete and rock dowels as required to the top of the cavern. The west shaft will be entirely within the Rideau buried valley and ground treatment by jet grouting will be implemented if it is identified as required during detailed design. The east shaft will then be filled with foam concrete, and re-excavated once the Station cavern permanent lining is in place.

MSF Connection Tunnel below VIA Rail Tracks

The rail connection to the MSF Facility requires construction of a 11.5 m-wide by 6.5 m-deep reinforced concrete box structure at a depth (to top of the box structure)of 1.6 m beneath the VIA Rail tracks. It is anticipated that opportunities for possession of the VIA Rail tracks will be limited and a methodology which involves tunnelling below the rail tracks to permit installation of the concrete box structure has, therefore, been developed.

Ground conditions at the crossing consist of fill and glacial till to a depth of 3.5-4.0 m with Billings Formation bedrock below. The groundwater table is located close to the surface and dewatering of the soft ground deposits will be required before commencing tunnelling operations below the VIA Rail tracks.

Drawings 1314-41SK-S4-8001 to 8004 detail our proposed methodology for constructing the tunnel below the VIA Rail tracks. It will be essential to minimize loss of ground in the upper soft ground deposits, and the key elements in our proposed tunnelling methodology to note from the drawings are as follows:

- Advance dewatering of the soft ground deposits below the railway. At this stage, it is expected that this can be achieved by the means of four dewatering wells drilled to bedrock.
- Secant piling on either side of the Via Rail tracks to permit establishment of retained cuts, from which tunnelling operations can proceed.

- The advance installation of an array of 23 x 22 m-long, 0.6 m-diameter steel tubes or casings at an approximate depth of 1.3 m below the VIA Rail tracks, using 'jack and bore' techniques to form an 'umbrella' which will permit tunnelling to proceed without disturbance to the tracks above. 'Jack and bore' methods are commonly used for installing sewer pipe crossings beneath road and rail corridors and involve jacking of steel tubes in advance of a continuous auger rotating which permits spoil removal behind a rotating cutter head. The auger and cutter head extend the full length of the casing being jacked. By jacking the steel casing a short distance ahead of the auger, it is possible to minimize the ground loss at the excavation face.
- Advancement of the tunnel in 1 m-long sections with temporary steel support frames installed below the steel tube 'umbrella' at 1 m intervals. These temporary support frames are left-in-place and become part of the final concrete box structure which will be cast-in-place on completion of tunnel excavation operations.
- Constant monitoring of the VIA Rail tracks during jack and bore steel casing installation and tunnel excavation operations with the necessary equipment on standby for adjusting rail levels where necessary.

5.3.3.4 Drawings for Cut-and-cover Structures in Soil and Rock

Initial Rock Support

Table 5.3-9 | Drawings for Cut-and-Cover Structures in Soil & Rock

Drawing Number	Title
1270 - 41DD - S2 – 1001	West Portal – Support of Excavation – General Plan
1270 - 41DD - S2 – 1002 thru 1004	West Portal – Support of Excavation – Plans 1, 2 & 3 of 3
1270 - 41DD - S2 – 1005 thru 100	West Portal – Support of Excavation & Concrete – Sectional Elevations – 1, 2 & 3 of 3
1270 - 41DD - S2 – 1101	West Portal – Support of Excavation & Concrete – Sections
1270 - 41DD - S2 – 1201	West Portal – Support of Excavation & Concrete – Section & Details
1270 - 41DD - DW – 1005	Downtown West – Support of Excavation – Plan
1270 - 41DD - DW – 1006 & 1007	Downtown West – West Entrance – Concrete - Plans 1 & 2 of 2
1270 - 41DD - DW – 1103	Downtown West – West Entrance – Support of Excavation Sections
1270 - 41DD - DW – 1104	Downtown West – West Entrance – Concrete Formwork Sections
1270 - 41DD – DE – 1008	Downtown East – Vent Shafts Excavation & Support – Plan & Sections
1270 - 41DD – DE – 1101	Downtown East – Elevator Shafts Excavation & Support – Plans & Sections
1270 - 41DD – DE – 1102	Downtown East – Escalator Tunnels Excavation & Support Sections
2050 - 41DD – DE – 1103	Downtown East – Construction Entrance – Support of Excavation Plan
2050 - 41DD – DE – 1104	Downtown East – Construction Entrance – Support of Excavation Sections
1270 - 41DD – RD – 1104	Rideau – East Entrance – Support of Excavation – Sections
1270 - 41DD – RD – 1005	Rideau – East Entrance – Concrete – Plans
1270 - 41DD – RD – 1006	Rideau – West Entrance – Support of Excavation Plans
1270 - 41DD – RD – 1005	Rideau – East Entrance – Concrete – Plans
1270 - 41DD – RD – 1104	Rideau – East Entrance – Support of Excavation – Sections
1270 - 41DD – RD – 1105	Rideau – East Entrance – Concrete – Sections
1270 - 41DD – RD – 1106	Rideau – West Entrance – Support of Excavation – Sections
1270 - 41DD – RD – 1107	Rideau – West Entrance – Concrete Sections
1270 - 41DD - S2 – 1009	East Portal – Support of Excavation – General Plan
1270 - 41DD - S2 – 1010 thru 1012	East Portal – Support of Excavation – Plans 1, 2 & 3 of 3

Drawing Number	Title
1270 - 41DD - S2 – 1013 thru 1015	East Portal – Support of Excavation & Concrete – Sectional Elevations – 1, 2 & 3 of 3
1270 - 41DD - S2 – 1102	East Portal – Support of Excavation & Concrete Sections
1270 - 41DD - S2 – 1103	East Portal – Support of Excavation & Concrete Sections

5.3.4 ANTICIPATED TBM & SUPPORTING TBM OPERATION REQUIREMENTS FOR PROPOSED BORING TUNNELS

This Section does not apply to the RTG bid, as our methodology does not require use of a tunnel boring machine (TBM) for excavation and lining of the running tunnel. Details of our methodology and analysis methods for the running tunnel are covered in Section 5.3.5 – MINED STRUCTURES – CONSTRUCTION METHODOLOGY & ANALYSIS METHODS

5.3.5 MINED STRUCTURES – ANALYSIS METHODS AND ANTICIPATED SEQUENCE OF EXCAVATION AND TEMPORARY GROUND SUPPORT FOR MINED STRUCTURES

5.3.5.1 Running Tunnel in Rock

Design and construction for the running tunnel in rock are described below.

Construction Methodology

Initial support for the running tunnel will be provided using epoxy or cement grouted rock dowels and shotcrete. The tunnel will be excavated using roadheaders in a single heading followed by an invert bench. Where required, rock bolts will be installed at every round of excavation with shotcrete following a short time afterwards. Due to the relatively high horizontal stresses along the majority of the tunnel, rock dowels and shotcrete will extend to just below the spring line to control side wall stability. Preliminary rock support classes (I, III, IV and V) were developed based on the RMT, stress and water conditions, and resulting ground behaviour:

- **Class I -** Spot bolting, mesh and shotcrete for support of rock wedges formed by distinct discontinuities
- **Classes III & IV -** Pattern bolting, mesh and shotcrete for support of rock mass behaviour caused by blocky conditions
- **Class V -** Pre-support using pipe spile canopy, heavy pattern bolting, mesh and shotcrete for poor rock conditions including faulting. Additionally, face support using fibreglass dowels is expected to be required in fault zones as well as areas of low cover and poorer rock conditions.

At both the West and East Portals, low rock cover does not allow for a proper rock arch to form and the rock support classes do not apply. To control deformations and support the overburden load, a sequential excavation approach with a pipe spile canopy, steel sets and shotcrete is envisaged. Preliminary support types (Type 1 and 2) were developed. As the cover increases, the support will be transitioned into the various rock support classes described above. Due to the low rock cover and the possibility of face collapse, face support using fibreglass dowels is expected to be required.

Design Analysis

The design, performance requirements, and general design methodology for the initial and permanent lining for the running tunnels will comply fully with the structural criteria in Project Agreement (PA) Schedule 15-2, Part 3.

Preliminary Design of Initial Rock Support

Rock mass types and rock strength parameters (RMR, Q, Hoek and Brown GSI, σ_{ci}, m and s values) have been determined along the length of the tunnel. Considering the rock mass type, strength parameters, groundwater and in-situ stresses condtions, rock mass behaviours were developed for various conditions. Rock support was then estimated using empirical methods (Barton's Q and Bienaswski's RMR) for each of these rock mass behaviours. The allowable length of unsupported rock was estimated based on construction considerations and rock conditions. FEM analysis for various conditions was performed using the program Phase2. To estimate the 3D effects of face support, an analytical approach (Hoek, Carranz-Torres, Diederichs, Corkum, 2008) was used to determine the longitudinal deformation and softening ratio. Ground-reaction curves were developed by modelling excavation stiffness at various stages of excavation. The selected rock support was then assessed using the ground reaction and support reaction curves considering the location of application rock support behind the excavation face. A minimum safety factor of 1.5 for the support system was used for this temporary condition.

For final design of the initial rock support, 3D finite-element or finite-difference analysis will be used to assess the effects of face support and the stability of the face considering the RMT and particular location along the alignment. The tunnel response and rock support will then be modelled using 2D finite element or finite difference analysis, again considering the location of rock support behind the face. The program UnWedge will be used to assess the rock support required for wedges created by distinct discontinuities. Output from these analyses will be rock-support classes for defined rock-mass behaviours. Application of these classes during construction will be based on geological mapping within the tunnel and assessment of the current rock condition at the face as well as measured performance of the tunnel as mining progresses. Reassessment of the rock classes may be required based on measured performance as compared to predicted performance of the tunnel for a particular rock condition and expected rock mass behaviour.

5.3.5.2 Running Tunnel in Soft Ground

Construction Methodology

The running tunnels will be excavated through the soils of the buried valley over a length of approximately 55 m west of the present location of Rideau Station. As described above, the soils deposited in the buried valley are mainly sandy silts, silty sands, and till and till-like deposits. The SPT N values of the deposits range from below 1 to more than 50, where the higher blow counts are likely associated with the presence of cobbles and boulders in the soil.

The following measures will be required to ensure the stability of the ongoing tunneling operation:

- Grouting of the sand layers and/or dewatering measures from within the tunnel
- Installation of additional face support measures and pre-support measures
- Shortening of the length of the excavation round

To facilitate tunneling of the running tunnels in soft ground conditions, a design approach has been selected which includes the following features:

- The subdivision of the excavation face into multiple drifts and immediate flashcrete support of the excavated ground, followed by a shotcrete arch with a thickness 500 mm.
- A grouted barrel vault, which will be installed over the entire length of the soft ground section from within the rock section.
- Probing ahead of the excavation face and grouting of the water bearing sand layers.

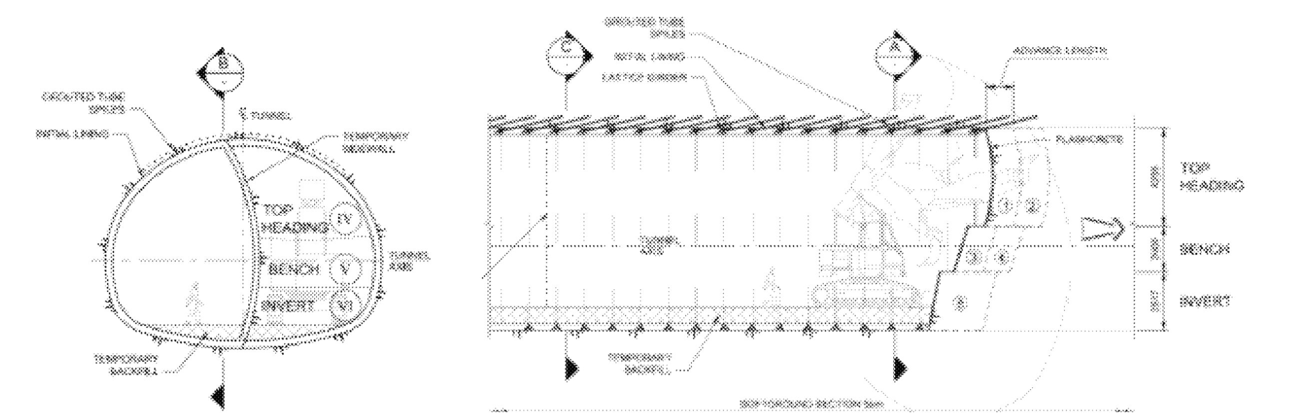
At the current tender stage of the design, three pre-support and/or pre-treatment methods of these soils are considered feasible:

- A systematic dewatering scheme installed from the surface and/or from within the tunnel, to depressurize the sand layers within the till, in conjunction with a heavy grouted pipe umbrella pre-support.
- Two rows of jet grouting columns forming a roof over the tunnel and cavern top headings installed from within the tunnel in conjunction with dewatering and depressurization of the sand lenses in the face ahead of the tunnel and around the tunnel perimeter, including below the tunnel invert.
- Full face jet grouting from the surface.

Although full-face jet grouting from the surface may be viewed as the most robust option, it is also the most expensive and most disruptive at the surface. In addition, as the expected jet grout column diameter depends on the locally treated soils, the variability of the glacial deposits may pose challenges to create a uniformly improved jet grout body. A cost/benefit/impact analysis determined the most-appropriate ground treatment method to be a systematic dewatering scheme installed from the surface and/or from within the tunnel, to depressurize the sand layers present within the till, in conjunction with a heavy grouted pipe umbrella pre-support.

Running tunnels in the buried valley section will be excavated in a single sidewall drift excavation and support sequence under the pre-support of a grouted pipe umbrella. Eighteen-metre-long perforated and grouted steel pipes (type "ALWAG" or "RODIO") will be installed at a lateral spacing of 300 mm above the tunnel roof. Pipes will be installed every 12 m length of tunnel, resulting in an overlap (and minimum length ahead of the advancing face) of the pipe umbrella of 6 m. The first sidewall drift will be excavated in a top heading, followed by bench and invert excavation. After closing the ring in the sidewall drift, the remainder of the tunnel is also excavated in a top heading, bench and invert sequence. In a last stage after closing the final support ring, the temporary sidewall will be removed to provide the full tunnel cross section. Details of this excavation and support sequence are shown in **Figure 5.3-13**.

Figure 5.3-13 | Excavation Sequence for Running Tunnel in the Buried Valley



Design Analysis

The preliminary design for this section of the works has been performed using 2D finite element analysis using the program Phase2. The described excavation and support sequence is input in a multi-stage modelling approach, and lining forces as well as round deformations are determined. For the final design stage of the Project, the stability of the tunnel excavation and support sequence will be assessed in more detail using 3D finite element analysis.

5.3.5.3 Station Caverns in Rock

The Downtown West and East Stations are nominally 18 m wide x 120 m long x 13 m high, while Rideau Station is nominally 20 m wide x 120 m long x 18 m high. The structures are in two levels with a continuous concourse above the track and platform level throughout, except at Downtown West where the concourse is interrupted by a pedestrian/vehicular underground link between the Canadian Chamber of Congress and the Sun Life Place Financial Centre buildings. This link is to be maintained and incorporated into the design.

Design and performance requirements for the permanent lining for the three Stations will comply fully with the structural criteria in PA Schedule 15-2, Part 3. Design and performance requirements for interior structural elements contained within the exterior shell of the underground mined Station structures, and renovations to existing buildings impacted by the Station construction, will comply fully with PA Schedule 15-2, Part 5, Article 3.

Construction Methodology & Design Analysis

Along the alignment of Downtown West and Downtown East Stations, there are three scenarios for the position of building foundations and basements relative to the proposed caverns:

- Footings and basements lie above the cavern crown (no buildings or shallow foundations)
- Footings and basements lie between crown and springline of the cavern
- Footings and basements lie directly adjacent to the newly constructed cavern, from springline to or below cavern invert level

For the latter two cases, the spatial locations of the cavern do not allow for the typical hard-rock temporary support scheme of rock bolts and steel-fibre reinforced shotcrete in the top heading arch of the cavern. As the required support length of rock bolts cannot be provided, a pre-support and support scheme similar to a typical "soft ground tunnel" is proposed.

With the limited rock cover, the rock cannot be used to mobilize a load carrying arch and a stiff shotcrete shell to support the full overburden load, and is proposed to be installed as tunnel excavation progresses. The arch will be supported on the sidewalls installed in the bottom drifts of the excavation. A heavy grouted steel pipe umbrella is designed to provide the necessary roof support and the multiple drift excavation and support sequence allows for timely installation of the required shotcrete support.

For areas with deep foundations and basements, the horizontal component of the arch thrust at the springline cannot be allowed to load the building basements. In these locations, the horizontal thrust component will be resisted by a tension tie installed during mining a short distance behind the excavation face across the arch at the bottom drift walls. A preliminary assessment of the feasibility of this excavation and support scheme for the mined excavation of Downtown West and East Stations was performed using a multiple stage Phase2 finite element analysis (see **Figure 5.3-14**). In this analysis, particular emphasis was put on the feasibility of mined Station construction in proximity to adjacent basement structures and the impact and interaction of the newly constructed cavern on existing buildings.

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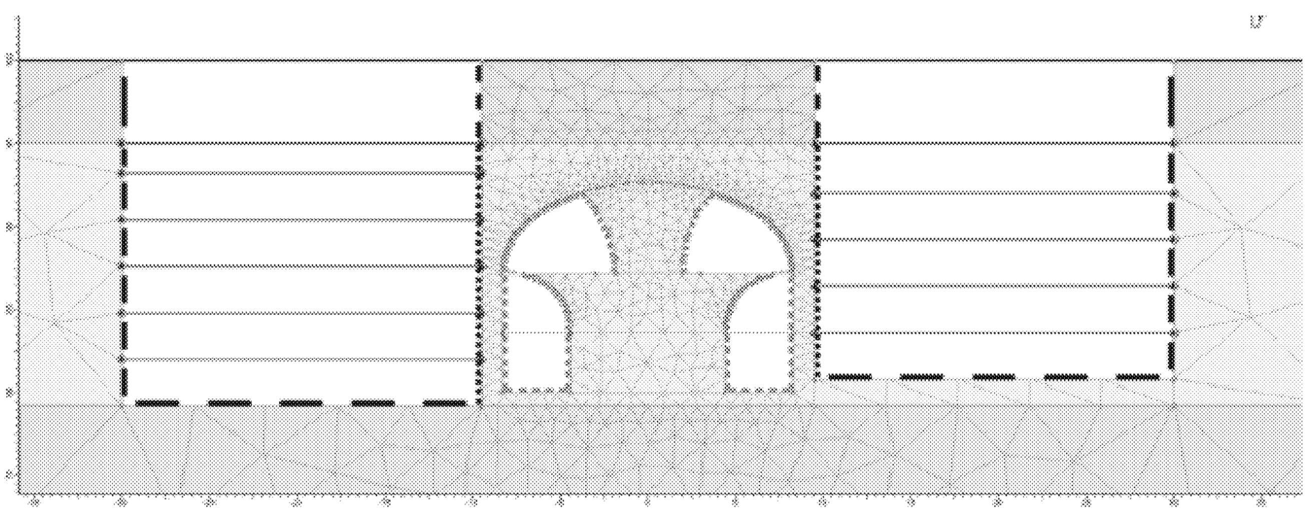
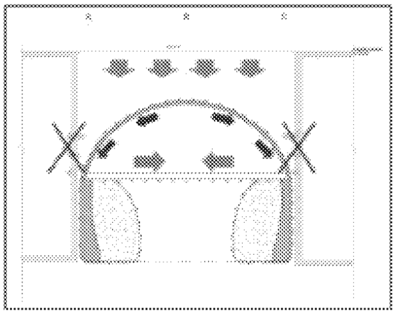


Preliminary finite-element analysis established the requirements for the tension ties/at the support points to the arch.

During the final design phase of the Project, three dimensional (3D) finite-element or finite-difference analysis will be undertaken to assess the interaction between rock, the newly constructed caverns, and the existing buildings along the tunnel alignment.

The tension ties are designed to resist the horizontal component of the arch loads due to the full overburden load of rock and soil above the arch of the Station cavern, without restraint or embedment from the adjacent rock and buildings (see **Figure 5.3-15**).

Figure 5.3-15 | Loading in Tension Ties



Preliminary analysis indicates that tension ties are required every 2 m along the section of the caverns where building basements are located at or below springline elevation of the Station caverns. Tension ties will be connected to the concrete arch and walls by prefabricated steel elements installed during sidewall and tunnel arch installation respectively.

To minimize the disturbance of the rock mass during the excavation of the drifts, GFRP rock bolts will be used as temporary support elements to ensure integrity of the rock pillar.

5.3.5.4 Station Cavern in Soft Ground

Construction Methodology and Design Analysis

Preliminary Design of Initial Cavern Support in Soft Ground

Over a length of approximately 60 m, Rideau Station Cavern will be excavated in the buried valley soils, primarily sandy silts, silty sands, and till and till-like deposits. The SPT N values of the deposits range from below 1 to more than 50, where the higher blow counts are associated with the presence of cobbles and boulders in the soil.

As for the running tunnel soft-ground section, the following measures will be required in the soft-ground portion of the Rideau Station cavern to ensure the stability of the ongoing tunnelling operation:

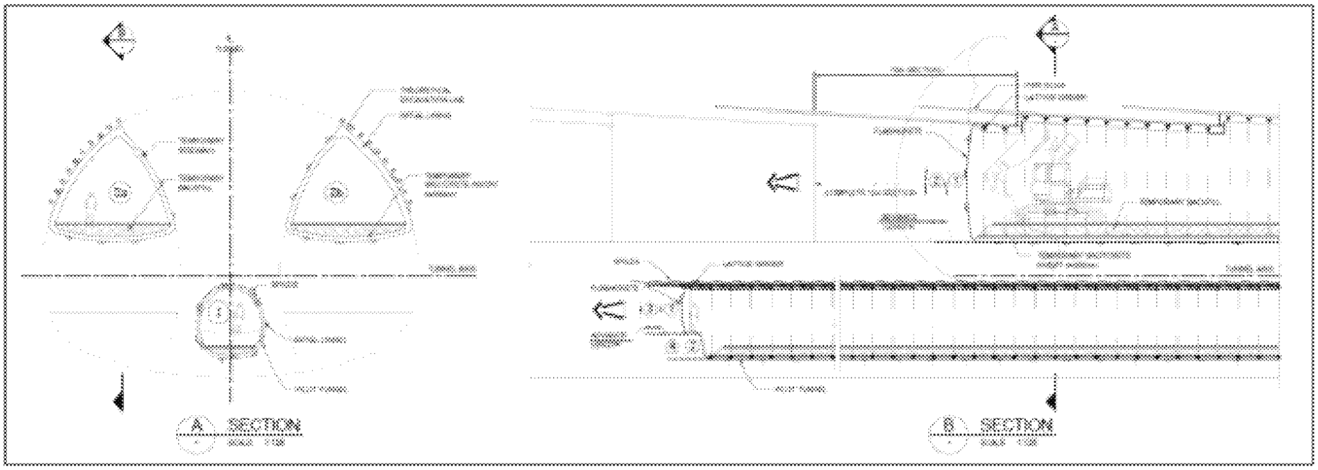
- Grouting of the sand layers and/or dewatering measures from within the pilot tunnel
- Installation of additional face-support measures and pre-support measures
- Shortening of the length of the excavation round.

To facilitate tunneling of this large cavern in soft-ground conditions, a design approach has been selected which includes the following features:

- The subdivision of the excavation face into multiple drifts and immediate flashcrete support of the excavated ground, followed by a shotcrete arch with a thickness 500 mm.
- An exploratory drift (pilot tunnel) with a small diameter, located at the bottom of the cavern, to safely evaluate the ground conditions ahead and implement ground-improvement measures.
- A grouted barrel vault, which will be installed over the entire length of the soft-ground section from within the rock section.
- Probing ahead of the excavation face and grouting of the water bearing sand layers.

The soft-ground segment of Rideau Cavern will be excavated in a double sidewall drift excavation and support sequence under the pre-support of a grouted pipe umbrella. Eighteen-metre-long perforated and grouted steel pipes (type ALWAG or RODIO) will be installed at a lateral spacing of 300 mm above the tunnel roof, both in the side drifts and center drifts. The pipes will be installed every 12 m length of tunnel, resulting in an overlap (and minimum length ahead of the advancing face) of the pipe umbrella of 6 m. The two sidewall drifts will be excavated in a top heading, followed by bench and invert excavation. After closing the ring in the sidewall drifts, the center portion of the tunnel is also excavated in a top heading, bench and invert sequence. In a last stage after closing the final support ring, the temporary sidewalls in shotcrete will be removed to provide the full cavern cross section. Details of this excavation and support sequence are shown in **Figure 5.3-16**.

Figure 5.3-16 | Excavation Sequence for Rideau Cavern in the Buried Valley



As for other sections of the underground alignment, a preliminary design using 2D finite element analysis has been undertaken for the soft ground section of Rideau Station cavern. In a multi-stage modelling approach, the described excavation and support sequence is modeled and lining forces as well as round deformations are determined, and lining thicknesses as shown on the preliminary design drawings are confirmed. In the final design stage of the Project, the stability of the tunnel excavation and support sequence will be assessed in more detail using 3D finite-element analysis.

5.3.4.5 Drawings

Running Tunnels Primary Support

Drg.No. 1276 - 41DD - S2 – 1101 through 1104:	Running Tunnel – Excavation and Rock Support - Section Details
Drg.No. 1270 - 41DD - S2 – 1008:	Running Tunnel – West End Portal - Excavation and Rock Support
Drg.No. 1270 - 41DD - S2 – 1016	Running Tunnel – East End Portal - Excavation & Rock Support

Station Caverns Primary Support

Drg.No. 1270 - 41DD - DW – 1201:	Downtown West – Excavation & Support Details
Drg.No. 1270 - 41DD – DE – 1201:	Downtown East – Excavation & Support Details
Drg.No. 1270 - 41DD – RD – 1101:	Rideau – Cavern Excavation & Support – Rock – Sheet 1
Drg.No. 1270 - 41DD – RD – 1102:	Rideau – Cavern Excavation & Support – Rock - Sheet 2
Drg.No. 1270 - 41DD – RD – 1103:	Rideau – Cavern Excavation & Support – Soft - Sheet 2
Drg.No. 1270 - 41DD – RD – 1201:	Rideau – Excavation & Support – Details

Lyon Street Pedestrian Tunnel Primary Support

Drg.No. 1270 - 41DD - DW – 1004:	Downtown West - Lyon St Tunnel – Excavation & Support – Key Plan & Profile
Drg.No. 1270 - 41DD - DW – 1102	Downtown West - Lyon St Tunnel – Excavation & Support – Sections

5.3.6 ANTICIPATED FINAL LINING DESIGN REQUIREMENTS

On completion of running tunnel excavation and temporary support, work will commence on the construction of the cast-in-place concrete final liner, which will be installed behind a travelling formwork structure. The final liners for shafts and other cut-and-cover structures will also be installed as cast-in-place structures installed behind temporary formwork. This section discusses the design approach for the final liner structures.

5.3.6.1 Proposed Approach to Analysis and Design of all Cut-and-Cover, Bored or Mined Structures

Running Tunnel

The final lining will be designed for loads as defined in the Project Design Criteria (e.g. ground loads [rock wedges and swelling as appropriate], hydrostatic loads, seismic loads, all traffic loads at portal structures).

The required design life for the completed tunnel is 100 years. To achieve this, a waterproof membrane will be used to isolate the initial rock support, rock dowels and shotcrete from the final lining of reinforced concrete. As the initial rock support, including shotcrete, will be subjected to aggressive groundwater conditions, it is assumed that it will degrade over the life of the structure and only the final lining will carry the permanent loads.

A preliminary design of the running tunnel lining for both the drained and undrained tanked tunnel was performed using a bedded spring model. An effective tunnel diameter equivalent to the tunnel excavated cross-sectional diameter was used in determining the rock foundation modulus for the spring constant. Only radial springs were considered in the analysis as the tunnel waterproofing system was assumed to eliminate tangential shear stresses at the concrete/shotcrete boundary. For preliminary design, a rock load equivalent to one tunnel diameter was considered.

For the drained tunnels west of Metcalfe Street, the hydrostatic pressure will be assumed to be 25 percent of the original hydrostatic pressure to account for the potential for blockage of the drainage system, while full hydrostatic loading will be used for the undrained tunnels east of Metcalfe Street.

For final design, analysis of the tunnel final lining will be undertaken using 2D and 3D analysis software and, where required, finite-element or finite-difference programs such as FLAC3D. Phase2D will be used to model and analyze complex ground-structure interaction behaviour.

In terms of the seismic loading case, the running tunnelling structure is assumed to be in contact with the ground, and the lining will be distorted by the various seismic waves within the rock and without structural excitation. These seismically induced ground movements result in axial, bending (curvature), ovalling, and racking deformations of the tunnel lining which result in axial, bending and shear loads imparted on the lining. In general, seismic loading does not govern; however, these effects will be reviewed during final design using the procedures described in "Seismic Design and Analysis of Underground Structures," by Youssef M.A. et al., as well as using various other publications for guidance (Jaw-Nan Wand, 1991, Earth Science Associates, 2003, Caltran, 2005).

Structures Waterproofing

PA Schedule 15-2, Part 3 specifies allowable post-construction seepage and waterproofing design requirements and that the design of waterproofing systems must meet specified minimum requirements. There are two basic types of waterproofing systems for tunnels and underground structures:

- Drained or open systems
- Undrained or closed (tanked) systems

Open systems allow groundwater inflow into the tunnel invert drainage system, while closed systems aim to prevent all groundwater ingress. Permanent linings for tunnels between Metcalfe Street and Campus Station will be designed and constructed as undrained/closed, as required by PA Schedule 15-2. The design of the drained waterproofing system will take into account the potential for precipitation of insoluble salts to block the tunnel drainage system.

Waterproofing systems will consist of plastic membrane sheets, double-seam heatwelded together to form panels around the tunnel or cavern structure. A smoothing or regulating layer of shotcrete may be required at the shotcrete face to meet waviness and roughness critieria for the membrane material. A geotextile felt material will be installed on the shotcrete as a protection layer and, in the case of the drained system, a dimple membrane will provide drainage behind the final lining. The membrane will be fixed to the shotcrete by heatwelding to discs nailed to the shotcrete. Membrane panels will be isolated at circumferential construction joints by grout/water stops to allow for isolation and repair of any leakage through the system. At tanked sections, a second layer of membrane will be applied at the invert as a protection layer.

Successful waterproofing installation necessitates high-quality workmanship: avoiding puncturing during the work and preventing leaks when attaching the membrane to the shotcrete. Quality control procedures will be established to thoroughly test the seals at all joints and seams to ensure no leakage occurs before casting the final lining.

The sheet membrane for the tunnels and caverns will be PVC except if aggressive groundwater conditions require a polyolefine FPO lining. This could be the case at Downtown West where the cavern intersects the Billlings Shale which has high levels of salinity and sulphates.

For access and vent shafts and cut-and-cover sections, waterproofing may consist of several types of materials:

- Liquid systems (e.g. hot applied rubber, tar, asphalt emulsions)
- Panel systems (swelling bentonite encapsulated in fabric roll or cardboard)
- Epoxy systems (two component systems)
- Spray applied systems (single component cold applied neoprene or polyurea)
- Sheet membranes (e.g. rubber, neoprene, HDPE and PVC)
- Hybrid systems (poly-rubber gel)

The selection of material will be determined by the type of construction, environment, durability and economics. In addition to a membrane, waterproofing (e.g. PVC, vinyl, swelling rubber waterstops) will be provided at all cold joints and penetrations.

Station Caverns

The design of the final liners for the station caverns is discussed in **Section 5.5**.

5.3.6.2 Drawings

Running Tunnels Final Liner

Drg.No. 1200 - 41DD - S2 – 1106: Running Tunnel – Typical Sections

Drg.No. 1200 - 41DD - S2 – 1107: Running Tunnel – Jet Fan Niche

Drg.No. 1200 - 41DD - S2 – 1108: Running Tunnel – Waterproofing Details

5.3.7 PRELIMINARY ASSESSMENT OF IMPACT TO ADJACENT STRUCTURES

Four areas are identified as critical for damage potential assessment:

- Downtown West Station
- Downtown East Station
- Tunnel and Rideau Station in the bedrock buried valley
- East Portal

Due to the similarity of potential ground movements, Downtown West and Downtown East Stations are combined in the damage potential assessment presented in the following sections. The assessment of damage potential of buildings considers the ground movements induced by running tunnels, Stations and shaft excavations in conjunction with those induced by groundwater table drawdown.

5.3.7.1 Analysis Methods

Ground Displacement Due to Stress Relief

Ground movements associated with stress relief at the mined excavations were estimated at selected locations using finite-element analysis. The analysis took into account the excavation sequence and temporary-support installation. To extrapolate the results of the finite-element analyses to other areas along the alignment, the results were calibrated against empirical methods where volume of the surface settlement trough is related to the area of excavation, tunnel depth, and soil type, and is assumed to be an inverted normal distribution function curve (as proposed by Peck and Schmidt (1969) and by O'Reilly and New (1982)). Ground-loss ratio, the ratio of the volume of surface settlement trough to the excavated tunnel section, is estimated to be 0.35 to 0.5 percent according to numerical modelling results. A higher ground-loss ratio of 0.7 to 1 percent, twice the values obtained from numerical analyses, was also used in the assessment to investigate the influence of higher ground loss on damage potentials.

Empirical methods proposed by Peck (1969) and Clough and O'Rourke (1990) were used to assess ground displacements behind shored-open excavations. These methods assume that ground movement associated with open excavations are a function of the types of soils being retained, excavation geometry defined as excavation depth and plan dimension, groundwater pressure, construction sequence, construction quality and overall stiffness of the support system. Our assessment used the following assumptions:

- Influence zone of ground movements is 2 to 3 times the depth of excavation
- Maximum ground settlement behind the retaining walls is 0.3 percent of the depth of excavation in sands and stiff to hard clays supported by flexible system
- 0.5 percent of the depth of excavation in soft to firm clays supported by a rigid system
- Ratios of maximum settlement to maximum horizontal displacement in different soil types is equal to one

The West and East Portal entry and ventilation shafts at Stations will be constructed by open excavation methods. We assumed that flexible support systems such as soldier piles and lagging will be used for the construction of the West Portal and various shafts. For the East Portal and shafts located at the west end of Rideau Station, we assumed a watertight rigid support system to reduce the potential for excessive ground settlement associated with groundwater drawdown as discussed below.

Ground Settlement Due to Groundwater Drawdown

Ground settlement induced by groundwater table drawdown results from the increase of effective vertical stress in the soils below the in-situ groundwater table. Negative pore pressure, induced in the clay due to capillary effect after drawdown, is assumed to extend linearly up to the elevation of the in-situ groundwater table before the occurrence of drawdown. Groundwater drawdown in the bedrock is not anticipated to cause settlement. Along the tunnel alignment, groundwater table drawdown during excavations will occur in the bedrock formations, and also at the bedrock buried valley, Rideau Station and East Portal areas unless ground treatment is implemented before excavation.

The extent and magnitude of groundwater drawdown associated with excavations in the bedrock buried valley, at Rideau Station and East Portal were obtained from a hydrogeological model that covered a large area beyond the limits of Segment 2 right-of-way. Ground settlements within the drawdown zone were estimated based on Terzaghi's 1D Consolidation theory.

Potential for Damage to Structures

Settlement and horizontal displacement profiles were generated by combining ground movements due to both stress relief and groundwater drawdown. Based on the combined ground movement profiles, horizontal strains and angular distortions were computed at building locations without accounting for structural stiffness and soil-structure interaction. The empirical method, first proposed by Boscardin and Cording in 1989 and later modified by Son and Cording in 2005, was used to assess the potential for damage to buildings based on both free-field horizontal strains and angular distortions.

The potential for damage to piled foundations, on bedrock and subject to downdrag loads, is expected to be low due to the low potential of exceeding the structural yield strength of the pile above its contact with bedrock.

The potential for damage to pedestrian bridges at Rideau Station is also considered to be low due to the relatively uniform settlement anticipated along these structures. However, if the pedestrian bridge at the west end of the Rideau Station is founded on spread footings in the soils of the bedrock buried valley, there is potential for differential settlement at the contact of the bridge abutments with the building structures. Additional details of the bridge foundation elements and the connection with the building structures will be required to permit more detailed analysis.

Assessments of damage potential for pedestrian tunnels and major utility pipelines within the influence zone are not included in this study due to insufficient information at this stage. However, based on finite-element analyses, the settlements, horizontal strains and angular distortions are anticipated to be small, resulting in low potential for damage.

5.3.7.2 Assessment Results

Downtown West and East Stations

Numerical analyses of the mined Station caverns indicate that surface settlements are estimated to be between 2 and 8 mm, and slightly less at the bedrock/overburden interface. Settlements of this order will result in small angular distortions and horizontal strains and are not anticipated to damage utilities within the roadway, utility connections to buildings, or surface structures which are founded on bedrock in the area of the Downtown West and East Stations.

Tension ties and a layer of compressible material is to be installed at the base of the crown arch and top of the Station walls at both Stations to resist the horizontal component of the arch loads, due to the full soil and rock overburden load acting on the arch of the Station cavern, without restraint or embedment from adjacent rock and buildings.

The open excavation for access and ventilation shafts at both Stations is assumed to consist of braced flexible systems such as soldier piles and lagging. At Downtown West Station, potential for damage associated with open excavations for two ventilation shafts is categorized to be very slight to slight for structures within 5 m of the edge of open excavations, and negligible for structures further away. Similarly, at Downtown East Station, potential for damage associated with open excavations for three entry shafts and two ventilation shafts is categorized to be very slight to slight for structures within 5 m of the edge of open excavations, and negligible for structures further away.

Running Tunnel and Rideau Station in the Bedrock Buried Valley

Approximately 40 m of running tunnel and 60 m of the Rideau Station cavern will be mined in the bedrock buried valley. For buildings with foundation elements founded on bedrock, the expected damage potential is expected to be negligible. Different loss-of-ground, ground treatment and dewatering scenarios were considered for the settlement analysis to assess their impact on the potential for damage to structures in the bedrock buried valley (see **Table 5.3-10**).

Table 5.3-10 | Maximum Settlements 24 Months after Construction Start & Damage Potentials in Bedrock Buried Valley

Building Name	Approx. Station	Foundation Type	Bearing Stratum	Maximum Settlement (mm)		Damage Potential	
				Full Groundwater Drawdown	Ground Treatment with Partial Groundwater Drawdown	Full Groundwater Drawdown	Ground Treatment with Partial Groundwater Drawdown
Rideau Centre	102+330	Footing and Pile	Rock and Soil	50 - 70	25 - 45	Slight to Moderate/Severe	Slight to Moderate/Severe
Sun Life Building	102+350	Unknown	Unknown	35 - 40	12 - 15	Negligible to Very Slight	Negligible
Freiman Mall	102+380	Footing	Unknown (EL. 60 m)	50 - 70	24 - 45	Slight to Moderate/Severe	Slight to Moderate/Severe

These assessments show that damage ranging from negligible to moderate to severe may occur depending on the degree of groundwater table drawdown and loss of ground associated with stress relief. The higher damage potentials are associated with full drainage conditions and relatively high loss-of-ground values. The assessments also show that due to the relatively flat nature of the groundwater table drawdown under the buildings, damage potential is governed mostly by settlements due to stress relief and associated loss of ground. Minimizing loss of ground at the excavation face in the tunnel excavations in the bedrock buried valley is, therefore, critical for reducing potential for moderate to severe damage.

East Portal Area

Ground movements associated with open excavations in the deep clay deposit are the primary cause of the potential for damage to buildings at the East Portal. A rigid watertight support system will reduce potential for large ground movements behind open excavation due to stress relief. Hydrogeological analysis shows that the East Portal area will be subject to drawdown due to the free draining characteristics of the tunnel between the East Portal and the Rideau Station and the drawdown in the bedrock buried valley. The assessment at the East Portal was carried out for buildings most likely founded on spread footings in the overburden; for different ground treatment and dewatering scenarios at the bedrock buried valley and treatment of the bedrock around the tunnel within 50 m north of the East Portal (see **Table 5.3-11**).

Table 5.3-11 | Maximum Settlements 24 Months after Construction Start and Damage Potentials at the East Portal

Building Name	Approx. Station	Distance to Excavation	Foundation Type	Bearing Stratum	Maximum Settlement (mm)		Damage Potential	
					Full Ground-water Drawdown (*)	Ground Treatment (**) with Partial Groundwater Drawdown	Full Groundwater Drawdown (*)	Ground Treatment (**) with Partial Groundwater Drawdown
Tabaret Hall	103+000	45 m	Footing	Unknown	0 (***)	0 (***)	None	None
Odell House	103+210	3 m	Stone Fdn. Wall	Unknown	50 - 55	30 - 35	Slight to Moderate	
Residential Complex	103+290	5 m	Footing and Pile	Unknown	30 - 35	15 - 20	Slight	Slight

(*) Full Groundwater Drawdown refers to condition in the bedrock buried valley

(**) Ground Treatment includes:

- Permeation grouting around the tunnel in faults and fractured zones in the bedrock within 50 m of the bedrock buried valley walls
- Permeation grouting in fractured zones around the tunnel within 50 m of the East Portal
- Permeation or jet grouting around the tunnel and station in the bedrock buried valley

Anticipated Damage Potential and Remediation

The settlement and damage potential assessments presented above were carried out assuming different ground treatments, dewatering, and loss-of-ground ratios at mined tunnels and Stations, and behind shored-open excavations. It is unlikely that the most unfavourable conditions will occur during construction, and also unlikely that the higher damage potential levels will be observed. Damage potentials will most likely range from negligible to slight, and possibly moderate. These damage and remediation levels are described in a publication by Burland et al., 1977, and summarized in **Table 5.3-12**.

Table 5.3-12 | Classification of Visible Damage to Walls with Particular Reference to Ease of Repair of Plaster and Brickwork or Masonry

Damage	Description of Typical Damage [a]	Approximate Crack Width (mm) [b]
Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible	< 0.1
Very Slight	Fine cracks which can easily be treated during normal decoration. Perhaps isolated slight fracture in building. Cracks in external brickwork visible on close inspection.	< 1
Slight	Cracks easily filled. Redecoration probably required. Several slight fractures showing inside of building. Cracks visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly.	1 - 5
Moderate	Cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired.	5 – 15 or a number of cracks >3

(a) In assessing the degree of damage, account must be taken of its location in the building or structures.
(b) Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

5.3.8 PROPOSED GEOTECHNICAL INSTRUMENTATION MONITORING

5.3.8.1 Overall Approach to Geotechnical Instrumentation and Monitoring

The construction of tunnels, Underground Stations, and shafts will result in ground movements associated with stress relief due to the excavations, and lowering of the groundwater table due to dewatering and free draining conditions of the proposed shoring systems. Depending on the structure foundation types and subsurface conditions, ground movements can result in structure movements, causing damage. For ground movements induced by excavations for running tunnels and mined Station caverns, geotechnical instruments are specified to monitor the surface settlement within the anticipated zone of influence and ground subsidence at depths above the tunnel crown. These instruments are installed in sections typically perpendicular to the tunnel alignment and aim to confirm the magnitude and distribution of ground settlements at surface and at depth.

5.3.8.2 Proposed Types and Locations of Geotechnical Instrumentation

A detailed program will monitor ground and building horizontal and vertical displacements and provide input to field engineers to adjust construction methods accordingly. **Table 5.3-13** summarizes anticipated instrumentation.

Table 5.3-13 | Anticipated Instrumentation for Monitoring Surface and Buildings

Instrument Type	Total	Installation Density
Inclinometer	28	One instrument every 30 to 50 m along retaining walls at portals and one to two instruments at each shaft.
Extensometer	29	One instrument every 100 m along tunnel axis.
Surface Settlement Point	247	One array of 3 or 5 instruments every 30 m above mined Stations and every 100 m along tunnel axis, two instruments every 50 m at portals, one to two instruments at each shaft.
Structural Settlement Point	403	Two instruments at each bridge abutment, numbers of instrument installed at buildings vary within zones of potential for damage.
Monitoring Well/Piezometer (*)	27	Installed mainly in the clay zone south of Downtown East Station, buried valley

Instrument Type	Total	Installation Density
		and East Portal area, see instrumentation plans for approximate locations.
Benchmark	0	It has been assumed that benchmarks installed for construction survey will be used for the monitoring program as well.

5.3.8.3 Proposed Data Collection Method & Reading Frequency

Monitoring of both surface structures and underground excavations will be continuous. Data will be captured in electronic form for rapid plotting and review. Detailed review of monitoring results will occur on a regular schedule and if unusual conditions or behavior are encountered. Before the start of the next day's excavation, the tunnel geotechnical engineer and construction manager will review monitoring information and daily excavation construction reports. The purpose of this review is to ensure that the construction method and tunnel temporary supports are adequate, and that there are no immediate concerns with movements either in the excavations or at surface structures. The daily review is additional to the more comprehensive review of monitoring data for trends, and actual versus predicted behaviour done on a scheduled basis. During the more detailed review, criteria will also be established to determine that a stable excavation condition has occurred before installation of the final lining.

Monitoring of Tunnel

For underground construction, and in particular for large sequentially excavated structures, monitoring, recording and interpretation of deformations and stresses in the initial lining are essential to ensure construction safety. The observed behaviour of the structure and surrounding ground must be consistent with expectations and predictions developed during the design. The introduction of a monitoring feedback loop/control cycle to consistently confirm the geo-structural behaviour and interaction is of paramount importance.

Both 2D and 3D measurements will monitor performance of the tunnel during and after excavation. Tape extensometers and 3D survey techniques using targets around the tunnel perimeter will measure tunnel convergence. Borehole extensometer arrays will be installed at selected locations to monitor deep-seated movements. Measurement data will be captured and plotted regularly and trends established. Criteria for trigger and response levels (e.g. max, rate, step) will be developed and compared to the total and trends that have been measured. Convergences will be compared to predicted tunnel ground behaviour and adjustments will be made to rock-support installation and design as required to ensure a stable excavation.

Monitoring of Adjacent Surface Structures

Based on detailed assessment of expected ground movements caused by tunnelling and groundwater table drawdown, a detailed program will be designed to monitor ground and building displacements, and to provide input to the field engineers to adjust construction methods accordingly. **Table 5.3-14** provides a preliminary list of collection methods and frequencies for each instrument type.

Table 5.3-14 | Preliminary List of Collection Methods & Frequencies for each Instrument Type

Instrument Type	Data Collection Method	Monitoring Frequency (Tentative)
Inclinometer	Inclinometer Probe and Readout Unit	Once daily during construction, once weekly after construction until movement ceases.
Extensometer	Depth Micrometer and Level Survey or Total Station	Once daily when tunnel face is within a distance of three times the depth of tunnel axis, once weekly afterwards until subsidence ceases. (*)
Surface Settlement Point	Level Survey or Total Station	Three times daily during excavation or when tunnel face is within a distance of three times the depth of tunnel axis, once daily afterwards until settlement ceases. (*)

Instrument Type	Data Collection Method	Monitoring Frequency (Tentative)
Structural Point	Level Survey or Total Station	Three times daily during excavation or when tunnel face is within a distance of three times the depth of tunnel axis, once daily afterwards until movement ceases. (*)
Monitoring Well/Piezometer	VW Readout Unit	Once weekly during groundwater table drawdown, once monthly after groundwater table stabilization. (**)
Inclinometer	Inclinometer Probe and Readout Unit	Once daily during construction, once weekly after construction until movement ceases.

(*) The equipment and methodology for level survey should be selected to produce elevations with an accuracy of +/- 2 mm.
(**) Monitoring should be carried out in the existing monitoring wells installed during the investigation program carried out by the City.

5.3.8.4 Proposed Approach for Developing Trigger and Action Levels

Trigger and action levels will be developed and integrated into the construction and management plan. Instrumentation results including trends will be reviewed regularly at a frequency consistent with the sensitivity of the current construction process, or if unexpected conditions are encountered. The instrumentation monitoring plan will be reviewed on a scheduled basis or if action or trigger levels are exceeded. Review of the monitoring plan will include at least the following:

- Reviewing/revising construction methods
- Increasing reading frequency for monitoring instruments of interest

5.3.8.5 Approach for Developing Contingency Plans when Limits are Exceeded

Contingency plans for when the alert level is reached will include at least the following:

- Ceasing all construction activities in problem area
- Increasing instrument reading frequency until readings stabilize
- Implementing remedial measures
- Modifying construction methods

5.3.9 PROPOSED APPROACH FOR GROUND IMPROVEMENT/CONTROL IN THE BEDROCK VALLEY AND EAST PORTAL

This section should be read in conjunction with **Section 5.3.5.4**. The assessment of potential damage to structures shows that damage potential can vary significantly depending on groundwater table drawdown and loss of ground associated with stress relief. Higher damage potentials are associated with full drainage conditions and relatively high loss-of-ground values. Reductions of groundwater table drawdown and face stability control are effective methods of reducing damage potential to structures, as follows:

- Permeation grouting as required to stop groundwater seepage into the tunnel in faults and fractured zones in the bedrock within 50 m of the bedrock buried valley walls
- Permeation grouting in fractured zones as required to stop groundwater seepage into the tunnel within 50 m north of the East Portal
- Permeation grouting of non-plastic deposits or jet grouting in and around the tunnel and the Rideau Station in the bedrock buried valley

5.3.10 OVERALL APPROACH TO DESIGN & CONSTRUCTION OF THE EMERGENCY VENTILATION SYSTEMS FOR TUNNELS & STATIONS

The Emergency Ventilation System (EVS) for the underground segment of the OLRT System will be designed in accordance with NFPA 130 requirements. A fan plant located at both ends of every Station will provide emergency ventilation of tunnels and stations. Jet fans installed in the tunnels will provide supplemental ventilation in the event of a fire within the daylighting tunnel sections. During normal operation, the OLRT is expected to be self-ventilating through the piston effect of the Trains travelling within the System. Draft (blast) relief is provided at the ends of the Stations to control Train-induced air pressures and air flows within public areas in accordance with PA criteria. Emergency ventilation fans can be operated at a reduced capacity during the summer, when the outside ambient temperature is highest, and in the event of system congestion when a Train(s) is stopped in the tunnel for an extended period.

We will undertake a Subway Environment Simulation (SES) analysis to evaluate and confirm the aerodynamic and thermodynamic behaviour of the underground environment and EVS performance in each of its modes of operation: normal, congested and emergency. Smoke control in tunnels will be provided through a push-pull response in which fans at one end of the ventilation section operate in supply (push) and those at the opposite end operate in exhaust (pull). To facilitate egress in either direction, the fans will be fully reversible.

If there is a fire within a Station, the EVS fan plant at the incident Station will operate in a pull-pull (all exhaust) response to pull smoke away from the public areas of the Station while drawing fresh air in through Station entrances to protect the path of egress. We will use Computation Fluid Dynamics (CFD) to analyze Station fires, providing a full understanding of smoke movement within the Stations so that smoke-control strategies can be developed in conjunction with a timed-egress analysis.

We will control EVS operation through a dedicated SCADA system from the Transportation Services Control Centre (TSCC) and Backup Control Centre (BCC). In addition to providing individual control of EVS equipment, this SCADA system will be preprogrammed with all EVS operating modes. Local control will be available at the fan plant itself, and each Station will also have a Fireman's Control Panel which will allow manual initiation or override of EVS modes. EVS emergency operation will be based on procedures developed during design in collaboration with the City (AHJ, TSCC, first responders) and other key Stakeholders.

5.3.11 SMOKE DISPERSION ANALYSIS FOR EMERGENCY VENTILATION SYSTEMS

Smoke-dispersion analysis will be performed in conjunction with the Station smoke-movement analysis during the early stages of design development. Coupling the two analyses ensures that smoke-exhaust rates and concentrations which are a fundamental input to the dispersion analysis are consistent with the fire scenario occuring within the Station and the mechanical ventilation response employed. The position of EVS shaft terminations at grade will be designed to minimize the risk of smoke recirculation into Station entrances and adjacent buildings in accordance with the PA and NFPA 130. We will apply a performance-based approach using computer analysis to evaluate smoke-dispersion characteristics at each Station site and, where necessary, to assist in developing mitigation measures. The significant positional constraints imposed by the streetscape at each site may require a collaborative approach with adjacent property owners to address the potential for recirculation, with one possible resolution being integrated emergency management plans.

5.3.12 SMOKE VENTILATION SITE DRAWINGS

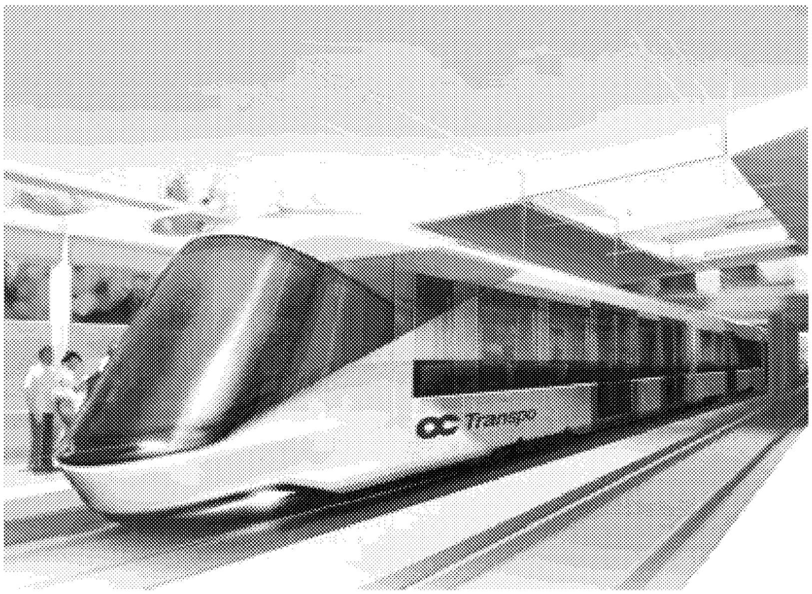
Drawings are provided in **Package B2 – Design Submission Part 2 – Volume 1 (of 4)** and include the following:

- Location of the smoke ventilation shaft in relation to Station entrances
- Station air intakes
- Openings of other buildings above grade and other objects

5.3.13 KENT STREET CSO

The lower limit of the proposed vertical alignment for the running tunnel lies above 50 m and, therefore, does not conflict with the proposed 3000 mm combined sewer overflow (CSO) at Kent Street.

5.4 LRT SYSTEMS AND VEHICLES



5.4 LRT SYSTEMS & VEHICLES

In accordance with RFP Schedule 3-1 instructions, this section describes the Rideau Transit Group solution for Vehicle and LRT Systems – a solution that brings together a world class light rail vehicle manufacturer with a state of the art supplier of Communication Based Train Control.

From the outset of the OLRT bid process, the RTG team was intent on finding the "right" solution for Ottawa's unique needs. We began by canvasing the globe in an international procurement process. For more than six months, the RTG team thoroughly reviewed submissions from the world's leading suppliers of rail vehicles and systems. We measured and evaluated their products and performance against the Ottawa challenges - cold climate operations, state of the art vehicles and train control but proven in service, modern low floor convenience plus 100 km per hour capability to name just a few – with a goal of putting the "best of the best" together in one integrated package.

Our selection of Alstom Transportation's CITADIS vehicle and Thales for train control and systems will place Ottawa's new light rail system at the head of the class, meeting the industry's highest levels of safety, comfort and reliability.

Worldwide, Alstom Transportation is a global powerhouse, having earned in excess of $8 billion in Revenue in the past operating year. The company also has significant experience in the North American rolling stock business. It maintains a large manufacturing plant in Hornell N.J (one of the largest in NA) and has produced more than 7000 transit vehicles for transit authorities and rail customers. In Canada the company has Transport division offices in Ottawa, Montreal and Toronto. Alstom is very experienced in technology transfer to meet both the letter and spirit of local content regulations as discussed in **Section 5.4.2**.

The Citadis vehicle is the ONLY 100 per cent low floor vehicle operating at 100 km in the world today. Its sleek urban design is the ideal solution for Ottawa's urban environment, offering the ideal blend of form and functionality in one vehicle. Its maintenance advantages are also proven. The Ixege pivoting bogie design (which utilizes conventional axels) has been shown to have lower life cycle and maintenance costs and better performance, particularly in the snow. The Ixege bogie allows the passenger interior of the car to have all of the accessibility and convenience of a 100% low floor LRV but many of the operational and performance advantages of a 70% low floor LRV. This will prove invaluable in winter operating conditions in Ottawa.

Thales is a global technology leader in the Transportation, Aerospace, Defense and Security markets. In 2011, the company generated revenues of $17 billion with 67,000 employees in 56 countries. With its 22,500 engineers and researchers, Thales has a unique capability to design, develop and deploy equipment, systems and services that meet the most complex security requirements. Thales has an exceptional international footprint, with operations around the world working with customers as local partners.

In Canada, Thales has been operating for more than 30 years, employing 1,300 people in its Transportation, Defense & Security, and Aerospace sectors. Canada is also headquarters to Thales Centre of Excellence in Signalling with offices are in Ottawa, Toronto and Vancouver that employ over 800 people. The CBTC signalling solution was first deployed by Thales on Vancouver's driverless metro in 1986. Today, CBTC technology has become the de facto standard for urban rail systems. Since then, with more than 35 systems equipped with its SelTrac CBTC solution and over 10 million cumulative hours of operation to its credit, Thales has more experience with this solution than any other provider in the world. Successful projects in Beijing (1.2 million passengers a day on the two lines equipped by Thales), Shanghai (1.6 million passengers a day on the 5 lines equipped by Thales), Wuhan, Guangzou and Hong Kong have made Thales a market leader for transit signalling systems in mainland China. Thanks to SelTrac CBTC technology, the Docklands Light Railway – one of the busiest lines in the London transport system, with 70 million passengers a year – delivers over 98% availability – a remarkable achievement since it includes the availability of the fixed block backup system. The SelTrac CBTC installation on the Canada Line achieves over 99.95% availability (again including wayside components) even though it does not have as extensive redundancy as will be provided for the OLRT.

Thales' technologies and solutions are particularly well suited to the requirements of transit systems. Safety, reliability and cost effectiveness are fundamental to modern light rail system operations. Thales' systems control train speed and direction with great precision; this optimizes use of system assets and translates into enhanced performance and cost savings for the city. Thales' systems are in operations with major metro operators worldwide, including those of Vancouver, London, New York, Shanghai, Hong Kong and Dubai.

In addition to each company's independent success stories, Alstom and Thales have worked successfully together on several joint transit projects – the London Underground Jubilee Line and on Shanghai Metro Lines 6 and 8. The Shanghai installations employed 1500 VDC as is proposed for the OLRT. Throughout the design phase, Alstom and Thales will work closely with an engineering joint venture (EJV) comprising SNC-Lavalin Inc., MMM Group, and specialty consultants selected for their Project-specific expertise to deliver the best solution to the City.

5.4.1 LRT SYSTEMS DESIGN PROCESSES

RTG brings together the strengths, capabilities and expertise of ACS Infrastructure Canada Inc.; SNC-Lavalin Capital, a division of SNC-Lavalin Inc.; and EllisDon Inc. On announcement of Preferred Proponent these companies will form a special-purpose vehicle (Project Co) to contract with the City for the OLRT Project. Our team will use their combined experience on past projects to deliver the LRT Systems and Vehicles using the formal set of design processes explained below.

5.4.1.1 Design Methodology & Lessons Learned

Successful system integration starts with developing proper processes to validate requirements, implement them in a timely manner, and verify that the delivered system is safe and reliable. Over many years of experience on successful transit projects, RTG has developed a set of practical and results-oriented system engineering processes. These are documented in the plans and specifications defined in the following sections and incorporate the following key lessons learned:

- Perform a thorough Requirements Analysis to fully understand the City's requirements
- Use a formal engineering process through all Project phases to manage the work, track requirements and conduct comprehensive test and verification planning
- Thoroughly document interfaces and, in particular, vehicle interfaces (e.g. Train Control and wheel/rail)
- Choose proven suppliers and subsystems best suited to the City's requirements
- Emphasize off-site acceptance testing and maximize the use of simulators and test tracks
- Involve operations and maintenance staff in commissioning as early as possible

The design methodology is shown graphically in **Diagram 5.4.1 D2.1A** and the interaction with the overall Project is shown in **Diagram 5.4.1 D2.1B**.

Systems Engineering Plan

The Systems Engineering Plan described in this section will apply to each OLRT system in a manner commensurate with the safety level it is designed to provide. The Plan will ensure the tracking of system requirements and configuration through Project design, implementation and test phases to support system assurance, quality, safety management and certification and to ensure a safe and reliable Maintenance Term.

The LRT Systems and Integration Manager will prepare the Systems Engineering Plan at the conceptual design phase, based on the current internationally recognized systems engineering standard: ISO/IEC 15288, Systems Engineering – System Life Cycle Processes.

The purpose of the Systems Engineering Plan is to define an integrated set of engineering processes, thus assuring the City that good engineering practices will be followed in the systems engineering of the Works, as follows:

- Establishing and evolving a complete and consistent set of requirements that will enable delivery of a feasible and cost-effective systems solution
- Satisfying requirements within cost, schedule, and risk constraints
- Providing a system, or any portion of a system, that satisfies the City over the life of the products that make up the system
- Satisfying Sustainability requirements including safe and cost-effective disposal or retirement of a system or part thereof

The Systems Engineering Plan will specify the following elements relative to engineering of the System:

- Agreement processes (e.g. product acquisition, product supply, subcontractor management and evaluation)
- Project management processes (e.g. planning, assessment, project control, and risk management)
- Technical processes (e.g. the City's requirements definition, requirements analysis, design, implementation, integration, verification, transition, validation, operation, maintenance, and disposal)
- Proposed technical review process
- Summary of documents required by the Plan

Design Planning

The LRT Systems and Integration Manager will prepare the Design Management Plan for System design activities at the conceptual design phase. The Plan will include the following elements:

- Organization of the Design Team
- System design activities:
  - Plan and schedule for managing the requirements, analysis, definition, and validation phases
  - Design review and audit schedule
  - Document submission schedule
  - Drawing submission schedule
- System design elements:
  - Document tree, illustrating the documentation hierarchy
  - Drawing tree, illustrating the drawing hierarchy

Design Reviews

There will be three design reviews for the OLRT System:

- Conceptual Design Review (CDR)
- Preliminary Design Review (PDR)
- Final Design Review (FDR)

In addition there will be a PDR and FDR for each major sub-system within the Works.

The formality and scope of these design reviews for the System or sub-system will depend on the complexity, size, and risk associated with the System or sub-system. In the following discussion, the term system (lower case) may refer to a system, sub-system, or component.

Conceptual Design Review

Senior designers from each discipline will prepare documentation for the CDR defining the theory of operation of the overall OLRT System, including major sub-systems, sub-system interfaces, interfaces to external systems, and any requirements the system may impose on external systems or equipment. Special attention will be paid to operator interfaces.

Preliminary Design Reviews

A primary goal of each PDR will be to validate system requirements to ensure that they are the complete, necessary, and sufficient set of requirements for the system, that they are consistent with the City's intent, and that the system supplier understands them. Typical documentation submitted for each PDR will include but not be limited to the following:

- Requirements analysis and other documentation to demonstrate that the proposed system meets the specified requirements
- Functional descriptions of the system and its major sub-systems
- Equipment layout and functional architecture
- Interconnection drawings
- Finalized interface specifications
- Mock-ups of operator interfaces
- Confirmation of the following:
    - Sub-system specifications have been defined appropriately
    - Enabling products have been defined adequately to initiate enabling product development, if required
    - Approaches planned for the next design phases have been appropriately planned
    - Project risks have been identified, and mitigation plans are feasible and judged to be effective
- System Assurance documents and checklists to confirm that the design conforms to quality safety and RAMS requirements (see also **Section 5.1.5.1**)

Open items from previous design reviews for the system will be addressed and/or resolved during the PDR.

Final Design Review

For each FDR, senior designers from each discipline will prepare documentation that confirms the following:

- Specifications, drawings, and/or software development files have been appropriately defined
- The end product designs satisfy system requirements
- The system meets one of these criteria:
    - Ready for continued design and development
    - Appropriately defined for purchase of products from an external supplier
    - Ready for manufacture/fabrication
    - Adequately defined such that off-the-shelf products and/or proven products can be used to fulfill system requirements and are available
- System Assurance documents and checklists to confirm that the design conforms to quality safety and RAMS requirements (see also **Section 5.1.5.1**)

For each FDR, detailed designs and other documentation will be prepared with sufficient information to confirm a complete design and allow manufacturing/construction to proceed. Typical submittals for an FDR will include, but not be limited to, final design and installation drawings, shop drawings, calculations and analyses to demonstrate that the system will meet the specified requirements. All open items from previous design reviews for the system will be addressed and/or resolved during the FDR.

For each FDR, a System Verification Matrix (SVM) will document how each of the validated requirements will be verified, and the status of that verification. The SVM will be updated periodically to maintain the status of the requirement verification.

Other Reviews

Other types of reviews may be held on an as-appropriate and as-required basis:

- **Pre-System Definition Reviews** which, during the Project's conceptual phase, will consider all concepts analyzed and select a preferred concept for further development that has the potential for satisfying identified City requirements. In addition, this review may assess progress towards converging on a viable, traceable set of System Technical Requirements that are balanced with cost, schedule, and risk. This review will also ensure the design is optimized in terms of safety, operations reliability, availability, maintainability and lifecycle cost, service dependability, failsafe design and failure management of the system operation. OLRT system optimization is discussed in detail in **Section 5.1.5.1**.
- **Readiness Reviews** which, during the Project's integration and test phase, will demonstrate that delivered end products from lower layer systems have been validated, or that validation tests are adequately planned, and that each set of integrated products forming a composite end product is ready for end-product verification and validation, if required.
- **Audits** which, during the Project's manufacturing, integration and test phase, will demonstrate and confirm the following:
  - End products comply with their specified requirements and product verification outcomes compare favourably against configuration documentation (e.g. drawings, test procedures, authorized changes, software development files, as-built/as-coded documentation)
  - The as-built/as-coded configuration has been favourably examined against its configuration documentation (e.g. drawings, bill of materials, specifications, code lists, manuals, compliance test, compliance data)
  - Products have been built to drawings and satisfy specifications
  - The information database represents the work products of the system development
  - Required changes to previously completed specifications have been implemented
  - Enabling products for downstream associated processes are available, can be executed, and meet the City's requirements
- **Process Reviews** which, during the Project's integration and test phase, demonstrate that the development of enabling products for associated processes is on schedule, and that designs satisfy related end-product needs. Examples of Process Reviews are production readiness reviews and test readiness reviews.
- **Independent Contractor Evaluations, Reviews, and Audits** may occur as required throughout the Project

System Requirements Specification

A System Requirements Specification that captures the City's requirements and System technical requirements will be prepared by senior designers. This specification will be reviewed with the City to ensure that RTG completely understands the requirements. The Requirements Management Database will be created and maintained using the DOORS requirements management database tool.

The System Requirements Specification and Sub-System Requirements Specifications will be reviewed as part of the Preliminary Design Review.

Requirements Validation

As summarized in **Table 5.4-1**, requirements have been validated when it is determined that the subject set of requirements describes the input requirements and objectives such that the resulting system products can satisfy the requirements and objectives.

Table 5.4-1 | Requirements Validation

Stage	Objective	Methodology
General	The LRT Systems and Integration Manager will ensure that technical requirement statements are well formulated	▪ Analyzing and ensuring that each requirement statement is stated with: clarity, correctness, feasibility, focus, modifiability, removal of ambiguity, singularity, testability, and verifiability ▪ Analyzing and ensuring that technical requirement statements in pairs and as a set are stated with connectivity and without redundancy and conflicts
Requirements Validation	Defined System requirements will be reviewed against the City's needs and expectations	▪ Selecting methods and defining procedures for validating that the set of System requirements is consistent with the level of system structure, and the Validation Plan as appropriate ▪ Analyzing and comparing identified and collected requirements to the set of defined System requirements to determine upward and downward traceability ▪ Identifying and resolving variances, voids and conflicts ▪ Recording validation results
System Technical Requirements Validation	Defined System technical requirements will be reviewed against validated the City's requirements	▪ Selecting methods and defining procedures for validating that the set of System technical requirements is consistent with the level of systems structure and the Validation Plan as appropriate ▪ Analyzing and comparing identified and collected System technical requirements with the set of defined System technical requirements to determine upward and downward traceability ▪ Analyzing assumptions made with respect to defining System technical requirements to ensure they are consistent with the System being engineered ▪ Analyzing System technical requirements that have been defined as essential for the design effort where there is no parent requirement in the set of the City's requirements, to ensure they are consistent with the System being engineered ▪ Identifying and resolving variances, voids and conflicts ▪ Revalidating System technical requirements whenever a requirement change affects the City's requirements, or System technical requirements ▪ Recording validation results

Computer-Based Systems

Software

Tasks will be undertaken to ensure that System software complies fully with the following requirements:

- Operates without degradation during all date changes
- Uses a formal methodology for structured modular code design and implementation appropriate to the application and safety integrity of the System
- Uses open standards and non-proprietary protocols for all interfaces except where proprietary protocols are required to facilitate integration with legacy systems or to meet City requirements

- Ensures that configuration details are available down to the appropriate software configurable item
- Is capable of local loading and, where operationally required, remote loading

Formal documentation, change control, testing and verification processes will be appropriate to the application and safety integrity of the System for software quality control.

Software Development Management Plan

Where the System includes components of proprietary software development, a Software Development Management Plan for the System will be prepared at the conceptual design phase, to include, but not be limited to, the following:

- Organization including identification of Software Development Manager and key team members, as well as position descriptions (e.g. qualifications, training)
- Identification of subcontractors including their qualifications, how the Plan and other plans apply to them, and how they are assessed and evaluated during System development
- Software development philosophy
- Software lifecycle including phase input and output details, and phase entry and exit conditions
- Quality assurance and control activities and procedures
- Development schedule (e.g. critical activities, how key dates will be achieved, resourcing levels)
- Quality schedule including audits and reviews
- Strategies to accommodate contingencies and changes (e.g. software development schedule, resources)

The Software Development Management Plan and the software lifecycle processes documented therein will comply with internationally recognized standards.

5.4.1.2 Systems Interface Management

Interface Management Plan

At the conceptual design phase, an Interface Management Plan will systematically identify documents and provide a management tool for resolving technical interfaces between subsystems and between the System and external systems across all disciplines. This will include all System elements that have a direct or indirect interaction with systems or equipment external to the System. The Interface Management Plan will be updated as the interfaces evolve.

Interface Specifications

Each interface will be managed within a system of interface-control documentation (primarily interface specifications), which will include, but not be limited to, the following definitions:

- The organizational entities responsible for managing and engineering the interface and other entities involved
- Details of the agreed interface arrangement (e.g. physical installation, civil, power supply, signal levels, transfer characteristics, message formats, communications protocols)
- The functional, performance, reliability, maintainability and safety requirements of the individual elements forming the interface
- The proposed method and schedule for verifying interface integrity, individual element performance, and combined system performance

The interface control documentation will be reviewed in the process reviews and design reviews and will be updated as the interfaces evolve.

When interfacing to systems provided by others that are part of the Works, RTG will jointly prepare the interface control documentation with the third party.

Interface Communications

An organizational structure and corresponding procedures will be created for coordination and communication of interface data among the suppliers of systems and sub-systems within the system and interfacing to it. The City will be provided with design criteria that clearly define interface requirements between the System and systems provided by others, including any civil, structural, and fixed facilities that may interface to the System.

Configuration Data

During execution, Works suppliers will exchange configuration data (e.g. Station identification, track locations) using a structured, well-normalized record format. Project-wide configuration data guidelines will provide an overview of configuration data formats and structures specifying items such as abbreviations and Project-level identifiers.

The exact format and content of configuration data to be exchanged will be specified in configuration data control documentation (primarily Configuration Data Specifications). Such documentation will include, but not be limited to, the following:

- Detailed description of each item of configuration data, including how it is intended to be used
- Detailed description of the format of the configuration data, using examples if possible

Typically, there will be one set of configuration data control documentation for each configuration data interface with another entity (e.g. supplier, subcontractor). Subcontractors will prepare the interface-specific configuration data control documentation and comply with Project-wide configuration data guidelines.

Configuration Data Management Plan

A preliminary version of the Configuration Data Management Plan will be prepared for the System at the conceptual design phase, with the final Plan prepared at the preliminary design phase. It will include the following:

- Detailed description of the process and methods to handle configuration data
- Description of configuration data to be supplied to and by third-parties
- Description of configuration data formats to be used
- Configuration management procedures
- Change control management procedures
- Configuration data schedule (e.g. when configuration data is to be delivered to, or is required from, others)

5.4.1.3 Verification & Validation Strategy

The LRT Systems and Integration Manager will coordinate system verification and validation activities with the appropriate design phase as shown in **Diagram 5.4.1 D.1C**. The System Validation process provides a comparative assessment to confirm that the City's requirements are correctly defined. By assessing services presented to the City, validation demonstrates that the correct system entity has been created. Tasks include Requirements Validation and End Products Validation.

The System Verification process will be used to ascertain the following:

- System design solution generated is consistent with its source requirements and the specified design requirements are fulfilled by the system end product
- End products at each level of the system structure implementation, from the bottom up, meet specified requirements
- Enabling system development or procurement for each associated process is properly progressing
- Required enabling systems will be ready and available when needed to perform

Test and commissioning plans will be developed, organized, and implemented to verify the adequacy of the System to meet all functional, safety, systems assurance, and performance requirements.

All materials furnished (including spare parts) and all work performed as part of the Works will be inspected and tested. If specific hardware, software, or documentation does not meet specific requirements, it will be repaired, replaced, upgraded, or added by the responsible supplier as necessary to correct deficiencies. After correction of a deficiency, all tests necessary to verify the effectiveness of the corrective action will be repeated.

Factory and site tests will be performed. Deliverables will not be shipped until all required factory inspections and tests have been completed and all deficiencies have been corrected. Site testing will ensure that the System has been properly installed, and that the System satisfies all performance, safety, reliability, and functional requirements while in actual service. Spare parts will be tested in the identical manner as other equipment.

Before testing starts, the City will have approved all test plans and procedures for the test, and all relevant prerequisite testing will have been completed. Inspection and Testing will comply with ISO-9001:2008, clauses 8.2.4 "Monitoring and Measurement of Product" and 7.6 "Control of Inspection Measuring and Test Equipment".

Test Documentation Submittals

RTG will submit test documentation to the City including the following:

- A Validation, Inspection, and Test Plan for acceptance at the Conceptual Design Review. This Plan will demonstrate that the Contractor has considered all testing requirements and made adequate schedule provisions for testing in the overall schedule.
- A System Test Plan and a Test Plan for each sub-system for acceptance at the Preliminary Design Review listing the tests required to fully verify that the System meets functional, safety, and performance requirements.
- Detailed test procedures for acceptance for each test identified in the test plans identified above, no later than 90 days before testing.
- A Commissioning Test Plan for the System for acceptance at the Preliminary Design Review. These plans will list the tests required to fully verify that the System has been properly installed and to demonstrate that the System satisfies all performance, safety, reliability, and functional requirements while communicating with a full complement of devices under actual service conditions.
- A 90-day look-ahead schedule detailing all testing activities proposed for the period covered. The first schedule will be submitted 90 days before the first test scheduled and a revised schedule will be submitted periodically as required.
- Test Reports containing the results of all tests conducted at any factory or field location.
- Deficiency report(s), periodically or as required.

Test Documentation

Validation, Inspection, and Test Plan

The Validation, Inspection, and Test Plan will include at least the responsibilities of individuals and documentation of validation and test results and will include, but not be limited to, the following items:

- Flow diagram indicating the logical sequence of validations and tests, starting with materials receiving tests and inspections and concluding with system demonstrations tests
- Validation schedule
- Test schedule
- Responsibilities
- Record-keeping assignments, procedures, and forms
- Procedures for performing validation
- Procedures for monitoring, correcting, and re-testing deficiencies
- Procedures for controlling and documenting changes made to hardware and software after testing starts

- Coordination needed from the City

System and Sub-System Test Plan

Test plans will demonstrate that the System supplied is complete, safe and operable and will include at least the following items:

- Test schedule
- Responsibilities
- Block diagrams of the hardware test configuration including external data transmission interfaces, and detailed descriptions of test and/or simulation equipment
- Estimated duration of each test
- Coordination needed from the City
- Calibration and its traceability to known standards of hardware, software, simulation tools and test equipment to be used for testing

Commissioning Test Plan

The Commissioning Test Plan will include at least the following:

- Commissioning test schedule
- Responsibilities
- Recordkeeping assignments, procedures, and forms
- Procedures for monitoring, correcting, and re-testing deficiencies
- Procedures for controlling and documenting changes made to hardware and software after testing starts
- Coordination needed from the City

Test Procedures

Test Procedures will describe individual test cases and the steps comprising each case, with emphasis on the methods and processes to be followed:

- Objective of the test
- Requirement(s) to be demonstrated and verified
- Required setup and conditions, including descriptions of test equipment and required data
- Descriptions, listings, and instructions for test software tools and displays
- Step-by-step descriptions including inputs and user actions for each test step
- Expected results including the pass/fail criteria
- Techniques and scenarios used to simulate system field inputs and controlled equipment

Test Records

Complete certified Test Records of all factory and field acceptance test results will be maintained and delivered to the City. Test Records will be keyed to Test Procedures and will include the following:

- Reference to the corresponding Test Procedure
- Date the Test Procedure was executed
- Description of test conditions, input data, or user actions differing from that described in the Test Procedure
- Results for each test case including a passed/failed indication
- Name of test engineer and the City's Representative (if present for execution of the Test Procedure)
- Provision for comments by the City's Representative
- Copies of any deficiency reports generated as a result of the execution of the Test Procedure

- Copies of reports, display copies, and any other hardcopy generated by executing the Test Procedure
- Configuration data that fully describes the hardware and software that was tested, including software version and build numbers/identifiers for every software module

Failure Reporting, Analysis, and Corrective Action

Throughout the periods of System field testing, demonstration, and warranty, a closed-loop Failure Reporting, Analysis, and Corrective Action (FRACA) system will determine the cause of all test failures, unscheduled part removals, and other deficiencies. To identify failed parts and pertinent data and actions relating to each failure, failures will be classified and a cumulative summary of all failure analyses maintained. RTG will apply this process to all OLRT System and subsystem failures including performance failures.

FRACA data will regularly and systematically be evaluated to identify and monitor failure trends, no-trouble-found incidents, and new-failure effects.

End-Product Audits

During the Project's integration and test phase, end-product audits of the System will be held which, during the Project's integration and test phase, will demonstrate and confirm the following:

- End products comply with specified requirements and product verification outcomes compare favourably against configuration documentation (e.g. drawings, test procedures, authorized changes, software development files, as-built/as-coded documentation)
- As-built/as-coded configuration has been favourably examined against configuration documentation (e.g. drawings, bills of material, specifications, code lists, manuals, compliance test, compliance data)
- Products have been built to drawings and satisfy specifications
- The information database represents the work products of the system development
- Required changes to previously completed specifications have been implemented
- Enabling products for downstream associated processes are available, can be executed, and meet City requirements

Readiness Reviews

Readiness Reviews may be held for the System which, during the Project's integration and test phase, will demonstrate that delivered end products from lower layer systems have been validated, or that validation tests are adequately planned, and that each set of integrated products forming a composite end product is ready for end-product verification and validation, if required.

Tests on Completion

Tests on Completion will include all testing to be performed before Completion of the Works.

First Article Inspection

To ensure units are suitable in all respects for the purpose intended, a First Article Inspection (FAI) will be conducted on the first production unit of each sub-system prior to the first shipment of equipment for that sub-system from the factory. The FAI testing will include, but not be limited to, the following:

- Electrical and mechanical construction testing
- Vibration and impact resistance testing
- Temperature and humidity testing
- Functionality, performance, and timing testing
- Accelerated life testing
- EMC testing

Critical items of the System's equipment that do not have a proven history will be subject to qualification testing.

Equipment Tests

Sample units from production will be subject to routine and Quality Control inspections and testing.

Factory Acceptance Tests

Where appropriate and reasonably practicable, Factory Acceptance Tests (FATs) will be conducted on systems and sub-systems in a factory environment representative of the actual operating environment, to demonstrate that System items under test can perform in accordance with specifications, before being installed. The deliverable hardware and software will be tested. Upon completion of testing, a FAT review will confirm that the system or subsystem under test is fit to be deployed and installed.

Post Installation Checkout Tests

Post-Installation Checkout (PICO) testing will demonstrate that all system hardware (including spare parts) and software functions properly in the installed environment. The installed system will be verified against installation drawings to verify correct installation and that system equipment has not been damaged subsequent to shipment from the factory.

The field installation test will include a complete system inspection including but not limited to proper installation, grounding, cabling, conformance to plans and drawings, neatness, equipment access and installed versions of hardware and software. All cables will be tested for opens, shorts, grounds and high resistance.

Tests will be performed on each sub-system and group of sub-systems (using a bottom-up approach) to verify that they are operating correctly in the target environment. Tests will also be performed on groups of sub-systems using a bottom-up approach to verify that they are operating correctly in the target environment.

Site Acceptance Tests

After PICO Tests, Site Acceptance Testing (SAT) will be performed on installed System equipment and subsystems using the approved set of SAT procedures. These procedures will generally be a subset of those performed during FAT testing, but will also focus on requirements which could not be verified during FAT testing. SAT will be performed to verify that the System has been properly installed and to demonstrate that the System satisfies all performance, safety, reliability, and functional requirements while communicating with a full complement of devices under actual service conditions. The proper operation and performance of all System features and functions will be verified during this test.

Tests after Completion

Tests after Completion will include all testing to be performed after Completion of the Works.

Integrated System Testing

Upon successful completion of SAT on two or more related subsystems, these subsystems will be integrated to commence Integrated System Testing (IST). IST will concentrate on inter-subsystem functionality and performance under normal, abnormal, and emergency scenarios.

Trial Running

Trial Running of the System will demonstrate that the System meets specified performance criteria and is capable of safely operating in accordance with initial service plans, including specified travel times, headways, and availability.

Trial Running will exercise and confirm operating reliability of the System in simulated operating scenarios. A full regular scheduled service will be operated on the full Line using peak and off-peak schedules for an extended period. Passengers will not be carried, but appropriate dwell times will be observed. Trial Running will also include a variety of failure-management scenarios that could reasonably be expected to occur in regular revenue service.

5.4.1.4 Configuration Control Methodology

Configuration management and change control management procedures and techniques will be used in the engineering of the Works. Where appropriate (for example, in systems with software components), these procedures and techniques will comply with internationally recognized standards.

Configuration Management Plan

A Configuration Management Plan for the System will be prepared at the conceptual design phase and will include the following:

- Detailed description of the methodology and procedures to be used to control and document System configuration during the Contract period (e.g. from the preliminary configuration at the time of the proposal through the design phases to the as-delivered hardware and software configurations)
- Detailed description of configuration management processes, procedures, and techniques to be used with respect to any subcontractors
- Organizational structure with respect to configuration management

Change Control Management Plan

A Change Control Management Plan for the System will be prepared at the conceptual design phase and will include the following:

- Detailed description of methods and procedures to be used to handle change (e.g. functional changes, performance changes) during the Project Term
- Detailed description of the change lifecycle and statuses
- Detailed description of change control processes, procedures, and techniques to be used with respect to any subcontractors
- Change control organization

Configuration Control during the Maintenance Term

RTG will maintain all systems plans, maintenance reports, remedial actions, instructions and procedures in an Asset Management System. System plans include the conformed design plans reflecting as-built conditions at final acceptance of construction. Design plans, including typical installation drawings that document installation standards, will be controlled by the Maintenance Director through implementation of a configuration management process embedded in the asset management program.

A Configuration Management Committee, staffed with key personnel and chaired by the Maintenance Director, will control configuration management. All configuration changes of a system or equipment will include a request, an evaluation of the change, an approval process, and the final recording and documentation of the change. This will be managed and recorded within RTG's Asset Management System to provide traceability. Where life-limited or serialized components are changed in any equipment, the overall impact on future maintenance and lifecycle of the parent asset will be accounted for and adjusted within our Asset Management System.

Configuration Control during the Maintenance Term is described in detail in **Section 5.1.5.1**. A Regulatory Working Group is defined in **Section 5.1.6.2** to address the Safety Management System (SMS) by apply the appropriate configuration controls both prior to and during service commencement.

5.4.1.5 Systems Assurance Process & Methodology

As specified in the RFP, RAMS, including a narrative on management of the systems assurance process, is discussed in **Section 5.1.5.1**.

5.4.1.6 Climatic Performance

RTG will ensure that all systems and equipment subject to the external environment are designed for Ottawa's extreme climate by applying the following principles:

- Use suppliers with a proven track record of delivering systems in extreme climate
- Select major subsystems that are service-proven in similar climates
- Use NRC's environmental chamber for environmental qualification testing when necessary
- Verify system environmental performance during site testing.

A key factor in maintaining service during inclement weather is the proper response by both operations and maintenance and rehabilitation (M&R) personnel. RTG will address this factor as follows:

- Providing tools to manage weather extremes. For example, the CBTC System will include the ability to reduce braking and acceleration rates if low adhesion is experienced.
- Preparing maintenance procedures to deal with extremes of weather, and training M&R personnel in these procedures.
- Preparing operations procedures to deal with extremes of weather in cooperation with the City, and training operations personnel in these procedures.
- Providing snow removal equipment and procedures.

Examples of equipment and subsystems operating in similar environments are included in the cut sheets.

Methodology for Dealing with Extremes of Weather During Testing

RTG will implement the Maintenance and Storage Facility (MSF) early to provide a local test track to integrate all major subsystems. This early implementation will allow three seasons of environmental testing to experience a wide range of weather conditions. By proactive test scheduling, we will use inclement weather as a test tool.

Operations, M&R and testing and commissioning (T&C) personnel will be trained and qualified in all relevant procedures before the start of each T&C phase. A CBTC Control Operators Training Simulator will be provided to support this process.

When necessary, RTG will simulate extreme conditions (e.g. soaping rails for adhesion testing).

5.4.1.7 System Integration Methodology

To deliver an LRT system that meets or exceeds the City's performance expectations, RTG is committed to managing the Project's integration risk. System Integration is discussed in detail in **Section 5.1.5** and summarized here.

The past 30 years have seen significant improvements in Train Control System interfaces that decrease integration risk. These improvements can be seen in standardized interfaces resulting from supplier consolidation and technological advances, particularly in communication equipment and protocols. Modular hardware and software design technologies have simplified overall designs

Both Alstom and Thales are contractually required to ensure design visibility (including providing access to their key contractors) to RTG. Through this environment, RTG's LRT Systems and Integration Manager will manage the design process, ensuring that interface requirements are well understood and are properly implemented.

Processes and documentation to control interfaces will include but not be limited to the following.

- Interface specifications for each major interface
- First Article Inspections
- Qualification tests
- Factory Acceptance Tests and subsystem integration tests

- Vehicle/Train Control integration tests are planned in the MSF early in the schedule

As per lessons learned, particular attention will be paid to brake and propulsion interfaces, and the wheel/rail interface.

To ensure that proposed systems and equipment can perform as required in the Ottawa environment, RTG will carefully review supplier submissions. The process of choosing our Team's Vehicle and Train Control supplier included a detailed review of their proposed interfaces and interface management plan to verify that both suppliers understood the interface requirements and had the necessary knowledge and experience to implement them. We have chosen two experienced suppliers with demonstrated systems integration capability who have worked together and with RTG. We believe that Alstom and Thales are ideally suited to integrate the best solution for the City.

Test programs will be developed to demonstrate all aspects of the interfaces. This will include First Article Inspections, qualification tests, Factory Acceptance Tests and subsystem integration tests. Vehicle/Train Control integration tests are planned in the MSF early in the schedule. These tests will be a key milestone for ensuring that all Vehicle/Train Control interfaces have been properly addressed. On-site testing will be planned in stages that demonstrate functionality in a logical sequence and ensure that, as far as possible, only one function within one system is being tested at a time. Once multiple systems have been tested to an appropriate stage, they will be combined for integration testing (see **Drawing 5.4.1.D.1D & E**).

RTG will manage integration of other subsystems by applying the principles used for the Vehicle/Train Control interface.

Lessons Learned from Other Project Integrations

Integration of the Canada Line project was based on a similar strategy to that outlined herein, with the following lessons directly applicable to the OLRT Project:

- Agree early which parties will authorize major steps in the start-up of the OLRT Project, such as:
  - Traction Power Energization
  - First Train Movement
  - Multiple Train Movements
  - Trial Running
  - Revenue Service

  (Note that this is an example list, and not necessarily a comprehensive list for the OLRT Project.)
- Agree with each party on the list of documents and other activities required in support of their signature authorizing start-up. Document this list in a System Activation Plan.
- Agree with each party the processes and/or standards to prepare relevant documents and other activities.
- Prepare and sign certificates as early as possible.
- Combine items in one certificate where timing is similar and signatories match.
- Ensure that Revenue Service Operating procedures and training programs related to safe operations during the T&C phase (e.g. Train movements, traction power energization, hand signals) are prepared well in advance of the start of T&C.
- Ensure that sufficient operators are trained for the start of T&C.
- Ensure that System access requirements for the Driver training program are scheduled well in advance of the start of T&C and coordinated with testing activities on an ongoing basis.
- Use experts for key Project challenges and to identify latent issues based on experience on other projects.

Lessons learned are also discussed in **Section 5.4.1.1.**

5.4.1.8 Systems Branding Strategy

The OLRT System has been described as the most important infrastructure project in the City since the building of the Rideau Canal. This is the first leg of a legacy project that will shape the growth and liveability of the City for generations to come. Branding this iconic system creates a unique opportunity to enhance the reputation and quality of life of the City and her citizens. Systems are a key component of the new OLRT brand – the quality and performance of this 'product component' will serve to build the System's reputation for safety, reliability and efficiency. The more visible system components, including equipment that is visible to or interacts with the public (e.g. Passenger information displays, signage and announcements) take on an even greater role as the 'voice' of the brand. RTG will work closely with the City to ensure these brand elements are harmonized and consistent. The fact that Thales is a Canadian success story with key development activities taking place in Ottawa adds to the brand messaging. The Vehicle branding strategy is discussed in **Section 5.4.3.1**.

5.4.2 COMPLIANCE WITH CANADIAN CONTENT POLICY

5.4.2.1 Canadian Content Compliance Strategy

RTG is pleased to propose a Vehicle that will achieve 27% Canadian content as detailed in the Canadian Content Certificate – Attachment B. In this section we are providing supporting information to demonstrate the compliance, this includes names of potential manufacturers, equipment type and place of manufacture and contact details of manufacturer (**Table 5.4-3**). **Table 5.4-2** indicates the breakdown of the requirements calculated in accordance with the Canadian Content Policy and in the specified categories. Of the 27% Canadian Content 16% is from Ontario.

Table 5.4-2 | Local Content calculation

Project Subdivision items	Items / Total proposed price (%)	Part Localized in Canada (%)	Local Content (% proposal price)
Labour	8%	85%	7%
Sub-components and components inc. CBTC	64%	22.4%	14.3%
Project management	6%	25%	1%
Engineering	16%	5%	1%
Manual, Training, Simulators	0.5%	0%	0%
Special tools	0.3%	0%	0%
Test equipment	2%	70%	1%
Freight	0.2%	0%	0%
Warranty	3%	100%	3%
TOTAL	**100%**		**27.3%**

* *The price excludes any Canadian sales taxes (GST and others)*

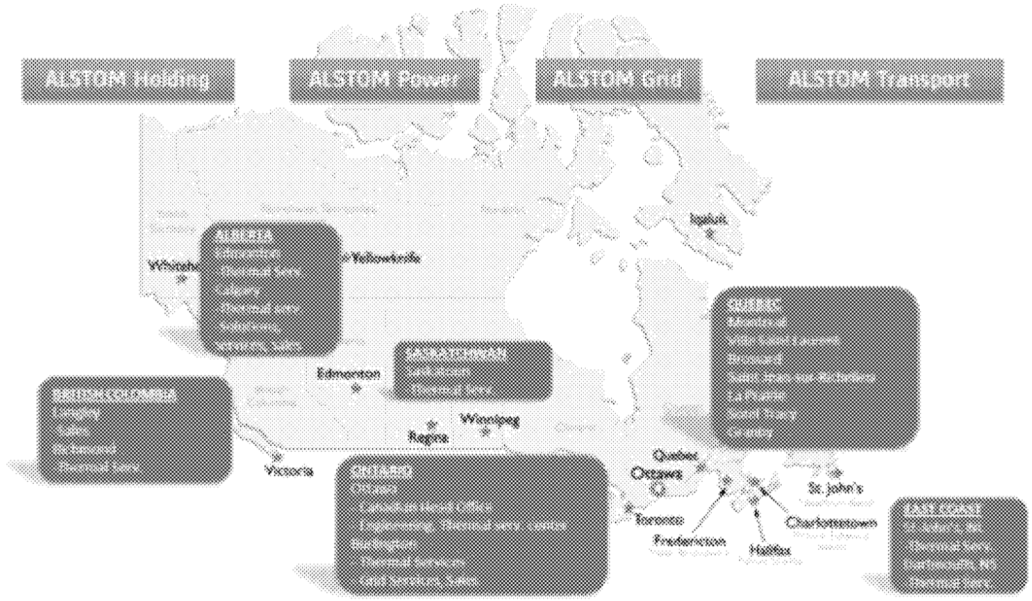
Alstom and RTG consent to the disclosure, verification and audit of the information forming the basis of their certification during the evaluation stage and any further steps taken before Commercial Close and, during and after the term of the Project Agreement. Such disclosure, verification and audit will apply to the Province of Ontario, MTO, the Auditor General of Ontario, and their designates.

70 Years of Experience in Canada

Alstom is able to exceed the required Canadian Content requirement of 25% by three means: local resources currently in place in Canada, local sourcing, and provision of final Vehicle assembly in Ottawa.

Alstom has been operating multi-specialist railway facilities in North America for more than 70 years. Alstom currently has more than 2000 employees working in Canada. Alstom Transport has available, qualified and experienced Canadian resources for the OLRT Project, including from the Center of Excellence for Passenger information, safety, communication and entertainment systems for rolling stock, station and trackside applications in Ville Saint Laurent's site in Quebec, and the Montreal railway maintenance centre (see **Figure 5.4-1**).

Figure 5.4-1 | Alstom Canadian Operations



Local Project Management

A local Project Manager will be appointed at the Project launch. Based in Ottawa, he/she will ensure that the targeted Canadian content is achieved. They will work in close cooperation with the various managers of the project who contribute to the Canadianization of the project. The team will include a Procurement Manager, Industrial Manager, Engineering Manager and Human Resources Manager for instance The Project Manager will help them to set up a localization strategy in order to satisfy and even exceed the local content. They will issue a regular internal report allowing the Authorities to check on the contractual conformity of the 25 % minimum Canadian content.

Supplier management

In order to guarantee the quality of Alstom's products, every supplier retained for the OLRT Vehicles will be qualified by Alstom's purchase quality department.

To date, Alstom already have in their qualified supplier data base a certain number of Canadian supplier such as indicated in Appendix B and **Table 5.4-3**. However Alstom will extend this Canadian supplier base and develop a specific procurement strategy for OLRT in order to deliver the objectives for sustainable procurement, including providing supply chain opportunities in the local area, especially to new and small and medium sized enterprises.

Alstom will advertise their upcoming contracts on their website, in local newspapers, procurement websites and relevant trade journals. In addition to this, they will include a list of key contacts for each current supplier contract and sub-contracted service, to encourage second and third tier potential suppliers to contact key suppliers and work in collaboration. Last but not least, Alstom will organize a Supplier Day in Ottawa to communicate the Project's main objectives and the needs in terms of purchase and schedules.

Management of the procurement process for new Canadian suppliers

A dedicated procurement team lead by the Procurement Manager will manage the procurement process, they will be supported by the various disciplines in preparation of the tender documents.

Procurement will be a key part of the design and construction progress meeting. Tender lists, procurement status, recommendations and performance against local supplier procurement targets will be discussed and monitored. If local supplier procurement targets are not being met the local Project Manager will instigate corrective actions.

Evaluation of tender submissions

A clear evaluation criteria will be established that provides a weighting in favour of local suppliers and sub-contractors.

The evaluation criteria will be a two stage process. The first stage will be a compliance check and submissions will either pass or fail. The compliance check will ensure that the suppliers/ sub-contractors have the capability to deliver the contract safely. The pass/ fail will be assessed on:

- Safety performance
- Capability (Turnover, relevant experience)

If suppliers/ sub-contractors pass the first stage then a weighted scoring criteria will be used to select a supplier/ sub-contractor. The scoring criteria will include:

- Location (Local, regional, national or international)
- Commercial competitiveness
- Programme and methodology
- Quality proposals
- Environmental control proposals
- The suppliers / sub-contractors use of local suppliers, sub-contractors, labour, plant and material
- The suppliers / sub-contractors recruitment and training opportunities for local people

The above scoring criteria with weightings will be developed at Preferred Proponent stage.

Management of suppliers/ sub-contractors

On contract award a start up meeting will be organized between RTG, Alstom and the supplier/sub-contractor. For suppliers this will be less involved, but for sub-contractors this will be an in depth meeting chaired by the relevant System or Element Project Manager. The following will be discussed and formalized:

- Management team
- Frequency and content of progress meetings
- Programme
- Quality standards and regime
- Health and safety outline (this will be followed with a Health and safety start up meeting)
- Environmental issues and control measures
- Commercial

Labour

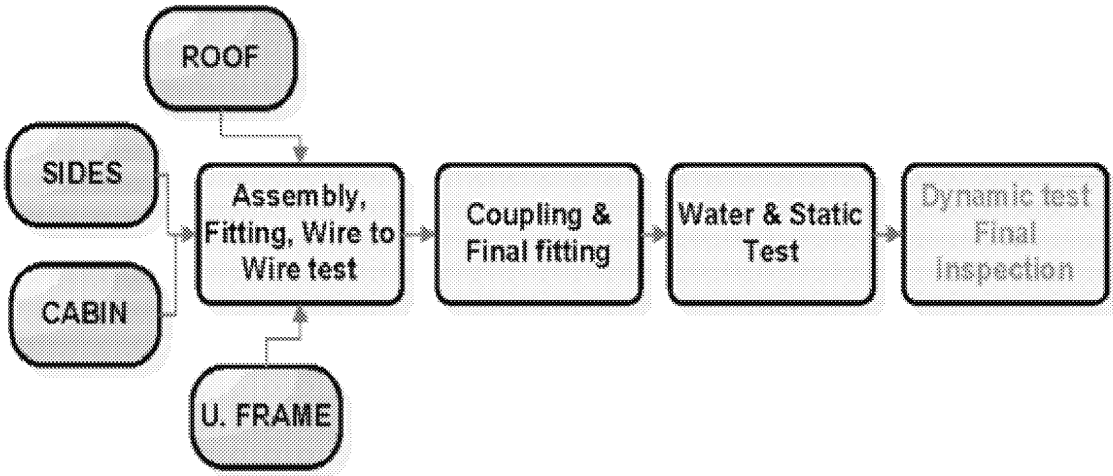
Alstom has develop a standard manufacturing process (APSYS) applicable to all rolling stock types and all manufacturing sites. This standard process will be deployed in the Ottawa MSF, where vehicles will be assembled.

A dedicated Ottawa Industrial Management Plan will be defined at the beginning of the Project. The objective of the industrialization plan is to:

- Define the manufacturing tools and process, and optimise the related investments.
- Build the Product Bill of Material (PBOM) from the Product Breakdown Structure defined by the Technical team

Final Vehicle assembly will be done using Canadian workers in the MSF in Ottawa. The modular design of Citadis Vehicles easily supports production and final assembly of the sub-assembly modules (roof, sides, cabin, and underframe) in the Canadian facility (see **Figure 5.4-2**).

Figure 5.4-2 | Modular Design Facilitates Production and Assembly



The final dynamic routine tests will take place on the OLRT System track.

Subcomponents and Components

Drawing on its supplier database, Alstom will use Canadian and Ontario suppliers for key components as shown in **Table 5.4-3**.

Subassemblies

The main subassembly frames (underframe, roof, cabin and end ring) will be produced individually including welding and painting outside the MSF building.

These frames will be delivered to the MSF where they will be pre fitted and partially tested including the cabling.

Section assembly

The pre fitted modules will be assembled to form each section based on riveting technology. After the dimensional control of the section structure, the final interior fitting and installation of roof equipment will be carried out. An assembly control (mainly electric continuity and dielectic test) is carried out before train assembly (see **Cut Sheet 5.4.1-CS-1001**).

Vehicles assembly

Each completed section is placed on bogie (s) and then coupled to the next vehicle. When the 4 cars of a train are coupled, final wiring is completed before the train is transferred to testing.

Vehicles testing

Each vehicle will be tested in static and dynamic mode according to a standard serial test program designed to test all vehicle functions.The final dynamic routine tests will take place on the OLRT System track.

Table 5.4-3 | Supplier Database Located in Canada

Supplier Name	Location	Product	Logo
Faiveley Transport Canada Inc.	1002 Rue Sherbrooke Ouest, Montréal, Québec	Brakes	Faiveley Transport
Mersen	88 Horner Ave, Etobicoke, Ontario	Electrical components	Mersen

Supplier Name	Location	Product	Logo
Wabtec	475 Seaman St, Stoney Creek, Ontario	Passengers doors	Wabtec CORPORATION
Ceit Groupe	5650 Rue Trudeau, Saint-Hyacinthe, Québec	Interior Lining	CEIT Groupe
Knorr Bremse	675 Development Drive, Kingston, Ontario	Brakes	KNORR-BREMSE
Dimension Composite	2530, 95e Rue, Saint-Georges, Québec	GRP Front End	DIMENSION composite
I Gard	7615 Kimbel St., Unit 1, Mississauga, Ontario	Braking resistor	i GARD
Alstom Canada Inc.	1010 rue Sherbrooke, Montréal, Québec	CCTV	ALSTOM
Prelco	94 Bouleverd Cartier, Rivière du Loup, Quebec	Windows & Windshield	Prelco

Other Items

- **Project management** - Alstom's Project Core Team will be based in Ottawa. This team will be in charge of all OLRT rolling stock requirements from the start of the Project until the end of warranty
- **Engineering** - Alstom's Field Engineer will be in charge of the warranty, reliability and maintainability growth phase. Work will be performed locally by Canadian engineers.
- **Test equipment** - Serial tests on each Vehicle will be performed on OLRT System track by Canadian Engineers. NRC's climatic chamber in Ottawa may be used for specific climatic-type tests.
- **Freight** - Canadian freight companies will be used to transport vehicles and goods.
- **Warranty** - During the warranty period, Canadian engineers will ensure Vehicle reliability and availability.

Technology Transfers

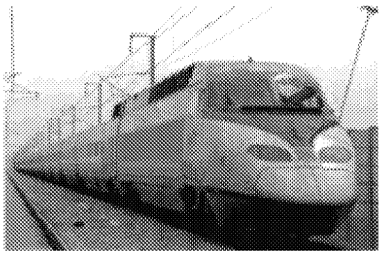
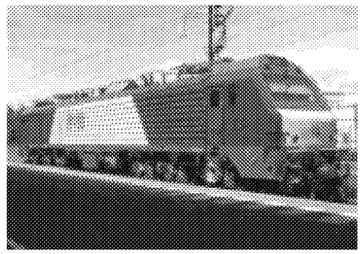
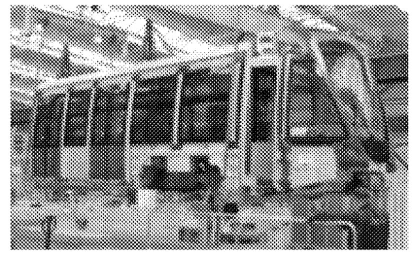
Alstom Transport has more than three decades of experience in technology transfer. In response to a diverse range of local content requirements Alstom Transport has implemented numerous partial and total technology transfers around the world. **Table 5.4-4** shows some of Alstom's main projects with a local content requirement.

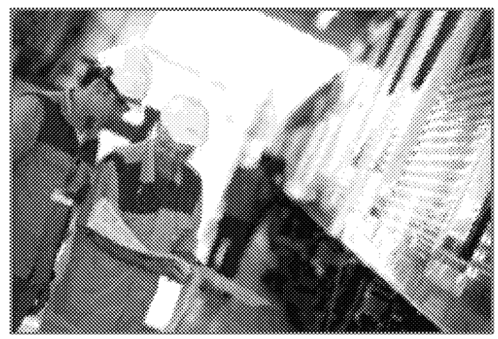
Table 5.4-4 | Examples of successful Technology Transfer

Header	Header
34 Korea - KTX (Korean High Speed Train)	Full transfer from France to Korean partners
500 China CoCo Electric locomotives	Full transfer from France to Chinese partners
Montreal Metro (Bogies)	Transfer from Alstom Le Creusot to Alstom Sorel Tracy (Quebec)
70 Madrid LRV	Transfer from La Rochelle (France) to Barcelona(Spain)
37 Istanbul LRV 20 Acela Express trains	Transfer from Valenciennes (France) to Katowice (Poland)

Header	Header
20 Acela Express trains	Traction cubicle: Transfer from Tarbes (France) to Hornell (USA) Trucks: Transfer from Le Creusot (France) to Bombardier (USA)

Figure 5.4-3 | Examples of Successful Technology Transfer

Korean High Speed Train	China Locomotives	Istanbul LRV
		



Once the two first OLRT Trains have been fully validated by Alstom's Center of Excellence in Valenciennes, France, Alstom will complete a technology transfer to Canada. This process ensures that the entire Train will be assembled in the Ottawa facility described below. Major components of the technology transfer process include the following:

- Preparing the manufacturing plant
- Installing and testing of validated tools for pre-assembly
- Preparing documentation, training and support for local staff

Manufacturing Facility at the MSF

Two main functional areas are required to produce the Citadis vehicle:

- A manufacturing building (4000 m² approx. + additional warehouse)
- A static test building to perform water tightness and functional static test – (2500 m² approx.)

The two MSF tracks designated for heavy maintenance will be used for final vehicle assembly. The MSF will be available for manufacturing equipment installation in early 2015. The vehicle wash facility area will be used to perform the water tightness test. The planned layout is shown in **Cut Sheet 5.4.1-CS-1001**.

Hiring Plan and Skills Development

Alstom intends to hire more than 100 people locally to manufacture the OLRT Vehicles. These workers can be transferred to maintenance activity on conclusion of manufacturing. The personnel breakdown will be approximately 80% workers and 20% management. In addition, the hiring plan will consider other personnel for the Project management team and local engineering team.

Alstom's recruitment strategy will be based on two search modes: active and passive.

Active Candidate Sourcing

- Posting the jobs on niche sites to reach a national audience within specific technical disciplines
- Utilization of "Banners" on the main page of niche sites to highlight Alstom jobs in comparison to competitors

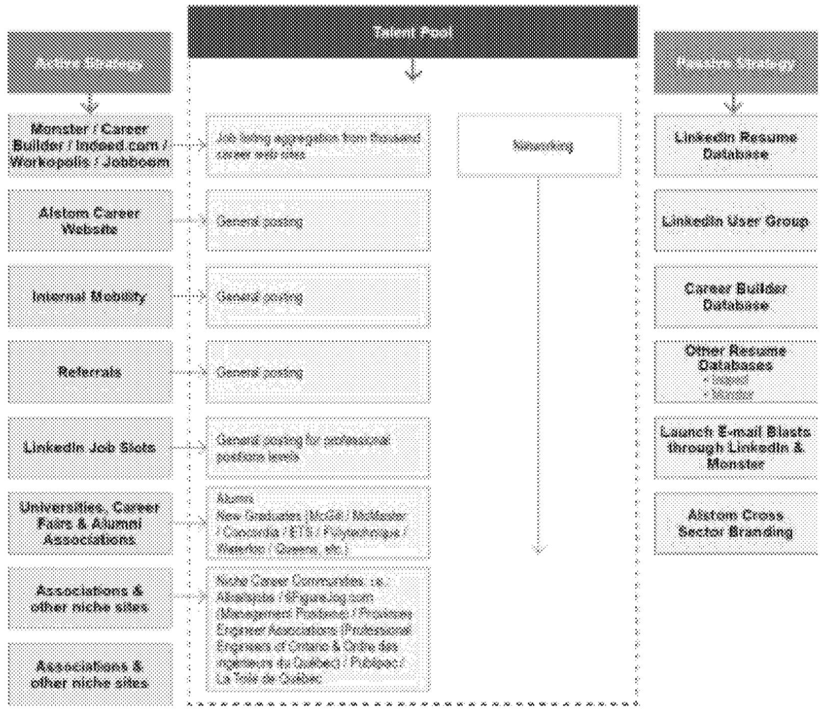
- Utilization of "e-mail blasts" to send Alstom job announcements to candidates who are registered viewers of these various niche sites

Passive Candidate Sourcing

- Using Social Media/Business networking tools
- "Mining" third party applicant databases containing résumés

These two sourcing methods are performed simultaneously and therefore have several benefits:

- Branding and visibility reinforcement
- Multiple sources of applications = multiple sources of advertisements
- Supporting the search for key technical talent: useful niche sites for technical experts
- Being able to compete with strong competitors using well advanced Social Media strategies
- Methodology is applicable to all other disciplines (Key Management positions, etc).



This strategy will be applied to all type of positions:

- Internships
- Technical Experts
- Production employees
- Senior Management
- Professionals

The standard recruitment process is as follows:

- The first selection of resumes is managed by the Human Resources Department
- The selected resumes are sent to the Managers for their review
- The relevant Manager and his/her team review the resumes and communicate the preferred selection to the Human Resources Department
- The HR Department phones the selected candidates with selected questions and send feedback to the relevant Manager
- The Manager, the HR Manager & his/her team interview the candidates face to face and make the final decision
- A background check is implemented on the final candidate. Some psychological tests could be added to the selection process

In accordance with the strategies discussed in this section, RTG is confident that the 25% Canadian Content can be achieved.

5.4.3 LIGHT RAIL VEHICLES

Passenger Vehicles are the dynamic linking element of any LRT system and contribute significantly to the customer's experience. The OLRT Vehicles must consistently address a wide range of factors including safety, comfort, availability and local conditions. For these reasons and more, the proposed OLRT vehicle is a Citadis 100% low-floor LRV. Since production of Citadis vehicles began in 1997, more than 1,500 Citadis LRVs have been sold worldwide. More than 40 cities have purchased the Citadis LRV, thereafter accumulating more than 245 million kilometres for this service-proven vehicle.

Citadis vehicles deliver a wealth of advantages in support of Passenger comfort, and system capacity, aesthetics, availability and safety. This superbly engineered vehicle is easily customizable, easily accessible and easier on the environment. Citadis is also the only 100% low-floor LRV in the world running in daily operation at 100 km/h. Key advantages of the proposed Citadis vehicle include the following:

- **Customer Comfort – Best in class**
  - Design focused on Passenger comfort and safety
  - Modular design allows multi-purpose areas
  - Large windows provide bright, attractive riding experience
  - Two-level suspension truck provides ultra-smooth trip and high comfort levels
- **System Capacity - 100% Low-floor Vehicle**
  - Vehicle interior is configured with no steps, allowing for safer, quicker and smoother Passenger flow and reduced dwell times
  - More efficient standing capacity compared to a 70% low-floor LRT
  - Improved access for Passengers with mobility restrictions
- **System Aesthetics – Visual appeal**
  - Sleek, lower profile Vehicle integrates beautifully into the urban environment
  - Iconic addition to the Ottawa landscape
- **System Availability – State-of-the-art systems; global expertise**
  - Citadis benefits from Alstom's global expertise as a Train maintainer
  - State-of–the-art on-board monitoring system for remote diagnosis and troubleshooting
  - Braking equipment, gear-box, traction motor and wheels are directly accessible for inspection and replacement from the side of the Train without truck removal
  - Exclusive rapid-mounting system replaces side window in 30 minutes
- **System Safety – Safety enhancements**
  - Designed according to the latest safety standards (EN 50126)
  - Safety is considered through the entire lifecycle of the Vehicle: from concept to O&M
  - Compliant with ASME-RT1 requirement for structure and crashworthiness
- **Easily Customizable – Modular design**
  - Designed to be easily customized to accommodate Ottawa's specific requirements
  - All Citadis Vehicles are based on the same proven-design sub-systems for improved availability
- **Increased accessibility – Mobility for all**
  - 100% low-floor allows ease of use for all Passengers
  - Leveling system ensures perfect alignment between platform and the LRV
  - Large corridors and gangway

- **Environmentally Sensitive – Reduced footprint and impacts**
  - Vehicle is recyclable at 95%
  - Reduced energy consumption
    - LRV features regenerative braking
    - Citadis is fitted with a single-stage gearbox for better efficiency
    - Interior lighting is based on low-consumption LED
  - Vehicle design reduces noise levels inside and outside the Train

5.4.3.1 Branding Strategy & Approach

Best or Leading Practices

The OLRT system has been described as the most important infrastructure project in the City since the building of the Rideau Canal. This is the first leg of a legacy project that will shape the growth and liveability of the City for generations to come. Branding this iconic system creates a unique opportunity to enhance the reputation and quality of life of the City and her citizens.

Station and urban design are critical components in developing a 'complete brand approach', but the Vehicles are the dynamic linking element and ultimately become the 'face' of the brand. Too often, Vehicle livery has been largely regarded as an extension of the agency, a "uniform" for vehicles. This ignores the potential to capture and communicate the brand promise with each passing view of, or travel experience onboard, an OLRT Vehicle.

As a member of RTG, Alstom is committed to working with the City to integrate the Vehicle brand with the overall brand of the System. We will work with the City during its System branding process to develop a full understanding of the complete identity for the OLRT. More specifically, the Vehicle brand will encompass the Vehicle front styling, interior and exterior colour schemes, window tinting and livery.

Brand Building

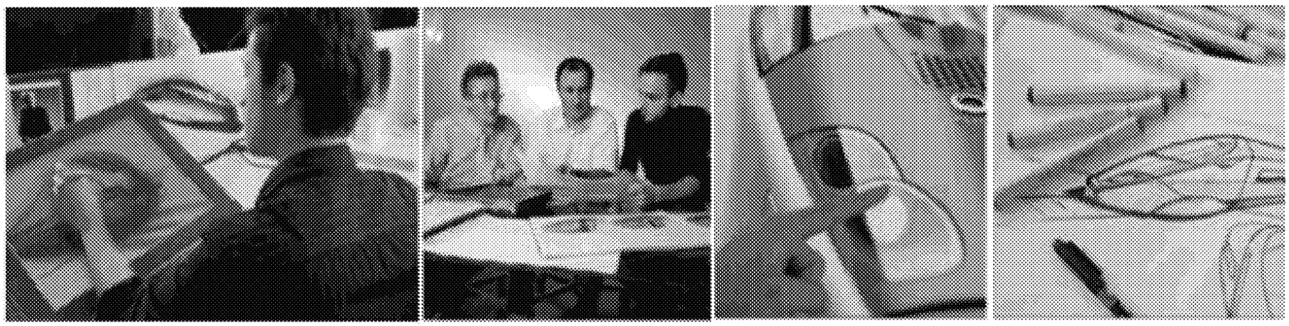
To develop a compelling and positive Vehicle brand, the branding strategy should incorporate the following elements.

- **A long-term vision** - An explicit definition of what the brand is to represent in the eyes of its target audience.
- **A better product** - Product quality is an ideal branding variable. Working within the budget envelope, RTG will assist the City in delivering a better product across Vehicles.
- **An analytical edge** - RTG will help the City use research and consultation for a clear understanding of transit users (current and prospective) and their needs.
- **An exercise of creativity** - Vehicle branding requires creative thinking, planning and execution through every element of the Vehicle.

RTG Approach – Fully Integrated Branding

RTG understand that branding goes beyond Vehicles and must have a 'complete design approach' to be successful. Our partnership approach with the City, our expertise, and our lessons learned will benefit the citizens of Ottawa and create a world-class LRT identity.

Alstom enjoys a long-established global reputation for expertise and innovation in transportation solutions. One reason for this is the Design & Styling (D&S) department created in 2005, and which is unique in the railway industry. The department comprises 20 top designers, each dedicated to creating designs that harmonize with the general configuration of the Vehicle - and ensure that Vehicle branding adds a compelling and exciting element to the overall System brand.



The D&S department's cross-functional organization is particularly well suited to meeting the specific needs of envisioning and incorporating key branding elements:

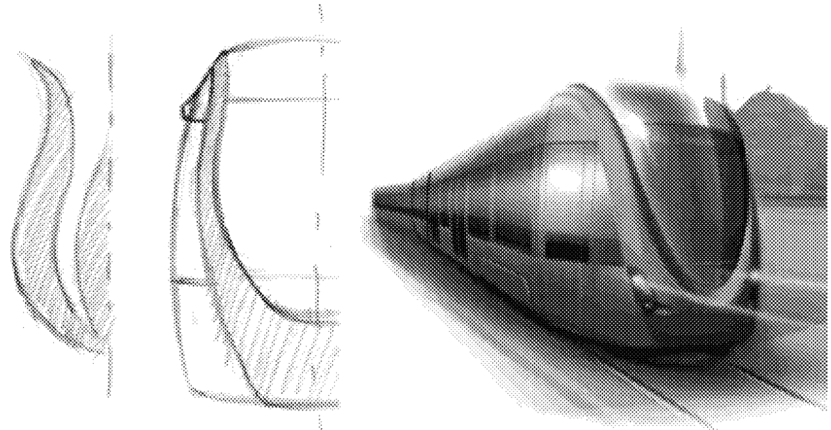
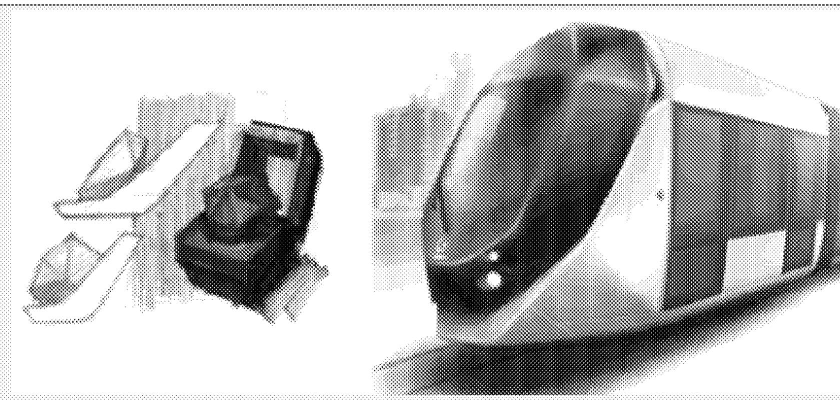
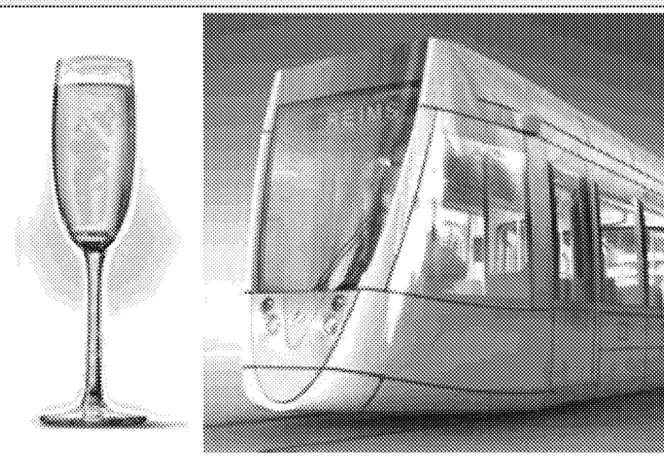
- Consolidating competencies in terms of design, digital modelling, colours, materials, and lighting
- Producing designs suited to each client's cultural context
- Stimulating creativity

For the OLRT Project, Alstom will follow its normal practice and use a highly collaborative approach to branding with active and ongoing involvement of the City and key Stakeholders. A multi-disciplinary team, including graphic designers, architects, planners, engineers, branding specialists, and Stakeholders is involved in strategy and ideation. Working with the City's branding process, the D&S department will analyze the cultural, economic, political and geographical context of the Project. This is summarized through photo reports and keywords. The objective is to define the artistic theme which will be used as a connecting thread for creation throughout the Project.

A unique competitive advantage of our modular product configuration is that the front end and interior arrangement can be customized and become a critical component of the brand. The D&S department will propose various versions of shapes for the interior and exterior, colours and trims in support of the final branding approach.

Branding is completely integrated into the industrial design process for the Vehicle. See **Section 5.4.3.7** for a complete description of the industrial design process. **Table 5.4-5** shows three examples of how Vehicle design becomes a key brand element.

Table 5.4-5 | Vehicle Design

City and Theme	Vehicle Design
LRV Istanbul – Theme: Tulip	
LRV Dubai – Theme: Diamond	
LRV Reims – Theme: Champagne Flute	

Branding by Design

The Alstom D&S department follows a multi-step iterative process that ensures Vehicle design delivers maximum branding value and quality results.

Design, Step-By-Step

The design process is divided into six steps: preliminary meeting, pre-choice meeting, choice meeting, freeze meeting, working mock-up and representative mock-up.

Round-The-Clock Dialogue

Teamwork is part of a methodology that has been proven over time. Face-to-face meetings will establish a rapport with the client that makes the choice process simple and straightforward. Once the design principles are agreed upon, they are integrated into product design. In addition, the Design & Styling department can work directly with external designers or local partners.

A Committed Team

The dialogue takes place over several months. An Alstom project manager first proposes a work schedule and this sets off a feedback loop involving designers, modellers and colours and materials experts. These in turn consult with engineers and suppliers who speak a common language.

A Proven Methodology

Listening to client needs is built into the team-based approach. It is imperative to ask the right questions to fully grasp the nature of each project. Only this kind of quality interaction gives rise to previously unexpressed needs.

Feasibility

All elements proposed during the selection process are feasible. The design team works with software that is compatible with the one used by railway engineers. Adjustments can be made at any stage of the process, from the rough sketch to the 3D model. A five-axis milling machine then renders the design into a volumetric model.

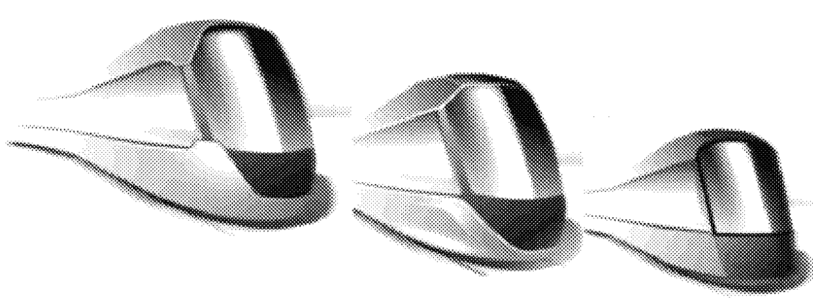
Design Manual

At the freeze meeting, customers are handed a Design Manual detailing the specifications of their proprietary train design. The Manual lists up to 80% of the shape characteristics of a Train, both interior and exterior. It also includes a graphic line, colour preferences, seating configuration, lighting options and materials. The signing of the Design Manual serves as a contractual agreement between Alstom and its clients.

OLRT Treatment Exploration – Positioning Led Design

Figure 5.4-4 shows examples of branding schemes are provided only as examples, to demonstrate how different positioning choices could inform final branding.

Figure 5.4-4 | Preliminary studies of three front end shapes proposed for OLRT



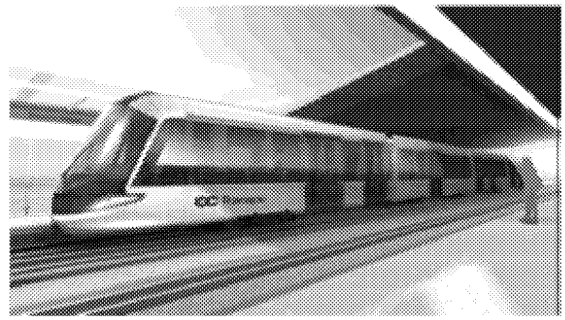
To demonstrate the scope and flexibility of our branding process the Alstom D&S department and RTG have created three preliminary design alternatives for exterior design and interior design. Following a review of what is building the City today, and what the City is building for tomorrow, these alternatives have been specifically created for Ottawa. Starting with the identification of key elements that could form the basis of a strong OLRT brand foundation, we have shown how we translate these into shapes, graphics and colours in the vehicle design.

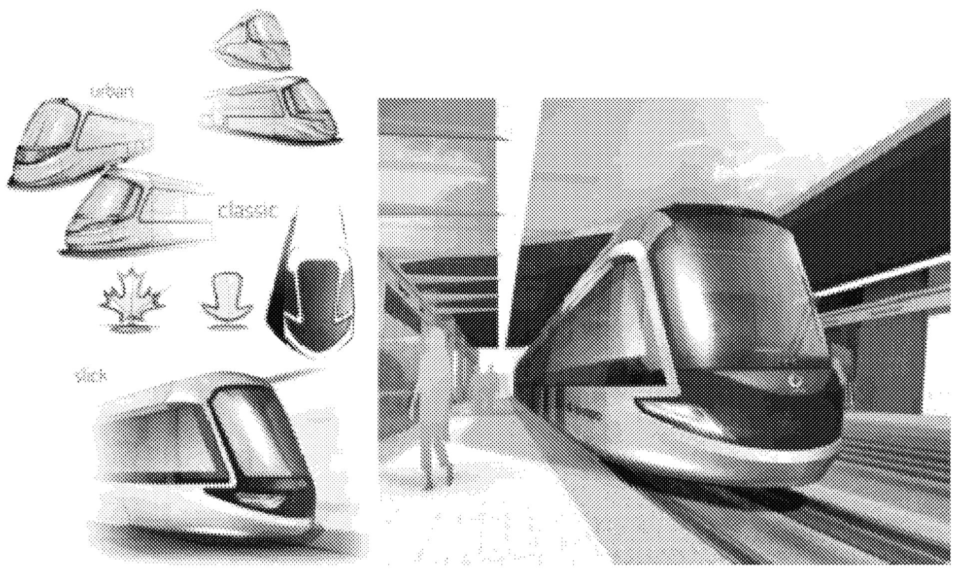
The Citadis product is a technically proven design, but the platform has been purposely designed such that it can easily be customized for each of our clients. This creates flexibility and possibility from the outset. The alternatives included here are intended to demonstrate the degree of differentiation possible – and are the starting point for a collaborative branding process with the city.

Exterior Design

Theme A: Strong and Free

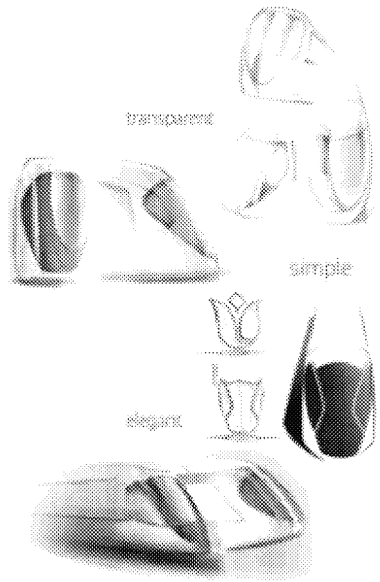
This design incorporates a strong graphic shape on the front end. It retains the essential lines of the maple leaf to create a design that recalls the national symbol without being literal and obvious. The graphic and form create a style that is contemporary today, and will become a classic in the future. It is strong, solid and present. The surface treatment is both detailed and sleek, conveying a sense of quality and pride befitting the stature of Canada's capital city.

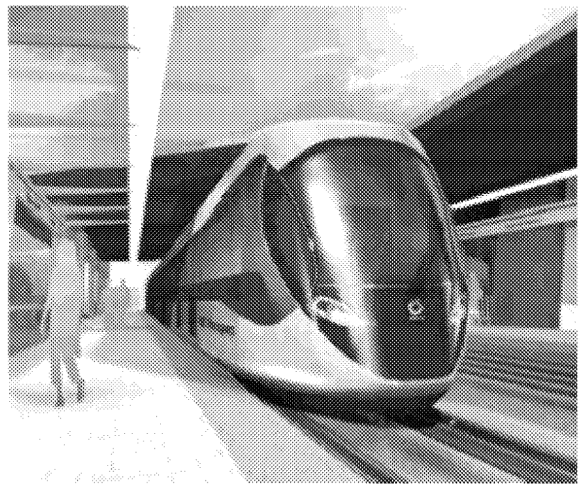




Theme B: Quiet Strength

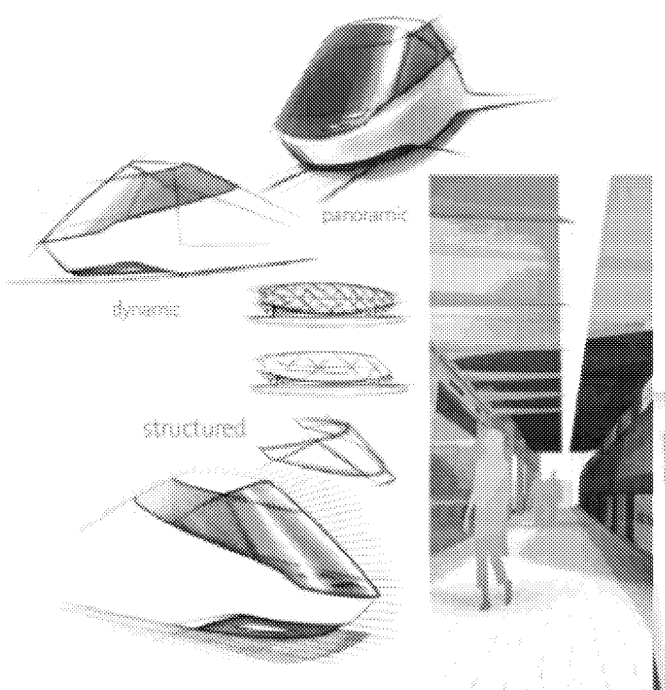
Ottawa is home to the world's largest tulip festival. This theme takes inspiration from the tulip petal and is well balanced and softly curved. The result is highly aesthetic and elegant, and conveys a sense of quiet strength. The large windscreen with integrated headlights creates a heightened sense of transparency and expansiveness. A comparison of this treatment to that of the Istanbul LRV is a strong example of how we take the essence of a city and transform it into a unique brand element. Although both cities claim the tulip as an iconic element, the OLRT expression is uniquely Canadian.

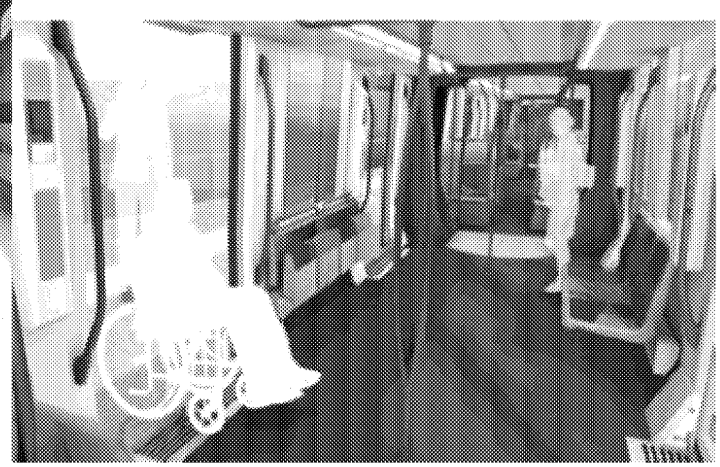




Theme C: Fast Forward

This theme takes its inspiration from some of the most advanced architectural features in the City. The design conveys a strong sense of purpose and motion; at once dynamic and panoramic. The sleek continuous front end is futuristic and powerful – with just a touch of attitude. The design makes a strong statement that the City has arrived.





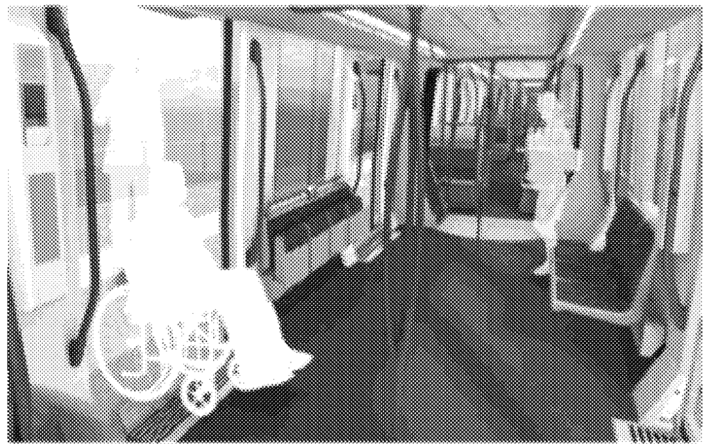
Interior Design

Theme 1: Geometry

Geometry is the basis of all strong composition. With a starting point of straight lines and geometric shapes this design theme shows how intriguing the basics can be when skillfully combined. In this simple but bold choice, a sense of animation is created by combining strong contrasting colours with neutral elements. The result is strong, contemporary and distinctive.

Theme 2: Facets

In this design it appears that facets of light from passing buildings are reflecting within the Passenger car. The diamond grid pattern on the ceiling gives the impression of light reflecting off the water - creating a bright, animated ambiance. The classic colour scheme produces a sense of calm and comfort. The use of red creates an additional feeling of warmth.



Theme 3: Tulip

This innovative interior design dramatically separates the ceiling from the rest of the interior. Nature images and landscapes in the ceiling panels give the impression of a contemporary photograph exhibition. These pictures are filtered using plain colours and low contrasts, creating a calm, contemplative atmosphere. The images are a subtle reminder of the simple pleasure of taking time each day to really look at our surroundings.

All of the elements shown in the three external and three internal design options are interchangeable. These design options demonstrate how character and interest can be added to the Vehicle branding process by integrating elements that reflect on local history, aspirations, culture, and unique aspects of the surrounding landscape.

5.4.3.2 Proposed Vehicle

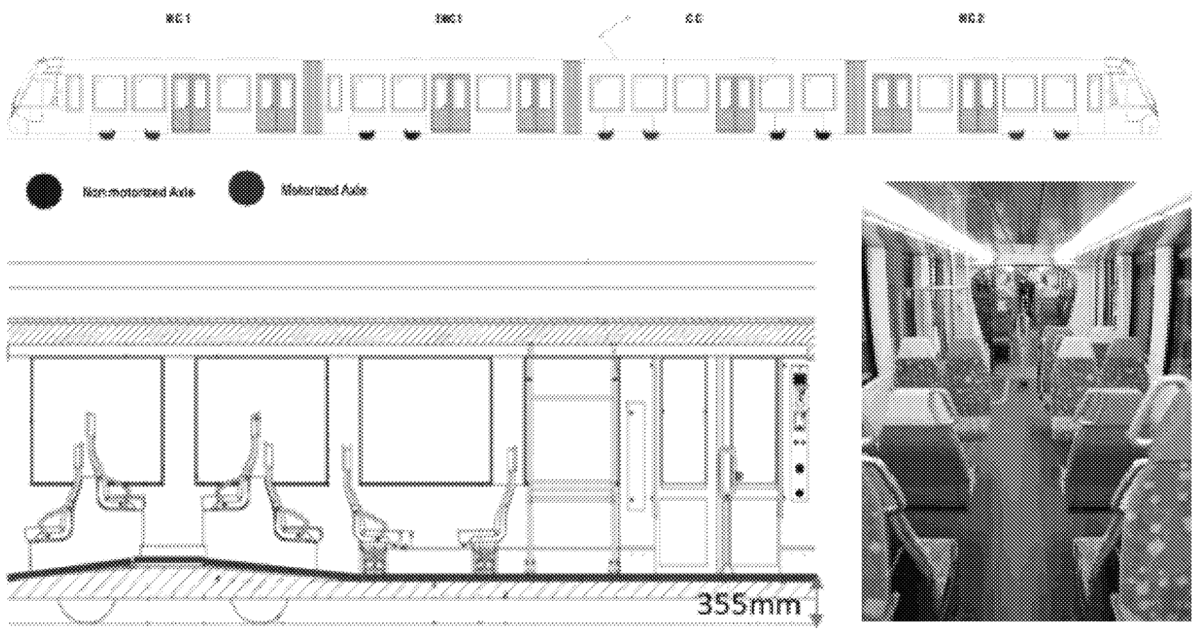
General Arrangement and Performance Level

The proposed Vehicle for the OLRT Project is part of the Citadis product range. As shown in **Figure 5.4-5**, each Vehicle is composed of the articulating sections.

- 1 extremity section with Driver's cabin and motor truck (MC1)
- 1 intermediate section with one trailer truck (IMC1)
- 1 centre car with one trailer truck and one motor truck (CC)

- 1 extremity section with Driver's cabin and motor truck (MC2)

Figure 5.4-5 | Articulating Sections and Low-Floor Arrangement



The Vehicle features 100% low-floor in the Passenger area for an improved ride experience:

- **Optimized Passenger Flow** - Safer, quicker and smoother Passenger flow inside the Vehicle to reduce dwell time.
- **Improved Comfort** - The flat floor provides Passengers with an increased sense of comfort.
- **Improved Safety** - No step means no trip-hazard in the Train.
- **Improved accessibility** - All Passengers, including those with restricted mobility, strollers or luggage can move easily within the Passenger area.
- **Optimized Capacity** - In partial low-floor vehicles, standing Passengers remain in the low-floor sections; in a 100% low-floor Train, they have full access to all available space within the Vehicle.
- **Improved aesthetics and urban integration** - 100% low-floor vehicles are lower than partial low-floor Vehicles resulting in smoother vehicle profiles and reduced visual impact.

Other key Vehicle features include the following:

- Maximum operating speed of 100 km/h for high-capacity line.
- Large windows in the Passenger compartment create a feeling of spaciousness.
- Seven dual-leaf sliding-plug Passenger doors are evenly distributed throughout the Train for reduced dwell time. The Passenger-exchange length over useful Vehicle length (i.e. not including the Driver's cabin) is higher than 20 percent.
- An HVAC unit located in each car ensures optimum thermal comfort in the Passenger cars.
- The proposed width and length combination optimizes capacity while ensuring a high level of Passenger comfort.
- Major sub-systems, such as HVAC, traction cubicle or air compressor, are roof-mounted and concealed by lateral roof fairing profiles presenting a pleasing, uniform appearance when seen from road level.
- Vehicle can be operated in multiple units of two vehicles.
- Bi-plan side walls produce a more aesthetic vehicle with a large Passenger compartment while reducing the vehicle dynamic envelop.
- The Vehicle's modular design enables large use of pre-assembly, making it easy to assemble and maintain.

The Vehicle layout is shown in **Drawing 5.4.1-SW-101**. **Table 5.4-6** summarizes the other main characteristics.

Table 5.4-6 | Vehicle Characteristics

Characteristics	Dimension/Performance
Length over coupler face	49 metres
Vehicle width	2,650 mm
Vehicle tare weight	78 tonnes
Number of sections	4
Number of trucks	5
Number of motor trucks	3
Seated Passengers	104 seats + 16 flip-ups
Standing Passengers with 3.33 pass/m²	180 Passengers
Total Train capacity at 3.33 pass/m²	300 Passengers
Comfort rate with 3.33 pass/m²	40%
Wheelchair areas	4
Double doors	7

Performance Reliability and Safety of Proposed Vehicle

The proposed Vehicle is an evolution of Citadis based on Istanbul Citadis and SNCF Nantes Citadis to fulfil OLRT requirements (**Section 5.4.3.3** provides more details). The main modifications to the Citadis Nantes are the following:

- Replacement of the 25 kV/750 Volts dual-voltage traction package by a 1500 Volts traction package
- Lengthen car body to provide Passenger capacity in line with OLRT System performances
- Addition of one door on MC1, MC2 and IMC1 to manage Passenger flow and reduce dwell
- Removal of the handicapped toilet in MC1
- Replace SNCF signaling system with Thales CBTC system
- Implementation of design solutions to comply with climatic conditions in OLRT environment
- Modifications to comply with standards and regulations specific to OLRT environment and Canadian content (for example: addition of service proven pneumatic secondary suspension to comply with ADA/AODA)
- Modifications to comply with Transport Canada regulations, only to the extent that the regulations are appropriate for LRV vehicles. For example RTG does not plan to provide onboard washrooms.

Performance

Table 5.4-7 | Performance of Proposed Vehicle

Parameter	Performance
Maximum Speed	100 km/h
Acceleration: Initial maximum vehicle acceleration (OCS voltage>1500 V, AW2 Loading) up to 32 km/h	1.34 m/s² +/-5%
Full service electric brake rate at AW3 loading from 64 km/h to 5 km/h	1.34m/s²
Full service blended (electric/friction) at AW3 from 80 km/h to standstill	1.34m/s²
Maximum service blended (electric/friction) + track brake up to AW3 from 88 km/h to standstill	2m/s²

Parameter	Performance
Full service friction brake rate at AW3 loading from 80 km/h to standstill	1.34m/s² +/-10%
Emergency Brake at AW3 load from 48 km/h to standstill	≥2.24 m/s²
Friction only at loads up to AW3 load from 80 km/h to standstill	1.78 m/s² +20%/-10%
Parking brake holds an AW3 Train on a 6% grade indefinitely	Yes
Jerk rate	From 0.44 to 1.34m/s3

Reliability

As with every product developed by Alstom, the Citadis range and Ottawa's Vehicle are designed to deliver a high level of reliability and to allow for easy maintenance operations. **Table 5.4-8** shows figures applicable for the proposed OLRT Vehicle.

Table 5.4-8 | Vehicle Reliability

Parameter	Performance
Mean distance between Service-Disrupting Failures over a 12-month period (per LRV)	52000 km
Mean Time To Repair failures (MTTR)	1.5 hour
Maintenance periods	12500 km 25000 km 75000 km 100000 km 300000 km 400000 km 600000 km 900000 km 1200000 km
Failure recovery achievable within "x" minutes of two Trains converging (i.e. time to couple to an immobilized Train, reconfigure the consist, and start moving it off the line)	30 min

Safety

Safety is at the core of every Alstom product. During development of the Citadis product range, close attention was paid to all safety-related aspects and items to make Citadis one of the safest Trains on the market. For the OLRT Project, a complete safety study will be part of product development. This study will take into account the tremendous amount of in-service experience on the Citadis product range as well as all the requirements, environmental and operational, specific to the OLRT. Safety studies will be conducted in accordance with the EN 50126 standard and the Safety Assurance process outlined in **Section 5.1.5.1**. For each hazard identified in the PHA (Preliminary Hazard Analysis), Alstom will submit proof that the Ottawa Vehicle complies with the safety target.

Safety Analyses

The subsystems or equipment liable to create events identified in the PHA will undergo detailed analyses, conducted in accordance with at least one of the following methods:

- **Fault Tree Analysis taking into consideration the different events -** A deductive method starting from a single and well identified event, leading to basic events that are each independent and amenable to calculation of their probabilities (e.g. breakdowns, human mistakes, external conditions).

- **FMECA (Failure Mode Effects and Criticality Analysis)** - An inductive method whereby, starting from the exact definition of the functions of a device or assembly, one can systematically seek out the failure modes and their consequences or effects on the Citadis set.

These analyses will demonstrate that the steps taken to deal with risks are or will be set up to reduce the probabilities of occurrence related to the events in categories of gravity 3 and 4 to a negligible level. These analyses will be entered in the "rolling stock safety level justification file". The steps needed to deal with risks may consist of the following:

- Structural provisions
- Functional provisions
- Provisions related to the detection of the failures
- Provisions related to standards
- Calculations
- Tests
- Quality procedures
- Maintenance procedures
- Operating rules

Corrective action will be taken if results do not meet objectives. Examples of safety hazards considered are as follows:

- Loss of command of Emergency Brake
- Insufficient Emergency braking effort
- Propulsion fails to cease when Emergency Brake is requested
- Train moves in wrong direction
- Door opens spontaneously when not commanded
- Door opens on wrong side of car
- Excessive currents or overheated equipment cause fire hazard
- Train moving when doors are not closed and locked
- Cars in Train separate when not commanded
- Indication of uncoupled when not uncoupled

Synthesis of Safety Analyses

Safety-Critical Item List

The safety level concerns all equipment which requires safety analysis during the Project by the Alstom RAMS team. The Engineering Department is in charge of designing these assemblies and validating them by using calculations or design principles (in accordance with the normative documents). Safety analyses are performed to verify the design.

Safety levels are attributed during the design phase by the safety department for the equipment being considered. The safety level of an assembly corresponds to the consequences of the rupture of a single component of the assembly in relation to its effects on people, the equipment and the environment. The classification of safety levels used for the design, whether screwed or welded assembly, is as follows:

- **Level 1 – High:** The rupture of the assembly leads to physical injury and global failure of the assembled system. => Disastrous level
- **Level 2 – Moderate:** The rupture of the assembly affects global operation of the system or may have consequences involving physical injury. => Critical and significant level
- **Level 3 – Low:** The rupture of the assembly does not directly affect the global operation. Consequences involving physical injury are highly improbable. => Minimal level

Safety Synthesis File Justifying the Safety Level of the Rolling Stock

The file justifying the safety level of the rolling stock consists of all safety notes relating to analysis of the events included in categories of gravity 1, as follows:

- An overall description of the event and the associated subsystems
- A qualitative and/or quantitative analysis of the event grouping together the structural provisions, the quality links, the operational surveillance systems and the requirements during operation and maintenance

Requirements for Safety during Operation (Line and Maintenance)

"Requirements for safety in operation" is the outcome of the safety analyses, bringing together all the customary maintenance and operating requirements needed for preserving safety. This document takes into consideration the conditions affecting safety and requiring application of one or several logistics actions to preserve safety.

Analysis of Test Plans

The objective of this task is to check that the requirements and recommendations resulting from safety analyses concerning the tests to be performed have been taken into consideration.

Analysis of Procedure for Application of Modifications

Following an encoded modification in design, a procedure is set up for applying these modifications. The objective of safety is to check that the proposed modifications in accordance with this procedure comply with safety requirements.

Safety File

The safety file consists of all documents describing the steps taken to deal with risks and/or those demonstrating for a given subject that the risk studied has been eliminated or controlled.

Winterization Measures

Due to Ottawa's extreme climate, some winterization solutions will be implemented on the OLRT Vehicle. Adaptation will be concentrated in two main areas:

- Ensure Passenger and Driver safety and comfort
- Ensure proper operation of rolling stock

The solutions implemented on the OLRT will be based on the following:

- Alstom's extensive experience in manufacturing vehicles for environments with heavy snow and extreme cold conditions (e.g. Citadis for Grenoble, X40 Train for Sweden, Helsinki-Saint Petersburg high-speed tilting Train, Moscow tramway, EP 20 and 2ES5 locomotives for Russia, KZ8A and KZ4AT locomotives for Kazakhstan)
- The future European Norm PrEN16251 - Railway Application – Environmental conditions - design and test of rolling stock under severe conditions

The extreme cold climate related issues are the following:

- **Extreme cold temperature** - This will affect material mechanical characteristics; reliability of electronic, pneumatic and hydraulic equipment; thermal comfort, and cold surfaces in Passenger area.
- **Snow** – This will impact filtration at air intake, roof and underframe accumulation, presence on track, and visibility.
- **Ice formation** - Main issues linked to ice formation are improper operation of unprotected moving parts such as doors or pantograph; risk of impact of ice blocks on underframe equipment wiring; and slippery conditions for Passengers.

- **Ice/snow removal** - Presence of salt, glycol or other products used to deal with snow on roads, walkways or rolling stock in the environment will be taken into account in the design of the LRV (risk of corrosion or chemical attack).
- **Condensation** - Condensation will impact interior comfort conditions, visibility, increase risk of corrosion, affect proper operation of electronic component and affect equipment's life expectancy. Particular care will be taken to deal with the 58°C thermal shock.

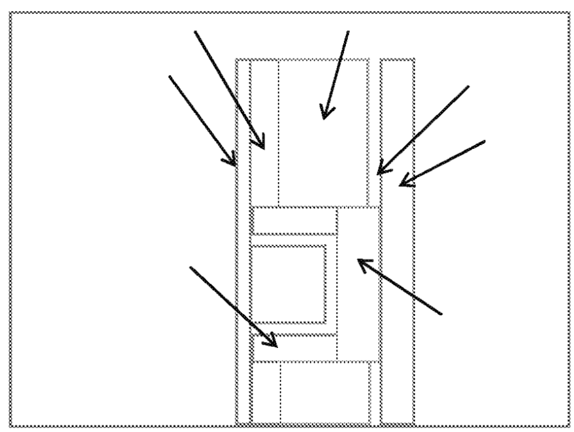
Winterization will be addressed at the Train level. Product adaptation linked with winterization will be validated by specific tests, at Train and sub-system level, as suggested by the PrEN16251 - Railway Application – Environmental conditions - design and test of rolling stock under severe conditions.

Based on operational experience from the Edmonton and Toronto LRT systems, during periods of extreme cold temperature (below -25°C), Trains will be parked either in a heated area (MSF), outside under catenary power, or outside without catenary power. Vehicle winterization measures will support each of these operational strategies.

Solutions to Ensure Passenger Safety and Comfort

Thermal insulation of Passenger compartment and Driver's cab. To ensure that temperature remains comfortable and homogeneous inside the Train in the most extreme conditions (hot or cold), thermal insulation is key. It serves three main purposes:

- Ensuring homogeneous temperature through the Passenger compartment
- Preventing Passengers from contacting cold and/or wet surfaces
- Reducing the energy needed to heat-up or cool down the Vehicle

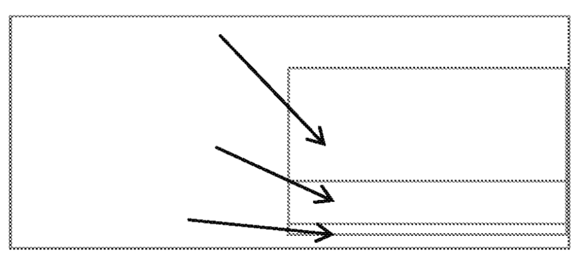


Insulating material will be used on walls, ceiling and floor of the Passenger compartment and the thermal coefficient will be increased to meet OLRT specifications for thermal comfort. The wall and roof insulation will consist of the following:

- A multilayer acetate celluloid insulating material to drain condensation water
- A layer of self-adhesive insulation material

In areas where structure could come in contact with the internal fitting wall, particular care is taken to prevent thermal bridges between the structure and the material accessible to Passengers, by using a combination of the following:

- A thermal and water vapour barrier made of a closed-cell insulating material
- Polymer wedges between steel structure and interior paneling



Floor insulation will be achieved by superposition of the following:

- A multilayer acetate celluloid insulating material to drain condensation water
- A layer of glass wool with a protective skin

Most floor insulation will be incorporated in the floor structure.

Safety of Passenger access. To reduce risk of slipping, heating will be located at floor level to prevent snow or ice accumulation. Door thresholds will be heated to prevent ice and snow accumulation in this sensitive area.

Passenger compartment heating. To provide thermal comfort performance required by the ORLT specification, heating will be provided by the roof-mounted HVAC unit, and heated air will be provided to the Passenger compartment through an air diffuser located on the ceiling and at floor level. Where required, heaters and a heating floor will provide additional heating.

Door adaptation to cold climate. Freezing rain in the Ottawa region will cause the formation of an ice layer on the Train car-body. To ensure proper operation of the doors in extreme cold conditions, the power of the motor actuators will be reinforced, thus allowing the actuator to open the door in case of ice formation around the door area on the Vehicle side. Additionally, the following door-operating mode will be proposed to the City for extreme cold conditions:

- **For an outside stop -** Door will only open when requested by a Passenger through a push button located inside or outside the door. This will prevent cold air from entering the Vehicle if no Passenger needs to get in or out of the Vehicle, thus increasing overall Passenger comfort.
- **For a stop in tunnel** - All platform side doors will open to ensure every door on the Train is open at least three times per round trip, thus preventing significant accretion of freezing rain on the door.

Door-edge elastomeric gasket will be adapted to -38°C operation.

Ensure proper braking performances of the Train. The Vehicle will be equipped with a state-of-the-art wheel slip/slide protection system as described in the braking equipment section of this section of the Response. Sanders and sand-boxes will be heated to prevent ice clogging the sand ejector circuit, thus ensuring functionality in cold weather and snowy conditions.

Solutions to Ensure Proper Vehicle Operation

Door adaptation to cold climate. The following measures will be taken to mitigate the effects of condensation on Vehicle components:

- Structural elements will be hermetically sealed or will contain drainage holes of at least 20 mm located to prevent condensation water from accumulating and freezing inside the structure. Drainage holes will be located to prevent water projection on sensitive equipment.
- External equipment will contain provisions (e.g. insulation, drainage holes) to reduce thermal shock and/or evacuate condensation water.
- A global draining frame will be located inside the Train to evacuate condensation water.
- Humidity resistance of electrical and electronic apparatus will be reinforced (e.g. use of specific varnish on electronic boards).

Material selection. All material used on the Train (including oil, grease, rubbers, plastics) will be selected and tested to ensure performance in Ottawa's extreme cold conditions. Particular care will be taken for subsystems located outside the car body such as the flange lubrication system, lubrication of truck components (bearings, gear-box), and rubber mounts.

Particular care will also be taken during design in locations when different materials will be used (for example steel/aluminium interface). In these areas, differential contraction values will be taken into consideration during the design process. Properties of all materials used in the Vehicle design will be validated by test at -38°C, including glues and joints. For all external components, material will be selected to ensure mechanical and chemical resistance to de-icing method used by the operator (glycol, steam). The salt used on regular roadways will also be taken into account as necessary.

Solutions to deal with snow accumulation. External panels and components will be designed to reduce snow accumulation on the roof. Particular care will be taken to prevent snow accumulation and/or to allow proper snow evacuation around the pantograph. The design will allow for evacuation of water coming from melted snow or ice. Air outlets will be designed to reduce the risk of "melting then freezing" around sensitive devices (pantograph). The full low-floor architecture does not allow sufficient room for significant snow accumulation in the truck area.

Protection against ice impacts. When necessary, screens and covers will be used to protect under-frame equipment, wiring and connectors from ice impacts. Components will be located to minimize exposure. In areas where protection screens cannot be installed (area around truck), the frame will be protected against impact by a protective coating.

Removal of snow on track. A snow plough will be mounted under the cabin and designed according to the operating principle used on the ORLT network (removal of major snow accumulation by use of dedicated vehicle or by revenue service vehicles).

Optimization of air inlet and outlet. The air inlet will be positioned and sized so that snow accumulation in any part of the Vehicle cannot obstruct an air intake. As much as possible, the air intake will be located as high as practically feasible in regards of the surface where snow can accumulate, and its shape will be designed to minimize the risk of complete obstruction (i.e. air inlet will be shaped to favour height over width).

Adapt pantograph to deal with snow accumulation on catenary. Pantograph raising and lowering will be done electrically. To ensure a good electrical contact between the pantograph and the catenary, the proposed pantograph will be fitted with an ice scraper that will remove ice from the catenary.

Adapt coupler to presence of snow and ice. Heated coupler faces will be used to prevent accumulation of ice and snow. When folded, the coupler will be protected from external pollution such as snow, ice, dust and salt.

Validation

All the proposed solutions, whether they are at the component or Train level, will be revalidated in the OLRT context. At sub-system level:

- Validation will be run at component level with our internal and external suppliers
- When required, specific mock-up will be built to reflect the actual OLRT environment

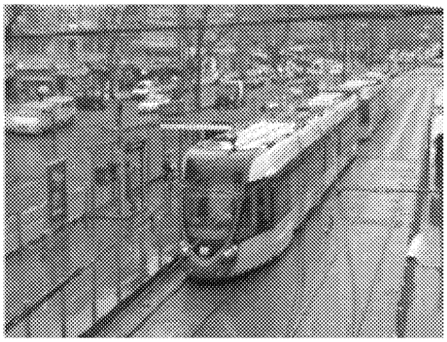
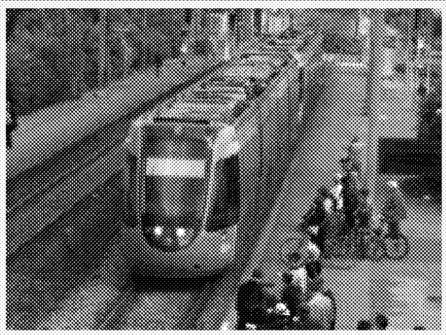
At the Vehicle level:

- Design adaptations linked with Vehicle winterization will be validated on the Train. When applicable, test procedures will be based on the recommendations of the PrEN16251.
- Train-level performance will be validated under the severe conditions described in the OLRT specification. Depending on the test, it can be run in one of the following climatic chambers:
  - In North America: in the Alstom facility in Hornell, NY or in the NRC facility in Ottawa
  - In Europe: in the Alstom facility in La Rochelle (France) and Vienna (Austria)

5.4.3.3 Service History of Proposed Vehicle

As described in **Table 5.4-9**, the existing Vehicles are substantially compliant with the four parts of the PA Schedule 15-1 definition of a *Service Proven Vehicle.*

Table 5.4-9 | Service History

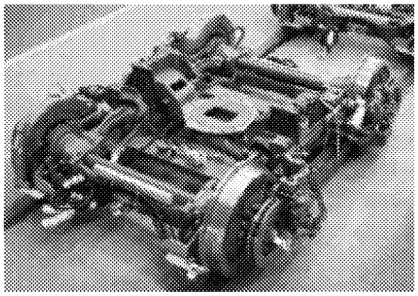
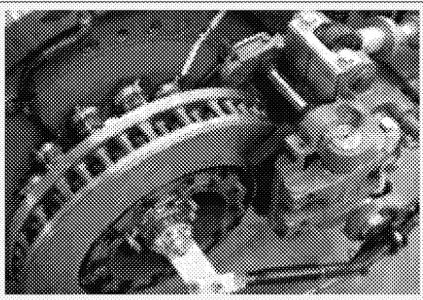
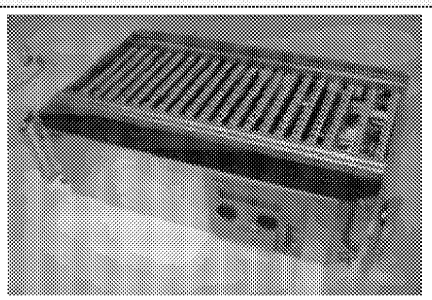
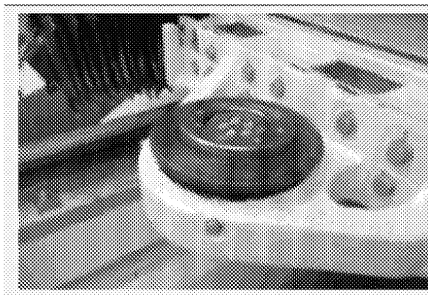
Vehicle	Service History
	**Istanbul Citadis** ■ 37 vehicles in service ■ System opened December 2010 ■ Operating Speed: 70 km/h ■ Operation in multiple unit of two vehicles ■ 120s minimum headway ■ 19.5 km line ■ 14,000 PPHPD at peak hour
	**SNCF Nantes Citadis** ■ 7 vehicles with 12 months of service ■ Operating Speed: 100 km/h ■ Operation in single and multiple units of up to three vehicles ■ Operated as a suburban Train ■ 26.5 km line ■ Only Full low-floor LRT running at 100km/h

As summarized in **Table 5.4-9**, all OLRT Vehicle subsystems are service-proven on both Istanbul and SNCF Citadis.

The Citadis vehicle has been operating worldwide since 1997 with more than 1500 LRVs in service. Alstom's experience in cold climates has been described in **Section 5.4.3.2**. Many of the Vehicles, including Istanbul, are operating in hot climates. The in-service MDBF of the Istanbul is as follows, with failures being defined as malfunctions causing Revenue Service delays of 4 minutes or more:

- Target MDBTD on Istanbul = 130,000 km
- Achieved MDBTD after 14 month = 575,000 km
- Target MDBTD on Ottawa LRT = 50,000 km

Table 5.4-10 | Vehicle Subsystems

Vehicle Component	Service History
	**IXEGE Truck** ■ Most recent Citadis truck generation specially designed for high comfort, 100% low-floor and 100 kph operation ■ This truck is pivoting and fitted with solid axle ■ Truck layout drawing is provided in **Cut Sheet 5.4.1-CS-208**
	**Hydraulic braking system** ■ Alstom has developed two alternative and interchangeable solutions for the Citadis family: - Faiveley system is mounted on Istanbul - Knorr system is mounted on SNCF Nantes ■ Drawings for Nantes brake system are provided in **Cut Sheets 5.4.1-CS-201 to 5.4.1-CS-207**
	**ONIX Propulsion system** ■ Alstom ONIX IGTB technology + Alstom AGATE control unit is the standard Alstom traction system ■ Equip all Citadis LRV
	**Articulation joint** ■ Standard and proven-design Citadis solution is installed on both Istanbul and SNCF Citadis

5.4.3.4 Experience with Consist Arrangements

Citadis is a modular product. The Citadis range is based on service-proven modules and subsystems assembled together to meet the client need precisely. Alstom has experience with coupling long consists and will design the OLRT Vehicles to account for the requirements for structural strength, pushing and towing, coupler structural strength, resistance losses for instance, as further described in **Section 5.4.3.21**.

Figure 5.4-6 | Vehicle Consist Modularity

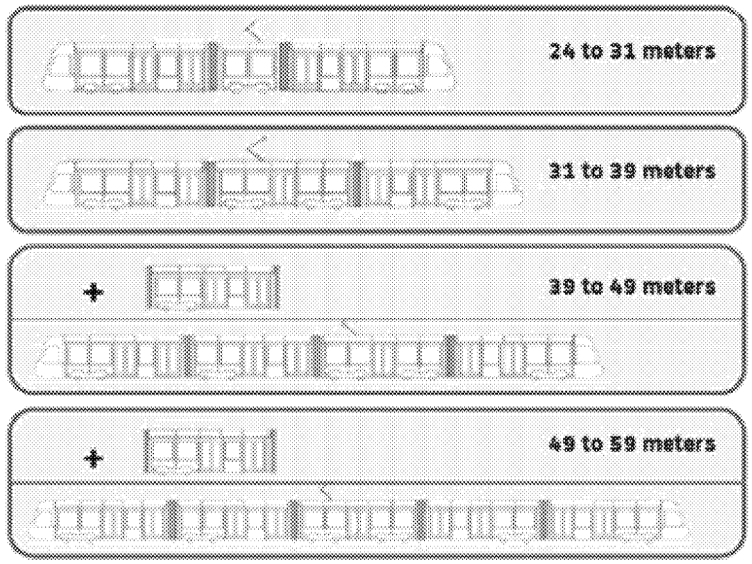
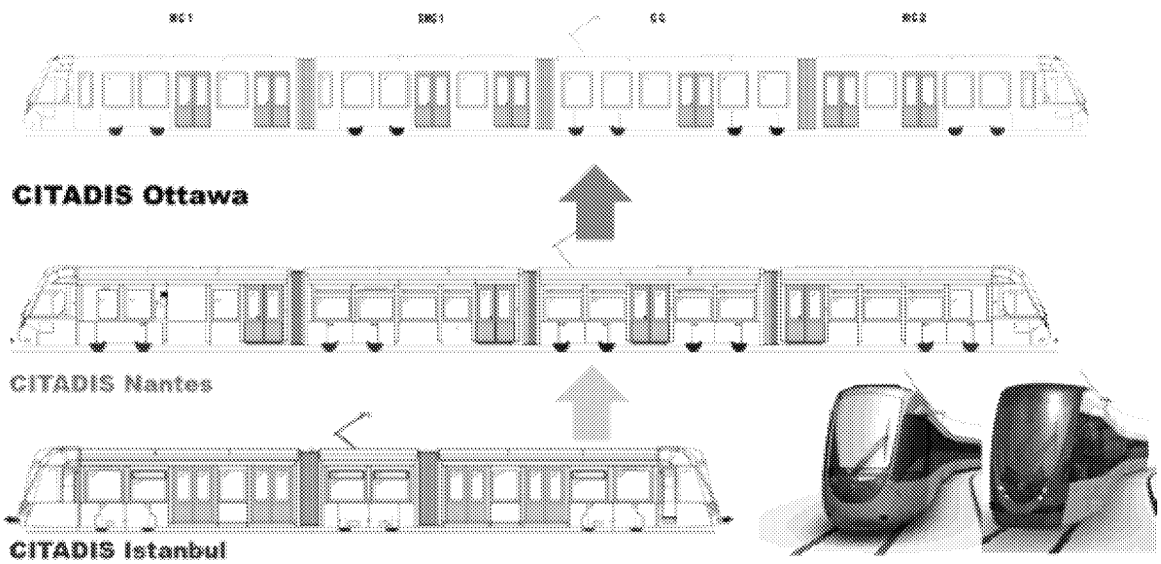


Figure 5.4-6 illustrates the Vehicle consist modularity principle of the Citadis range fitted with pivoting trucks. Ottawa's Vehicle will be an evolution of SNCF Nantes Citadis and specific design modifications are, therefore, not required.

Train consist and architecture is similar but the carbody shells are slightly extended for Ottawa, to comply with ridership and door arrangement expectations. Particular attention has been paid to comply with truck axle weight limitation and minimum radius curves.

The Citadis Nantes is operated daily in multiple units of 2 or 3 Vehicles for a maximum Train length of 126m. As shown in **Figure 5.4-7**, the typical proposed OLRT Train will be a multiple unit of two 49 m Vehicles for a maximum Train length of 98 m. Based on our experience with long Train consists, the maximum Train length in normal operation (2-Vehicle Train) as well as during rescue missions (one 2-Vehicle Train towing another) is taken into account in the design of the Train (e.g. structural strength car-body and coupler, Train line design for losses due to Train length and coupler passage).

Figure 5.4-7 | Train Consists



5.4.3.5 Testing

List of Tests

Serial Tests

The serial tests are tests performed on each Vehicle to confirm, by simplified tests, that the main performance levels checked by the type test are effectively reproduced. The serial tests, performed on the series sub-assemblies and parts of the Vehicles, are aimed at verifying the main characteristics of the concerned sub-assemblies and parts; these can be systematic or statistical.

Static Serial Tests

All tests necessary to prove proper functionality of the Vehicle will be performed:

- Current return circuits and protection circuits tests
- Dielectric strength and insulation of all 1500 V and low voltage circuits
- LV functional tests (e.g. exterior signaling and lighting circuits, Driver's cab)
- HV static tests including auxiliary supply
- Door functional tests
- Ventilation and heating tests
- Traction – braking static tests
- Brake system and hydraulic circuits tests
- Passenger information and CCTV tests
- Interface with Train control system tests.

Dynamic Serial Tests

For each Vehicle, the dynamic performance will be tested to prove that the City's requirements are fulfilled:

- Geometric checks
- Weighing of Vehicles
- Water tightness check of complete Vehicle
- Wheel flange lubrication and sanding system tests
- Safety devices tests
- Door functional tests
- Traction functional check
- Braking functional and performance tests

Type Tests

To ensure the City's complete satisfaction, Alstom will set up a Validation Type Test plan, to demonstrate compliance with the technical specification as well as the legal requirements.

The validation strategy will cover the full range of activities from component validation, through Vehicle integration testing, functional static and dynamic type tests, as well as dynamic performance type tests to Vehicle integration testing in Ottawa. Type tests are performed on new items, or new sub-systems. A type test proves that the specified contractual performance and functional requirement has been achieved. Validation activities will be structured in the following sequences:

- Design Phase
- Component Validation
- Integration Testing
- Functional and Performance static Validation
- Dynamic Performance Validation
- On-site Integration tests

Alstom has incorporated in its quality system the requirements set forth in the EN 17025 "General Requirements for the Competence of Testing and Calibration Laboratories. For the main system integration, accredited test laboratories will be used.

Design Phase

During the design phase the Validation team will prepare the Validation Plan, identifying the main verification and test activities of the Vehicle and the Train, and draft the test procedures. The main input for the validation plan will be the IEC 61133 "Railway applications – Rolling stock - Testing of Rolling stock on completion of construction and before entry into service" and the technical specification requirements that need a test to demonstrate Vehicle and Train compliance.

On the basis of a gap analyses with the reference solution, a FMECA-based critical risk analysis will define the depth of the validation activity – need for specific design reviews, simulations, mock ups or test. The Validation Plan will be refined throughout the design reviews of the specific subsystems.

Component Validation

During the testing phase the Validation team will work with the different subsystem suppliers and internal subsystem experts, to prepare component type tests, and participate in testing critical systems, i.e. doors, traction, brake, bogies, and Train Control and Monitoring System (TCMS).

A significant component validation test will be the static car-shell structure test, performed at Alstom's Valenciennes site. During this test, the car body will be outfitted with strain gauges and all the main structural tests, as defined in EN 12663, will be performed.

Integration Testing

Integration of the different equipment and subsystems will be tested with their suppliers during the initial integration of the first Vehicle. To prepare this phase, a functional integration test bench will be used to validate the functional design including vehicle low voltage, TCMS logic and subsystem control logics. The functional integration test bench will incorporate at least one electronic unit of each type under test while the others, as well as their environment, may be simulated. The test bench will be used for functional validation in single mode Vehicle use as well as multiple-unit Train.

Functional and Performance Static Validation

Complementary to the functional integration test bench, static functional test will be performed in Vehicle (single unit) and Train (multiple unit) configuration. Static performances such as battery autonomy, lighting levels, and acoustic levels will be measured. ODA compliance will also be tested at this stage.

To demonstrate Vehicle performance under winter conditions, tests will be performed under extreme temperatures, and under winter conditions, in a climate chamber. During this test the important systems such as the brake system, air supply, and door system will be tested.

Dynamic Performance Validation

Dynamic traction and braking performances will be tuned and tested on a test track in France, prior to testing on-site in Ottawa. The program will focus on the different braking modes in nominal and degraded mode in several load cases as well as testing with degraded adhesion. The dynamic performances will be performed in Vehicle (single unit) mode. The Train (multiple unit) configuration testing will demonstrate a smooth operation without performing braking performance tests. During this phase, the ability to rescue a Train with another Train will also be tested.

On-Site Integration Tests

The on-site Integration test will focus on tests requiring either the final interfaces or localizations. This testing will include: dynamic gauge, bogie stability and comfort, EMC, dynamic noise, the correct localization of Passenger announcements, radio and Vehicle/ground communication.

Test Results from Equivalent Vehicles

Even though most components are service proven, most type tests at Train level will need to be performed for the specific Ottawa Train configuration and operation interfaces. However, the component type tests performed for existing Citadis will be used as a reference and will be supplied.

Available applicable Test Result reports from Nantes Citadis (**Reports 5.4.1.A-TR-101 to 5.4.1.A-TR-119**) are listed in **Table 5.4-11A** below. Please see applicable test reports.

**Please Note: Due to the length of test results, the following reports have been submitted in electronic format only.*

Table 5.4-11A | Available Test Reports

Reference Number	Type	Report Name	Entitled Report Title
5.4.1.A-TR-101	Testing	TEST REPORT TRAM-TRAIN NEW GENERATION WINDSHIELD	RAPPORT D'ESSAIS Tram-Train Nouvelle Génération ▪ Pare Brise
5.4.1.A-TR-102	Testing	TYPE TEST REPORT CDRL 7-08 AUXILIARY CONVERTER FOR CITADIS OPTIONS 7, 9, 11, 12, 13, AND 16	
5.4.1.A-TR-103	Testing	TEST REPORT TRAM-TRAIN NEW GENERATION ALSTOM BRAKING PERFORMANCE ON FRENCH NATIONAL RAILWAYS	RAPPORT D'ESSAI TRAM-TRAIN NOUVELLE GENERATION ALSTOM PERFORMANCES DE FREINAGE SUR RFN
5.4.1.A-TR-104	Testing	TYPE TEST PROJECT TTNG SWIVELLING AND SLIDING DOOR WITH 2 PANELS AND STEP	Essai de type – projet TTNG Porte louvoyante coulissante à 2 vantaux & marche
5.4.1.A-TR-105	Testing	TEST REPORT ACOUSTIC SPECIFICATIONS	EXIGENCES ACOUSTIQUES AU CAHIER DES CHARGES
5.4.1.A-TR-106	Testing	CITADIS 35 kW TTNG PROJECT QULIFICATION TESTS	
5.4.1.A-TR-107	Testing	TYPE TEST REPORT MEASURES OF ILLUMINATION/LIGHTING	Measures de l'éclairement
5.4.1.A-TR-108	Testing	▪ TYPE TEST REPORT ▪ SANDING	▪ Sablage
5.4.1.A-TR-109	Testing	▪ TYPE TEST REPORT ▪ NVR, CAMERA AND EMB	

Reference Number	Type	Report Name	Entitled Report Title
5.4.1.A-TR-110	Testing	■ TYPE TEST REPORT ■ VEHICLE MEDIA CONTROLLER – 4T	
5.4.1.A-TR-111	Testing	■ TYPE TEST REPORT ■ INTERNAL LED DISPLAY	
5.4.1.A-TR-112	Testing	■ TYPE TEST REPORT ■ INTERNET ONBOARD SYSTEM	Système Internet on bord Rapport d'essais de type
5.4.1.A-TR-113	Testing	■ TYPE TEST REPORT ■ 6U PA PACK	
5.4.1.A-TR-114	Testing	■ TYPE TEST REPORT ■ SURVEILLANCE CAMERA (IP)	Caméra IP Rapport d'essais de type
5.4.1.A-TR-115	Testing	■ TYPE TEST REPORT ■ RACK CCTV ■ NVR/EBM/WIFI	Rack CCTV - NVR / EBM / WIFI Rapport d'essais de type
5.4.1.A-TR-116	Testing	■ TYPE TEST REPORT ■ BREAKER	■ Disjoncteur Arc 1520 M
5.4.1.A-TR-117	Testing	■ TYPE TEST REPORT ■ BRAKING RESISTANCE ■ AIR COOLED	■ Rapport d'essais de type ■ Résistance de freinage à ventilation naturelle ■ TTNG
5.4.1.A-TR-118	Testing	■ IMPACT SIMULATION FOR ALSTOM ■ PROJECT TTNG/FRANCE ■ AUTOMATIC COUPLER ■ TYPE SD330	
5.4.1.A-TR-119	Testing	■ STATIC TESTS ■ EXTRACT FROM STANDARD NF F 31-119 ■ RAILWAY ROLLING STOCK ■ BEHAVIOUR OF ROLLING STOCK'S SEATS AT STATICS STRESS, ■ FATIGUE STRESS, VIBRATIONS STRESS AND SHOCKS STRESS	■ Extrait de la norme NF F 31-119
5.4.1.A-TR-201	Car Body	■ STATIC RESISTANCE TEST OF ■ CAR BODY STRUCTURE ■ TTNG	■ Essais Statiques De Resistance De Structure ■ Sur Chaudrons De Caisses TTNG De Fabrication ■ Alstom

Reference Number	Type	Report Name	Entitled Report Title
5.4.1.A-TR-202	Car Body	■ DESIGN NOTES ■ CAR BODY STATIC AND FATIGUE DESIGN ■ CALCULATIONS ■ CEx WITH 2 DOORS PER SIDE	■ CALCULS EN STATIQUE DE LA ■ STRUCTURE DE CAISSE CEx ■ AVEC 2 PORTES PAR FACE
5.4.1.A-TR-203	Car Body	■ DESIGN NOTES ■ CAR BODY STATIC AND FATIGUE DESIGN ■ CALCULATIONS – CX	■ CALCULS EN STATIQUE ET EN ■ FATIGUE DE LA STRUCTURE DE ■ CAISSE Cx
5.4.1.A-TR-204	Car Body	■ DESIGN NOTES ■ CAR BODY STATIC AND FATIGUE DESIGN ■ CALCULATIONS – C2B	■ CALCULS EN STATIQUE ET EN ■ FATIGUE DE LA STRUCTURE DE ■ CAISSE C2B
5.4.1.A-TR-301	Crash	■ DESIGN NOTES ■ CRASH TESTS REFERENCE SIMULATIONS	■ Simulations des collisions de référence
5.4.1.A-TR-302	Crash	■ REGISTRATION OF CRASH TEST	■ Recalage de l'essai collision cabine
5.4.1.A-TR-303	Crash	■ TEST REPORT ■ CRASH TEST LEVEL 1 ON CABIN	■ Essais de collision échelle 1 ■ sur la cabine TTNG ■ RAPPORT ■ D'ESSAI
5.4.1.A-TR-401	Thermal Load	■ CITADIS OTTAWA ■ HVAC THERMAL LOAD CALCULATION	

Table 5.4-11B lists component-type tests and Train-type tests.

Table 5.4-11B | Component Type Tests and Train Type Tests

Validation Activity	Test on Equivalent Vehicle	Test on Proposed Vehicle
Component Type Test		
Windscreen Performances	●	
Bogie System	●	●
Winterization/Climatic Adaptation	●	●
Aux: Auxiliary Supply	●	
Brakes	●	
Doors	●	
Horn	●	

Validation Activity	Test on Equivalent Vehicle	Test on Proposed Vehicle
HVAC	●	
Internal Lighting	●	
Sanding	●	
PA/PIS	●	
Signaling Interface		●
TCMS	●	
Main Circuit Breaker	●	
Traction Converter		●
Braking Resistor	●	
Motor		●
Carbody Shell	●	●
Automatic Coupler	●	
Seats	●	
Interiors		●
Smoke Detector		●
Train Type Test		
Resistance to Motion		●
Dimensional and Gauge		●
EMC: Electromagnetic Compatibility		●
Acoustics/Noise		●
Railway Dynamics		●
Weight Management and Allocations		●
Winterization/Climatic Adaptation		●
Aux: Auxiliary Supply		●
Break		●
Doors		●
Horn and End Lights		●
HVAC		●
Internal Lighting		●
Sanding		●
PA/PIS		●
Signaling Interface		●

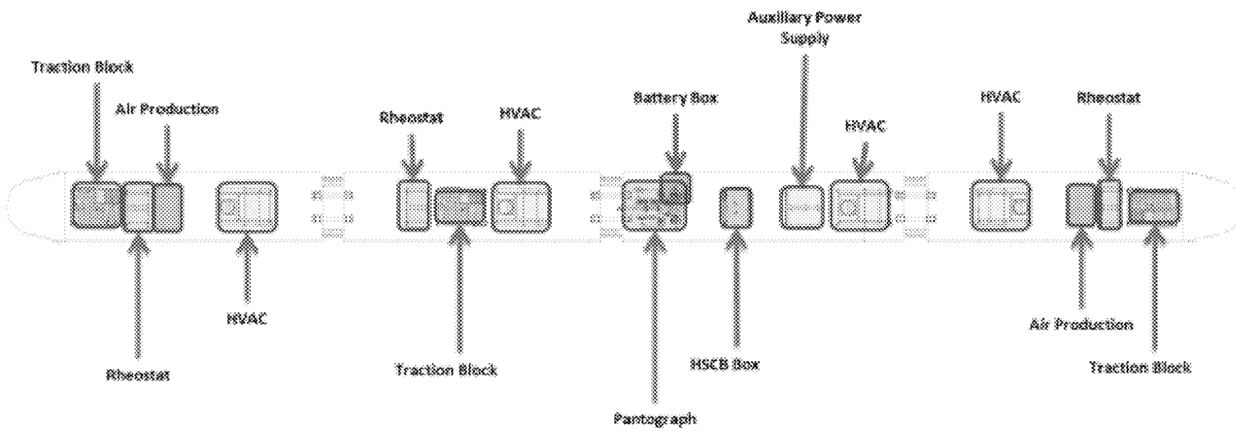
Validation Activity	Test on Equivalent Vehicle	Test on Proposed Vehicle
TCMS		●
Traction		●
Safety Earthing (grounding)		●
Fire Protection System		●
Train: Journey Time		●

5.4.3.6 Preliminary Drawings & Electrical Subsystem Schematics

Roof Equipment

Figure 5.4-8 shows our proposed distribution of roof equipment on the proposed OLRT Vehicle.

Figure 5.4-8 | Roof Equipment



The Vehicle's high-voltage architecture is shown in the Traction Block Diagram (**Cut Sheet 5.4.1-CS-901**):

- The power supply (see 1 on the diagram) collected by the bi-directional pantograph
- The lightning arrester (2), protecting the high-voltage equipment against over-voltages
- The circuit-breaker box containing:
  - The ultra-fast circuit-breaker (3) protecting and isolating the traction chain
  - The HV presence indicator
  - The auxiliary protection fuse

All equipment listed above is located on the CC car (see **Figure 5.4-8**).

The power is then distributed to the various power blocks located on the MC1, IMC1 and MC2 cars and the Auxiliary power supply located on the CC car.

Traction Block Control Unit

The traction block contains the following apparatus (see **Cut Sheet 5.4.1-CS-901**):

- Pre-charge circuit (6 and 7)
- Line inductor (8)
- Rheostatic chopper (12)
- Filter capacitor (11)
- A traction inverter (14) driving the two associated three-phase induction motors (18.1 and 18.2) located on the motor truck
- Associated current sensors (17)
- The rheostatic grids (13) are located on the roof next to the traction box

Return Current

The return current scheme has been designed to provide redundant paths to return current safely to the rail in a manner that protects bearings while reducing interference to wayside equipment. Resilient wheels are provided with four shunt straps between the wheel hub and the rim.

Auxiliary Power

The redundant auxiliary converters (see architecture and layout drawing in **Cut Sheets 5.4.1-CS-401 to 5.4.1-CS-405**) deliver different types of power output to operate the various on-board systems and devices:

- 28.5 Volts dc that supplies all LV equipment (on-board CBTC, Train lights, rear facing cameras, Passenger saloons' normal and emergency lighting, Train Control and Monitoring System, track brakes, door motors, windscreen wiper, battery charger)
- 480 V 60 Hz, three-phase, fixed frequency that supplies the Driver's cabin heater, saloon heaters and air compressors
- 480 V 60 Hz three-phase with variable frequency from 45 Hz to 60 Hz (U/f constant) that supplies the compartment HVAC units

Alstom's auxiliary power design complies with the redundancy requirements of the PA. In the case of failure of one auxiliary converters all loads and limited battery charging shall be maintained. Upon complete failure of auxiliary converters or loss of the OHL voltage, the two 28.5 Vdc batteries provide back-up power supply to critical loads for up to 90 minutes. In normal operation the battery chargers charge the batteries to ensure that they are kept at full load all the time.

All auxiliary loads (ac and dc) are circuit breaker protected. All circuit breakers are available from the cab compartment.

Batteries

The nickel-cadmium batteries, charged by the static converters deliver the following:

- Energy for low-voltage circuits (e.g. track brakes)
- Emergency loads
- Various devices (e.g. pantograph motor, windshield wiper motor)

The battery capacity was calculated taking the following design criteria into account:

- Restart the LRV after 48 hours in the stabling yard with the parking lights turned on
- Supply essential loads in operation following a loss of power for 90 minutes
- Supply energy in stabling for at least 3 hours

Depot Supply Sockets

When the batteries are discharged, they can be recharged by an external source through dedicated sockets. These sockets are located on the low-voltage control box on the MC2 section roof near the battery box.

This operation must be carried out when the Train is in sleep mode and the battery isolated from the 28.5 V Train network. The battery is isolated from the Train by means of the battery isolation switch and is then connected directly to the socket. Connection of this socket to an external charger then enables the battery to be recharged. Note that it is not possible to power Train equipment via this charging socket.

5.4.3.7 Industrial Design Representations

Alstom has long established a global reputation for know-how in transportation solutions. Unique for the railway industry, the Design & Styling department was created in 2005 to meet the needs of today's railway customers and guarantees quality results.

With a dual role in the engineering and manufacturing of rail vehicles and infrastructure, Alstom has established its own dedicated Design & Styling (D&S) department, comprising 20 designers dedicated to the full spectrum of railway products, from streetcars to very high-speed Trains. This multi-disciplinary approach allows us to create innovative designs that meet clients' aesthetic and performance expectations, while respecting the general configuration of the vehicle under development.

The department's cross-functional organization is adapted to meet the specific needs of rail transport markets:

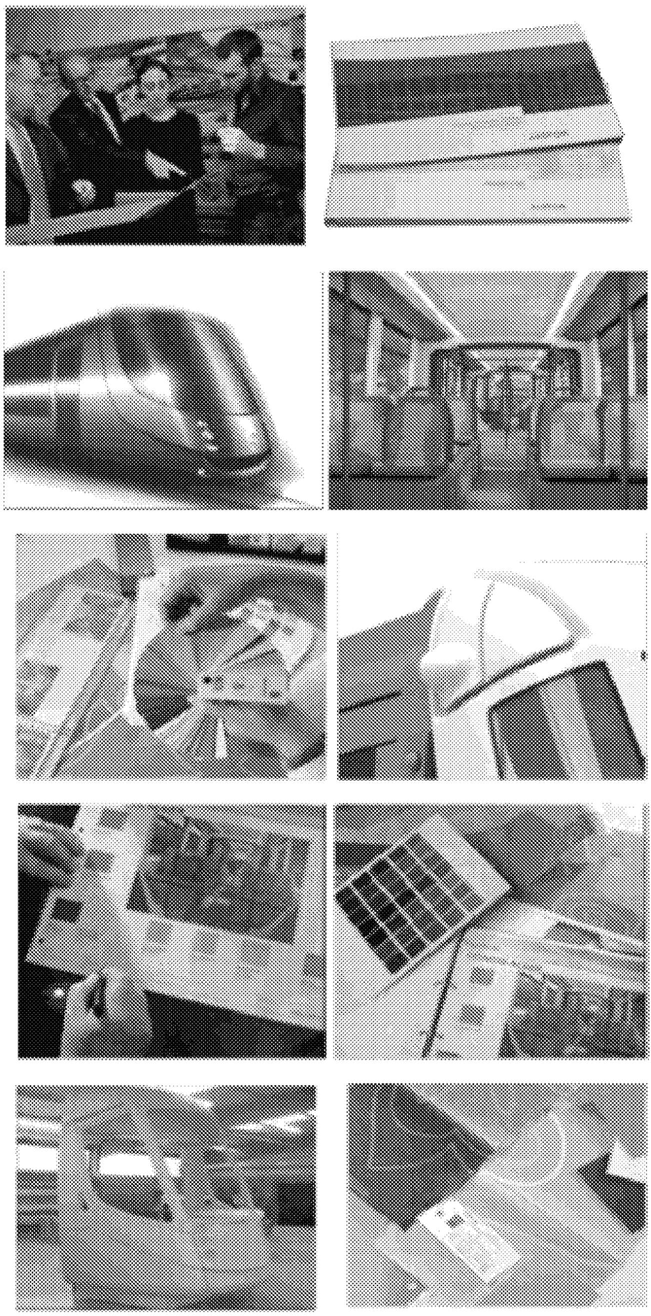
- Consolidating competencies in design, digital modelling, colours, materials, and lighting
- Benefiting from the knowledge of a network of industrial design experts in different regions
- Stimulating the creative process and producing designs suited to each client's cultural context
- Meeting design expectations for the entire range of Alstom Passenger Trains, from urban to main line Trains

With more than 100 successful projects completed, the process encourages customer input, creates a common vision and identifies and integrates the efforts of potential project partners. In the past, D&S has worked with civil contractors including Systra, Impresa Pizzarotti, Isolux Corsan; and international architects including Dubus Richez, BillingsJacksonDesign, RKD architects, Cepezed.

Our highly collaborative approach to design actively involves the client and key stakeholders. Working with each city's branding process, the D&S department analyzes the cultural, economic, political and geographical context of the project. This is summarized through photo reports and keywords. The objective is to define the artistic theme which will be used as a connecting thread for creation throughout the project.

A unique competitive advantage of our modular product configuration is that the front end and interior arrangement can be customized and become a critical component of the brand. The D&S department will propose various versions of shapes for the interior and exterior, colours and trims in support of the final branding approach.

Alstom has laid out a collaborative design process that guarantees quality results. The objective of this process is to develop a product that fully satisfies all stakeholders and results in production of a full scale mock-up. As soon as the mock-up is accepted by the City, it will be sent to Ottawa and made available for community and Stakeholder programs.



Preliminary Meeting

After the notice to proceed, Alstom meets with city representatives to gather input regarding requirements.

Pre-Choice Meeting

New proposals based on information collected through preliminary meeting are presented. Selection of these proposals serves as a departure point for shape definition, colour schemes, graphic lines and materials.

Choice meeting

The shape, colour and graphic line of a Train car is further determined with 3D software. Virtual images allow customers to get a feel of the object from different angles. It is also a way to confirm the details and options agreed upon previously.

Freeze of options

Customers sign off to 80% of their preferences. This marks the beginning of the manufacturing phase for products related to styling and design. The shapes, colours and materials chosen are specified at this stage. Alstom then submits a life-size impression of the graphic line for approval by the client.

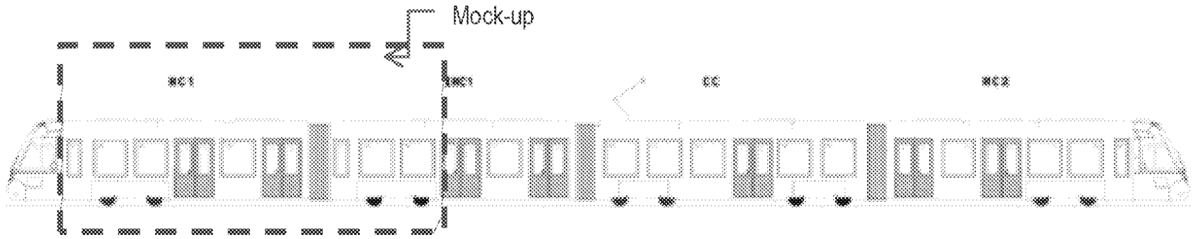
Working mock-up

Customers can see working mock-ups of components such as the front-end cab or seating, among others. The mock-ups represent 90% of the design choices made. This step is optional, but highly recommended. Clients see factory samples to check for colours, patterns and trims.

Representative Mock-up

The representative mock-up is an accurate model of the future Vehicle unit. All specifications may be reflected in the mock-up, from front-end cab design to the colours and trimmings inside. The mock-up proposed for OLRT will consist of a section as shown in **Figure 5.4-9**.

Figure 5.4-9 | OLRT Vehicle Mock-Up



Constructions, surfaces and finishes will be as close as practicably possible to the final product specification. Volume and location of interior components will be representative to the serial product to ensure representative spacing between components. The mock-up will not be functional and will not be equipped with trucks but will be fitted with lighting and Passenger Information Display Systems (PIDS). It will be connected to the 110 V, 60 Hz network to provide energy to the functional equipment. **Figure 5.4-10** illustrates the concept, showing the exterior and interior of the Reims LRV mock-up.

Figure 5.4-10 | Reims Vehicle Mock-Up

5.4.3.8 Vehicle Dynamic Modelling and Simulation results

Traction Performance

Except where otherwise specified, the traction system performances and curves are defined with the following parameters:

- Maximal load 4 pass/m²
- Power supply voltage: 1500 V
- Inverter filter voltage: 1800 V in braking modes
- Half worn wheels
- Jerk limitation to 1.3 m/s³

The values specified in the curves and text below, are to be assigned with a tolerance of ±5%. The specified values take into account of the following:

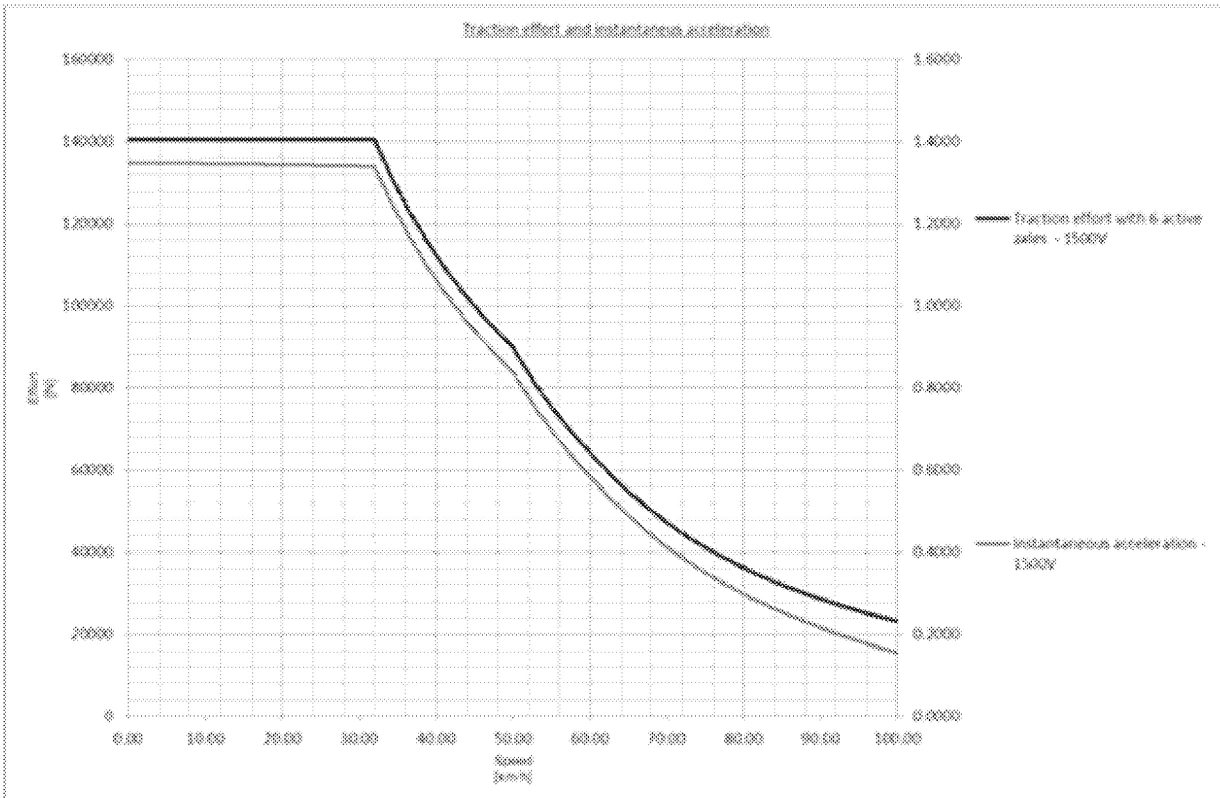
- Acceleration of flywheel masses

- Resistance to forward motion calculated with Davies formula (R)
- Starting resistance
- Resistance due to slopes (where specified)

Traction Characteristics on Flat Track

Figure 5.4-11 presents the traction Train level curves of the Citadis in single unit. The propulsion system will provide initial maximum vehicle acceleration of 1.34 m/s² +/-5% (OCS voltage>1500 V, AW2 Loading) up to 32 km/h as required by the PA.

Figure 5.4-11 | Single Unit Nominal Traction Characteristic



Train Simulation Results

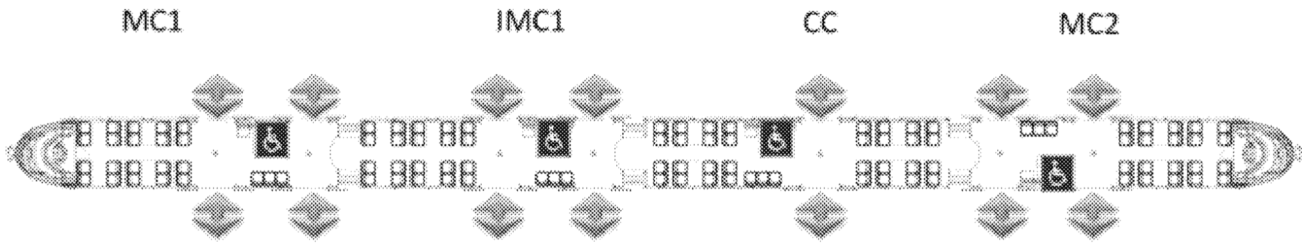
The Vehicle dynamic modelling and simulation results are presented in **Section 10.0** and summarized in **Section 5.4.5**.

5.4.3.9 Accessibility

Approach to Vehicle Accessibility

The Vehicle interior is designed with full low-floor Passenger area and seat arrangement (longitudinal and transversal) to provide full accessibility in compliance with AODA/ADA requirements. Transport Canada requirements will be complied with only to the extent that they are applicable to LRVs. The Vehicle is equipped with seven dual leaf Passenger access doors per side to optimize Passenger accessibility and reduce exchange time at stations (see **Figure 5.4-12**).

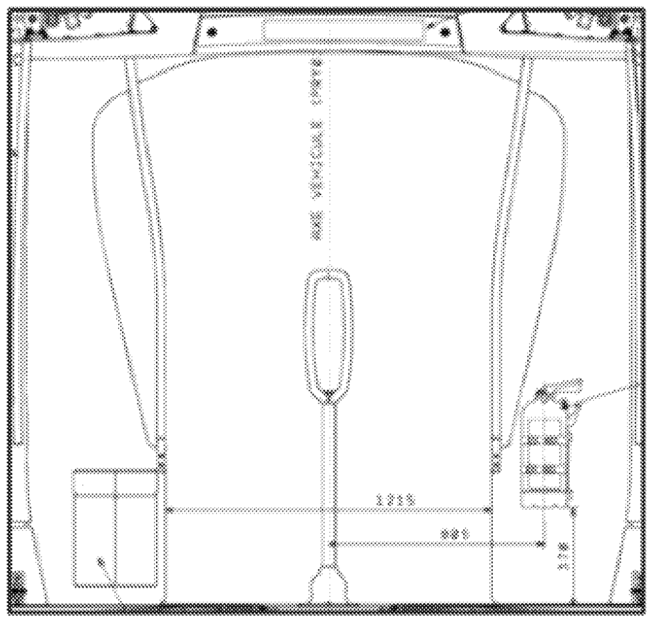
Figure 5.4-12 | Door Placement



In addition:

- The Ottawa Vehicle, part of the service-proven Citadis product range, guarantees a continuous unobstructed path connecting all accessible elements and spaces of the Vehicle with a low-floor which includes slopes (less than 8 percent in accordance with TSI Requirements)
- The accessible space between seats, handrails matches with the ADA requirement (600 mm)
- Proposed Vehicle accommodates the needs of individuals with or without restricted mobility
- All thresholds are equipped with a colour band running along the full width which contrasts with the step tread and is adjacent to the floor
- Vehicle access points are located to facilitate entry and to maximize passenger flow. The proposed Vehicle doors provide a width of 1300 mm when opened, facilitating access for people with restricted mobility.
- For boarding, the proposed Vehicles are equipped with a leveling system (air suspension) which ensures a gap of plus or minus 15.8 mm between the height of the Vehicle floor and the platform. The maximum horizontal gap between the Vehicle at rest and the platform is 76 mm.
- The gangway walkway links two sections and includes a floating tread plate. The width in the gangway is 1215 mm.

Figure 5.4-13 | Vehicle Cross-section



Accommodation of AODA and ADA Requirements

The proposed Vehicles comply with subparts A and D (Light Rail Vehicles and Systems) of the Americans with Disabilities Act (ADA) reference 49 CFR 38 for Transportation Vehicles. During design, manufacturing construction, and revision of Trains, Alstom covers the ADA requirement by taking into account anthropometric dimensions.

Wheelchair Access

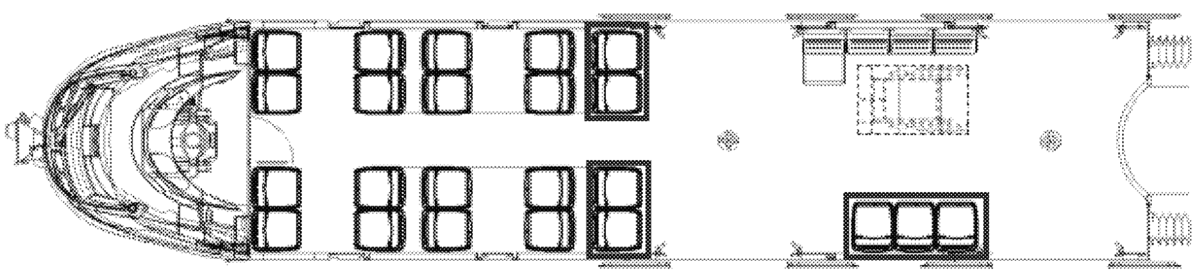
At each entrance, the dual-leaf doors providing an access width of 1300 mm, to allow passage of one wheelchair or mobility aid users. A 1220 mm by 760 mm wheelchair spot is conveniently located next to each door area and allows smooth Passenger flow around the area. Priority seats are located next to the wheelchair area.

Information Displays

Signage

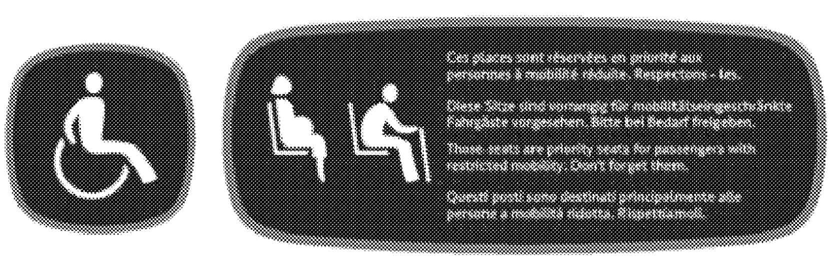
All signs are bonded on the Train with International Symbol of Accessibility and are displayed on the exterior of each operating Vehicle. The doors use auditory and visual warning signals to alert Passengers when doors are closing. Each Vehicle contains signs which indicate that certain seats are priority seats for persons with disabilities (see **Figure 5.4-14**; seats in front of display and close to the doors-as outlined in red).

Figure 5.4-14 | Signage



OLRT Vehicles will accommodate persons using wheelchairs or other mobility aids. In these areas, signs indicate the location and advise other Passengers of the need to permit wheelchair and mobility aid users to occupy them (see **Figure 5.4-15**). Signage dimensions will meet ADA/AODA requirements.

Figure 5.4-15 | Example of Accessibility Signs



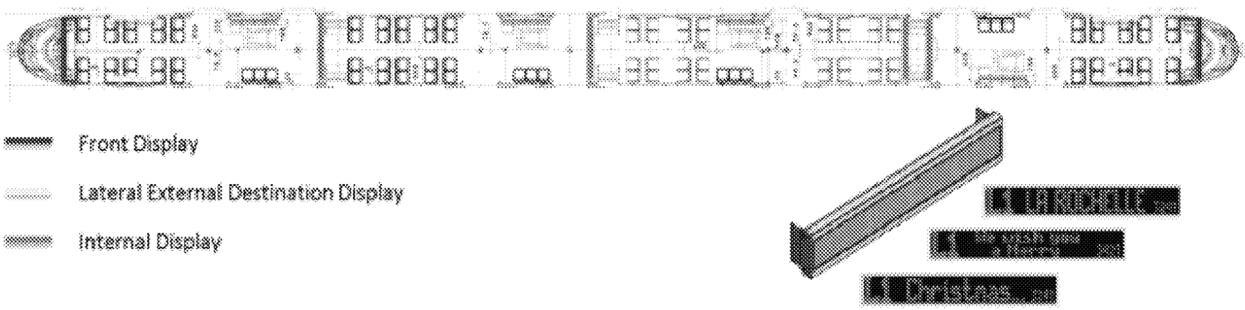
Passenger Information Displays

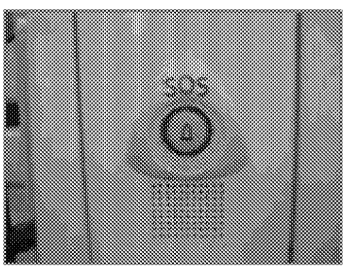
Proposed Vehicles are equipped with displays which inform Passengers of the route (see **Figure 5.4-16**). The system is designed to provide synchronized audio and visual Passenger information announcements including destination, station stops, time, and emergency announcements according to Train route. The displays will meet these standards:

- Visible from the platform
- Located on the face to be visible (two per face of the Vehicle)
- Integrated behind the window and have a glare-free surface, and a consistent shape. Text letters are yellow, contrasted with the black serigraphy of the window which permits a clear view.

The Ottawa LRT information system is also equipped with an interior public address system operated by OLRT personnel, or digitized human speech messages to announce Stations and provide other Passenger information.

Figure 5.4-16 | PIDs

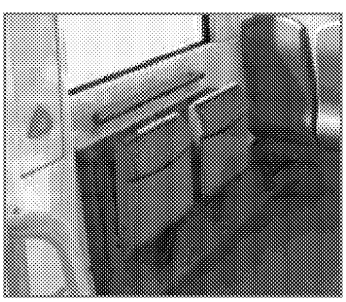




Pushbuttons

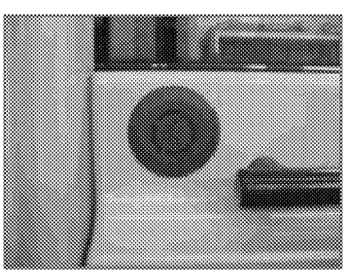
All Passengers have access to push buttons for access-door opening request or to communicate with the Driver in an emergency. Provisions are made to integrate these push buttons according to ADA/AODA requirements:

- Located to be accessible by Passenger in wheelchairs
- Contrast with internal fitting on which they are mounted



In wheelchair areas, a push button allows Passengers to request the automatic opening of the adjacent Passenger door at the next Station. This allows Passengers in wheelchairs to request door opening before arriving at a Station, allowing time to go out of the Train comfortably.

Interior – Handrail and Stanchions



The handrails in Ottawa's Vehicle are sufficient to permit safe boarding, onboard circulation, seating and standing assistance, and alighting by persons with disabilities. The proposed Vehicle also fulfills the TSI requirements so it is possible to grab the handrails everywhere in the Train. The OLRT Vehicle is equipped with grab bars, handholds, handrails or stanchions located as follows:

- In appropriate locations
- By each priority seating area intended for use by persons with disabilities
- At each side of any entrance or exit used by persons with disabilities

- In location at any entrance or exit used by a person with a disability. The bars are accessible from ground level and are mounted inside the Vehicle when the doors are closed.
- At appropriate locations throughout the Vehicle to support independent and safe boarding, on-board circulation, seating and standing assistance and de-boarding for persons with disabilities.

The grab bars, handholds, handrails or stanchions do not interfere with the turning and manoeuvring space required for mobility aids to reach the allocated space from the entrance. They are contrasted (K>3 as TSI requirement) with their background to assist with visual recognition. Every grab bar, handhold, handrail or stanchion will have these characteristics:

- Rounded and free of any sharp or abrasive element
- With an exterior diameter of 35 mm that permits easy grasping by the full range of Passengers and sufficient clearance from the surface to which it is attached
- Designed to prevent catching or snagging of clothes or personal items
- Equipped with a slip resistant surface

Grab bars, handholds, handrails and floor-to-ceiling stanchions have a smooth curve. Their precise shape will be finalized during the design phase.

5.4.3.10 Train Systems & Safety Critical Items

During development of the Citadis product range, safety analyses have defined critical items and assemblies. Safety-critical equipment is equipment whose failure might induce a safety hazard; for example, structural elements, braking system, traction systems, doors and signaling equipment. A preliminary list, provided in **Cut Sheet 5.4.1.B-7**, is based on Alstom's experience and will be updated for OLRT in the design phase. A brief description of the main sub-systems is provided in this Section, with a summary of the associated safety approach where relevant.

Doors

The Vehicle is equipped with seven dual-leaf sliding plug doors on each side of the Train. Doors are largely glazed. The electric type actuator (one per dual leaf door) is in the upper part of the door. The door leaves are made up of an exterior glazing of the laminated glass type, bonded onto the structure and covering the door-leaf surface area. The panes include black silkscreen printing all around the edges, to round off their aesthetic appearance and protect bonded areas from UV radiation. The door leaves' leading edges are fitted with elastomeric joints to ensure safety when closing, and tightness. Tightness all around the door edges is ensured by an elastomeric sealing joint on the door leaf itself and the frame, concealed for aesthetic reasons and mechanical strength. The doors are equipped with a fixed threshold to reduce the gap between Train and platform. Doors' main characteristics are provided in **Cut Sheet 5.4.1.B-2**.

Our approach to access safety has the following elements:

- **Train-speed criteria -** The doors (except emergency working) can only be opened if a zero-speed threshold information signal is present. The door's closed-and-locked status is interlocked with propulsion.
- **Closing control -** Doors are fitted with special safety devices that allow each door to be locked after its closure and which authorize Train start-up once all doors are closed and locked.
- **Obstacle detection on door closure** - An obstacle-detection device inhibits the closure of the relevant door as long as a Passenger is detected between the door posts.

Truck

The proposed truck is a truck from the IXEGE family used on Citadis LRTs. For the OLRT, this truck will be fitted with a pneumatic secondary suspension to meet the levelling requirement specific to the OLRT Project. This truck benefits from all validation tests completed for the IXEGE truck. The main truck characteristics (see **Cut Sheet 5.4.1.B-5**) include:

- Achieves simultaneously the goals of having a pivoting motor truck for a low floor with a conventional truck configuration with primary suspension, secondary suspension and axle drive.
- Allows negotiation of tight curves, even without transition, while reducing wheel /rail contact forces and the resulting wear, due to pivoting trucks in the lead Vehicle position.
- Provides optimum accessibility for wheels, brakes and traction equipment. Wheels can be removed without separating the truck from the Vehicle, or removing the axle from the truck.

Braking System

Detailed information about the braking system is given in **Cut Sheet 5.4.1.B-1**. The safety approach related to the braking function is as follows:

- **Safety Brake -** Safety brake command is reversed logic, which means safety brake is applied when the safety braking trainline is not energized. This safety braking trainline is galvanically insulated to ensure that a single-point failure cannot lead to the non-application of the safety brake. Magnetic track brakes are applied independently.
- **Mechanical Brake** - Brake actuators are also reversed logic, so if no voltage is applied on the line, sufficient braking is applied to stop the Train and hold it still.

Traction System

The traction system is described in **Section 5.4.3.6**.

Safety Approach

Driving direction is distributed to traction equipment through two independent trainlines. These trainlines are powered by a stable multiple-position commutator. If a driving selection occurs when the Train is running, it will not be taken into consideration. Traction power application depends on activation of the dead-man system by the Driver. Traction is inhibited by trainlines when brakes are applied and the main circuit breaker is open upon safety braking.

Traction motor

The 4 LCA 1651 traction motor is a closed, self-ventilated, three-phase induction motor. Its nominal power is 150 kW. Additional information is given in the traction motor **Cut Sheet 5.4.1.B-4**.

Train Control/Monitoring System

The Train Control/Monitoring System (TCMS) is based on the latest generation of Alstom computerized processing software. The basic architecture for the Citadis is designed for operation in both single and multiple units without requiring reconfiguration.

The philosophy for the Citadis is to enable the TCMS to process a maximum of functions, both vital and non-vital ones. This is accomplished largely by using data-processing techniques (digital computers, software and communication by local information networks) with the aim of decreasing the number/lengths of hard-wired circuits needed, while increasing the service level, focusing on providing assistance in driving and maintenance.

Control Electronics are dedicated to performing a given Train function (e.g. the door function) that is linked with the TCMS. The TCMS inputs/outputs and the data network are used to exchange information between all electronics units of the Train. In all cases, the MPU performs the main control/command and monitoring functions, with other equipment performing its own local functions. Following this principle, data sent by the MPU to one or several electronic equipment is called "commands"; data sent by electronic equipment to the MPU or others devices is called "controls" or "monitoring".

The software programs concerned are not designed to accomplish safety-critical functions. Vital functions will be achieved by hardware logic. The software has been developed in compliance with the EN50128 software development standard.

Architecture of the Train Control/Monitoring System (TCMS)

The main architecture deployed is based on the following:

- Trainlines to perform Train safety command functions (e.g. traction/braking, doors opening/closing authorization) and controls (e.g. all doors closed status), at Train and unit level
- A redundant MVB network allowing communication between all electronic equipment inside the same unit (e.g. Traction Unit, Brake Control Unit)
- A WTB network linked (via the unit coupling cable) with the MVB network of each unit via a Gateway WTB/MVB, and allowing communication between Train units (when in multiple unit mode)
- An Ethernet network interfaced with major sub-systems for collection of maintenance and diagnosis data, at Train unit level (when in multiple unit mode)

Cut Sheet 5.4.1-CS-903 provides the preliminary TCMS architecture for the OLRT Vehicle. This architecture is given for information and may be subject to change during the design stage. It indicates the various types of equipment connected to the networks but does not represent an exhaustive quantitative list.

5.4.3.11 Spin/Slide Control system

Each truck type is equipped with an anti-slide device. Slide is detected axle per axle on the motor trucks and wheel per wheel on the trailer truck. Brake release during vehicle slide is performed truck per truck (both on the motor truck and trailer truck). The anti-slide module automatically activates the release of sand.

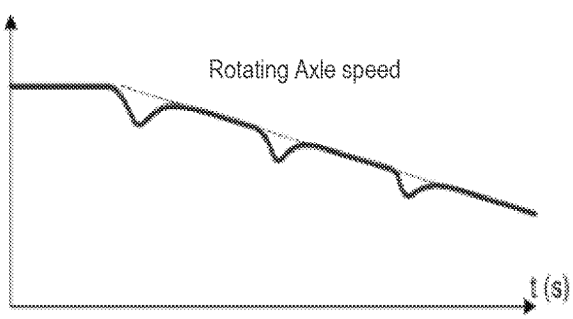


Figure 5.4-17 | Rotating axle speed regulation on a sliding wheel (trailer truck)/axle (motor truck) during service brake

In the event of a slide, in service brake, the control system quickly reduces the effort (Kill the slide) on the truck that has slid. The effort setting is reduced to adapt the effort to the adhesion available. The effort correction is calculated to match the wheel (trailer truck)/axle (motor truck) deceleration and the difference between the speeds of the wheel (trailer truck)/axle (motor truck) and the reference speed as shown in **Figure 5.4-17**. This type of regulation (Kill the slide) allows for quick and stable slide deletion.

In a slide during emergency brake, the control system reduces the effort on the truck that has slid to maintain a certain controlled level of slide (15-20%) to stay as close as possible to the maximum effort request (Keep the slide). This type of regulation (Keep the slide) allows for high efficiency in high-adhesion level braking (**Figure 5.4-18**).

In a skid, the effort rapidly regresses. The gradient and amplitude of this regression depends on the acceleration of the axle (motor truck) and the difference in the axle (motor truck) speed compared to the reference speed. When there is no more spin, the traction effort is gradually applied again (**Figure 5.4-19**).

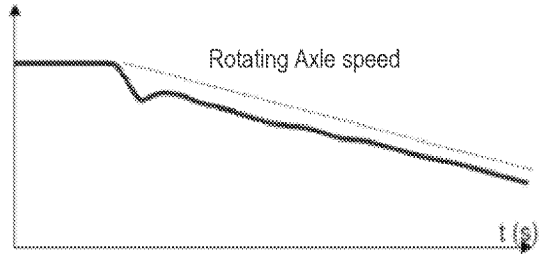


Figure 5.4-18 | Rotating axle speed regulation on a sliding wheel or axle during emergency brake

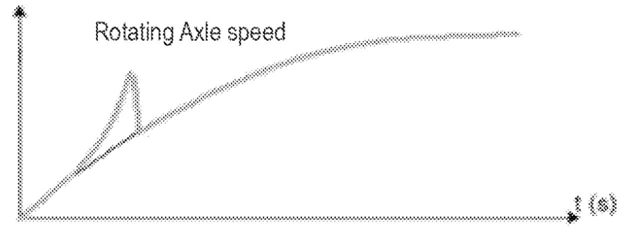


Figure 5.4-19 | Rotating axle speed regulation on a skidding axle (motor truck) during traction phase

5.4.3.12 Vehicle Delivery & Partial Assembly

The Vehicle will be shipped separately in two sections from France to the MSF in Ottawa.

5.4.3.13 Vehicle & Wayside Subsystems

Communication between Vehicle and wayside is managed by the Train Control/Monitoring System (TCMS). The proposed TCMS for the OLRT Vehicle is part of the service-proven standard Citadis product range.

Communication Based Train Control

The on-board and wayside portions of the CBTC system are described in **Section 5.4.4**.

On Board Communications Network

All Train-wide voice communications, control of destination signs and Passenger information signs and transmission of video within the Train will take place over a dedicated Ethernet network (see **Cut Sheet 5.4.1-CS-903**).

The vehicle will communicate with the wayside via a Wi-Fi system with transceivers at Stations and the MSF. This link will be used for non-vital information such as video, Automatic Passenger Counting (APC)

Radio

On-board Train Radio will be specified as defined in PA Schedule 15-2 Part 4 to fulfil related interface requirements with the planned City Radio System.

Closed Circuit Television

Exterior Surveillance

In each Station, video cameras will monitor boarding platforms. Video will be streamed to the TCMS via Wi-Fi communication and displayed to the Driver. Cameras will also be installed aboard the Trains, enabling the Driver to monitor the sides of the Train when not in a Station.

Interior Surveillance

The video-surveillance system is based on a complete digital technology system. The CCTV function is integrated with the Ethernet backbone. Electronics cards which ensure "supply, network communication and recordings" functionalities needed by this system are located in the same shelf (called Universal Mobile Controller) as Public Address.

This CCTV system consists of the following elements:

- Cameras to monitor the Passenger compartment
- Cameras to monitor the view out of the cab front and rear window
- One recorder with a hard disk(s) integrated in the UMC racks

Automatic Passenger Counting (APC)

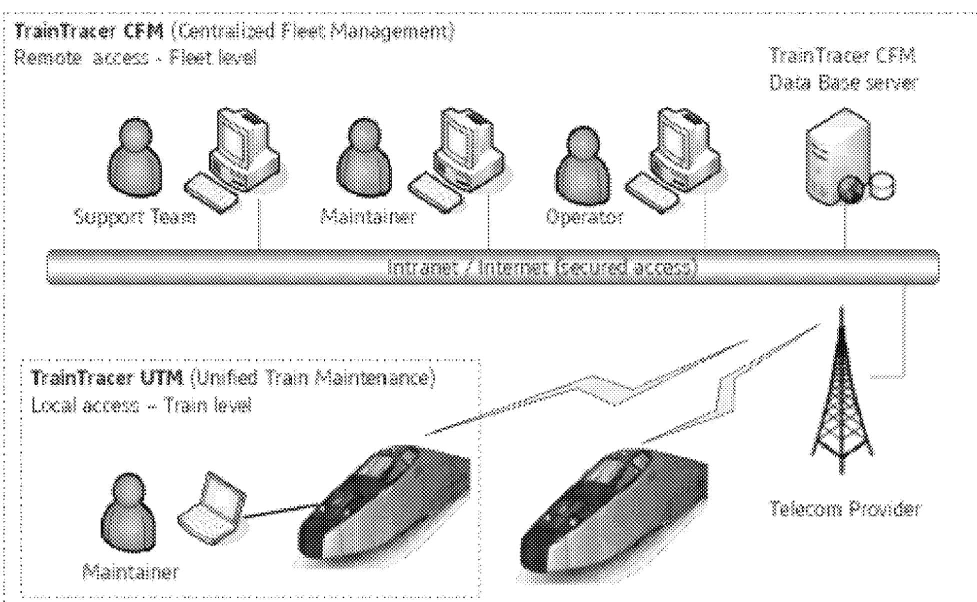
The APC system will provide an accurate count of passenger traffic and report the data to the Performance Monitoring System in real time.

Remote Diagnosis - Train Tracer

TrainTracer is the Alstom solution to facilitate Train diagnostics, interfacing Train on-board equipment with the M&R Team. Besides the usual access to Train data using a laptop PC directly connected to the Train, TrainTracer offers remote access to full fleet data through intranet and internet. Health data is automatically monitored on board each Train in operation and moves to back-office Web server through cost-effective wireless communications (see **Figure 5.4-20**).

Using a web-based server enables technicians to access Train data anytime and from anywhere there is intranet or internet access. Data will be available to the M&R Team, as well as for a remote support team or maintenance manager. As an option, access to TrainTracer could be made available to the Operator. This approach provides unprecedented visibility into the real-time operation and health of each Train. It expedites corrective maintenance, supports the Train crew and prevents some failures. TrainTracer reduces maintenance cost and simultaneously improves Train availability. This section describes the technical aspects of TrainTracer solution proposed by Alstom Transport as the maintenance assistance system for rolling stock.

Figure 5.4-20 | TrainTracer



TrainTracer Application Overview

To assist the Train maintainers, two TrainTracer applications will be available:

- **TrainTracer CFM (Centralized Fleet Management)** - A centralized application, managing data at fleet level, accessible using a thin client through a secured intranet or internet access
- **TrainTracer UTM (Unified Train Maintenance)** - A local application, managing data at Train level through a laptop PC. The connection to the Train is direct.

Main faults generated by the Trains are automatically sent to TrainTracer CFM server and recorded:

- Alarms related to failures affecting current commercial service
- Faults to be fixed at depot

Other faults and detailed information are accessible through a laptop in the MSF using TrainTracer UTM and other servers using open protocols. They are used for deeper investigation of faulty equipment.

These two applications may collaborate since CFM imports maintenance data that has been recovered by UTM. This solution enables us to manage the case where a remote connection is unavailable and a direct local maintenance operation has been necessary.

Catenary System

Interface with catenary system is described in **Section 5.4.3.14**.

Wheel Rail Interface

Information on wheel rail interface is given in the truck **Cut Sheet 5.4.1.B-5**.

5.4.3.14 Power System

The OLRT Vehicle complies with the EN50163 standard, concerning the supply voltages for traction systems. **Table 5.4-12** summarizes the lowest, highest and nominal voltages.

Table 5.4-12 | Voltages

Lowest non-permanent voltage	Lowest permanent voltage	Nominal voltage	Highest permanent voltage	Highest non-permanent voltage
U_{min2} [V]	U_{min1} [V]	U_n [V]	U_{max1} [V]	U_{max2} [V]
1000	1000	1500	1800	1950

Table 5.4-13 shows the estimated power balance on the catenary power supplied for nominal catenary voltage.

Table 5.4-13 | Estimated Power Balance

Parameter	Performance
Maximum Power for auxiliaries	325 kW (including 4*75 kW for heating)
Maximum Power for low voltage network and equipment	16 kW
Maximum Power for Traction	1050 kW
Maximum Power required on Catenary Power Supply	< 1400 kW (estimation)

5.4.3.15 Carbody Strength

To ensure maximum safety for Passengers, the carbody will exceed requirements of ASME-RT1. Cars are composed of the following equipped modules:

- Underframe (version depending on Vehicle)
- Driver's cabins (in head Vehicle only)
- Roof
- Sidewalls (symmetrical left and right)

Final assembly between the sub-assemblies will be performed either by welding, riveting or fastening, as required by structural, manufacturability and maintenance requirements. Several lifting and jacking points are present in each Vehicle, designed and calculated to ensure correct performance for re-railing and maintenance operations. The exact position and design of the support surfaces shall be developed to ensure compatibility with existing and service-proven elements.

See **Test Reports 5.4.1.A-TR-201 to 5.4.1.A-TR-204** for the car-body strength calculation results of the Citadis Nantes.

5.4.3.16 Vehicle Weights and Axle Loads

Table 5.4-14 shows Vehicle weights and axle loads under different configurations.

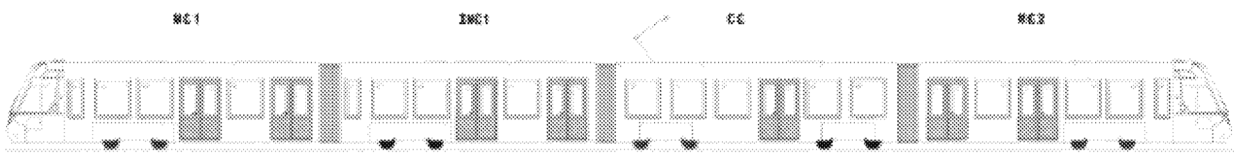


Table 5.4-14 | Vehicle Axle Loads

Tonnes	MC1		IMC1		CC				MC2		
Condition	Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	Axle 6	Axle 7	Axle 8	Axle 9	Axle10	Total
Tare Load	8,341	8,341	6,945	6,945	7,271	7,271	7,998	7,998	8,276	8,276	77.6T
3.33p/m²	10,229	10,229	10,267	10,267	9,227	9,227	10,731	10,731	10,164	10,164	101.2T
4 p/m²	10,797	10,797	11,589	11,589	9,933	9,933	11,851	11,851	10,732	10,732	109.8T
8 p/m²	11,365	11,365	12,910	12,910	10,369	10,369	12,970	12,970	11,301	11,301	118.4T

5.4.3.17 Crashworthiness

The end cabins provide appropriate protection to both Driver and Passengers. The design integrates ASME RT-1 required elements. It includes crash-energy absorption devices designed to deform in a preprogrammed fashion and located as shown in **Figure 5.4-21**.

Using a modular concept allows for a quick re-entry into revenue service of any Train involved in one of the considered crash scenarios. In the event of low speed crashes, impacted elements (central absorber and/or coupler assembly) are designed to be easily replaced. In the event of a higher-speed collision, end cabins are bolted on the end of the frame and can be easily and quickly replaced.

From the structural point of view, the Driver's cabin can be divided into two main elements:

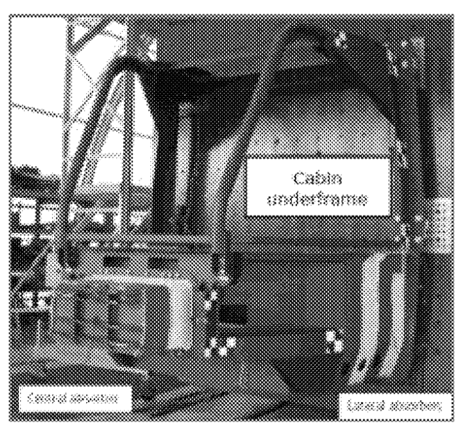
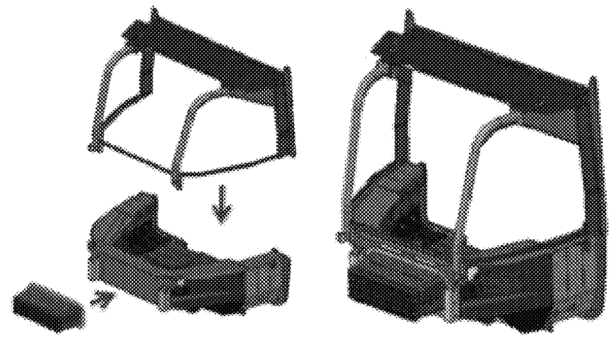


Figure 5.4-21 | Crash-Energy Absorption Devices

- A top frame composed of corner posts and a top structural shelf as specified in ASME RT-1
- An underframe integrating the crash absorption elements, the driver's survival cell, full-width anti-climber, collision posts and the interfaces with the top frame and all required equipment supports to comply with ASME RT-1



Detailed design will be finalized in conformance with the client's aesthetical design requirements. See **Test Reports 5.4.1.A-TR-301 to 5.4.1.A-TR-303** for the preliminary crash calculations.

5.4.3.18 Development, Production, Testing and Commissioning Schedule

See **Section 5.4.1.E** for the preliminary schedule. **Section 5.4.3.5** details the Testing and Commissioning Strategy.

5.4.3.19 Compliance Matrix

See **Section 5.4.1.F** for the compliance matrix.

5.4.3.20 Heating and Cooling

The Passenger compartment air conditioning is ensured by a roof-mounted fully unitized air conditioning unit on each car. All units can be maintained from the roof.

Equipment Description

The HVAC unit is a fully unitized roof-mounted unit developed to achieve heating and cooling performances while minimizing noise. The cooling circuit is hermetically sealed and uses homologated refrigerant liquid (R407C) in accordance with current European Standards and the Montreal protocol, and complies with Canadian laws and regulations. Drawings of the proposed HVAC are provided in **Cut Sheets 5.4.1-CS-501 and 5.4.1-CS-502**, with further details of the HVAC unit in **Cut Sheet 5.4.1.B-3**.

The HVAC unit has been designed to provide 8 m^3/hr of fresh air per Passenger in AW2 loading conditions. The fresh air damper can be closed by the Driver for faster warm-up and cool down of the Passenger compartment. If over temperature is detected, thermostatic and electrical protection is provided. An emergency shutdown switch is also provided in the Driver's cabin.

System Capacity

HVAC capacity has been designed for optimal comfort. The proposed unit offers 35 kW of cooling power and 30 kW of heating power. To ensure system capacity in terms of temperature stratification, treated air will be distributed to Passenger compartment by air outlets located on the ceiling and at floor level. Thermal load calculations used to define the heating and cooling capacity required are provided in **Test Report 5.4.1.A-TR-401**.

Controller

The controller regulates temperature in the Vehicle through multiple operating modes. These operating modes are determined by system configuration, analogue input values, digital input states, and the system set point. The following functions are provided by the controller:

- Safety and shutdown protection
- Diagnostics
- Fault monitoring and annunciation to MPU
- Self-health check

- Sequential starting of motors
- Includes a +/-2°C set point adjustment for all switching points

Cabin Equipment

The ventilation, heating and cooling functions for the Driver are ensured as follows:

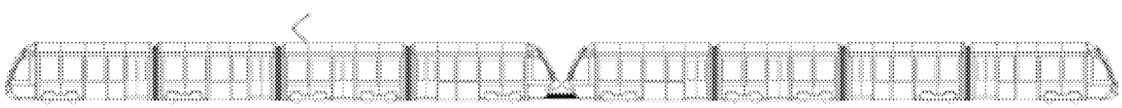
- An overhead air diffuser with volume and directional adjustability fed from the main HVAC unit
- Two thermostatically controlled cab heaters
- Side window defrost
- Electrically heated windshield

5.4.3.21 Approach to Pushing/Towing, Fire Safety and Ride Quality

Pushing/Towing

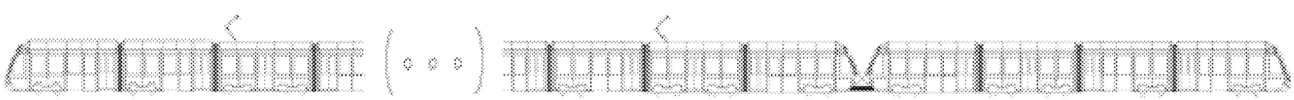
Alstom Citadis products are service-proven on diverse railway networks and are designed to rescue and to be rescued. The proposed OLRT Vehicle is designed for the following towing/pushing operations:

- A single Vehicle rescues another single one



Rescuing single Vehicle *Rescued single Vehicle*

- A multiple Vehicle rescues a single unit



Rescuing multiple Vehicle *Rescued single Vehicle*

- A multiple unit rescues another identical multiple unit

Rescuing multiple Vehicle *Rescued multiple Vehicle*

In rescue operation, the allowed operating speed is limited to 30km/h.

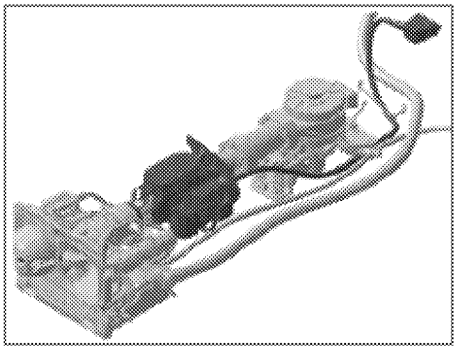


Figure 5.4-22 | Automatic Coupler

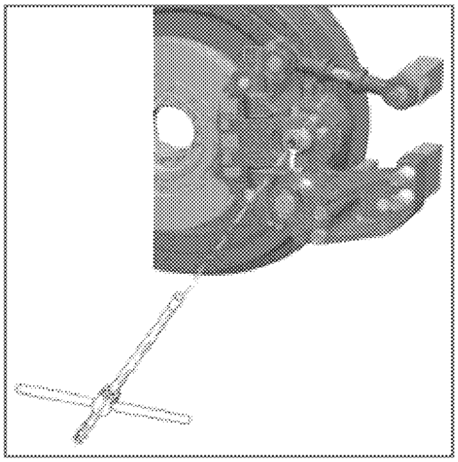


Figure 5.4-23 | Brake Release

Coupling

In normal rescued condition, the automatic coupler is used (see **Figure 5.4-21**), which contains all necessary trainlines for rescue mode. It can be manually deployed in cases of low battery or motor breakdown.

Rescue Mode Description

The rescuing Train provides low-voltage energy for all necessary functions. Mechanical brakes are released with the auxiliary hydraulic pump thanks to shared low-voltage energy.

In an emergency stop button or an unwanted uncoupling, all rescued mechanical brakes are actuating to stop the Vehicle, preventing all cases of unbraked Trains.

In the exceptional case of non-brake release through auxiliary hydraulic pump, the Driver can release the brake mechanically (**Figure 5.4-23**). Brake application will be possible only when hydraulic pumps are activated again.

In addition, the following functions are available in the rescued Vehicle (the rescuing one is fully operational):

- Emergency stop buttons (in both cabins)
- Windshield wiper
- Exterior lighting
- Cabin lighting
- Train radio

Fire Safety

All non-metallic components used on the Vehicle are smoke-, flame- and toxicity-tested to NFPA 130, 49 CFR part 238 and BSS 7239. Equipment will meet NFPA 130 requirements. All materials used on the Vehicle, as well as their weight, location and their fire/smoke/toxicity test report will be recorded in a database and maintained through the Vehicle lifecycle. **Table 5.4-15** summarizes the fire loading values.

The underframe and roof are made of steel to ensure sufficient fire resistance. Design will be validated by performing tests in accordance with ASTM E119, NFPA 130 and 49 CFR part 238. Smoke detectors are located in fresh air intake sections of each car. If smoke is detected, fresh air intake will be automatically closed to prevent external smoke from entering the Vehicle. Two additional smoke detectors will be installed in the vehicle's interior to alert both the driver and the Control Operators in the TSCC of a possible onboard fire. To ensure proper Vehicle evacuation in case of fire, all doors are equipped with an external and an internal manual door release. Two fire extinguishers will be located in each Driver cab.

Table 5.4-15 | Fire Loading

Item	Value
Estimated fire loading for MC section (MC1 & MC2)	43 GJoules
Estimated fire loading for IMC section	36 GJoules
Estimated fire loading for CC section	39 GJoules

Item	Value
Estimated fire loading for an entire Vehicle	**161 GJoules**

Ride Quality

Thanks to its unique truck architecture, the proposed Vehicle features comfort levels in line with international standards for Passenger comfort:

- ISO 2631 associated with UIC 513 (Measurements will be performed as per UIC 518
- ISO 2631-1985: Evaluation of reduced comfort boundary for urban application

5.4.4 TRAIN CONTROL

RTG is pleased to offer the SelTrac Communication Based Train Control (CBTC) System from Thales Canada for the OLRT Project. SelTrac's proven CBTC architecture provides comprehensive Train Control functionality with the highest levels of performance, reliability, availability and safety. The SelTrac CBTC System provides the 21st century urban transit system operational capabilities required for the OLRT:

- Fully protected bidirectional operation over the entire alignment
- Moving block Train protection to maximize Passenger throughput
- Flexible Control Operator interface that supports fully automatic scheduled operation while providing tools to manage incidents
- Proven safety record – the longest in the CBTC industry
- Proven performance in severe climatic conditions
- A fully automatic maintenance yard with unattended coupling and uncoupling to promote Project sustainability

Thales has operated in Canada for more than 30 years employing 1,300 employees in Transportation, Defence & Security, and Aerospace sectors. Thales' centre of excellence for signalling is located in Toronto, with offices in Vancouver and Ottawa employing more than 800 people. These Canadian offices pioneered the development of CBTC Systems for the world market in the 1980s and continue to be leaders in delivering CBTC systems that exceed client performance expectations, and in defining CBTC industry standards (IEEE 1474). Thales' Software Defined Radio, which will provide network communications for the OLRT CBTC System, was developed in their Ottawa office.

Thales has 31 lines in revenue service totaling 900 line kilometres, with a total of 1100 line kilometres contracted, and has installed CBTC solutions around the world for more than 26 years. There are currently more than 900 transit track kilometres signalled with Thales SelTrac CBTC solution in over 35 cities including major transit centres such as London, New York, Hong Kong, Shanghai, and Beijing. Thales has never failed to successfully deliver a SelTrac CBTC project and, once delivered, the system has never been replaced. (See **Cut Sheets 5.4.1.C-1 & 2** for the full project list) RTG and Thales are excited to work with the City to bring this unique Canadian success story to the nation's capital.

5.4.4.1 Modelling & Results of Expected Systems Performance & Applicability to the OLRT

As the most experienced CBTC provider using the globally proven free-space radio technology, Thales' SelTrac CBTC System exceeds the City's operational and headway requirements, ensuring Passenger comfort and optimum travel times. All features specified by the City are either included as generic SelTrac functions or have been previously implemented as a site-specific function in another system. This section provides an overview of how the SelTrac CBTC System will be applied to the OLRT and describes the modelling that was performed to validate the CBTC System design as integrated with the chosen Vehicle and alignment.

Applicability to the OLRT

The SelTrac CBTC System proposed for the OLRT consists of the following major subsystems which are distributed as shown on **Diagram 5.4.1.D-SK-202**:

- The Automatic Train Supervision (ATS) system which provides the high level OLRT control functions such as Train schedule regulation, Control Operator interface and the interface to other OLRT systems (e.g. SCADA, Passenger Information, City systems)
- Zone Controllers (ZC) that ensure safe Train separation and provide the interlocking function on a section of guideway
- Vehicle Onboard Controllers (VOBC) that ensure Trains are operated at a safe speed and within the Movement Authority commanded by the Zone Controller
- The Data Communication System (DCS) which provides the fibre-optic backbone for communication between the fixed subsystems as well as the high-speed wireless data network for communication with the VOBCs
- Track Circuits that provide broken rail protection and tracking of maintenance equipment and non-communicating Trains[1]
- Track-mounted equipment including wireless Access Points, switch machines, signals at interlockings, Train location norming transponders, intrusion detection at tunnel portals and Stations, proximity detectors at Stations, and signage

RTG will also provide a training simulator to assist in the delivery of Control Operator training and certification programs. This system will be entirely independent of the revenue service equipment listed above.

All these subsystems will be supplied and integrated by Thales and are described in more detail in **Section 5.4.4.6** and **Cut Sheets 5.4.1.C-3 to 5.4.1.C-18**. The system configuration is based on the highly successful Canada Line in Vancouver, including a fully automatic storage yard. Unlike Canada Line, all major OLRT CBTC subsystems[2] will be fully redundant, thus providing even higher CBTC system availability.

Operating and maintenance procedures and training are an important factor in achieving high system performance. Canada Line operations personnel will coordinate the development of OLRT operating procedures with the City and will participate in developing and delivering operations training programs. Similarly Canada Line maintenance personnel have participated in the design of the CBTC System and will oversee the associated maintenance procedures, training, and participate in the testing and commissioning of the OLRT. This strategy will ensure that the CBTC System design is supported by well-trained personnel, thus ensuring high system performance.

Simulation Modelling Results

Thales simulated the performance of the CBTC System on the OLRT alignment using a simulator that has been validated against actual performance of Trains in other systems. The simulation used conservative values of braking and acceleration derived from actual Train performance characteristics provided by Alstom. Actual guideway civil speeds and CBTC System tolerances and processing delays were used. The Thales CBTC System uses a proven safety distance algorithm that applies a conservative safety distance based on the worst-case braking distance calculated for actual Train speed, which allows the System to safely maximize throughput.

The simulations confirm that RTG's proposed system for the OLRT meets or exceeds all of the City's operational requirements by achieving the following:

- [redacted]

[1] RTG has chosen to provide track circuits because, although they are not required by the SelTrac CBTC System, we believe that they are the City's preferred option. We are open to exploring other options which may improve system availability at the Conceptual Design Review.

[2] Canada Line Interlockings are not redundant.

- [redacted]
- System capacity for all operating scenarios

Simulation results are summarized in **Section 5.4.5** and details are presented in the Operation Performance Simulation. A narrative can be found in **Section 10.0.4**.

5.4.4.2 Interaction of the Train Control System with Vehicles

Revenue Vehicles

Using proven interfaces, the VOBC will control and monitor major Vehicle subsystems including propulsion, brakes, and doors. In general these interfaces will be Ethernet, MVB and discrete trainlines for safety critical functions. Vehicle networks and CBTC networks will be independent, and the CBTC Ethernet network will be redundant. The functional description of the VOBC can be found in **Section 5.4.4.6**.

Thales has successfully installed their system on Trains built by all major manufacturers. They have worked with Alstom on the London Underground Jubilee Line and on Shanghai Metro Lines 6 and 8. The Shanghai installations employed 1500 Vdc as is proposed for the OLRT. The preliminary Train network design prepared jointly by Alstom and Thales is shown in **Drawing 5.4.1.D-SK-201**.

Non-Revenue Vehicles

SelTrac protects non-communicating Trains (NCT - either failed Trains or unequipped vehicles such as maintenance equipment) with a Manual Route Reservation (MRR, which sets and locks a route from an origin to destination for an NCT move) and tracks the NCT using track circuit status.

The Zone Controller interfaces with the track circuits and monitors their status to determine block occupancy, which is reported to the ATS. The Zone Controller will use block occupancy to determine the location of the NCT and will release the route behind the Train based on a check-in/check-out algorithm using block occupancy status.

NCT tracking is performed automatically by the ATS function. The ATS operator can use the Occupancy Train Correlation command to manually associate an NCT with a block occupancy. The ATS Line Overview graphically shows all Trains in CBTC territory – equipped, unequipped, and non-communicating.

5.4.4.3 Interaction of the Train Control System with Operators

Train Driver

The Train Operator Display (TOD) in the Driver's cab of the Vehicles provides status and commands to the Driver in a clear and easily understood format. The TOD is ergonomically designed to present data in a clear and concise display. The VOBC will provide data to the TOD via an Ethernet interface (see **Figure 5.4-24**):

- Speed (Maximum permitted speed, Actual speed, and New target speed)
- Train operating mode (UTO, ATO, ATP, Coupling, Non-CBTC Territory, Manual Release, ATP Cut-out)
- Indicates direction of travel, distance to go (to the next stopping point, to a new target speed, and to the movement authority limit)

Figure 5.4-24 | Typical TOD Operation Screen

- Dwell countdown timer, Faults, Alignment at the Station
- CBTC Available modes
- Side of doors that open, overspeed indication
- Train doors status
- Train identification number
- Current Station
- Next Station
- Train destination/Headcode
- Ready-to-depart indicator (audio/visual)
- Local Time
- Station Overrun Message
- Indication of Station hold at (next) platform
- Indication of Station skip
- Open/Close Train Doors command
- Train operator ID, Rolling Stock ID
- Travel Direction, Emergency Brake Status

Mainline Operators

The mainline Control Operators (COs) are the command level of authority for the OLRT. The SelTrac ATS function provides COs with an interface where they normally run the railway in accordance with a prearranged schedule with minimal intervention, but which provides powerful tools to intervene as required to manage special circumstances such as Passenger emergencies, large crowds, system failures or severe weather. ATS workstations and overview displays provide real-time status of, and alarms for, the full rail network. Operational procedures will be developed in cooperation with the City to define the appropriate response to alarms and delays. ATS functions and screens are described in detail in **Section 5.4.4.6**.

COs are assigned a command Level of Authority (LOA) based on their training and certification. They are also assigned a Region of Authority (ROA) based on the portion of the railway they have been assigned to control. ATS command level authorization and territory control are controlled through the User Administration ATS function. ATS operators are required to log in with a defined user account to access ATS functions. Each user account is associated with one or more LOA user groups, which determine what commands are accessible to that user.

For those commands which perform a function in a specific territory of the railway, the logged-in ATS operator must acquire control of the ROA that includes that area before being able to issue the command. Only one CO may have control of an ROA at a given time. The user account specifies for what ROAs the operator is authorized to request control. Assigning ROA and LOA groups is restricted to authorized personnel.

All commands executed by an operator are logged in the archive server with the user account and workstation from which the command was issued.

Maintenance & Storage Facility (MSF) Yard Control Functions

The MSF Yard ATS workstations provide similar capabilities as the mainline, plus certain yard-specific functions such as the Train Wake-Up Command and a Train Park Command. The ROA function ensures that the yard Control Operator (YCO) cannot execute commands that affect the mainline. The yard control functions are described in **Section 5.4.4.7**.

5.4.4.4 Train Control System

The SelTrac CBTC Subsystems outlined in **Section 5.4.4.1** are further described here. Equipment location and interconnections are shown in high level architecture **Diagram 5.4.1.D-SK-202**. System hardware is described in **Cut Sheets 5.4.1.C-3 to 5.4.1.C-18**. System software, including development life cycle and configuration control are discussed below.

The CBTC product offered by Thales has an optimized architecture built around the integrated Zone Controller (ZC), which implements both CBTC and Computer-based Interlocking System (CIS) functionality.

The vital components of the system are the Vehicle On-board Controller (VOBC) on the Train and the Zone Controller (ZC) on the wayside. Together they provide the Automatic Train Protection functions of the SelTrac CBTC. The non-vital ATS provides the operator with a high-level set of operation management functions for Automatic Train Supervision. The Data Communication System (DCS) provides the communication means for all components to exchange data. A wayside Train detection system is implemented to track non-communicating Trains using track circuits.

Automatic Train Supervision (ATS) is the top-level system management and supervision component of the SelTrac CBTC, providing the ATS functionality:

- Schedule and headway automatic regulation, including energy-saving features
- Automatic and manual routing
- System status (e.g. status of Trains, switches, emergency-stop system) monitoring and display
- Operator control functions and user interface
- Data logging and report generation
- Interface with external systems, including Passenger information systems

The function of the ATS Server is to perform predictions, routing, schedule regulation, and to maintain the system status and alarm database. The ATS Server will write all log information (i.e. events, alarms) into the clustered database in the MSF. The Database Storage Unit (DSU) is the repository of the system databases. It is used to securely distribute application data to the system components remotely. The ATS is non-vital and performs no safety critical functions.

ATS Servers are redundant and implemented in a hot standby configuration. Redundancy of ATS workstations is achieved by providing multiple workstations in each control room and allowing any workstation to be configured for any function.

The **Zone Controller (ZC)** is the core Automatic Train Protection (ATP) component of the wayside vital Train control, which integrates the Limit of Movement Authority calculation with interlocking functionality. Each Zone Controller manages a section of the railway (zone) in accordance with various operation and configuration requests from the ATS. The ZC controls and monitors the following:

- All track-mounted equipment in its zone
- All Trains in its zone via continuous communication with the VOBC
- Trains entering or leaving its zone via continuous communication with the neighbouring Zone Controller(s)

The ZC is a vital subsystem and is configured as a 2 X 2oo2 (see **Section 5.4.4.9**) subsystem to achieve high safety and availability. Each ZC is equipped with a local ATS workstation to maintain basic ATS functionality in the unlikely event of loss of communication to the central ATS Servers. In case of complete loss of the ZC CBTC System process, the ZC will function as a conventional interlocking in a standalone fashion.

The **Vehicle On-Board Controller (VOBC)** is the core onboard train control system component which provides driver controlled operation (ATP Only mode), driver supervised operation (ATO mode), and driverless operation (UTO mode), by implementing Automatic Train Protection and Automatic Train Operation functionality, including safe automatic or manually driven Train movement, including Driverless turnback and accurate Station stopping, automatic door operation and protection.

The VOBC performs ATP and ATO functions in accordance with ZC and ATS commands, with which it maintains continuous communication over the CBTC wireless network. The ZC provides the Limit of Movement Authority (LMA) used by the VOBC to safely operate the Train in accordance with the maximum speed profile. The VOBC, using its sophisticated safe-braking model, calculates in real-time its safe braking curve, allowing the Train to stop very close to the end of its LMA, thus reducing the required overlap distance. The VOBC reports the position, speed and status of the controlled Train to the ZC.

The VOBC is a vital ATP component of the SelTrac CBTC system and is designed and built redundantly for high safety and availability. Each 48.5 m Vehicle is equipped with a safety redundant (2oo3) VOBC (see **Section 5.4.4.9**). In addition to on-board tachometers and accelerometers, the VOBC uses transponders to maintain Train position and proximity plates which support accurate Station stopping in ATO mode.

The **Data Communications System (DCS)** is the SelTrac CBTC communication component. Its main function is to enable fast, bidirectional, secure and dependable communication between all subsystems (see **Figure 5.4-25**).

Figure 5.4-25 | Data Communication System Context

[redacted]

The radio component of the DCS is based on IEEE 802.11 successfully deployed over more than 300 line kilometres. The radio layout provides geographical redundancy (zones have overlapping coverage) and on-board redundancy (with a pair of antennae installed at each end of the Train to provide diversity).

DCS security devices ensure that communication between the wayside trusted network and the wireless trackside and on-board network is secure.

The modular system architecture provides built-in expandability to support line extensions and/or fleet expansions to realize the full capacity of the OLRT. The system architecture of the Train control system is supported by trackside equipment and three classes of software.

Trackside Equipment

The following equipment will be installed at the trackside:

[redacted]

- [redacted]

Software Classification

The software for this Project falls into three classifications:

- **Vital Software –** Software which, if implemented incorrectly, may reduce System safety. The development and modification of vital software is subject to rigorous reviews and procedures (e.g. ZC and VOBC software).
- **System-Critical Software –** Software which, if implemented incorrectly, may reduce System day-to-day operational capability. The development and modification of system-critical software, although not required to meet the same standards as vital software, is subject to a complete design/review/test program to ensure that the functional requirements are met (e.g. ATS software).
- **System Support Software –** Software which, if implemented incorrectly, will not have an immediate effect on the level of System service but which is required to meet the overall System specification. The development and modification of System support software is designed with a less rigorous method, compatible with ensuring specified functionality (e.g. Training Simulator software).

Software Development Lifecycle

This section describes the software development process for producing software to meet functional requirements.

Software V-Model Life Cycle

The V-Model for the software development process is used to manage the relationship between each phase of the development cycle and testing, as indicated in **Diagram 5.4.1.D2.3A**. The model deploys a well-defined structure, in which each phase is implemented in accordance with the outputs from the previous phase. System requirements are input to the model.

Software Configuration and Control Management

Software configuration and all associated documentation will be controlled and managed according to Thales' proven Software Configuration Management work instruction. The software system will be segmented into Computer Software Configured Items (CSCIs) that will be version managed by use of the software tool ClearCase. Defects to these CSCIs will be managed through the accompanying software tool ClearQuest.

During the development, software configured items include the following:

- Software Requirements Specification (ClearCase)
- Software Design Documentation(ClearCase)
- Software Source Code (ClearCase)
- Software Test Plans (ClearCase)
- Software Test Specifications (ClearQuest/ClearCase)
- Software Test Source Code (ClearCase)
- Software Test Scripts (ClearCase)
- Software Test Results (ClearQuest)

When an anomaly is detected, a Software Change Report (SCR) report is submitted to the defect tracking system. This report is handled as per Thales' Change Control Process. Closure of this report will follow the documented development process complete with all reviews and checkpoints. Thales's Change Control Process ensures the following:

- Any perceived hardware, software or document fault is reported, recorded and resolved.
- Change instructions are represented in a clearly stated, structured and consistent manner.
- Proposed changes are fully evaluated (in a defined way, by all relevant parties), and are properly resolved.

- There is visibility on the status of all changes.
- All communication paths are well defined.

Hardware Configuration Control

All Line Replaceable Units (LRUs) that are identified as hardware configuration items are serialized during manufacturing. As part of final inspection, the configuration of each LRU will be verified and recorded.

Where items are procured from a subcontractor, the subcontractor will record the configuration and submit the configuration log with the item in accordance with the purchase order requirement. The configuration log will be verified as part of Thales' inspection procedures.

5.4.4.5 Key Functions and Modes

This section is divided into two major tables. **Table 5.4-16** defines key functions for both normal and abnormal conditions. Abnormal conditions are defined to be failure conditions or extreme weather. **Table 5.4-17** defines the interaction of operational modes and identifies how Drivers interact with the system.

Key Functions

Table 5.4-16 | CBTC System Key Functions

Key Function	CBTC System Condition	
	Normal	Abnormal
Automatic Train Supervision		
[redacted]		

Key Function	CBTC System Condition	
	Normal	Abnormal
[redacted]		
Automatic Train Operation		
[redacted]		

CBTC System - Operations Mode Interaction

Because of its large installation base, the Thales CBTC System supports all the features of each operating mode specified in the PA, generally as part of the generic product and in a few cases as site-specific functions implemented on previous projects. **Table 5.4-17** shows how the subsystems interact to manage the operations modes. Vehicle modes are further described in the **State Transition Diagram 5.4.1.D2.6**.

Table 5.4-17 | CBTC System Operations Mode Interactions

Mode	Description	CBTC Interaction (Key Functions)				Driver Interaction
Train Modes		ATS	ATP - ZC	ATP – VOBC	ATO	
[redacted]						

Mode	Description	CBTC Interaction (Key Functions)	Driver Interaction
[redacted]			

Mode	Description	CBTC Interaction (Key Functions)				Driver Interaction
		uncoupling	Supervision			
ATS Modes						
[redacted]						

5.4.4.6 Train Control System Functional Description

The functional description is organized by the classic categories (i.e. ATS, ATP and ATO), summarized as follows:

- ATS performs all signalling and control functions but has no responsibility for safety
- ATP is responsible for safe Train separation and routing in accordance with control requests from the ATS
- ATO is responsible for automatic operation of the Train in accordance with commands from the ATS and under the supervision of ATP

Automatic Train Supervision (ATS)

ATS for OLRT can be divided into two major modes: ATS Automatic Mode and ATS Manual Operation Mode. Both modes operate with minimal intervention and provide the CO with powerful tools to intervene as required to manage special circumstances such as Passenger emergencies, large crowds, system failures or severe weather. Any automatic operation can be manually overridden by the CO. A preliminary list of commands is shown in **Table 5.4-17.**

ATS Automatic Mode

This is the normal mode in which the OLRT will run. The CO loads a timetable at the beginning of the day. The timetable defines a set of runs for each level of service (LOS) and each run defines the schedule of operation for a Train in that LOS. ATS will wake up each Train at the required time, send it to a Driver pick-up platform, route it to the mainline, and assign it to a run. Trains are routed from Station to Station according to their assigned timetable run. Once the run is no longer required, ATS routes the Train back to the yard.

Automatic Train Regulation

This function regulates Train movements to either a schedule or defined headway. Schedule regulation minimizes deviations between the operating timetable and actual Train movements. Headway regulation ensures that the time between Trains is consistent.

ATS will modify a Train's acceleration rate, maximum speed and/or Station dwell time to address a difference (late or early) between its actual Station arrival time versus the target arrival time according to the active regulation strategy. ATS can also apply the following regulation functions in real time to provide significant energy savings:

- **Adaptive Slow Running** – Modify a Train's driving profile to reduce acceleration rate and limit speed to avoid stopping between Stations due to the preceding Train being behind schedule.
- **Arrival/Departure Coordination** – Coordinate braking and acceleration of nearby Trains to reuse energy from regenerative braking.
- **Constrain Peak Demand** - Limit the number of Trains departing simultaneously to reduce power spikes.

The timetable compilation tool provides Energy Efficient Planning capabilities similar to these three to optimize a timetable for energy efficiency.

Automatic Train Routing

[redacted]

ATS Manual Operation Mode (Interlockings)

ATS Manual Operation Mode allows the CO to control the interlocking process of the ZC from an ATS workstation (either central or local). This mode may be useful in case of loss of CBTC Train-to-wayside communication or during the maintenance window when operating with unequipped vehicles. The ZC will operate as a conventional interlocking performing all the functions specified in the PA including allowing the CO to do the following:

- Set up routes by selecting entrances and exits or by selecting switch position for each switch
- Block and unblock switches
- Call, cancel and fleet signals
- Set the Interlocking to operate in an automatic turnback mode

ATS CO Interface

The ATS provides the human-machine interface (HMI) to the CO. The SelTrac HMI is powerful and flexible, again due to Thales' experience and large installation base. The CO uses the ATS workstation to issue commands and to monitor the state of the system. The ATS Line Overview provides a complete visual representation of the OLRT state including of the location of Trains, their routes and Movement Authority, the state of wayside devices, system alarms, and Traction Power status. **Cut Sheet 5.4.1.D2.2** shows typical ATS screens, and the NetTrac MT **Cut Sheet 5.4.1.C-4** provides further information. **Table 5.4-18** provides a preliminary list of ATC commands. The details of the ATS HMI interface will be developed at the CDR and will fully support the operating procedures that RTG will prepare in cooperation with the City.

Table 5.4-18 | Typical ATC Commands

Typical ATC Commands		
ATS Level		
Online timetable updates	Run assignment	Re-determination
Line assignments	Regulation mode	System hold
Train hold	Train stop / proceed	Shuttle operation
Platform hold	Platform skip	Server switchover
Train reset	UTO Train park	UTO Train wake-up
point to point Train routing	Region & Level of Authority	Occupancy Train Correlation
ATP Level		
Temporary speed restriction	Set/clear work zone	Emergency brake set/reset
Manual switch control	Interlocking mode control	Manual route reservation
Open/close track	Route blocking	Platform close
Signal block	Authorize UTO mode	UTO Train couple/uncouple
Switch block		
ATO Level		
Speed adjustments	Dwell adjustments	Door control
Acceleration rate adjustment	Brake rate adjustment	

Automatic Train Protection (ATP)

The heart of the ATP function is the ZC: it determines the Limit of Movement Authority (LMA) and provides route locking while supporting full bidirectional operation. The VOBC is responsible for enforcing the LMA and accurately reporting Train position. The ZC reserves a block (section of guideway) for the Train up to the end of the route (typically the next Station) unless there is an obstruction along the way (e. g. preceding Train). As the Train moves within this block the VOBC reports the Train's new position allowing the ZC to release that part of the block now behind the Train. If the LMA is restricted by a preceding Train, the ZC will advance the front end of the block as the preceding Train moves ahead, hence the CBTC term "moving block." These functions are described below.

Safe Train Separation and Interlocking

[redacted]

[redacted]

Train Tracking

Using position reports from the Train and its known length, the CBTC system safely and accurately determines the location of both the front and rear of the communicating Train. The VOBC vitally determines Train length, using Vehicle length and coupler status. Vehicle length is defined by the Vehicle ID plug, and coupler status is used to determine if the Train is a single Vehicle or a coupled consist. Train position is maintained as described below.

[redacted]

Tracking Communicating Trains

The ZC uses the position reported by the VOBC to track communicating Trains. As a Train approaches an area associated with a neighbouring ZC, the VOBC begins to communicate with this 'takeover' ZC. During the transition between zones, the VOBC communicates with both ZCs, which also communicate between themselves. The VOBC stops communicating with the handover ZC once the Train is completely inside the takeover zone.

Train Doors

If door status is lost when the Train is stopped, the VOBC will prevent the Train from moving. If door status is lost while the Train is moving, the VOBC will stop the Train and alarm the Driver and CO. Upon restoration of Train-door closed-and-locked status, the ATS Operator will reset the emergency brake and the Train will start moving.

The VOBC will provide a door-enable signal on the platform side (as determined from its guideway database and Train orientation) only when the Train is aligned with a Station and is stationary with propulsion disabled. Upon completion of the platform dwell, and once the doors have closed, the VOBC will remove the door-enable signal.

Automatic Train Operation (ATO)

SelTrac ATO governs mainline functions such as speed regulation, programmed Station stopping and automatic door operation. ATO commands are always subordinate to ATP supervision functions. The ATO component of the CBTC system is primarily designed to provide automatic Train operation, Train movement, door open/close, alarms and communications, and information transmission to the ATS. The ATO process will monitor the active cab's master controller to allow the Driver to assert control as per the PA.

Data Communication System

All communications between subsystems are via the non-vital Data Communication System (DCS). Vitality of the data transferred via DCS is ensured by incorporating sequence numbers and CRCs in each message, and using an authentication algorithm applied to each message. Algorithms for generating sequence numbers and CRCs are known only by the vital devices, to prevent corruption by non-vital components of the DCS.

[redacted]

Backup Methodology in Case of Communication Failure

The SelTrac CBTC System has a high level of availability due to a robust architecture. The equipment is configured fully redundantly to provide high availability (in addition to redundancy to provide vitality). This is implemented from the processor through to field Input/Output modules. In this way the system tolerates the failure of one component with no impact to system operation.

[redacted]

System redundancy is explained further in **Section 5.4.4.9**. The following sections explain the reaction to specific failures.

Non-Communicating Trains (NCT)

[redacted]

Zone Controller Failure

[redacted]

Communication Failure

[redacted]

ZC to VOBC Communication Loss

[redacted]

COW0544752

[redacted]

Methodology for Broken Rail Detection

[redacted]

Yard Operations

The yard is divided into functional operations areas (see **Drawing 5.4.1.D-SK-106**):

- The area where the OC Transpo Drivers operate to pick up and drop off Trains will be equipped exactly as per the mainline to ensure common operating procedures. OC Transpo Drivers will pick up and drop off Trains as described below.

- The remainder of the yard will not be equipped with track circuits and signals. The YCO will control Train operation throughout the yard as required to support mainline operations and manage maintenance activities. Movement of unequipped Trains will be controlled by the YCO using Manual Route Reservations (MRR) in accordance with proven Canada Line procedures.
- The Transition Zone (TZ) is used to move Trains to and from the Maintenance Hall and to test Trains returning to service from maintenance. The TZ is within CBTC Territory while the Maintenance Hall and its approach apron are manual operation areas.
- The YCO will control moves between the Maintenance Hall and the TZ using an MRR to control the two-aspect signals which will be set to stop unless the YCO has set a route in response to an equipment move request (via radio) from an M&R hostler. Transponders in the TZ track will notify the VOBC that it is moving into or out of CBTC Territory and it will react as specified in the PA
- Similarly the YCO will control moves to and from the maintenance-of-way (MOW) storage track using an MRR. The MOW track is provides quick access to the mainline to maximize the usable nightly maintenance period.

Yard operations will not affect the mainline. The yard/mainline control boundary will be on the connector track between them. The precise location will be determined in conjunction with the development of operating procedures in cooperation with the City. The transfer of Trains across the boundary will be transparent to the CO, as is the transfer of Trains across any ZC boundary. To control the yard the YCO will use an ATS workstation which has full ATS functionally. The Region of Authority function will ensure that the YCO cannot execute commands that affect the mainline. Failure of the yard ZC will not affect the mainline. An FMECA will demonstrate that there are no credible CBTC yard equipment failure modes that can affect the mainline (including network failures).

Train Launch for Revenue Service

Prior to service start the mainline CO will select a timetable which defines the service level. The ATS will then:

- Select which parked Trains will be used to meet the service level (the YCO can edit this "launch list")
- Send each one a wake-up command at a configurable time before the Train is scheduled for service (to ensure that the interior temperature is comfortable)
- Route each Train as scheduled to one of the handover platforms for the OC Transpo Driver to board
- Route the Train onto the mainline upon Train mode changing to ATO (or ATP Only) and assign it to a run

Exceptions are as follows:

- The VOBC performs a start-up test upon receiving the wake-up command. The ATS informs the YCO if the test fails. The YCO will then route the Train to an inspection point or, if necessary, dispatch M&R personnel to manually drive the Train to the Maintenance Hall for service. The YCO will assign another Train to the launch list.
- If the OC Transpo Driver does not arrive in time the ATS will alarm the YCO to address the delay before service is affected.

Train Exit from Revenue Service

The ATS will select Trains to be taken out of service in accordance with the timetable as follows:

- Before arriving at the exit Station the ATS informs the Driver and the Passenger information system that the Train is being taken out of service.
- Upon completion of the dwell at the terminus Station the ATS routes the Train to one of the handover platforms in the yard.
- The Driver drives the Train to the handover platform, turns the cab off and exits the Train.
- Upon confirming that the Driver has left the Train, the YCO will normally command the VOBC to change to UTO mode and route the Train to a storage track where the Train will enter a low-energy-usage mode until commanded to wake-up. The YCO may also perform other actions as required:
- Route the Train to an inspection platform for inspection by a technician and/or cleaning staff.

- Route the Train to the wash and/or sanding facility.
- Route the Train to the Maintenance Hall. In this case the Train will come to a stop at the CBTC Territory boundary (see TZ in **Drawing 5.4.1.D-SK-106**) and wait to be boarded by an M&R hostler who will change the Train to Non-CBTC Territory mode and request a route into the Maintenance Hall as described above
- Uncouple a two-car Train to prepare for a timetable that requires shorter Trains, or to send one Vehicle to the Maintenance Hall.
- Couple to another Vehicle to prepare for a timetable that requires longer Trains.

5.4.4.8 System Safety Verification Standards

For the OLRT Project, Thales will adapt the System Safety Programme Plan (SSPP) plan that defines safety objectives, targets, and the required safety tasks for each of its projects. The OLRT SSPP will describe the methodologies and techniques to perform each safety task and address 'product' technical and management aspects. Other types of safety issues, such as site safety, will not be covered in this document.

This SSPP will describe the tasks and activities supporting application of the Thales generic SelTrac product safety case to the Project, building on the tasks and activities that have been performed in support of the product baseline. The tasks and activities within this scope, in many cases, take as inputs the artefacts produced in developing the product baseline, evaluating and updating based on the impact of the implementation details of the Project. The proposed solution is based on field-proven design which has been subjected to independent Safety Assessment, the core of which remains intact for this Project. The existing safety artefacts will be confirmed and reused for this Project, where appropriate. In all cases, the existing artefacts are thoroughly reviewed to determine appropriateness and extent of reuse potential. The reuse of existing safety artefacts aids in building strong safety arguments for the OLRT Project.

The SSPP embodies the principles, methods, and best practices used in the transit signalling industry, and complies fully with PA safety requirements. It is based on the processes defined in EN 50126, EN 50128, EN 50129 and EN 50159 specifications. The SSPP also defines tasks and documentation per Thales' own ISO-9001 Manuals and Work Instructions (WI) as referenced.

This SSPP consists of eight sections which will describe each component of the Safety Programme for this CBTC Project:

- Section 1 defines the scope of this document and provides a brief description of each section.
- Section 2 (References & Terminology) identifies the standards and references that will be used to guide system design and implementation to achieve required safety targets. Abbreviations and acronyms used in this document are listed and definitions of safety terms are provided in this section.
- Section 3 (System Description) describes the proposed CBTC System with focus on system architecture and its interface with other systems.
- Section 4 (Safety Targets) describes the safety objectives required to be met by system design and implementation and the safety process used to demonstrate the achieved performance.
- Section 5 (Safety Management Organization and Responsibilities) describes the CBTC project team organization and their responsibilities with respect to the safety programme.
- Section 6 (Safety Engineering) describes the CBTC project lifecycle and the safety tasks corresponding to each stage. The process to control safety-related hazards and service affecting failures throughout the Project lifecycle is described in this section. This process ensures that the implemented CBTC system attains the required safety targets.
- Section 7 addresses the strategy and necessary activities of the safety assurance and certification process.
- Section 8 lists the Project safety deliverables and briefly describes their content and delivery milestones.

5.4.4.9 System Redundancy

[redacted]

[redacted]

With all its servers being redundant, hot-standby configured, Thales ATS offers high availability through an architecture that accommodates two modes:

- Multiple users, with either central or local (Station) access
- Multiple types of operator responsibility configuration in terms of authority and area of control

DCS is a redundant network implemented using high-quality COTS components, distributed between control locations (TSCC, BCC, Stations, YCC), equipment rooms, trackside and on-board the Trains. The wired (802.3) and the wireless (802.11) components of the DCS use open-standard network protocols.

Redundancy of the Train-to-wayside radio network is discussed in the next section.

5.4.4.10 Train/Wayside Communications Reliability

In a Train Control environment, performance, reliability and mobility are key considerations. The Thales DCS ensures performance by providing a low mean message (IP packet) latency and a low packet error rate (PER) by providing a redundant on-board radio link and redundant wayside radio coverage. Each Train has a radio at both ends, and all VOBCs on the Train are connected to both radios. All messages between the VOBC and ATS or ZC are sent twice, and the IP addressing scheme transmits messages over two separate radio links. Only one message needs to be received for a successful transmission to occur.

[redacted]

[redacted]

5.4.5 OPERATIONAL PERFORMANCE REQUIREMENTS

This section summarizes the results of simulations performed to demonstrate that the proposed system meets all the City's Operational Performance requirements. Simulation details are presented in the Operation Performance Simulation. A narrative can be found in **Section 10.0.4**.

5.4.5.1 Validation of Operational Capabilities & Capacity through System Performance Simulations

System Performance Simulation is performed using a software program known as Muesli Standard which simulates Train movement through the entire guideway. Numerous functions are incorporated into the simulation to model the characteristics of a modern transit system:

- Train data: acceleration, service deceleration, emergency brake rate, brake application delay
- Guideway data: grade, civil speed limits, Stations and switch locations
- System data: speed measurement errors, Train positioning errors
- Overspeed tolerance, safety distance calculation algorithm, process delays
- Routing data

To take into account the variations in travel times at different Station segments, stochastic simulations were carried out to estimate terminal-to-terminal trip time variances. These simulations confirm that RTG's proposed system for the OLRT meets or exceeds all of the City's operational requirements:

- Peak line capacity of 11,429 PPHPD in Operating Scenario 1 and 18,151 in Scenario 2, which can be increased to an ultimate capacity of 24,000 PPHPD in Scenario 3
- Average standee density of 3.33 Passengers/m^2 during peak service, with 40 percent of the capacity provided by seats, and average standee density of 0.80 Passengers/m^2 during off-peak service
- Minimum turnback headway of 79 seconds (Tunney's Pasture) and 88 seconds (Blair) in ATO mode and 86 seconds (Tunney's Pasture) and 90 seconds (Blair) in manual operation (ATP Only mode)
- Single-track outage headway of 14:52 minutes in the longest single-tracking segment
- Maximum trip time of 22:21 minutes including Dwell Time in ATO, and 22:46 minutes in Manual mode

5.4.5.2 Proposed Consist Arrangements

The proposed Train consist for peak service is a two-car configuration. Each Vehicle has a length of 48.5 m, with the distance between the farthest doors in the two units being 83.7 m (see **Drawing 5.4.1-SW-102**). The carrying capacity of the Vehicle is illustrated in **Table 5.4-19**.

Table 5.4-19 | Vehicle Capacity

Passenger Capacity	Scenarios 1 and 2 3.33 standees/m²		Scenario 3 4.0 standees/m²		Off-Peak 0.8 standees/m2	
Seated Passengers	120	40.13%	120	35.82%	120	73.62%
Standing Passengers	180	59.87%	216	64.18%	43	26.38%
Total Passengers per Vehicle	300	100%	336	100%	163	100%

Each Vehicle is capable of carrying 300 Passengers at 3.33 standees/m^2 in Scenarios 1 and 2, and 336 Passengers at 4.0 m^2 in Scenario 3 during peak service. In off-peak service the average standee density of 0.8 standees/m^2 provides an even higher degree of Passenger comfort. Seated Passengers account for 40 percent of the total capacity in Scenarios 1 and 2, and over 35 percent in Scenario 3, thus meeting the comfort level requirement outlined in PA Schedule 15-2, Part 1, Article 2.6 (c).

5.4.5.3 Terminal Operations

To optimize for lower Driver hours and tighter headways, the double-platform turnback is preferred during peak periods for the following advantages:

- Shorter minimum turnback headways, especially for Scenarios 2 and beyond
- Fewer Drivers required
- Longer dwell time at the terminus for Drivers to travel to the opposite cab to reverse direction

Under the double-platform turnback, the terminal dwell is set to be identical to the operating headway. Terminal dwell during Peak Period is illustrated in **Table 5.4-20**. Under all scenarios the terminal dwell offers more than enough time for Passenger loading and unloading, as per PA Schedule 15-2, Part 1, Article 2.6 (f).

Table 5.4-20 | Terminus Stations - Peak Period Dwell

Peak Terminal Dwell	Scenario 1	Scenario 2	Scenario 3
Tunney's Pasture and Blair	189 seconds	119 seconds	105 seconds

To comply with the Article 2.6 (f) (iv) requirement to demonstrate the ability to reliably meet terminal time requirements, we undertook performance simulations to verify the minimum turnback headway at both Tunney's Pasture and Blair. The result (see **Table 5.4-21**), confirmed that the minimum turnback headway at both termini is well below the shortest operating headway in Scenario 3.

Tunney's Pasture is not expected to be a terminus Station in Scenarios 2 and 3, as per the AM Peak boardings and alightings data for Service Levels 4 to 9 in PA Schedule 10. Nevertheless the proposed solution shows that the Tunney's Pasture Station can meet the strictest turnback headway requirements, should the City choose to use Tunney's Pasture as a terminus in Scenarios 2 and 3. **Section 10.0.4.3** describes terminus operations.

Table 5.4-21 | Terminus Stations - Minimum Headway

Terminus	Turnback Headway (ATO)	Turnback Headway (Manual Operation)
Tunney's Pasture	79 seconds	86 seconds
Blair	88 seconds	90 seconds

5.4.5.4 Station Dwell Time Analysis

As per PA Schedule 15-2, Part 1, Article 2.6 (e), nominal dwell times at all Stations were determined based on directional peak hour boardings and alightings provided in the Schedule. Factors taken into account for the determination include boardings and alightings, number of doors per Train, operating headway, Passenger throughput per door, system communication factors etc. As per Article 2.6 (e) (iv), an absolute minimum Dwell Time of 20 seconds is applied at all Stations. Dwell Times are then included in calculating the maximum terminal-to-terminal travel time, as per Article 2.6 (e) (i). **Section 10.0.4.4** fully describes the analysis.

5.4.5.5 Capability to Reliably Support Headway Requirements

To demonstrate the capability to reliably support headway requirements, RTG carried out two simulations. First, the minimum turnback headway was determined and compared against the peak headways of the System in Scenarios 1, 2 and 3. Second, the design headway of each inter-Station section of the guideway was also determined and compared against the peak headways.

The first step involves determining the minimum turnback headway. This is illustrated in **Section 5.4.5.3**, where minimum turnback headways at Tunney's Pasture and Blair are calculated to be 79 seconds and 88 seconds in ATO, and 86 seconds and 90 seconds in manual operation. All minimum turnback headways are comfortably below the tightest requirement of the105 seconds headway in Scenario 3. The second step involved determining the design headway of the guideway by performance simulation. Results of the simulation are presented in **Table 5.4-22**, where design headways in all guideway sections meet the 105 seconds headway. Combining the two steps demonstrates compliance with PA Schedule 15-2, Part 1, Article 2.3 (a): the System can reliably support a sustained operational headway of 2 minutes or less.

Table 5.4-22 | Design Headway at each Inter-Station Section

Inter-Station Section	Design Headway (Eastbound)		Design Headway (Westbound)	
	ATO	Manual	ATO	Manual
Tunney's Pasture – Bayview	59	61	36	36
Bayview - LeBreton	57	59	58	60
LeBreton – Downtown West	71	74	57	60
Downtown West – Downtown East	82	85	77	79
Downtown East – Rideau Centre	74	77	81	83
Rideau Centre – Campus	62	63	70	73
Campus – Lees	72	75	68	70
Lees – Hurdman	63	66	67	67
Hurdman – Train Station	62	65	69	72
Train Station – St. Laurent	57	60	55	57
St. Laurent – Cyrville	61	63	71	73
Cyrville – Blair	31	32	58	60

5.4.5.6 Single-Track Operation Headway

As per Schedule 15-2, Part 1, Article 2.3 (b), the System is designed to support a sustained operational headway of 15 minutes during a single track outage. To comply with this requirement, RTG simulated performance to determine the sustainable headway in all single track outage scenarios in the System. **Figure 5.4-25** illustrates the single-tracking scenarios. This calculation of the single-track operation headway takes into account the track length, number of Station dwells, and allowable speed between the switches used to bypass the failed track. The result of the simulation is presented in **Table 5.4-23**.

The worst-case single track outage headway is 14:52 minutes. System design thus complies with the Article 2.3 (b) requirement. The SelTrac CBTC System also supports "fleeting" of Trains through a single tracking section whereby multiple Trains can be sent through the section in alternating directions. This function has proven to significantly increase single tracking Passenger throughput on the Canada Line. RTG will recommend single0tracking fleeting when preparing OLRT operational procedures in cooperation with the City.

Figure 5.4-25 | Single-Tracking Scenarios

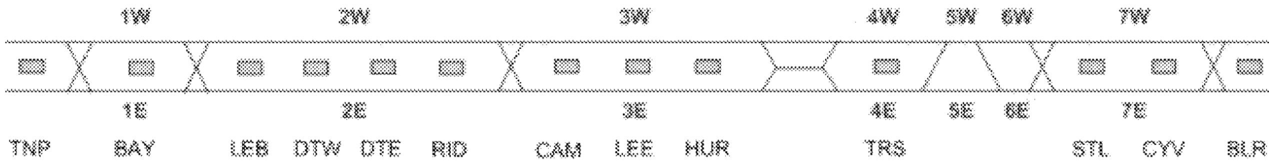


Table 5.4 -23 | Single-Track Operation Headways

Segment with Outage	Bypass Route	Minimum Headway (minutes)
1E	1W	5:10
1W	1E	5:03
2E	2W	14:43
2W	2E	14:52
3E	3W-Pocket	10:43
3W	Pocket-3E	10:02
4E	Pocket-4W-5W	4:37
4W	4E-Pocket	3:12
5E	5W	0:51
5W	6E-5E-4E-Pocket	4:59
6E	5W-6W	2:09
6W	6E	1:41
7E	7W	9:09
7W	7E	9:01
Pocket Section	4E-3E	13:53

5.4.5.7 Project End-to-end Trip Times

With all Inter-Station Travel Times and Station Dwells determined for Year 2021 and 2031 in both ATO and Manual operation, the End-to-End trip times are presented in **Table 5.4-24**. All scenarios meet the maximum terminal-to-terminal trip time requirement of 24 minutes in Manual mode and 23 minutes in ATO mode, as defined in PA Schedule 15-2, Part 1, Article 2.7.

Table 5.4-24 | End-to-End Trip Times

Direction	Year	Operations Mode	Trip Time
Eastbound	2021	ATO	22:17 minutes
Eastbound	2021	Manual	22:44 minutes
Westbound	2021	ATO	22:21 minutes
Westbound	2021	Manual	22:55 minutes
Eastbound	2031	ATO	22:15 minutes
Eastbound	2031	Manual	22:46 minutes
Westbound	2031	ATO	22:10 minutes
Westbound	2031	Manual	22:44 minutes

5.4.5.8 Validation of Operating Scenarios 1 and 2

With the relevant data presented in the above sections, **Table 5.4-25** presents the System capacity for Scenarios 1 and 2.

Table 5.4-25 | System Capacity

	Scenario 1 (Year 2021)	Scenario 2 (Year 2031)
Peak Headway	189 seconds	119 seconds
Terminal Dwell	189 seconds	119 seconds
Cycle Time	3052 seconds	2903 seconds
Capacity per Train	600	600
AM Peak Capacity	**11,429**	**18,151**
Capacity Requirement (Schedule 15-2 Part 1 Article 2.5)	**11,360**	**18,040**

5.4.5.9 Approach to System Expansion for Operating Scenario 3

At-grade Station platforms will be built to accommodate Scenario 2 (90 m) and designed to be expandable to 100 m to accommodate Scenario 3. The Underground Stations will be built to accommodate Scenario 3. The MSF site will be built to accommodate the LRVs required to meet Scenarios 1 and 2, as well as any non-revenue and specialty maintenance vehicles. The MSF Building will be designed to be expandable to accommodate Scenario 3. **Table 5.4-26** shows the headway for Operating Scenario 3 with the proposed Vehicle operating as a two-Vehicle Train, as well as options to achieve the compliant headway of 105 seconds.

Table 5.4-26 | Scenario 3 Operating Headway

Line Capacity	Vehicle Capacity	Passenger Density (p/m^2)	Percent Seated (%)	Proposed Headway (s)	Specified Headway (s)	Total Vehicles[1]
24,000	336	4	35	101[2]	105	58
For Compliant Headway:						
23,040[3]	336	4	35	105	105	56
24,000	351	4.27[4]	34.3	105	105	56

Line Capacity	Vehicle Capacity	Passenger Density (p/m²)	Percent Seated (%)	Proposed Headway (s)	Specified Headway (s)	Total Vehicles[1]
24,000	351	4	29.7[5]	105	105	56
24,000	Average 351[6]	4	35	114	105	10+46

Notes:

1 Not including spares

2 The system design will accommodate the 101s headway. A shorter headway is achieved regularly on by the Thales CBTC System on Vancouver SkyTrain between Broadway and Waterfront Stations

3 Non-compliant capacity by 4%

4 Non-compliant Passenger density by 7%

5 Non-compliant seated% by 5.3%

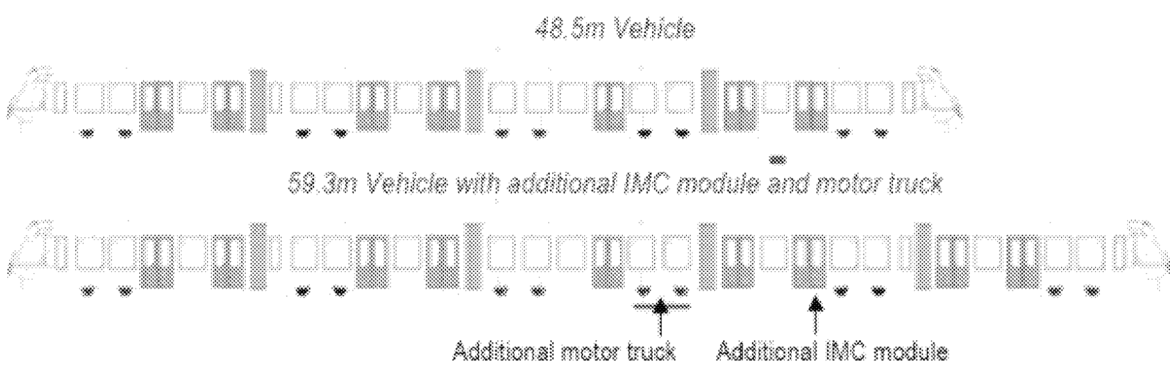
6 Average capacity of a mixed fleet of 48.5 and 59.3m long Vehicles (see below)

RTG will procure the Vehicles to accommodate the opening year. This will be accomplished with a two-Vehicle Train, each Vehicle being 48.5 m long (including the coupler the overall Vehicle length is 98 m). The distance between the outside faces of the end doors is 83.7 m. The Vehicles will allow for future fleet expansion to accommodate Scenarios 1, 2 and 3.

A headway of 114 seconds for Scenario 3 can be achieved with a mixed fleet of 48.5 m and 59.3 m long Vehicles as follows:

- The 59.3 m Vehicle is obtained by adding a new IMCx module to a 48.5 m Vehicle to increase Passenger capacity to 419 (see **Figure 5.4-26**).
- Coupling a 59.3 m Vehicle with a 48.5 m Vehicle will result in a 108.8 m long Train. The distance between the outside faces of the end doors is 94.5 m. The Underground Station platforms are sized to accommodate this and the At-grade Station platforms will be extended to 100 m to accommodate the longer Train. The MSF Building will be designed so that it can be expanded as required. Additional storage tracks will need to be built as shown on the drawings. The City can elect whether a storage shed is needed for these Vehicles.
- To comply with the specified peak hour headway, the average consist capacity should be 752 Passengers. This can be achieved with ten 108.8 m Train plus eighteen 98 m Trains. Therefore, 10 of the longer Vehicles are required.

Figure 5.4-26 | Addition of New Modules



The proposed timing of the changeover to the longer Vehicle is as follows. For Scenario 2 in 2031, 50 Vehicles (25 Trains) are required. This fleet will be increased to 58 Vehicles to handle Service Level 9 in 2046.

Once the City elects to initiate Scenario 3, the 10 additional IMCx modules will be manufactured and added to 10 of the existing 48.5 m long Vehicles. It will take six weeks to extend each Vehicle. To limit service impact, we propose to modify one Vehicle every three weeks, so only two Vehicles will be out of service at any one time. However, since two extra Vehicles are required for Service Level 9 the fleet will be fully operational even when two Vehicles are being extended. The total retrofit duration will be less than 1 year.

However, there are other options to achieve a 105 second headway which are more economical for the City:

- Slightly increasing Passenger density from 4 Passenger/m^2 to 4.3 Passengers/m^2 OR
- Nominally reducing the percentage of seated Passengers from 35 to 30 percent (a difference of approximately 10 seats)

5.4.6 NON-REVENUE VEHICLES

This section examines non-revenue vehicles, their specific tasks and lessons from other projects about purchasing vehicles.

5.4.6.1 Vehicles for Specific Maintenance Activities & Tasks

The non-revenue equipment that RTG proposes to use for maintenance of the system will consist of both Hi-Rail and Rail-Bound equipment (see **Table 5.4-27**). The strategy is to use Hi-Rail (road/rail equipment) wherever possible to maximize work time and accessibility to the system. Because much of the OLRT will be at grade, access points can be provided at various points on the system where Hi-Rail equipment can be driven to by public roadway. This will maximize available work time as this equipment can be ready to access or clear the system immediately at the start and end of the work window, and typically much closer to the work location. Because Rail-Bound vehicles are confined to rail movement, they have to be driven on the rails between the MSF and the work location, and typically after all Trains have cleared the system or before Trains have launched onto the system. This significantly reduces the amount of productive work time that is available for Rail-Bound equipment. Despite this disadvantage, there are numerous operations where Rail-Bound equipment is more capable; thus, RTG intends to use both. For specialized equipment that will not be used on a frequent or consistent basis, RTG intends to contract this work out rather than purchase and maintain equipment that would be vastly underused. Examples of such equipment would be production tampers, stabilizers, track geometry measurement equipment, and ultrasonic rail flaw detection equipment. All these services are readily available in the Ottawa area.

Table 5.4-27 | RTG Non-Revenue Equipment List (RB = Rail Bound, HR = High Rail)

Description	Type	Qty	Primary User	Anticipated Specifications
Train Shunter	RB	1	Shunt and position Trains in the MSF where no overhead power is available	Rechargeable battery-powered electric
Utility Maintenance Vehicle	RB	1	Crew transport, materials handling, track and OCS maintenance, Train rescue.	Requires towing capacity, deck, crane, crew compartment, bucket, hydraulic circuits, and Train couplers on both ends.
Trailers	RB	3	To be towed behind utility maintenance vehicle. One for general materials handling, one for cable handling, and one for tunnel wash equipment.	10 tonne useful load, air brakes, 7.0 m x 2.5 m decks.
Large Hi-Rail Trucks	HR	2	One for welding and heavier track maintenance One for OCS inspection and work	Ford F-750 or equivalent. One with complete welding set-up, one with double buckets for OCS work.
Smaller Hi-Rail Trucks	HR	2	One for guideway inspection and light repair One for signal system inspection and light repair	Ford F-350 4x4 crew cabs or equivalent
Ballast Regulator	RB	1	Regulating ballast in summer, snow clearing in winter	Industry standard ballast regulator with snow fighting attachments
Rail Grinder	RB	1	Rail grinding to address corrugation and rail	Minimum 8 stone, programmable

Description	Type	Qty	Primary User	Anticipated Specifications
			profile	rail profiling, sealed pressurized cab, dust collection.
Multifunction road/ rail Loader/ Excavator	HR	1	Multi-function materials handling, excavating, loading, rail handling, snow fighting, vegetation control.	360° road rail excavator with attachments
Spot Tamper	RB	1	Spot surfacing of slab to ballast sections, switches, low spots	Spot utility 16 tool tamping machine

NOTE: All motorized equipment will be diesel powered and equipped with scrubbers to reduce emissions and be tunnel safety compliant.

5.4.6.2 Lessons Learned about Non-Revenue Vehicle Purchases from Other Projects

Purchase Equipment that is Industry Proven when Needed

Purchasing hi-tech equipment/vehicles (requiring specialized training to operate and maintain) at the start of an operation usually means that this equipment is not used as intended when required. The employees trained to operate and maintain the equipment are usually not the ones around when the equipment or vehicle is needed to perform maintenance or repairs. Technology changes and, in most cases, the equipment becomes obsolete.

Purchase Vehicles and Equipment that Fit your System

Purchase vehicles and equipment that can negotiate the track geometry in the yard and main line. On transit systems, smaller vehicles and equipment work better in the tighter clearance areas. Also, the hi-rail vehicles can manoeuvre better in urban environments and access the track easier.

Purchase Equipment that can do Multiple Tasks

A bucket truck can replace a platform truck for OCS maintenance and be more flexible in low-clearance areas. It can also be used by facility maintenance to support lighting maintenance and platform maintenance.

5.4.7 TRACTION POWER

5.4.7.1 Traction Power Supply Design Process

The design methodology of the traction power supply employs a computer simulation technique, computer-based "traction load flow modeling". The model used for this Project is Train Operation Model (TOM) comprising two parts: Train Performance Simulation (TPS) and Electric Network Simulation (ENS).

TPS requires accurate Train and guideway data as well as Train loading, Station dwell times and speed restrictions for inputs. TPS modeling results should provide the following information:

- Train power profile output
- Train trip distance shown in TPS output summary
- Train trip time shown in TPS output summary
- Train energy consumption in each trip shown in TPS output summary
- Train energy consumption per km per car in TPS output summary

The computer ENS modeling requires accurate traction power electric network data, Train operation data as well as the Train power profile from the output of the TPS. ENS simulates a fleet of Trains based on Train operation data and calculates the current voltage and power flow on the proposed traction power network modelled. ENS modeling results should provide the following information:

- Current output measurement along the traction power electric network, which includes transformer-rectifier dc rms current at each substation, RMS currents on dc feeders from each substation to OCS
- Load curve output at each substation rectifier
- Transformer-rectifier dc current graphs in each substation
- Train voltages, in voltage scattering charts

ENS results will be used to verify adequacy of substation capacity, OCS and its associated dc feeder cable current rating in the proposed traction power supply system and the minimum Train operation voltage given by Alstom. If the simulation indicates components of the traction power system are overloaded or under-used, adjustments would be made to the traction system model and the simulation redone.

5.4.7.2 Traction Load Flow Modelling Results & Parameters

The traction power system will be designed for the capacity of Scenario 2 (18,040 pphpd) with the capability to be upgraded to Scenario 3 (24,000 pphpd). The system will be able to sustain full performance service in both normal (all TPSS in service) as well as in contingency (any one TPSS out of service).

A simulation was performed based on equipment sizes and TPSS locations indicated in **Section 5.4.7.5**. The traction power system characteristics included the following:

- 8 TPSS – each with one 3 MW extra heavy-duty rectifier
- 1500 V dc traction voltage
- Feeder Cables from TPSS to OCS – 3x500 kcmil
- OCS – one 500 kcmil messenger wire and one 350 kcmil contact wire (20 percent wear)
- Running rail – 115 lb AREMA with 10 percent wear

Scenario 2 was simulated with all TPSS in service and each TPSS out of service, for the contingency situations. The following acceptance criteria validated the proposed traction power system:

- Rectifier RMS current does not exceed 2000 A (rated load of rectifier) if no TPSS is out of service
- Rectifier RMS current does not exceed 3000 A (150 percent rated load of rectifier) if the neighbouring TPSS is out of service
- No more than one percent of the total Train voltage samples falls below the minimum Train operation voltage of 1000 V

Simulation results indicate the traction power system proposed meets or exceeds OLRT requirements. **Table 5.4-28** summarizes the TPSS loading and Train voltage from the simulation. See **Cut Sheet 5.4.3-RP-100** for the simulation graphs.

Table 5.4-28 | Scenario 2 – TPSS Transformer Rectifier Unit Loading

Traction Power Substation	Normal Case Rectifier Output Current (A rms)	TPSS Out of Service Maximum Rectifier Output Current (A rms)
TPSS-01	896	1385
TPSS-02	1126	1808
TPSS-03	1052	1541
TPSS-04	819	1356
TPSS-05	843	1332

Traction Power Substation	Normal Case Rectifier Output Current (A rms)	TPSS Out of Service Maximum Rectifier Output Current (A rms)
TPSS-06	1086	1401
TPSS-07	1305	1697
TPSS-08	978	2161

Scenario 3 was simulated with all TPSS in service and each TPSS out of service, for the contingency situations. The result of the simulation indicates an extra messenger wire will be required to minimize voltage drop along the OCS and therefore increase the Train voltage to an acceptable level for the contingency cases. An additional feeder cable (to 4x500kcmil) from the TPSS to the OCS will also be required. **Table 5.4-29** shows is the TPSS loading and Train voltage with these additions. See **Cut Sheet 5.4.3-RP-100** for the simulation graphs.

Table 5.4-29 | Scenario 3 – TPSS Transformer Rectifier Unit Loading

Traction Power Substation	Normal Case Rectifier Output Current (A rms)	TPSS Out of Service Maximum Rectifier Output Current (A rms)
TPSS-01	1439	2277
TPSS-02	1719	2558
TPSS-03	1629	2375
TPSS-04	1391	2063
TPSS-05	1079	1626
TPSS-06	1104	1657
TPSS-07	1160	1697
TPSS-08	707	1299

5.4.7.3 Traction Power Supply Design, Failure Modes & Mitigation

Traction Power Supply Design

The traction power system will be designed based on the loadflow study. The medium-voltage ac switchgear, transformer rectifier units, 1500 Vdc switchgear, isolating disconnect switches, feeder cables and overhead contact system will be designed to accommodate the rms current loads as well as peak overloads typical for a transit system without detriment to the equipment.

A negative rail grounding switch will be provided in each TPSS to ensure the negative bus-to-ground voltage does not exceed PA requirements by shorting the negative bus to ground if the voltage exceeds a preset level. The rail grounding switch also provides an analog output to SCADA of the negative bus voltage to ground voltage

Failure Modes & Mitigation

To mitigate service deterioration in system failure mode all OCS sections are tied at substation locations through dc switchgear buses. Each OCS section is fed from two neighbouring substations at both ends. Two bypass power switches will be provided for both eastbound OCS and westbound OCS at each substation location except two terminal substations. In addition one power switch will be provided at each terminal substation for emergency tie between eastbound OCS and westbound OCS.

If the traction power supply system is in failure mode (either the substation out of service or breaker in dc switchgear tripped), the bypass power switches will close to ensure that the OCS section passing through the failed substation is still fed from two neighbouring substations at both ends. If the terminal substation is out of service or the breaker in terminal substation dc switchgear is tripped, the emergency tie switch will close to ensure that the OCS section passing through the failed substation is still fed from two dc feeder breakers at both ends, although two breakers are located in the same dc switchgear in the neighbouring substation.

Since all OCS sections are tied and fed from two ends in both normal mode and failure modes, this traction power supply design is very reliable. Since the traction power equipment rating in this design is based on 150 percent overload for two hours, the OLRT system can operate with one substation out of service for two rush hours without any service degradation.

Even if the traction power supply system is in failure mode with more than one substation out of service, all OCS sections are still fed from two ends and the system is still very reliable and can operate with reduced service.

The two lead tracks to the MSF will be provided with feeds from the MSF Yard TPSS and the mainline TPSS-06. In normal operation the lead tracks will be fed from the MSF Yard TPSS with the feeds from mainline TPSS-06 normally open. If a Hydro Ottawa outage occurs to the MSF Yard TPSS, the feeders from mainline TPSS-06 can be closed to provide limited 1500 Vdc traction power to the MSF Yard.

The MSF Yard will be sectionalized with separate feeders to the storage lanes and other tracks in the Yard. Each feeder for the storage lanes will not feed more than four lanes. Tracks to the vehicle wash, vehicle inspection platforms and vehicle lathe will also be separately sectionalized. All sections, with the exception of the vehicle wheel lathe, will be provided with manually operated disconnects to provide alternate feeding to the section.

Interfaces to Hydro Ottawa (HOL)

Medium voltage service of either 13.2 kV or 27.6 kV will be provided by HOL for the Traction Power Substations, underground stations and the MSF. The feeds provided will be looped, radial or distribution loop. The medium voltage will follow HOL's Planning Report.

For each medium voltage service, RTG is responsible to provide HOL switchgear pad (or room for Downtown West Station, Rideau Station and MSF Building), grounding and the necessary ducting as per HOL requirements. HOL will supply and install the HOL switchgear and metering transformers.

A branch feed will be provided at the TPSS to feed the Station transformer for Stations close to the Traction Power Substation:

- Tunney's Pasture
- LeBreton
- Hurdman
- Train
- Cyrville
- Blair

Stations that are not close to traction power substations will be fed separately via low voltage from HOL, in which HOL will provide and install the HOL switchgear, metering and power transformer. These Stations are as follows:

- Bayview
- Campus
- Lees

Underground Stations (Downtown West, Downtown East and Rideau) will be fed from a dual loop from HOL at Downtown West and Rideau and the two feeds will be looped between the three Stations. The HOL feeds will be as per Option F of the HOL Planning Report.

Power Management and Monitoring

The medium-voltage ac switchgear feeder cells will be provided with digital metering devices to monitor power flow. This will be connected to SCADA for monitoring and logging at the Control Center. For Stations that are not fed from a nearby traction power substation, digital metering will be provided on the main low-voltage switchboard and will be connected to SCADA.

5.4.7.4 Preliminary Single Line Diagram

Preliminary single line diagrams are provided for the mainline and MSF:

- For the mainline, refer to **Drawings 5.4.3-SW-101 to 5.4.3-SW-106**
- For the MSF, refer to **Drawings 5.4.3-SW-108 and 5.4.3-SW-109**

5.4.7.5 Proposed Substation Locations

The eight TPSS will be located along the mainline and two TPSS will be located in the MSF as per **Table 5.4-30**. The actual location and space requirements of the mainline are shown in **Drawings 5.4.5-SW-101 to 5.4.5-SW-108**.

Table 5.4-30 | TPSS Locations

TPSS	Chainage	Location
TPSS-01	98+150	West side of Tunney's Pasture Station
TPSS-02	100+270	LeBreton Station
TPSS-03	102+470	Within Rideau Station
TPSS-04	104+110	
TPSS-05	105+540	
TPSS-06	106+850	
TPSS-07	108+710	West of Cyrville Station
TPSS-08	110+610	East of Blair Station
TPSS-YARD		
TPSS-SHOP		Within Admin/Shop Building

5.4.8 OVERHEAD CATENARY SYSTEM

5.4.8.1 OCS Description

The mainline OCS will a simple catenary consisting of a 350 kcmil hard drawn copper contact wire and a 500 kcmil, 37 strand hard-drawn copper messenger wire. Typical stagger will be 300 mm maximum. The OCS will be designed for the temperature variation and ice loading of the Ottawa environment.

5.4.8.2 Typical OCS Arrangements

For the at-grade and elevated sections of the mainline, Simple Catenary auto-tensioned will be used. The contact wire height from top of rail will vary to provide clearance from the structures, and system depth will be 1200 mm. The poles will be round tapered and generally be between the tracks with spacing no more than 60 m. The poles may be coloured to blend into the surroundings. Tension lengths will be no more than 600 m to accommodate the large variation of ambient temperature in the Ottawa environment. Tensioning will be by balanced weight assemblies. Short tensioning sections, for example in the special trackwork, will be done by spring tensioners.

Insulated overlaps will be provided at TPSS for sectioning the OCS. Insulated overlaps will also be provided at crossovers to further sectionalize the OCS. These overlaps will be located to allow for Train movement and turnback without loss of traction power. Pole-mounted disconnect switches (normally closed) will be provided at these overlaps to allow normal power flow in the OCS section.

For the MSF Trolley, fixed termination system will be used. The contact wire will be supported by either single or back-to-back pole-mounted cantilever arms or head-span arrangements. For the storage lanes, the single contact wire will be supported by head spans.

Tunnel OCS Arrangements

For tunnels and underground areas, rigid conductor rail will be used for this Project. This includes the downtown section underground section, St. Laurent and the tunnel on the MSF connector. The benefits of rigid conductor rail include the following:

- Ease of installation
- Minimal maintenance required
- Higher conductivity than simple catenary to reduce voltage drop to the Trains
- Reduced tunnel height
- No tension, therefore wire breakage is not an issue

Height-Constrained OCS Arrangements

Elastic supports will be used at existing overpasses with minimal clearance:

- The Transit structure just west of Tunney's Pasture Station (4.44 m clearance)
- Highway 417 at Lees Station (4.6 m clearance)
- Highway 417 off-ramp (4.6 m clearance)

For these low-clearance areas, the messenger wire may be terminated onto the overpass (fixed termination) or guided under the overpass using insulated pulley wheels.

5.4.8.3 Minimization of the Visual Impact of the OCS

To minimize the visual impact of the OCS on the mainline, the OCS will be designed to have a pole spacing of 60 m and typically be located in the centre to minimize the number of poles. The poles will typically be round and tapered and can be coloured to match the surrounding environment. Further aesthetic design to ensure the OCS poles blend into the surroundings will be developed.

5.4.8.4 Power Controls & Sectionalization

Sectionalization will be provided as shown on the preliminary traction power system single line drawings. For the mainline, sectionalization will be provided around crossovers. For the isolation of faulted sections, the mainline will be provided with motorized disconnect switches and the MSF will be provided with manually operated disconnect switches. Control of the mainline switches and monitoring of all the switches will be provided through SCADA from the Control Centre.

5.4.8.5 Passenger & Public Protection from OCS Failures

Clearance to the live parts of the OCS will adhere to EN 50122-1. Where clearances cannot be met, protective screen or guards will be installed. Metallic guards or other metallic items which may become energized due to an OCS failure will be properly bonded to the grounding system.

Catenary shrouds will be provided on bridges and other locations where pedestrian traffic is close to the messenger/contact wire. Signage warning will be provided along the guideway warning the public of the proximity of high voltage.

5.4.8.6 Methods to Reduce EMI Impacts to Sensitive Receptors along the Alignment

EN 50121 will be used as the design basis for the component and overall System emissions and immunity. All equipment procured will be expected to carry certification of testing and compliance with the section of the standard relevant to the equipment and its application.

Knowing the design basis, and in accordance with the requirement of PA Schedule 15-2, Part 4, Article 9.1 (h), we will then develop an "Electromagnetic Compatibility Identification" document which will lay out all expected sources and levels of electromagnetic noise coming from the OLRT, seek to identify all sensitive receptors along the alignment, and then provide information to those receptors on the EMI emanating from the new OLRT.

It is expected that these receptors, along with other Stakeholders, will use this information to review their equipment and operation and advise if they believe that there is a risk from rail operation to their systems or equipment. Upon receipt of any concerns from the receptors and external Stakeholders, we will review the nature of their concerns and, if necessary, discuss and agree on the most appropriate way of mitigating such interference to an acceptable level.

Additionally, the document will also identify any known, existing, external systems that lie within the limits of the OLRT's operating area that may themselves pose a risk to the safe operation of the railway and need to be mitigated accordingly.

Having identified the potential risks, both from and to the railway, we will develop an "EMC Control Plan", based around EN 50121-1, that will lay out a systematic, layered approach to all identified risks, ensuring we meet the required level of management of the risk of EMI to the OLRT and to the parties adjacent to the line.

This is the approach adopted and used successfully to engage with parties such as the Vancouver Airport Authority and NAV CANADA for the Canada Line in Vancouver.

5.4.9 COMMUNICATION SYSTEM

RTG's OLRT Communications System will meet PA Schedule 15-2, Part 4 requirements. The systems and their component elements will use modern, Project-appropriate technology for safe, efficient operation to be centred in the MSF and TSCC.

Fixed-facilities communication systems will be designed around a backbone of a new Communications Transmission Systems (CTS) linking Belfast Road's TSCC and MSF with the new transit Passenger Stations and sub-stations. The CTS will be the transmission medium for all internal operations-related communication systems (e.g. SCADA, public address (PA), telephony, CCTV) and external systems (e.g. Fare Collection

Communication systems transmission between Train and wayside will be designed around high-speed radio systems transmitting CCTV and other bandwidth-intensive data both to and from the Train, when the Vehicle is either in a Station or in storage at the MSF. Lower-speed data and voice communications to and from the Train will use the future Ottawa PSR system linked to dispatchers in the TSCC and servers in the MSF.

The individual communication systems provided will be built to comply with the latest editions of the codes, regulations, and standards listed within PA Schedule 15-2 Part 1 and will meet the reliability, availability, maintainability, and safety

(RAMS) requirements. See **Drawings 5.4.6-SW-102** for Communications Systems context and interaction and **5.4.6-SW-103** for overall system topology.

5.4.9.1 Facilities

OLRT Control Centres

There are three Control Centres to be delivered as part of the OLRT Project: the Transportation Services Control Centre (TSCC) at 875 Belfast Road, the Back-up Control Centre at the MSF and the Yard Control Centre, also at the MSF. Additionally, the main communications servers for the OLRT System will be located in the Main Communications Room (MCR) in the MSF.

TSCC

The TSCC is currently the Bus Control Centre that will be extended to become the main control centre for the OLRT System. As part of the Project, we will provision three new workstation locations in the existing Bus Control Centre at 875 Belfast Road; each workstation will be fully equipped to interface with the systems detailed above. In addition to workstations, we will install CTS communications equipment, video servers and long-term storage and a new Overview Video Wall displaying SCADA, CCTV and CBTC information.

We will also interface to existing systems such as the PA/PIDS workstation, the existing IAC system and the TSCC PABX as well as to future systems including the new Ottawa PSR system.

The TSCC will interface to the communications servers in the MCR at the MSF over the CTS; it will also communicate out to the Constellation Data Centre for off-system OLRT data storage.

BCC

The Back-up Control Centre (BCC) will be located adjacent to the Yard Control Centre in the MSF. It will provide an alternative control centre location for OLRT Operations should the TSCC become unavailable for any reason. As with the TSCC, it will interface to the Communications servers in the MCR.

YCC

The Yard Control Centre (YCC), located adjacent to the BCC in the MSF, will provide for operation of the MSF Building and yard including security and facilities monitoring and control. The YCC will use the communications servers in the MCR to monitor and control the Yard in the same way as the TSCC and BCC use the servers to monitor and control the main line.

OLRT Stations and Fixed Facilities

The OLRT has 13 Stations along the alignment each allowing Passengers to enter/exit the OLRT System and, in several cases, providing intermodal transfer with buses. Additionally, 10 Traction Power Substations (TPS) will be built to provide electrical motive power to the Trains along with Station power in instances where facilities are co-located. These facilities will be monitored by the Communication Systems with data provide to both TSCC and YCC staff.

At Stations, the communication systems will include CCTV for both operational and security needs, PA system to inform the public audibly on travel and other important information, and Passenger Information Display Systems (PIDS) that will provide visual information. Help Phones will be located throughout the public spaces to provide Passenger assistance facilities, with other telephony devices distributed throughout the facilities to provide service for both OC Transpo and RTG staff. Other facilities such as BAS/BMS and SCADA will enable TSCC staff to manage Station facilities with IAC systems providing building and facility security protection.

Similarly, other fixed facilities (e.g. TPS) will be managed through SCADA and provided with telephony communications and IAC system for protection

Main Communications Room

Central communication systems equipment will be located in the Main Communications Room (MCR) in the MSF with local facilities being located in Station communication rooms and satellite locations such as TPSs. Links will be established between the MCR and TSCC operator workstations to enable interaction between TSCC staff and the distributed communication systems; in a similar fashion, local links within the MSF Building will connect the BCC and YCC workstations to the MCR.

5.4.9.2 OLRT Key Subsystems

This section describes the following key OLRT subsystems:

- CTS – Communications Transmission System
- PA – Public Address
- PIS (PA and PIDS)
- CCTV – Closed Captioned Television
- IAC – Intrusion Access Control
- Telephone and Intercom
- SCADA – Supervisory Control And Data Acquisition
- CBTC – Communication-Based Train Control
- BAS
- BMS
- Radio – Radio communications
- Train-to-Wayside Wireless system

The overall systems topology diagram, communications subsystems conceptual diagram, and all other subsystem specific diagrams referenced in the following text are listed in **Table 5.4-31** with their drawing numbers.

Table 5.4-31 | System and Subsystem Drawings

Drawing Title	Drawing Number
Communication System Context Diagram	5.4.6-SW-102
Overall Systems Topology/ Connection Diagram	5.4.6-SW-103
Communications Fibre Cable Distribution Conceptual Diagram	5.4.6-SW-104
Comms Passenger Information System Conceptual Diagram	5.4.6-SW-106
Communications Telephony System Conceptual Diagram	5.4.6-SW-107
Comms CCTV System Conceptual Diagram	5.4.6-SW-108
Comms SCADA System Conceptual Diagram	5.4.6-SW-109
Comms Train-To-Wayside Wireless System Conceptual Diagram	5.4.6-SW-110
Comms Station BMS Connection Diagram	5.4.6-SW-113
Communications General Connection Diagram	5.4.6-SW-114
Comms Station LAN Connection Diagram	5.4.6-SW-115
Comms TSCC & Data Centre LAN Connection Diagram	5.4.6-SW-116
Comms MSF LAN Connection Diagram	5.4.6-SW-117
Communications-Train Control Context Diagram	5.4.6-SW-119

Communications Transmission Systems

The Communications Transmission System (CTS) will comply with PA Schedule 15-2, Part 4, Article 6 requirements; it will comprise both WAN and LAN components in each operational building and it will be equipped with a Network Management System (NMS).

CTS – System Description

The CTS will comply with the PA Schedule 15-2, Part 4, Article 6 operational and performance requirements; it will comprise both WAN and LAN components in each operational building and will be equipped with a Network Management System (NMS).

In general, the system will provide operational interfaces, connectivity and transportation for the following:

- Supervisory Control and Data Acquisition system (SCADA)
- Telephony and PABX
- Closed Circuit Television System (CCTV)
- Public Address system (PA)
- Passenger Information Display System (PIDS)
- High-Speed Wayside Radio Communications subsystem
- Automatic Fare Collection system (AFC)
- Signalling system
- OC Transpo and M&R corporate LANs (Station LANs back to TSCC or MSF)

Provision will be made on the direct fibre network to support fire- and life-safety system connectivity. RTG recognizes that we cannot carry certain fire- and life-safety services over core hardware due to regulatory restrictions.

The overall fibre-based network will provide high-speed, resilient transmission and connectivity of the systems listed above between all Stations and substations on the new line, and to the new MSF and TSCC. Local fibre and copper cabling will be used to connect individual devices and local networked equipment to the dual-pathed and redundant high-speed network nodes.

The CTS deployed will be of the latest proven technology, will comply with all applicable standards and will be compatible with the existing OC Transpo CTS system as required in PA Schedule 15-2, Part 4, Article 6. The final selection of equipment, functionality and topology will be carried out during the design phase to gain maximum benefit from the latest available and transit proven technologies.

Nodes

All CTS node equipment, including local device interfaces, will comply with IEEE standards and International Telecommunication Union ITU-T recommendations for Ethernet based networks. All nodes will have common features across the deployed system:

- High reliability and availability as shown through RAMS analysis
- Flexible equipment configuration and control
- Integrated interface for maintenance operations through the Central NMS
- Integrated alarm monitoring on all local nodes and through the Central NMS
- Non-traffic affecting test points on all nodes.

CTS nodes will provide network connections for all interfaces required for this Project; we do not anticipate any need for separate converters. All nodes are to be supplied with a minimum 50 percent spare capacity that can be used by any selected function or facility as required.

The CTS network will provide 100 percent protection to all traffic in the event of a network fibre break and will be capable of executing a network re-route in less than 50 ms from detection of network failure on the primary path; the final protection strategy will be agreed during the design stage. **Drawing 5.4.6-SW-114** shows the general network connection design for RTG's proposed CTS with drawings showing Station LAN, TSCC LAN and MSF LAN listed in **Table 5.4-31**.

Integration with OC Transpo systems and details on security of the overall network are discussed in **Sections 5.4.9.3, 5.4.9.4** and **5.8.4.5** of this Response.

CTS Fibre Architecture

Two single-mode, 48-strand fibre-optic cables will be run from the TSCC passing through the new MSF and out to the Stations and other operational buildings. The cables will be installed in a Station-hopping configuration as described below to provide communications path redundancy and diversity. The fibre cable used for the CTS will be standalone from the CBTC fibre backbone and Access Point fibre distribution cables.

All fibre optic cables will be installed in accordance with the manufacturer's recommendations in terms of minimum active bend radius, cable support requirements, tensile loads and temperature. All fibres, including connections, will be tested in accordance with Telecommunications Industry Association standard TIA/EIA 526-7 OFSTP-7, Method A2 and Method B.

The fibre cables will be protected for their service, will be sheathed to be water- and UV-resistant and will meet Low Smoke Zero Halogen (LSZH) requirements as required by the application into which they are being installed. The fibre backbone proposal is shown in **Drawing 5.4.6-SW-104**, for full reference this drawing also shows the CBTC backbone that is run in an independent fibre cable.

Central Network Management System

The Network Management System (NMS) will manage the network equipment and devices for faults, administration, configuration, performance, and security. Located in the MSF MCR, it will provide system information in a hierarchical, graphical format with the top level of the hierarchy showing the fibre loops and Station network nodes, lower level screens will show individual nodes and individual cards/ports at the lowest level.

Public Address System

The system will be designed to provide clear, audible announcements throughout the Stations and MSF from both local microphones and the Control Centres (TSCC/YCC/BCC) with both ad-hoc and pre-recorded message broadcasts being supported. See **Drawing 5.4.6-SW-106** for details of the PIDS conceptual design including the Public Address System.

The OLRT Public Address (PA) system has two main subsystems; the Station/MSF PA systems and the Vehicle PA systems. The Train-based system will comply with the Operational and Performance requirements in Schedule 15-2, Part 4, Article 3 and is discussed elsewhere within this Response.

PA System – System Description

Station-based PA systems will comply with Schedule 15-2, Part 4, Article 6 operational and performance requirements with the MSF PA system complying with Part 6, Article 7 requirements. These systems will comprise speakers, microphones, amplifiers and signal processors in each operational building, with microphone facilities available at the TSCC and MSF as necessary.

It will be possible to make ad-hoc announcements from the local Station and the TSCC, to trigger pre-recorded general and emergency announcements, and to trigger automatic Train movement and travel announcements. Automatic Train arrival announcements will be generated through data connectivity with the Train control system and will be delivered to the arriving platform and to concourse areas where applicable. All pre-recorded messages will be available in English and in French.

All messages not manually generated at the Station will be delivered or triggered over the CTS network for the Control Centres. Transportation Control messages will be delivered using VoIP or similar technology over the CTS network to the Station signal processor, and recorded messages will be stored digitally at the Stations and triggered from the Control Centres. All local, manual, Station announcements will be generated as analogue audio from local microphones.

Delivery of synchronous audio and visual messages to Passengers will be accomplished through links between the PA and PIDS subsystems so that standard travel messages and normal operational recorded messages are delivered to the Station subsystems together. Ad-hoc messages built at the TSCC will also have this functionality, allowing important travel and emergency information to be coordinated.

To achieve this level of functionality, the PA system will be integrated with the following systems.

- SCADA System
- CTS network
- Central Master Clock
- Train Control system
- PIDS subsystem
- Fire Detection & Alarm System

RTG has successfully integrated Public Address systems with these capabilities on projects such as Vancouver's Canada Line.

PA System – Basic System Design Philosophy

PA system design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards, including NFPA-130, EN 54-16, IEC 60849 (buildings) and IEC 60268-1
- Service-proven design in a similar application environment
- Ease of maintenance and low lifecycle cost with interchangeable line-replacement modules
- High reliability and availability with redundant modules as necessary
- Adherence to operational performance requirement while being environmentally friendly

Train PA System Operation

The Train PA System will provide audio coverage for Passenger areas of the Vehicle with control of PA announcements available from the Driver's cab, from the TSCC and microphones, and through the use of recorded general travel and emergency announcements. The operation of the Train-based public address systems is detailed elsewhere in this Response.

PA System – Coverage and Environmental Intrusion

The building PA System will provide audio coverage of all public areas and all non-public areas, including the MSF, with control of audio volume through zone-selectable announcement areas and Ambient Noise Sensing (ANS) microphones as appropriate. To ensure the delivery of clear, audible and understandable PA messages, speaker design will be coordinated with building design to ensure a high final design STiPA value.

RTG recognizes that some Stations will be located in residential areas and that loud PA announcements can be a source of annoyance and environmental intrusion to local residential populations. During the design stage, Station PA modeling will be undertaken to aid in the selection of speaker location and type to meet the performance specification while minimizing environmental intrusion. Additionally, time-based volume reduction strategies will be used to minimize night-time intrusion into local communities.

PA System – Prioritization of Messages

Important Passenger announcements will be prioritized to take precedence over normal operational announcements. It will be possible to set different priorities for announcements from different sources. For example, ad-hoc voice announcements could be configured to take priority over recorded messages at all times. Life-safety and emergency announcements will take precedence over all other announcements with Station PA systems being interfaced to the Station FDAS for such purposes. The final determination of priorities will be made with the City during the design stage.

PA System – Availability

The individual Station and MSF systems will be supervised at all times for equipment and speaker line failure with alarms being reported both through the local system and through the SCADA system to TSCC operational staff.

The PA system will be designed to have an availability of greater than 99.3 percent for any one Station PA system with an overall OLRT PA system availability of 99.9 percent as required by Schedule 15-2, Part 4, Article 6.3 (c) (v). System design will ensure that failure of any local Station PA, or local Station PA facility, does not cause a failure of the overall PA system.

PA System – Speaker Types

The speakers shown in **Table 5.4-32** are expected to be deployed to buildings along the alignment, with the possibility of an additional type being deployed in storage sheds at the MSF.

Table 5.4-32 | Speaker Types

Speaker Type	Description
Projection Speakers	■ For Station platforms, projection speakers will be used, allowing sound to be delivered to a targeted area.
In-ceiling Speakers	■ For locations within Stations where false, or drop ceilings are used, in-ceiling speakers will be used to provide a flush finish.
Surface Speakers	■ In ancillary rooms and corridors, metal box wall and ceiling speakers will be used.
Horn	■ Within the Maintenance Hall at the MSF, horn speakers will used to provide coverage.
Yard	■ For the main rail storage areas

Passenger Information Display Systems

OLRT Passenger Information Display Systems (PIDS) have two main subsystems: Vehicle PIDS and Station PIDS. Vehicle PIDS will comply with PA Schedule 15-2, Part 4, Article 3 operational and performance requirements and are discussed elsewhere within this Response. Station PIDS will comply with PA Schedule 15-2, Part 4, Article 6 operational and performance requirements and will comprise variable text/graphic signage displaying pre-recorded and Control Centre generated ad-hoc messages as necessary. There will be no PIDS installed at the MSF other than units used for training, which will comply with the requirements of the Stations. See **Drawing 5.4.6-SW-106** for details of the PIDS conceptual design including Passenger Information Signage.

PIDS – System Description

Station PIDS will comprise ADA/OADA compliant dynamic electronic signage and Station controllers in Station arranged to provide Passenger travel information on both Station platforms and concourses.

Delivery of synchronous audio and visual messages to Passengers will be accomplished through links between the PA and PIDS subsystems so that standard travel messages and normal operational recorded messages are delivered to the Station subsystems together. Ad-hoc messages built at the TSCC will also have this functionality, allowing important travel and emergency information to be coordinated.

To achieve this level of functionality, the PIDS will be integrated with the following:

- The existing PIDS
- CTS network
- Public Address subsystem
- Central Master Clock
- Train Control system

PIDS – Basic System Design Philosophy

PIDS design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards
- Service-proven design in a similar application environment
- Ease of maintenance and low lifecycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Low energy consumption
- Adherence to operational performance requirements

Station PIDS Operation

Station PIDS will provide travel, operational and emergency information messages to the public using alphanumeric characters and graphics. Signage will be designed and located to provide maximum visibility to Passengers. Use of ADA-compliant colours and legible text fonts will enhance the usability and visibility of the signage.

The signs will provide date and time information, destination of the next two to three Trains along with their expected time of arrival. This information may be augmented with ad-hoc and recorded OLRT operational information, bus travel information and weather information, and may also be used for emergency or other informational messages such as 'No Smoking' or future maintenance activities. To comply with ADA, we will use monochrome, amber-on-black LED signage to provide maximum visibility with fonts chosen to provide maximum readability.

All TSCC messages will be developed on the PA/PIDS Customer Service Console and delivered over the CTS network using IP communications to the Station controller from where they will be sent to the PIDS. Recorded messages and graphical displays will be stored digitally at the Stations and triggered from the TSCC. Local Station triggering of recorded messages will be possible in case of network failure allowing service interruption messages; for example, to be displayed without connectivity to the TSCC. Train arrival and departure information will be triggered using data received from the CBTC system at the MSF and passed to local Station controllers in the same way as TSCC-generated messages.

Displays will be designed, arranged and mounted to ensure maximum visibility for Passengers, with two mounted on each platform and others located throughout Station public areas, especially around fare collection areas. Messages will be formatted and delivered for specific locations, functions and occasions. The system will be designed to enable each PIDS display to be individually addressed from the TSCC.

PIDS – System Availability

Individual Station units and overall system will be supervised at all times for equipment and major subsystem failure with alarms being reported through the SCADA system to the TSCC operational staff.

The system will be designed to have an availability of greater than 99.3 percent for any one Station system with an overall OLRT PIDS availability of 99.9 percent. The design will ensure that failure of any local Station PIDS display does not cause a failure of the overall Station display system.

PIDS Signs

All PIDS signs will be housed to prevent damage from moisture, dust, ultraviolet light and vandalism. Where signs are mounted outside, for example on platforms, they will be configured to ensure readability in direct sunlight by changing their light output in line with changing ambient light levels.

CCTV

The OLRT Closed Circuit Television (CCTV) system has two main subsystems: the Station/guideway/MSF (fixed facilities) CCTV systems and the Vehicle CCTV system. The Vehicle CCTV system is detailed elsewhere in this Response.

Fixed-facilities CCTV systems will comply with PA Schedule 15-2 Part 4, Article 6 and Part 6, Article 7 operational and performance requirements including interfacing with the IAC and emergency telephone systems to provide staff with the best view of an event. **Drawing 5.4.6-SW-108** provides details of RTG's conceptual CCTV system design.

CCTV – System Description

The CCTV system will be built up from several subsystems: cameras, power supplies, network devices, video recorders/storage and displays, all of which will be integrated into one coherent system providing security and operational monitoring for the OLRT.

Fixed and PTZ cameras will be deployed at Station entrances, along Station platforms, in Passenger circulation areas, covering DWAs, at tunnel entrances, for monitoring fare collection equipment, and at other areas that need to be covered following CTPED reviews. These cameras will be connected back to their respective Station equipment using a mix of fibre and copper technologies as determined by their location, distance and application. Data compression at the camera, (e.g. H264/MPEG4), will be used to provide high quality video at a manageable bandwidth.

A digital link, via the wayside high-speed radio system, will enable Station streams to be sent to the Vehicle for display on the Vehicle cab's video panel when it is stationary.

Fixed Facilities CCTV System Design Philosophy

CCTV system design will use the following basic principles:

- Application of the latest applicable Codes of Practice, International Standards and Laws, including Transport Canada guidelines, APTA IT-CCTV-RP-001-11, ULC-S317-96 and all applicable Privacy Legislation
- Service-proven design in a similar application environment
- Ease of use and maintenance together with low lifecycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Adherence to operational performance requirement

Cameras will be designed to operate in the environment at all times, day and night, and at all times of year without the need for additional or augmenting floodlights within the operational parameters of an LRT system. Cameras will use ¼" or 1/3 CCDs with fallback from colour to black and white images in times of low light. In some more specialist cases, specific thermal image CCTV devices may be deployed for perimeter or intrusion detection.

Within the MSF, cameras will be deployed for operational and security purposes such as perimeter and intrusion monitoring, monitoring of Train movements and covering of any track crossings. Data from these cameras will be routed over a fibre network to the local MCR in the MSF.

At the local Communications Room, cameras will be networked into facility-based storage providing a minimum of 31 days of high-quality (30 FPS at 4CIF) video archiving. Long-term storage, at reduced frame rat, will be provided on networked video storage devices located in the Belfast Road TSCC, with backup system servers installed in a Data Centre. Data will flow between these two locations using the existing data connection between the Data Centre and 875 Belfast Road.

Sentry or guard tours will be configurable for areas where intrusions are a concern and the use of analytical detection techniques will enhance the ability of the system to detect anomalies. The system will support analytical technologies to both detect intrusion into unpermitted/unauthorized areas and to support more advanced security features, the use of which will be limited to approved personnel and Transit Law staff. Selected Station images, such as platform edge cameras, will be sent to a new Overview Video Wall installed in the TSCC and BCC; in the MSF, selected cameras will be sent to a new video wall in the YCC.

All images will be made available through the head-end CCTV display system with access to specific views restricted by specific access controls with security related streams being available to Transit Law and other authorized personnel and operational streams being delivered to the TSCC/YCC. Authorized personnel will be allowed to configure the inclusion or exclusion of automatic display of video coverage of any device, type of device, specific event, or general event type as needed. It will be possible for streamed images to be copied or recovered from the system by authorized personnel for use outside the transit system. Such copying will be logged within the system.

The system will be designed for future expansion of the installed camera base and deployed with spare storage capacity protecting for the addition of up to 40 percent more camera feeds.

CCTV – Cameras

All cameras deployed under the Project will be commercially available, "off-the-shelf" units; there will not be any specific manufacture or customization of any units. All units will be of good quality from a reputable, established manufacturer with a proven record of equipment deployment into applications similar to the OLRT.

The cameras in the Stations will be chosen both for their ability to meet functional specifications and also for their appearance. They will be able to operate in all expected light levels down to a level of <1 lux with auto-switching from colour to black and white image capture should it be deemed to be necessary during the design stage.

All cameras, both indoor and outdoor, will be housed in enclosures that are sympathetic to their surroundings and environment with mounting options for pole, ceiling, wall and post. Enclosures will be to NEMA 4X (IP66), have tamper/impact resistant covers and be made of material that is suitable for the environment into which it is to be deployed.

CCTV – Operating Environment

Fixed-facilities cameras will be designed to meet environmental conditions for service and operation in the differing conditions to be found in the Stations, Yards and along the guideway. All will meet the operating temperature requirements; those exposed to harsher conditions will be provided with blower and/or heaters as well as wipers if deemed necessary during design development.

CCTV – Applications & Integration Software

CCTV application software will provide several basic and advanced functions to enable the system to operate as required and to provide the Controller or Station staff with the facilities to carry out their monitoring and security functions. For instance, the SCADA system will interface to the CCTV system to pass Emergency Telephone or IAC activation information so that cameras can be homed to a pre-determined position that will show the device generating the input. To achieve these interactions, the CCTV application software will use several interfaces to other systems:

- SCADA
- CTS
- Video Wall

With the alarm/event handling functionality enabled, it will be possible to trigger audio files over the network and, possibly, interact with other systems such as the Passenger Information System for Public Address announcements. All alarms captured into the CCTV system, such as IAC notification or E-Tel activation, will be watermarked and archived along with the images captured during the event.

CCTV – Surveillance Systems – Central Management System

As part of system deployment, RTG will configure the system to provide "Smart Detection" on general motion in an image area, if an item is no longer present (missing) within an image area, and if a definable foreign object appears within the image area. Such smart detection will cause an internal alarm to be stored to a central alarm database on the Central CCTV Server which will also store details of any externally generated alarms passed to the CCTV system, such as those from the SCADA system causing a PTZ camera to 'home' to a pre-set position.

CCTV – Overview Video Wall

Part of the new Video Wall system for the TSCC will be dedicated to providing fixed camera views from platform edge cameras while other elements will be allowed to display operator selectable images from elsewhere with the system; for example, Station entrance doors.

The Video Wall will be configured so that each camera image takes up 1 of 9 or 1 of 16 squares of any single wall panel, the final layout and size being agreed during the design phase in consultation with the City. The Video Wall will also be configured to enable at least one panel to be set aside to provide a full (panel) size video image from individual cameras selected by the Communications Operator or, possibly, triggered by an event captured by SCADA or the CBTC.

Video walls deployed to the BCC/YCC will be more dynamically configurable, allowing selection of images depending on operation needs.

Intrusion and Access Control (IAC)

The IAC system will control the access to all non-public areas of the OLRT System as well as detecting any unauthorized entries into these areas or into key elements of the alignment such as tunnel portals and the MSF Yard. See drawing 5.4.6-SW-118 for details of the initial IAC design from RTG.

IAC – System Description

Entrance to non-public areas will be controlled through Access Cards, which will be read by a door controller that will release the lock if the card is authorized for the door at which it is presented. If the card is not authorized the door will remain locked and an alarm will be raised on the workstation in the Control Centre.

As a minimum, the following areas will be secured by the IAC system:

- Public to non-public doorways
- TPSS
- Communication rooms
- Elevator machine rooms
- Escalator machine rooms
- Electrical equipment rooms BCC
- MCR
- External doors, entrances and exits of the MSF
- MSF Yard perimeter and access gates

Should an unauthorized entry be made into a room or area (e.g. the door is forced), the IAC will send an alarm to TSCC operators over the SCADA system as well as to the IAC system within Transit Law.

A subsystem will be deployed at the tunnel portal and Station tunnel entrances to monitor for intrusions by humans or other large objects into the tunnel segments. This subsystem will be monitored by the CBTC to pass a message to the Driver of the intrusion detection, and at portal locations to cause the Train to stop. At the MSF, data will be passed between the CBTC and SCADA system to cause the alarm occurrence to be flagged to TSCC operators for response by Station or Transit Law staff as appropriate and to cause CCTV image display.

At the MSF, the system will interface to Yard perimeter monitoring systems to capture unauthorized intrusions. The perimeter monitoring system will protect both fenced areas and access gates, and will be linked with the CCTV system to cause camera homing and image display to the MSF operator.

IAC – Service Life

IAC equipment and cabling deployed as part of the OLRT System will be designed to have a minimum service of 20 years and will be compatible with the City's chosen IAC system.

Telephony System

OLRT Telephony system has two main subsystems: the telephones/intercoms connected to the existing TSCC PABX and the telephones/intercoms connected to the new MSF PABX. The various telephony devices deployed throughout the OLRT will provide service to the travelling public, OC Transpo operations staff and M&R Team personnel.

Telephony - System Description

Telephone systems will comply with PA Schedule 15-2, Part 4, Article 6 and Part 6, Article 7 operational and performance requirements and will comprise emergency telephones, elevator telephones/intercoms, staff telephones and maintenance telephones in various quantities and arrangements in each operational building reporting to either the TSCC or MSF as per their function. **Drawing 5.4.6-SW-107** provides details of RTG's conceptual design of the OLRT Telephony Systems.

In addition to providing line-based voice-communication services, emergency telephones and elevator telephones/intercoms will be interfaced to the CCTV system for Passenger security purposes and non-public telephones will be interfaced into the Ottawa Public Service Radio (PSR) telephone system for operational purposes.

Telephony – Design Philosophy

The telephone systems design will use the following basic principles:

- All telephones will use VoIP communications and provide clear and intelligible communication suitable for the environment in which the telephones are installed
- All telephone traffic will be carried over the CTS infrastructure Station Emergency telephones, elevator telephones/intercoms and staff telephones will be routed through the existing TSCC PABX
- Emergency telephone and elevator telephones/intercoms will be automatically routed to the OLRT Control Desks in Belfast Road
- Station, substation and MSF-mounted maintenance telephones will be routed through a new PABX in the MSF

Telephony – MSF PABX

The new MSF PABX will be sized to provide the service and functionality required to maintain the OLRT and operate the MSF facility, including the Yard. The PABX will be tied into the TSCC PABX to support routing of calls directly between TSCC and MSF staff and to enable OC Transpo staff operating out of the MSF to contact OC Transpo staff throughout the organization. It will interface to maintenance and administrative telephones and intercoms located throughout the alignment, the Yard and the MSF Building.

Telephony – TSCC PABX

The TSCC PABX will be expanded under the Project to support the additional devices mounted throughout the OLRT and to provide tie-connections with the MSF PABX.

Telephony – Instrument Types

All telephone handsets will use VoIP technology.

All staff and administrative phones will be conventional, office-style devices with dial pads and handsets, and will be capable of being wall mounted or located on a desk. Maintenance phones will be more rugged, but will still be supplied with dial pads and handset.

Emergency telephones (E-Tels) will be provided with a handset that automatically connects the device to the TSCC when lifted; they will not be fitted with a dial pad as it is not required. At this time the E-Tels are not required to be supervised for availability, we would welcome the opportunity to discuss this with the City during the design phase.

Elevator telephones/intercoms will be hands-free devices requiring the user to simply push a 'call-button' to raise a call to the TSCC. Where necessary, this button will also activate an alarm to the SCADA system to indicate its activation. All intercom speakers will be amplified to comply with ADA/OADA volume requirements.

Telephony – Communication Interfaces

All local telephone extensions will be wired to Station MDFs in the local Communication Rooms from where they will be connected to Station CTS node telephone multiplexing equipment. From the local node, data will be transported back to the TSCC/MSF over the CTS and fibre network where it will be presented to the appropriate PABXs.

Telephony – Service Life

PABX equipment and cabling deployed will be designed to have a minimum service of 20 years in the application and the environment of the OLRT. While it is possible for some telephony handsets to last 20 years, it is not practical to expect such devices to last more than 7 – 10 years.

SCADA for Stations, Traction Power, Tunnel Ventilation, BAS and BMS

SCADA – System Description

The SCADA system will comprise a redundant server Master workstation with operator workstations at the TSCC and MSF (BCC and YCC) providing graphical and text-based monitoring and supervisory control of Station E&M Systems and Traction Power systems for the complete OLRT. The system will also provide remote monitoring and alarm handling for the distributed communication systems across the line.

Remote Terminal Units (RTUs) will be provided at all Stations, traction power substations and the MSF to act as the field interface between the SCADA Master station and the end field devices. Depending on the application, the RTUs may be passive input/output (I/O) devices or may be more complex and able to carry out some level of intelligent control.

General interfaces between field devices and RTUs will be via digital (discrete) I/O whereas interfaces that are more complex and measurements will be carried out using analogue I/O. However, to capture BAS and BMS data more completely, we will be providing BACNet interfaces for all RTUs and connecting building systems to them using this interface.

All interfaces between the RTUs and the central SCADA Master station will be IP-based and will occur over the OLRT's CTS network, with individual RTUs connected to the CTS over a mix of copper and fibre as appropriate for the distance travelled and service that are monitoring.

At the TSCC, the colour-mimic, alarm, event and historian screens will be used to provide interfaces for the staff to both monitor and control the systems that they are looking after. Graphical displays will provide Schematic, TP one-line, pictorial, and alphanumeric displays of the plant being monitored.

The CBTC system will not be displayed through the SCADA system but will instead use its own discrete user interface directly coupled to the main CBTC servers. The Tunnel Ventilation System, although PLC-based and not reporting through a SCADA RTU, will connect to the head-end SCADA over the CTS and the TSCC HMI will provide operator interaction for this facility.

Drawing 5.4.6-SW-109 provides a high-level introduction to the SCADA system network and system connectivity design.

SCADA – Systems Design Philosophy

SCADA system design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards, including IEC 60870 or DNP 3 protocols, EEMUA 191, IEE 730 and 829
- Service-proven design in a similar application environments
- Ease of use and maintenance together with low lifecycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Redundant servers
- Adherence to operational performance requirement

The Master station will communicate with 13 new Station RTUs, 8 new Traction Power RTUS and 3 PLCs over the new CTS equipment.

The system provided will be built to comply with the latest editions of the applicable codes, regulations and standards listed within and will be designed to meet RAMS requirements.

SCADA – Master Station Overview

The architecture will be a dual redundant Master Station at the centre of a distributed architecture with all system interconnections being made over Ethernet Local Area Networks (LANs) utilising TCP/IP for communications.

SCADA – Hardware Architecture

Two new SCADA Servers will be provided and installed in the MSF MCR together with seven new workstations: three at the TSCC, two at the Depot YCC and two for the BCC. All workstations will be connected to the SCADA LAN together with any printers and network switching/routing devices.

The SCADA Master Station LAN will be designed in a redundant configuration with two intelligent switches forming the core of the local area network in both the MSF and the TSCC.

The SCADA LAN will connect to the main OLRT CTS for data communications to the Remote Terminal Units (RTUs) to support data recovery from, and supervisory control to the Passenger Stations, Traction Power Sub-stations and TVS plant. The CTS NMS will connect to the SCADA LAN to enable data to be recovered from the NMS and presented to the TSCC staff for review.

The system will interface to the upgraded Overview Video Wall installed in the TSCC and to the new units to be installed in the BCC/YCC. .

SCADA – RTU

The new RTUs will be mounted in a 19" cabinet, will be microprocessor-based, will be 120 V AC (Station) or 125 V dc (Traction power) powered and equipped with dc power supplies suitable for delivering all required voltages for operating the RTU and delivering the I/O. Drawing 5.4.6-SW-113 provides an overview of the systems and equipment that are expected to connect to the local RTU network.

Each RTU will have a front panel display to aid in maintenance and fault diagnostics and will support a diagnostic terminal. Each RTU will also support duplex communications and be provided with dual communication ports to provide redundant path connectivity to the CTS and from there to the TSCC.

The RTUs will be sized to meet the expected requirements of the OLRT and will be provided with a minimum of 25 percent spare capacity above the configured and wired I/O compliment.

SCADA – Discrete Plant Interfaces

All monitor and control wiring from Station equipment and TPS equipment will be terminated at the respective marshalling panels before interface with the Remote Terminal Units.

For Station equipment, all Digital Inputs (DIs) will be interfaced to the RTU using dry contacts wetted at 24 V dc while all Digital Outputs (DOs) will be interfaced using relays outputs, rated for the appropriate service.

For traction power equipment, all DIs will be interfaced to the RTU using dry contacts wetted at 125 V dc, with DOs will be interfaced using change-over relays rated for the application.

The analogue inputs for both services will use 4-20 mA or 1-5 V dc inputs with any analogue outputs using 4-20 mA.

The communication between the SCADA servers in the MSF MCR and the field devices will be via industry standard open protocols.

SCADA – Intelligent Plant Interfaces

For facilities management systems, such as Building Automation Systems (BAS), Building Management Systems (BMS) and escalators/elevators we will implement intelligent interfaces to the RTU and through the SCADA system to the TSCC and maintenance systems in the MSF. These are described more fully in the *Facilities Management Systems* section below.

SCADA – Life-Safety Interfaces

The Tunnel Ventilation System (TVS) performs a fire- and life-safety (FLS) function and will be interfaced directly with the tunnel and Station Fire Command Post (FCP) at the below-grade Stations including that at St Laurent.

The TVS has a direct impact on Passenger safety and well-being. Controls for this system are complex and are best handled by a dedicated PLC-based control system linked to the SCADA system. TVS alarms will be immediately raised on the SCADA system and seen by an operator who can alter settings and direct Passengers accordingly. The TVS will not be operated automatically based on smoke detection or sprinkler system activation as neither smoke detectors nor sprinklers are provided in the public areas of the Stations. See elsewhere in this Response for further details on the control of the Tunnel Ventilation System.

Facilities Management Systems

The control and monitoring of HVAC systems and sumps for Stations will be available through the BAS at that Station's SCADA RTU, and will be monitored from both the TSCC and the MSF on the main SCADA system.

Room thermostats will be used to control the amount of heating and cooling supplied to maintain the specified temperature range of each room. A sensor will be located in the outdoor intake shaft to determine when economizer cooling will be used instead of mechanical cooling. Direct digital controls and a series of motorized dampers will be used to control this system. Where unit heaters are provided, electrical interlocks will be provided to ensure heating and cooling by ventilation does not occur simultaneously.

A separate computer room and remote-controlled air-conditioning system will be provided.

FM System – System Overview

To fully monitor each Station, maintain an acceptable Passenger environment, and provide controlled environments for deployed technical equipment, two systems will be used alongside each other that together make up a complete Facilities

Management System: a Building Automation System (BAS) and a Building Management System (BMS). Each system is a composite collection of facility data brought together to provide component- and system-level control.

The BAS will be deployed to each Station to monitor and control Station mechanical and electrical facilities that have some level of automation associated with them:

- Environment management, including HVAC plant
- Station sump pumps (where needed)
- Station lighting

Each system will be built around an open protocol (BACNet) LAN to interconnect all devices in the Station and to interface to the SCADA connection for onward connectivity to the TSCC and MSF. At each Station, a workstation will be provided to enable local monitoring of the system and the associated plant.

The BMS will be deployed to monitor all non-automated Station facilities for normal/abnormal operation and to allow general overview of Station mechanical and electrical items and devices:

- Doors
- Fire Detection and Alarm System (FDAS)
- Station sump levels (where appropriate)
- Operational room temperatures
- Vandal/tamper alarms, some of which will come from the IAC

It is expected that the BMS will monitor some elements that are controlled by the BAS, thus providing a level of redundancy over critical plant monitoring. These two Facility Management Systems (FMS) will report to the Station SCADA RTU from where their information will be sent to the TSCC (operational monitoring) and the MSF (alarm/failure management) for display to Control Room Staff.

FM System – BMS

Door Monitoring

Door monitoring is carried out in conjunction with the IAC system. Monitoring door status (open/closed) through the BMS provides an independent and redundant status check. This is especially important for Station public area security (vandalism) and technical room security (break-ins) where unauthorized entry must be detected.

Fire Detection and Alarm System (FDAS)

The FDAS will be self-contained units and are described elsewhere in this Response. However, it is important that key alarms are picked up and transmitted to the Control Centres (TSCC and MSF) for remote monitoring and response. Alarms received will include the Station Fire Alarm being active, and tunnel dry-stand pipe valves being operated.

Station Sump Levels

As a redundant measure against loss of the BMS or pump controllers, we will monitor each sump with a separate high-level alarm that will trigger an alarm to the TSCC and MSF control centres before water levels affect operations.

Operational Room Temperatures

Technical room temperatures must be controlled within tight tolerances; if room temperatures are too far out of specification, damage may occur to the equipment that could lead to downtime and loss of service. For example, Communications and Signals Rooms with sensitive electrical equipment will be monitored and alarmed back to the MSF if their temperatures go too low or too high.

FM System – HVAC

Room thermostats will be used to control the amount of heating and cooling supplied to maintain the specified temperature range of each room. A sensor will be located in the outdoor intake shaft to determine when economizer cooling will be used instead of mechanical cooling. Direct digital controls and a series of motorized dampers will be used to control this system. Where unit heaters are provided, electrical interlocks will be provided to ensure heating and cooling by ventilation does not occur simultaneously. A separate remotely controlled air conditioning system will be used for the computer room.

Vandal/Tamper alarms

Fare equipment, such as Ticket Vending machines, is a target for vandalism (breakage/disabling and robbery). Such machines will be monitored (e.g. for tipping over), with alarms routed to TSCC for response by Transit Law.

FM System – BAS

Station Sumps

Where Station sumps are required, they will be configured with a two-pump arrangement (duty/standby or duty/duty assist) using centrifugal pumps with level monitoring achieved via level probes or ultrasonic heads depending on operational conditions. Operation controls will be based upon level monitoring and will ensure complete discharge of the sump into City facilities. It is expected that this control will use a packaged discrete controller interfacing into the overall BAS network.

Station Lighting

For Station lighting, the BAS will provide a facility level control of interior and exterior lights in functional (e.g. platform, concourse, ancillary) or operational (e.g. all Passenger areas, all non-Passenger areas) configurations. Such lighting control will allow illumination to be determined remotely (TSCC staff via SCADA), locally (OC Transpo staff on site) or automatically (local photocells), with each being determined by lighting type, function and location.

FM System – Elevators/Escalators

Elevators and escalators will be linked on an intelligent network with a gateway to the Station SCADA RTU allowing monitoring, and permitted remote control, functions to be carried out by TSCC and YCC staff via the OLRT SCADA system.

FM System – Tunnel Ventilation

RTG notes the requirement for Tunnel Ventilation to be part of the BAS and for the control network to be UUKL-864 listed. We would welcome the opportunity to discuss this further as we do not believe this is the best approach to achieving the control and operation of this life-safety critical function. The controls for transit tunnel ventilation systems typically prove to be too complex for a standard BAS.

We believe it more appropriate to build a discrete TVS system based around redundant, high-availability controllers with redundant I/O and meeting SIL-2 as a minimum. This system would be independently linked to the main OLRT SCADA system and would interface directly into local FDAS and local control panels for emergency personnel use.

Lastly, we recommend not operating the tunnel ventilation system automatically based on smoke detection and/or sprinkler system activation. It is not possible for the system to automatically know all the parameters necessary to determine how to initialize the TVS. We believe activation is best achieved by TSCC staff in consultation with the Driver.

Radio Communications System

Radio systems will form a key part of the operational deployment of the OLRT providing Train control communications, availability of wayside data and voice/data coverage for all staff and Vehicles. Three systems will be deployed: two dedicated to the OLRT and a third, part of the overall City of Ottawa radio system.

RTG believes the delivery of cellular communications into the tunnels and below-grade Stations, in a similar manner to that achieved on Canada Line and Calgary West, should be considered as part of the radio system roll-out.

RC System – System Description

The first system (DCS) will be for the CBTC and is not discussed in this section as it is an integral part of the Train control system (see **Section 5.4.4**).

The second system is the new high-speed wireless data network for interfacing the wayside with the Vehicle at both the Stations and the MSF. This system will comply with PA Schedule 15-2, Part 4, Article 6 and Part 6, Article 7 operational and performance requirements and will comprise antennae, wireless access point radio nodes and interface equipment for connection into the local CTS network node. This Wi-Fi will be used to pass streaming and recorded CCTV data to/from the Vehicle, to pass Passenger count information to the wayside and to automatically collect non-CBTC diagnostic information from the Vehicle.

The third system will be the new Ottawa P25 system that we understand will replace the existing Ottawa Public Service Radio (PSR) in 2015. The radio will be used for wayside/Vehicle voice communications, including ad-hoc PA messages, and for low-speed data transfers, for example to trigger recorded PA announcements or update Train PIDS. The design of this system does not lie within the scope of this Project and only its potential use within the system is described herein.

RC System – Wayside High Speed Radio System

For new data radio systems deployed on Station platforms; the antenna will be located so that Train communication can commence a specified distance away from the platform, enabling Station arrival/departure information, maintenance information and streaming video to be delivered when required and providing maximum time for information transfer.

Design Philosophy

The wayside radio system design will use the following basic principles:

- Application of the latest applicable Codes of Practice and International Standards, including 802.11, EN 50155/50121-3-2 and EN 50121-1/50121-4
- Service-proven design in a similar application environments
- Ease of maintenance and low life cycle cost
- Use of interchangeable and module line replacement units
- High reliability and availability
- Redundant modules as necessary
- Adherence to operational performance requirement

The overall conceptual design of the Train-to-Wayside Wireless System is shown on **Drawing 5.4.6-SW-110**.

Wayside Implementation Considerations

As the system will operate in the 802.11a frequency bands, consideration must be given to the public use and the unlicensed nature of these bands. The system will need to be secure from outside-the-network interference and be designed to provide maximum bandwidth even when operating close to a large Wi-Fi user base, such as Campus Station. The design must also consider the operating presence of the CBTC radio system in the 802.11b/g/n bands.

Radio equipment will be housed in enclosures that provide equipment security and environmental protection. Antennae will be constructed of robust corrosion-resistant materials and antenna cabling will be connected with high-quality, co-axial cables and connectors supplied by a reputable manufacturer. As with other key systems, power will be sourced from a four-hour protection UPS.

Radio Coverage

Radio coverage will be provided for the Station and +/- 15 seconds of travel time in each direction from each platform. This will provide ample time to exploit this system to its fullest.

Digital Radio Capacity Requirements

The system will use 802.11a technology to get maximum data capacity over the network whilst maintaining segregation from the CBTC radio. It will interface to Station CTS and CCTV systems to transfer information and video data with the smallest possible latency.

Vehicle Mounted Ottawa PSR Equipment Considerations

As the Ottawa P25 system will be installed by others during the life of the Project, we do not anticipate carrying out any work on radio infrastructure; however we will collaborate with the P25 Radio System Supplier to manage the supply, installation and testing of the radio system within the OLRT alignment and to ensure that the OLRT design is not compromised.

RTG is expecting to be able to use the new Vehicle mounted P25 radio system to transmit low-speed data messages between TSCC and the Trains for activities such as PA message triggering. See **Drawing 5.4.6-SW-106** to see how this interface will be executed along with **Drawing 5.4.6-SW-110** to see how the future Ottawa PSR fits in with RTG's expected Wayside Radio System.

Operation Control Centre Voice Recorders (OCCVR)

OCCVR – System Overview

The existing Voice Recorder system at the Belfast Road TSCC will be upgraded and expanded, as necessary, to support the additional PA and telephony traffic resulting from the OLRT Project. Project work includes upgrading and enhancing equipment, adding new interfaces as necessary and commissioning the upgraded system with the new equipment to ensure that all OLRT telephone and TSCC ad-hoc PA messages are recorded. Other recording and replay facilities will be provided as per the existing system.

OCCVR – Functionality

The upgraded and expanded Voice Recording system will capture all speech communications into and out of the OLRT Control Centre and all speech communications over the new radio system whether originating at the Control Centre or not. All recordings made by the system will be able to be reviewed by authorized personnel should the need arise.

Central Time System

To keep all operational systems synchronised, a Central Clock will be installed at the MSF MCR with GPS antenna diversely mounted on the building roof.

System Overview

The system will comprise two GPS-based network time-management servers configured to provide a redundant Stratum-1 level service to the Communications systems and the Thales CBTC system using NTP. See **Drawing 5.4.6-SW-117** for network location and connectivity.

5.4.9.3 System Safety and Security

OLRT Operational Systems

The CBTC and Communication systems are directly involved in the real-time operation and control of the OLRT System and must be protected from interference, either deliberate or accidental, to maintain the inviolate state of the System. To achieve this, real-time systems will be closed from all external connections except those required to achieve data transfer for performance reporting and operational travel planning data which will occur through secured firewalls at the MSF.

Data transfer between the systems, such as Train position information from the CBTC system to the Communication system, will occur over secure links within MSF equipment rooms with security between systems achieved through mechanisms that meet the requirements of the system suppliers without affecting throughput at the time of implementation.

With a closed system, there should be no route for external software to be introduced in an uncontrolled manner other than through unprotected disk drives or USB ports. To provide maximum security against unauthorized software installation, or file removal, access to all external drives/ports will be protected via system configuration and password controlled user privilege. Operational computer systems will also be provided with current revisions of commercial grade security and anti-virus software that will be maintained by the M&R Team as part of their system administration and maintenance tasks.

All servers will be maintained in secured rooms with strict access control protocols restricting entry to authorized personnel. All equipment directly involved in Train operation will be protected behind secure doors with access limited to personnel who are directly involved in CBTC operation and maintenance.

External Systems

For data transfer to agreed external systems, such as the Operations and Maintenance Interface (OMI) and Operation Performance & Travel Data (OP&TD) servers, firewalls will control data flow between these systems and the operational equipment delivering the data to them.

For receiving and developing the Daily Reports (among other data), the OMI server will reside within the M&R Team's network, secured from the operational systems by a firewall (see **Drawing 5.4.6-SW-117**). Data for reports will be pushed from the CBTC and Communications Systems to the reporting server in an unsolicited manner; there will not be any requests for data to these systems allowed through the firewall to protect them from activity within the M&R Entity's corporate network. Data from within the M&R Team's network (e.g., Help Desk statistics, Asset Management information), will be secured in a manner consistent with M&R Entity IT security policies.

The Operational Travel Data server will be placed in a DMZ between the operational systems providing data and the OC Transpo corporate system(s) requesting it (see **Drawing 5.4.6-SW-117**). The OP&TD server will receive real-time operational and travel service related data from the CBTC and Communication Systems through a back-end firewall as well as receiving ad-hoc and scheduled data from the OMI server across the M&R Team's network. Connection from the OP&TD server to the OC Transpo network will be via a second front-end firewall that will further protect and secure the OLRT operational systems as well as isolating and protecting OC Transpo and the M&R Team networks from each other.

Access to these servers will be secured and protected in the same manner as the Operational systems described above.

Network and System Management

To manage the CTS, a Network Management System (NMS) will be installed in the MSF's Electronic Equipment Room. This NMS will be configured to monitor system performance, detect and annunciate faults, allow configuration/re-configuration of devices and services, and manage overall CTS security.

5.4.9.4 Open-Data Link

From PA Schedule 15-2, Part 4, Article 6.2 (b) (iii), RTG understands that the City wishes to have OLRT operational travel data provided for use by external, City-approved, third-party software applications through a firewalled server supplied as part of RTG's delivery. It is not expected that operational performance data will be provided outside OC Transpo. Further, the requirement calls for data to be provided in XML format for use by SIRI or other such applications.

CBTC system design includes an SQL database containing data relating to the signalling system and Train operational performance (e.g. destination, next Station, time to next Station). This database will be replicated to the OP&TD server forming the basis for information to be provided to external applications. Other information, such as the daily timetable, will be uploaded from other sources to the OP&TD system to provide a comprehensive data repository of OLRT travel information. In addition to this scheduled and real-time information, provision will also be made for ad-hoc service interruption or special-event information to be input to the system either manually or selected through menu options.

Information received from these various sources will be combined within the OP&TD server to provide a robust data service for real-time travel information on OLRT services that will be made available to external third-party applications in accordance with the provisions of CEN standard TS 15531 (Service Interface for Real-Time Information relating to Public Transit Operations).

The system will support both Request/Response (ad-hoc request from an external interface) and the Publish/Subscribe (scheduled and repeated data pushes to a subscribed external interface) Client/Server interaction patterns. The final functional delivery specification of which SIRI features and data exchange the interface will support, will be defined during design development and review.

5.4.9.5 Integration of Proposed Communication Systems with Existing City Communication Systems

Five existing City communication systems will be integrated into the new OLRT systems:

- Ottawa Public Service Radio (PSR)
- TSCC Private Automatic Branch Exchange (PABX)
- OC Transpo PA/PIDS
- OC Transpo Intrusion and Access Control (IAC)
- OC Transpo Corporate Systems

RTG recognizes that there are several existing City communication systems that the new OLRT systems must integrate with and there are different levels at which that integration may occur.

OC Transpo and Passenger telephony equipment will link through the CTS to the existing, expanded PABX currently housed in 875 Belfast Road. This equipment will use Voice over IP (VoIP) technology to communicate with the PABX routed through the CTS. The M&R Team's PABX, to be installed at the MSF, will be used for OLRT maintenance and M&R Team telephony communications, and will be linked through to the OC Transpo PABX to allow operational and M&R parties to contact each other easily.

Ad-hoc Public Address (PA) announcements made from the TSCC will be recorded on existing City voice recorders at 875 Belfast Road in accordance with the requirements of Schedule 15-2, Part 4, Article 6.3 (c) (xii).

The Intrusion and Access Control (IAC) system deployed will monitor the Stations, TPSS, guideway, MSF and other ancillary facilities for unauthorized access, as well as provide controlled access for authorized parties to authorized areas. It is expected that OC Transpo and M&R Team staff will use the same system with some areas of common access and some areas of restricted (to each party) access. RTG will work with the City to ensure the deployed IAC system is compatible with the City's future IAC system to allow ease of card access for OC Transpo and City staff to authorized OLRT facilities.

The IAC will be interfaced to the CCTV system allowing images to be called directly to an operator's screen or to the video wall in the event of an intrusion or alarm. During system commissioning, the City will be involved in selecting the images to be called in the event of such an occurrence; after commissioning/set-to-work the City will be capable of including or excluding automatic display of video images of any device, type of device, specific event, or general event type in accordance with PA Schedule 15-2, Part 4, Article 6.3 (e) (vi).

All images recorded on the CCTV system will be stored, sufficient for evidentiary purposes, for 31 days on servers installed in the Data Room at 875 Belfast. RTG understands that the City wishes to use an off-site Data Centre to house back-up storage and system servers and that the existing data connection between the Data Centre and 875 Belfast is to be used for data transfer. The bandwidth available on this link is unknown to RTG. Should any upgrade be required it is assumed that this will be undertaken by the City outside the OLRT Project.

The SCADA system will provide the head-end interface to the BAS, among others, at the TSCC as in PA Schedule 15-2, Part 4, Article 6.2(i) (iv) and providing a common Control Room interface to all E&M facilities across the OLRT System. At each operational area (e.g. Stations) dedicated building automation control equipment will look after each service and/or function (e.g. temperature control, HVAC management); where end devices (e.g. air flow dampers) provide tight shut-off to prevent smoke they will be independently interlocked with the FDAS for activation should the need arise.

The BAS equipment network will communicate over a local redundant link to the Station gateway, provided by the Station SCADA RTU, from where it will use the CTS to pass data upstream to the SCADA Master Station and TSCC Operators. This design of the local BAS equipment and network will be such that local control will continue should connectivity to the SCADA Master station fail.

The CTS will be fault-tolerant, diverse-path, redundant-ring architecture designed to provide the OLRT with the required level of performance to meet OLRT operational needs and speed. Final system layout and equipment selection will be defined during the design phase in consultation with the City's Representative, ensuring that the design is compatible, where possible, with existing City systems while noting that the OLRT CTS must, for reasons of operational integrity, be kept separate.

Ottawa PSR

The Ottawa PSR provides the primary voice communications path between the TSCC/BCC and OC Transpo staff operating the OLRT. We understand that the City is implementing a new P25 system during the Project Term and that RTG will be integrating terminals of this new system into Train fleet where it can be used for bi-directional voice and low-speed data transfer.

TSCC PABX

All new Passenger and OLRT operations telephony devices will use the existing TSCC PABX for telephony routing and management. The PABX will be expanded as necessary to provide the requisite number of internal lines with expanded PSTN interfaces should they be required following anticipated use requirements.

OC Transpo PA/PIDS

PA Schedule 15-2, Part 4, Article 6 requires the OLRT and OC Transpo PA/PIDS to interface at the TSCC. We assume this is to keep a common interface between bus and Train operations. Part of the design process will be to review the ability to include the CBTC System in these communications and extract the maximum benefit from interfacing with the CBTC and High Speed Data Radio systems.

OC Transpo IAC

To maintain common accessibility control across the OC Transpo network, the OLRT Access Control system will be an extension of the existing OC Transpo IAC. This will allow existing access cards to be used to gain entry to the new facilities by a simple reprogramming of the existing system rather than having to issue new and additional cards to OLRT staff; it will also enable M&R staff to have access to OLRT facilities through common access control infrastructure.

OC Transpo Corporate Systems

To allow external approved parties and third-party applications hosted on the OC Transpo Corporate LAN to retrieve operational performance and travel data from the OLRT systems, a data server will be established as part of the extended CTS. This server will produce data in an XML format and will be designed to be interoperable with Service Interface for Real Time Information (SIRI) or other applicable standards. The final configuration of data transfer and content will be defined during the Design Phase.

5.4.10 MEDIUM VOLTAGE DISTRIBUTION

5.4.10.1 Typical Medium Voltage Service

For the mainline, each traction power substation will provided with either 13.2 kV or 27.6 kV feeders from Hydro Ottawa (HOL) to HOL switchgear and metering cubicle assembly. The pad and grounding for this switchgear and the associated ductwork will be provided by RTG. **Table 5.4-33** provides the expected feeder types for each TPSS as per the Planning Report provided by HOL.

For the MSF, three HOL 13.2 kV feeds will be provided as per the Planning Report. A separate feed will be provided for the TPSS Yard, TPSS Maintenance Shop and MSF Building distribution.

Table 5.4-33 | Expected Feeder Types

Traction Power Substation or Underground Station	Feeder from Hydro Ottawa Substation	Feeder Type	Voltage
TPSS-01	Hinchey TS	Looped	13.2 kV
TPSS-02	Lisgar TL	Looped	13.2 kV
TPSS-03	King Edward TK	Looped	13.2 kV
TPSS-04	Riverdale TR & King Edward TK	Looped	13.2 kV
TPSS-05	Riverdale TR	Looped	13.2 kV
TPSS-06	Overbrook TO	Looped	13.2 kV
TPSS-07	Cyrville MTS	Radial	27.6 kV
TPSS-08	Cyrville MT	Distribution Loop	27.6 kV
Downtown West Station	Lisgar TL	Dual Looped	13.2 kV
Rideau	Slater TS	Dual Looped	13.2 kV
TPSS-MSF Yard	Overbrook TO	Looped	13.2 KV
TPSS-MSF Shop	Russell TB	Looped	13.2 KV
MSF Building	Russell TB	Looped	13.2 KV

Stations

A high-voltage feed and distribution transformer will provide low-voltage power to At-Grade Stations close to the traction power substation:

- Tunney's Pasture Station from TPSS-01
- Le Breton Station from TPSS-02
- Hurdman Station from TPSS-05

- Train Station from TPSS-06
- Cyrville Station from TPSS-07
- Blair Station from TPSS-08

Medium-voltage distribution for the facilities will be provided for the Underground Stations (Downtown West, Downtown East and Rideau). The feeders from HOL will be based on Option F as outlined in the Hydro Ottawa Planning Report for this Project. This will provide a dual looped 13.2 kV feed to Downtown West Station and a dual looped 13.2 kV feed to Rideau Station. Each HOL feed will be cabled to the three Underground Stations providing redundant power feeds to each Station.

Medium-voltage distribution will provide redundant 13.2 kV power feeds required to provide power to the tunnel ventilation system. For single line diagram, refer to **Drawing 5.4.3-SW-121**.

Although TPSS-03 will be located in Rideau Station, it will be provided with a separate feed from HO, and HOL Metering Switchgear will be housed in a separate room in Rideau Station.

St. Laurent Station is an existing Station which will also require redundant utility feeds to supply the emergency ventilation system. It is assumed that the existing HOL feed will be used as the primary feed. For the redundant back-up feed a 13.2 kV feed will be provided from TPSS-07.

TSCC

A separate HOL MV feed will be provided for the MSF Building. This will provide power for the TSCC, YCC and BCC.

YCC & BCC

Discussed in **Section 5.6**.

5.4.10.2 Drawings

Drawings 5.4.5-SW-101 to 5.4.5-SW-108 include the location of substation transformers and ancillary equipment (breakers, bus bars and isolation switches).

5.4.10.3 Redundant Supply Methodology

Discussed in **Section 5.5**.

5.4.11 CORROSION CONTROL

5.4.11.1 Corrosion Control Strategy

The OLRT traction power system will be 1500 V dc overhead contact system with the running rails as negative return to feed power to the Trains. With the running rails as a return there will be various levels of dc stray current leaking into the surrounding structures or ground which can cause corrosion of nearby metals.

Stray current cannot be eliminated but can be mitigated to reasonable levels. As a general strategy to mitigate the corrosion due to stray current, the following will be considered:

- Minimize the level of stray current through track design
- Review underground metallic utilities under or near the guideway and provide necessary protection
- Ground and bond guideway structures
- Provide surveys of stray current levels during stages of construction and operation

A NACE-certified corrosion specialist will be provided for this Project with these duties:

- Soil resistivity measurements and analysis along the guideway and yard

- Review of structure design
- Review of grounding system design
- Review of underground utilities and existing cathodic protection
- Provide recommendation on cathodic protection requirements and test points
- Stray current and corrosion measurements during construction and start of revenue service.

Corrosion Control – Underground Elements

Underground metallic utilities near or crossing under the guideway will be documented. Each Utility Company will be contacted to determine the type of underground material and existing corrosion protection (e.g. coatings, cathodic protection), as well as their ability to monitor any adverse effects to that protection when the OLRT goes into service.

Corrosion Control – Structural Supports & Services

The effect of any corrosive environment on guideway bridges, structural culverts, retaining walls and general structural supports for LRT systems will be controlled through the means of design and construction, utilizing methods that are compliant with the requirements of Schedule 15-2 of the Project Agreement. These methods will ensure the indicated service life is attained, without replacement of any major components. For concrete structures, these methods may include providing sufficient concrete cover to the outer layers of reinforcing steel, using epoxy coated, stainless steel, or Glass Fiber Reinforced Polymer (GFRP) reinforcing bars, if required, and will consider the requirements for bridge substructures in splash zones of adjacent roadways. For steel structures, appropriate coatings will be applied, if required this may include hot dip galvanization for general structural supports for LRT systems. For steel piles, site specific soil corrosion levels will be considered during detailed design.

To minimize the corrosive effect of stray current in guideway structures, metal in the structures will be provided with bonding so that it is electrically continuous along the guideway. This will be done by installing continuous bonding conductors along each track, providing bonds to the rebars at a maximum of 30 m intervals, as well as at any discontinuities of the structures. Using metal wire ties and welding selected rebars will also ensure electrical continuity of structure rebars. These measures will ensure the metallic reinforcements in the structure are electrically continuous which will allow stray current to flow along the structure and minimize stray current flowing in the ground. For bored tunnel where metal reinforcements in the segments will be difficult to bond together, metallic mesh will be provided in the invert and will be bonded to the continuous bonding conductor to provide a low-resistance path for the stray current to flow, thus minimizing stray current flow outside the structure.

5.4.11.2 Reducing Stray Current

Design Concepts

The primary method to control the level of stray current is to provide good electrical insulation between running rails and the guideway structure or ground, and provide a low-resistance path for the negative return current to travel back through the running rails to the TPSS. Good electrical insulation between the running rails and the guideway structure or ground can be achieved as follows:

- Insulated rail fasteners
- Good drainage of the trackbed
- Clean ballast of proper depth, kept from contacting the running rails
- Insulated track switch operating, locking and point detection rods
- Prevent any grounded equipment or materials from touching the running rails

A low-resistance path along the running rails for the negative return current will minimize the voltage rise from running rail to earth and therefore reduce the level of stray current. This can be accomplished as follows:

- Large weight running rail
- Continuously welded rail
- Cross-bonding between rails and tracks (coordinated with signalling)
- Electrically bonded rails around movable points and other mechanical connections in special trackwork areas

Stakeholders & Sensitive Receptors Requirements Management

Metallic utilities which may be affected by stray current from the LRT system will be documented. Each Utility Company will be contacted to determine the type of underground material and existing corrosion protection (e.g. coatings, cathodic protection) as well as their ability to monitor adverse effects to that protection when the OLRT goes into service. The Utility Company and RTG would also discuss and agree if additional measures are required to ensure the OLRT system does not affect their utility.

The Project Agreement has identified three Stakeholders which might be affected by EMI from the OLRT system: CBC, NRCan and University of Ottawa. Other Stakeholders may be identified through the Public Engagement Process in which they will have the opportunity to bring their concerns to RTG. RTG will contact Stakeholders that could be affected by EMI to advise them of the standard levels the OLRT system equipment will emit.

5.4.11.3 Stray Current Monitoring & Metering During Construction & Operation

Stray current measurements will be performed and documented in three phases:

- Stray current levels once construction of the guideway and relocation of underground utilities is completed
- Stray current levels after the completion of all construction
- Stray current levels after the commencement of normal revenue service

Measurements will be documented and checked to ensure that stray current emanating from the OLRT during normal revenue operation does not exceed the polarized potential of the structures as outlined in NACE RP0169.

Rail-to-ground insulation resistance will also be measured and verified during construction. For each section of completed track, the resistance will be measured as per ASTM G165 and to ensure it is at least 250 Ohm per 300 m. Completed track will have insulated rail joints which are required for the signalling system. This can be used to isolate sections of track for rail-to-ground insulation resistance measurements after construction.

5.4.11.4 Stray Current Best Practices

Other best practices which will be applied on the OLRT Project to minimize stray current include the following:

- Use of 1500 Vdc instead of 750 Vdc to reduce traction current and therefore reduce the rail-to-ground voltage
- A floating negative traction system for mainline, no diode grounding
- Electrically isolate the Mainline, Yard and Maintenance Hall running rails
- Track design with running rail to earth electrical isolation of at least 250 Ohm per 300 m and provide a rigorous testing program during installation to ensure this criterion is met

5.4.12 EMI/EMC

The presence of electromagnetic interference (EMI) and the resulting need for determination of electromagnetic compatibility (EMC) is a problem faced by all electrified railway systems around the world. It is important the OLRT system is designed to operate safely with the presence of an acceptable limit of EMI and to generate only an acceptable level of EMI to parties adjoining the alignment.

5.4.12.1 EMI/EMC Strategy

In line with PA Schedule 15-2, Part 4, Article 9 requirements, we will use EN 50121 as the design basis for the railway and the subsystems within it.

First and foremost, the railway has to operate safely at all times, so immunity to EMI of all major subsystems is of prime importance; this includes the Vehicle, CBTC and overlaid signalling (e.g. track circuits). All rolling stock or wayside equipment determined to be safety critical, or feeding into safety-critical systems will be reviewed for their proven compliance with EMI emission and immunity requirements in EN 50121. Where possible, all equipment used on the system will have a proven track record in a similar operating environment where it can be shown to not cause and to not suffer from EMI at the levels acceptable under EN 50121.

We will generate an "Electromagnetic Compatibility Identification" document and an "EMC Control Plan" to describe and identify the risks both to the railways from adjacent parties and to the adjacent parties from the railway (including the Sensitive Receptors identified in **Section 5.4.11.2)**. Toward the completion of construction we will generate an "EMC Demonstration Plan" that will set out the method of demonstrating that the system has met required performance criteria and can operate safely. After executing this demonstration, we will prepare and issue an "EMC Demonstration Report" outlining and summarizing the results of the tests.

5.4.12.2 Applicable Design Techniques

Good design practice and the use of established design guidelines is the starting point of all design. In North America, APTA, AREMA and IEEE standards and guidelines are used extensively; European (EN) standards and International (IEC) standards are also used should the project require them or where they are seen as best practice.

The starting point for all system design is to confirm that equipment procured for the Project has an EMI impact (to the Vehicle, wayside or adjoining parties) complying with EN 51021. This will limit exposure of the overall system to unwanted levels of EMI and EMC.

Once equipment has been selected, it is important to look at the installation of that equipment together with its protection from external forces. Lightning protection and grounding are two important design issues to be addressed. We expect to produce a Lightning Protection and Grounding strategy document at the outset of the Project to provide common understanding of the problems and design direction across all Project elements.

One key component of the system that produces EMI is the Overhead Catenary System (OCS), especially in Ottawa where ice formation on the lines and the subsequent removal of it by the pantograph has the potential to generate EMI across a large frequency range. Any arcing at the pantograph/contact wire junction will cause EMI. During the design phase we will work with Alstom to determine the best method of mitigating these problems.

Other traction power considerations that have an effect on EMF, and therefore EMI, are the location and size of substations relative to the expected draw from the system.

5.4.12.3 Mitigation Measures

Most EMI problems exist for only a few tens of metres around the source due to the limited power available within the equipment to generate high-voltage fields. The traction power system is an exception to this by virtue of its function and operation. For low-voltage equipment, positioning within the Vehicle and/or alignment should be sufficient to nullify EMI effects as it will allow the EMF to fall away to non-impacting levels before reaching sensitive equipment outside the Project.

If we determine that a piece of equipment is susceptible to EMI or will generate EMI problems for other equipment, we will review the product and then either replace it or take steps to reduce its footprint in accordance with standards and recognized practices. Obvious exceptions to this are wayside signalling equipment mounted close to the tracks that will be expected to operate close to the Vehicle trucks, some of which will have traction motors mounted to them. Working with key vendors of this equipment to test and certify their systems together will allow us to, if necessary, take steps to protect components and subsystems.

The final selection of mitigation techniques will be made if a problem is identified and needs to be mitigated because it cannot be reduced to non-impacting level.

5.4.12.4 EMI/EMC Best Practices & their Applicability to the OLRT Project

Standards-based design to reducing EMI/EMC and recognizing potential sources and receptors is the best approach to reducing and mitigating unwanted EMI and EMC.

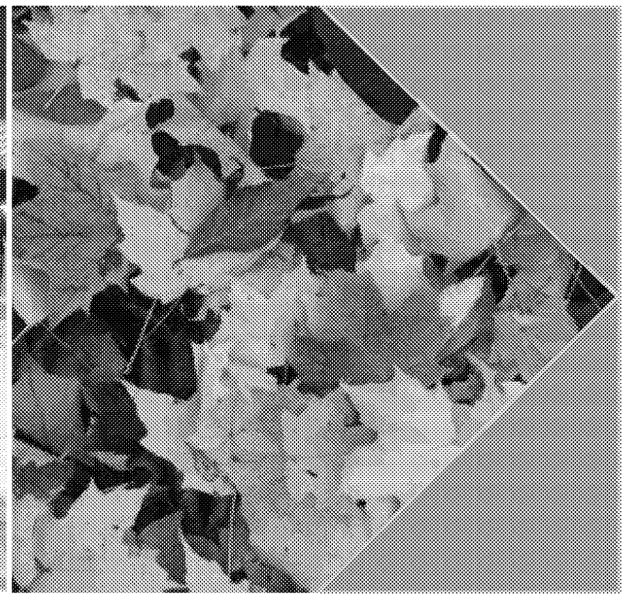
Best Practices

The US Department of Transportation's Federal Transit Administration has produced a document, "Guidance on the Prevention and Mitigation of Environmental, Health and Safety Impacts of Electromagnetic Fields and Radiation for Electrical Transit Systems". This document discusses and summarizes best practice for reducing and mitigating EMI/EMC to both equipment and to persons.

Applicability to the OLRT Project

We recognize the importance of reducing the risk of EMI and EMC on the OLRT and of mitigating it where there is a risk of occurrence that cannot be removed. To do this we will employ best practices from both North America and Europe in our designs, using the skill sets of our international Design Team and recognized external experts to review and advise on individual issues.

Appendix B - Canadian Content



APPENDIX B

CANADIAN CONTENT CERTIFICATE

	Sub-Systems	Typical Components (but not limited to these)	Manufacturer's name and address	% of Vehicle Contract Total Value	% of Canadian Content	% of Vehicle Supply Costs from Canadian Sources
Vehicle Subcomponents and Component Cost Estimate	Propulsion system	Traction inverters		7%	0%	0%
		Traction control unit (motor and gearbox)				
		High Speed Circuit Breakers				
		Transmission				
		Pantograph				
		Ice Scraper				
		Wiring				
	Carshell	Stainless steel and aluminum body		14%	22%	3.08%
		Under frame/ chassis				
		Insulation Material				
		Corrosion prevention (paints and decals)				
		Windshield (includes wiper)	PRELCO 94 BOULEVARD CARTIER RIVIÈRE-DU-LOUP QUÉBEC, CANADA			
		Cabinet Assembly				
		Air horn	FAIVELEY 1002 RUE SHERBROOKE OUEST, MONTREAL, QUEBEC			
		Panels (exterior)	DIMENSION COMPOSITE INC., 2530, 95E RUE, SAINT-GEORGES, QUÉBEC			
		Fixings and Fastenings				
		Fibre Reinforced Plastics	DIMENSION COMPOSITE INC., 2530, 95E RUE, SAINT-GEORGES, QUÉBEC			
	Trucks & Suspension	Bearings		14%	0%	0%
		Coil spring				
		Traction rod				
		Cabling				
		Terminations				
		Suspension control unit				

	Sub-Systems	Typical Components (but not limited to these)	Manufacturer's name and address	% of Vehicle Contract Total Value	% of Canadian Content	% of Vehicle Supply Costs from Canadian Sources
		Fixings and Fastenings				
		Pipe work				
		Wiring				
		Hydraulic levelling system				
	Interior	Panels	CEIT 5650 RUE TRUDEAU, SAINT-HYACINTHE, QUEBEC	3%	28%	0.84%
		Material/ fabric				
		Carpet/ flooring				
		Glass partitions				
		Advertising panels				
	Low voltage Power supply	Auxiliary supply converters	MERSEN 88 HORNER AVE, ETOBICOKE, ONTARIO	6%	28%	1.68%
		Circuit breakers				
		Wiring				
		Batteries				
	Brake Equipment	Brake Control Unit (BCU)	FAIVELEY 1002 RUE SHERBROOKE OUEST, MONTREAL, QUEBEC	9%	63%	5.67%
		Brake Resistor	I-GARD CORPORATION , 7615 KIMBEL ST., UNIT 1, MISSISSAUGA, ONTARIO			
		Friction brake (track brakes and sanding system)	KNORR 675 DEVELOPMENT DRIVE, KINGSTON, ONTARIO			
		Hydraulic Accumulators	KNORR 675 DEVELOPMENT DRIVE, KINGSTON, ONTARIO			
		Piping				
		Fixings and Fastenings				
		Electrically actuated bi-parting sliding-plug door assembly	WABTEC 475 SEAMAN ST, STONEY CREEK, ONTARIO			
		Automatic passenger counter				

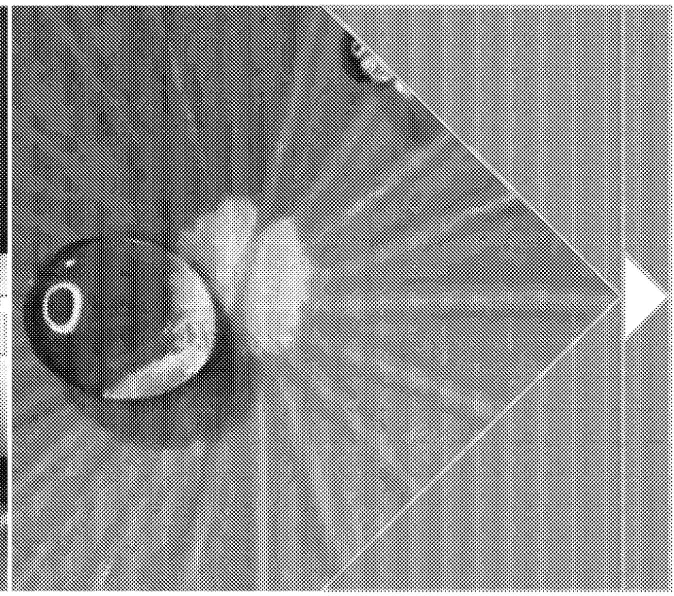
	Sub-Systems	Typical Components (but not limited to these)	Manufacturer's name and address	% of Vehicle Contract Total Value	% of Canadian Content	% of Vehicle Supply Costs from Canadian Sources
		Photocell obstruction detection system				
		Passenger push buttons	WABTEC 475 SEAMAN ST, STONEY CREEK, ONTARIO			
	HVAC	Cab heater		2%	0%	0%
		Floor heater				
		Underseat heater				
		Booster fans				
		Smoke alarm system				
		Wiring				
		Fixings and Fastenings				
		Piping and ducts				
	Misc. Equipment	Emergency window		1%	90%	0.9%
		Passenger intercom	ALSTOM 1010 SHERBROOKE, MONTREAL, QUEBEC			
		Barriers and guard rails				
		Push button panel				
		First aid box				
		Bicycle racks				
		Hand lamp and emergency hammer				
		Fire extinguisher				
	Cab Compartment	Train computer system & diagnostic system		2%	5%	0.1%
		Desk	DIMENSION COMPOSITE INC., 2530, 95E RUE, SAINT-GEORGES, QUÉBEC			
		Panels				
		Seat (spare instructor seat if required)				
		Desk controls				
		Deadman's Switch				
		Wiring				
		Pipe work				
		Screens (Includes video display screens from CCTV)				
		Radio Handset				

	Sub-Systems	Typical Components (but not limited to these)	Manufacturer's name and address	% of Vehicle Contract Total Value	% of Canadian Content	% of Vehicle Supply Costs from Canadian Sources
		Control handle				
	Articulation Assemblies	Insulated articulation bellows		1%	0%	0%
		Fixings and Fastenings				
	Couplers and Draft Gear	Wiring		1%	0%	0%
		Fixings and Fastenings				
		Anti-climber				
		Pipe work				
		Interior lighting				
		Emergency interior lighting				
		Hazard and indicator lights				
		Front and rear lighting (including headlamps)				
	Seating	Fixings and Fastenings		1%	0%	0%
		Interior passenger seats				
	Vehicle Train Control System	Vital onboard computer		0%	0%	0%
		Axle speed detectors				
		Wiring and connectors				
		Vehicle location system				
		Fixings and Fastenings				
		Antenna				
		Doppler shift modules				
	Communication Equipment	Public address system (including loudspeakers)	ALSTOM 1010 SHERBROOKE, MONTREAL, QUEBEC	1%	100%	1%
		Passenger Emergency Intercom (PEI)				
		Integrated Diagnostics and Fault Reporting System				
		Electronic Displays (PIS/ PID)				
		CCTV system				
		Event recorder				
		Hi-speed data radio and antenna				
		Train computer				
		Radio and radio antenna				
		Wayside communication system				
	Glazing	Vandal-resistant sacrificial film	PRELCO 94 BOULEVARD CARTIER	1%	100%	1%
		Laminated glass panes				

	Sub-Systems	Typical Components (but not limited to these)	Manufacturer's name and address	% of Vehicle Contract Total Value	% of Canadian Content	% of Vehicle Supply Costs from Canadian Sources
		Rubber trim/ sealant	RIVIÈRE-DU-LOUP QUÉBEC, CANADA			
	TOTAL veh sub-components & component cost estimate			**64%**	**22,4%**	**14.3%**
Soft Costs	Labour		ONTARIO	8%	85%	7.0%
	Project Management			**6%**	**20%**	**1.0%**
	Engineering			**16%**	**5%**	**1.0%**
	Manuals, Training, Simulators			**0.5%**	**0%**	**0%**
	Special Tools			**0.3%**	**0%**	**0%**
	Test Equipment			**2%**	**70%**	**1.0%**
	Freight			0.2%	0%	0.0%
	Warranty		ONTARIO	3%	100%	3%
	TOTAL soft Costs			**36%**	**35.8%**	**13%**
	Total Local content calculated					**27.3 %**

The individual ratios indicated in this table are indicative only. Local content for specific items may change during the process of design development and development of specifics of each supplier's scope of supply. The total Canadian Content of the Vehicles shall comply with the Canadian Content policy. and specifically shall be at least 25%.

5.5 STATion DeSiGn



5.5 STATION DESIGN

Contracted by RTG for design and construction services, the DBJV (a fully integrated design-build joint venture comprising SNC-Lavalin Constructors (Pacific) Inc., Dragados Canada Inc., and EllisDon Corporation) will deliver all fixed facilities comprising the 13 Stations, the 10 Traction Power SubStations and the Maintenance and Storage Facility (MSF, described in **Section 5.6**). The DBJV has subcontracted the entire design to the engineering joint venture (EJV), a fully integrated joint venture comprising SNC-Lavalin Inc. and MMM Group. The EJV has retained industry-leading experts including HMM (tunnel design and ventilation analysis); IBI Group, Adamson Associates Architects and bbb Architects (Station architecture), Fast + Epp (Station structural working with MMM); Sereca (fire and life safety), Thurber Engineering (geotechnical), ATS Consulting (Noise and Vibration), and Total Lighting Solutions (lighting) to support the design effort. The remainder of the design work will be performed jointly by SNC-Lavalin and MMM, which will include environmental, hydrology, civil, drainage, utilities, guideway and Stations' structural, Stations' mechanical and electrical, pavement, energy modelling, security, landscape, and systems design including trackwork, communications, tunnel ventilation system and power supply and distribution. Coordination and management of the Vehicle design and train control systems, as provided by Alstom and Thales, will also form part of the EJV's design scope, to effectively manage and deliver a fully coordinated and comprehensive design solution for the DBJV to successfully construct and implement.

Throughout design and construction, the RTG Design, Construction and Maintenance and Rehabilitation (M&R) Teams will continue to work in a highly integrated manner to appropriately select whole-life design solutions that deliver the quality and reliability envisaged for the System and as specified in the Output Specifications.

5.5.1 ARCHITECTURAL DESIGN

For the OLRT Project, RTG has developed a unified suite of Stations. Federally Mandated and Non-Federally Mandated Stations share one 'brand identity': an identity that is both iconic and enduring in its architecture. Designed primarily to serve the OLRT Project, the Stations establish a System identity unique to Ottawa and the City's aspirations: a brand that is adaptable and expandable, suitable to be applied to future network extensions.

Designed primarily with Passengers in mind, the Stations are safe, accessible, visually pleasing and functionally efficient. Careful integration of art across the system, the warmth of the Stations' materials palette and 'acts of place making' achieved at selected entrance plazas combine to elevate the Passenger experience, and achieve a pride of ownership that will attract and expand ridership in the short term and also lead to sustained growth in the long term.

Five Key Features of the Station Design

RTG's design approach evaluated and assessed every aspect affecting Station design, adopting a holistic and rigorous analysis process. From macro transit planning to urban design and contextual fit, from Station functional planning to detailed design, this work effort has led to a broad range of changes and improvements to the System, tailored to realize the City's 11 stated goals, the National Capital Commission's 'capital interests' and compliance with the PSOS. From these numerous improvements, **Table 5.5-1** summarizes five substantive Station design features that RTG believes offer the City lasting benefit and that distinguish our design.

Table 5.5-1 | Principal Station Design Features and Client Benefits

Station Design Feature	Client Benefit
Development of an appropriately scaled iconic architecture that achieves a consistent and coherent identity for Passengers to easily find and navigate in their use of the OLRT. The brand is consistently applied across all Stations and exhibits a quality of public architecture that uplifts the Passenger experience.	■ A distinctive, high-quality architecture as shown in the Station renderings promotes civic pride and respectful use of the system. ■ Easy identification, wayfinding and navigation reinforces Passenger familiarity in using the system, instills a sense of safety, ease and comfort, which in turn encourages use and ridership growth.
Optimized platform length of 90 m, suitable for scenarios 1 and 2 with a required expansion of only 10 metres to meet the ultimate ridership of 24,000 pphpd which reduces the platform footprint from a possible 120 metres to only 100 metres	■ A reduced platform length significantly reduces future capital and operational costs for the City, and achieves more compact and efficient Stations to operate and maintain. ■ Shorter platforms offer improved alignment geometry and Station integration, and better ridership quality for passengers, especially at LeBreton, Rideau, Campus, Lees, Cyrville & Blair.
Underground mined Station construction methodology has been incorporated into Station designs to minimize surface disruption and relocation of utilities	■ Impact to traffic, businesses and the public in the downtown core is significantly reduced. The City will be credited for preserving functionality of the city, and for considering public interests. Businesses—especially small businesses—will be protected.
Station designs have been tailored based on ridership demand and contextual fit, aimed at providing appropriate levels of capacity and shelter needed for each Station to function efficiently and effectively.	■ Sizing, capacity and functional optimization of Stations distributes Client investment equitably, leading to an affordable Project in terms of initial capital cost, and long-term maintenance and operations. Key modifications that reflect this rationale are found at Tunney's Pasture, LeBreton, Campus, Lees, Train, Cyrville and Blair Stations.
Station designs optimized for reliability, taking into account core operational and maintenance considerations to respond to the broad range of scenarios encountered through the life of the system, including the extremes of winter and summer operations, event conditions, and narrow maintenance periods.	■ Incorporation of operational and maintenance daily, weekly, and periodic activities in terms of opening, closing, securing, cleaning, maintaining, and rehabilitating the Stations achieves long-term efficiencies and preserves the quality of the Stations over time, thereby sustaining the quality of the capital investment and extending its operational life.

5.5.1.1 Functional Design of Stations

RTG has optimized the functional designs of all 13 Stations, while still meeting PSOS requirements. **Section 5.5.1.3** describes refinements and improvements related to integration of Station entrances into the local urban context. This section, dedicated to Station Functional Design, focuses on Station size and capacity, organization and functional layout, and on achieving solutions that are firmly rooted in Crime Prevention Through Environmental Design Principles (CPTED).

Station Size and Capacity

As part of RTG's four-tier Station planning process, we analyzed peak ridership volumes to determine the numbers of Passengers using each Station, and to observe any major changes between the three operating scenarios. Significantly, results of the analysis demonstrated the following:

- Clear distinction and classification of Stations by Passenger-demand forecasts (see **Figure 5.5-1**). Where six Stations exhibit high to very high demand (Tunney's Pasture, Downtown West, Downtown East, Rideau, Hurdman and Blair); three Stations exhibit moderate demand (Bayview, Campus and St. Laurent), and four Stations exhibit very low demand (LeBreton, Lees, Train and Cyrville Stations).

- Tunney's Pasture Station will experience a reverse demand, and will change from a very high capacity Terminal Station to a moderate line Station once the OLRT is extended west.
- Bayview will experience a major increase in demand if and when the O-Train extension is implemented. Otherwise it will remain a low-capacity Station.

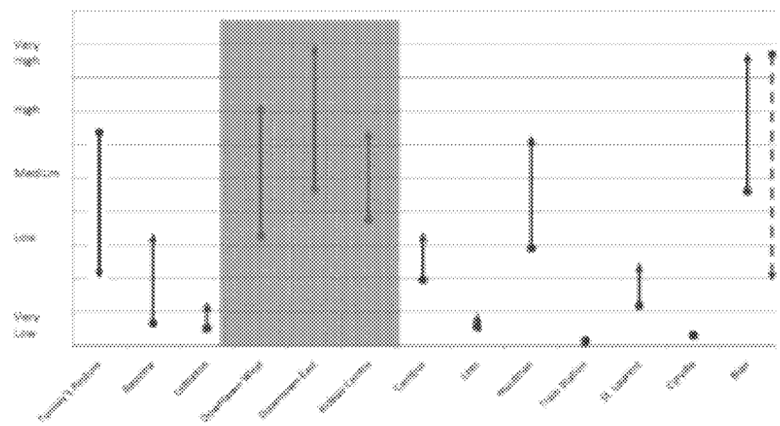


Figure 5.5-1 | Change in Peak Ridership Demand Across Stations Between Operating Scenarios 1 and 3

Conclusions drawn from the ridership analysis have been used to size each Station appropriately to match its anticipated demand. Thus, the high-ridership Downtown Stations typically have more entrances, vertical circulation elements, and more generous circulation areas. Very low ridership Stations, where the maximum number of Passengers standing on a platform at any one time is no more than 20 people, require less platform coverage to provide adequate Passenger weather protection, and smaller primary public circulation to satisfy circulation and emergency egress. Influence of the peak Link Load has also been factored into all capacity and egress requirements as required by code.

Not only is the ridership during normal operation an important factor, but special events also need to be considered. Special event crown management has been factored into the design of Lebreton and Train Stations where provisions of generous plazas to hold event crowds have been incorporated as part of the Station urban design.

Demonstration of how ridership demand has been applied throughout the Stations is provided in several ways. Firstly the code analysis described in **Section 5.5.1.14** provide the minimum capacity to meet OBC and NFPA130:2010 requirements. Secondly, flow diagrams show the capacities and flow volumes provided at each element within each Station (see drawing list 5.5.1-DS-100 for list of passenger flow diagrams for each station).

A key feature of RTG's Stations is the primary circulation elements have been sized to accommodate normal peak period operational requirements for all three operating scenarios including Ultimate Demand of 24,000 pphpd. Sizing of vertical circulation elements has included the 1.3 surge factor for peak within the peak" demand, and a 0.8 headway clearance period for Passengers to leave the Station platform. In addition, public stair capacity has been checked to ensure that if one escalator is out of service, the stairs can still handle peak demand albeit at a lower level of service (LoS E considered as being acceptable in restricted operations mode).

While RTG's PA obligations are to satisfy Scenario 2 ridership volumes, it is in the City's best interests for the design to meet all normal operating scenarios, and to limit any future expansion ofexit capacities without requiring expansion of primary public circulation and, potentially, the addition of new public concourses. Expansion to meet Ultimate Demand is addressed in **Section 5.5.1.6**, but RTG's design approach has been to limit the City's exposure to additional capital investment for future infrastructure expansion.

Most significantly, RTG has optimized the Vehicle-to-platform interface and achieved a single 90 m-long platform that will satisfy all normal operating scenarios, with the underground stations at 120 m. At 189, 119 and 105 seconds, respectively, the minimum operating headway for Scenarios 1 to 3 comply with PA Schedule 15-2, Part 1, clause 2.6. A two-car Train consist coupled together measures 97 m and, when positioned at the platform, provides a 3 m surge zone for queuing between the edge of the last door and the end of platform. These clearances are consistent with the Canada Line, and have proven to be sufficient for Passenger entraining and detraining movements on platform. **Section 5.4.1** details the Vehicle-to-platform interface.

Functional Organization and Pedestrian Flow

Organization and configuration of the Station functional plans has captured key considerations for Passengers, plus those of the Operator and M&R Team. Beyond the Station footprint, the 'Station hub' area provides hierarchy to intermodal transfers and interface, and creates a public realm that is welcoming and harmonious with the surrounding context (see **Section 5.5.1.3**).

Passenger Considerations – Organization of the Station's public areas follows a simple and logical progression from Station identification and arrival, through ticket purchase and passing through fare control, travel from concourse to platform, arrival and waiting at platform, completed by Vehicle boarding and Passenger departure. This same sequence is also designed for reverse movements to account for Passengers arriving by train, exiting through the Station and leaving the Station hub. Righthand-flow principles have been adopted throughout as a principal organizing concept, which is demonstrated later with diagrams illustrating the principles of pedestrian movement for each of the main functional areas of the Station. CPTED principles have been incorporated throughout the design of public areas and refinements will continue through the detailed design phase, supported by secondary elements such as CCTV for surveillance and overlook, and secured access-control points to contain Passenger activities within the public areas.

Operations and Maintenance Considerations – The primary ancillary areas of the Stations have been consolidated and grouped to optimize Station organization and to clearly demarcate public from non-public spaces. At this stage all ancillary rooms have been space-proofed to ensure equipment can be accommodated during detailed design. Key functional relationships of desired room adjacencies have been accounted for. Large-equipment-removal pathways have been planned into all Stations, but especially into the Underground Stations where spatial constraints and level changes require provision of lifting beams and access hatches to accommodate the replacement of large equipment.

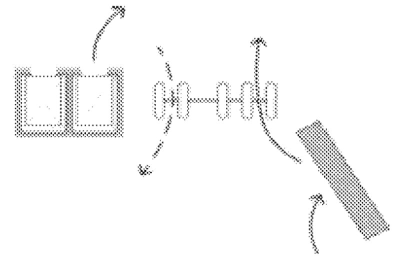
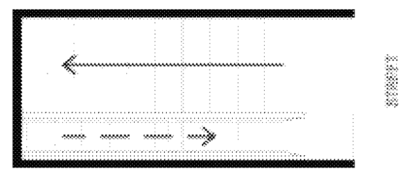
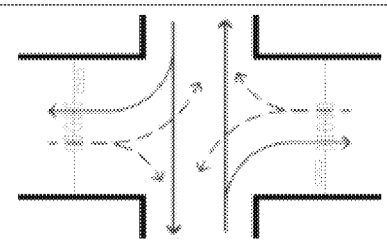
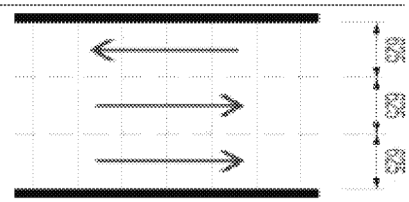
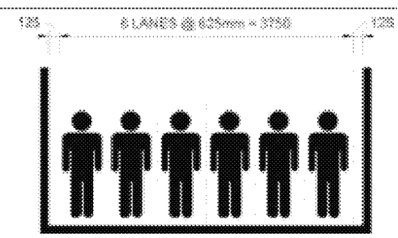
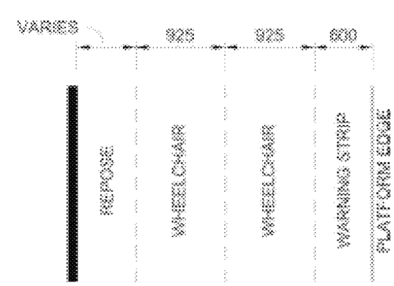
Maintenance requirements for storage rooms, janitor closets, snow removal and snow storage areas have been included in the functional plans.

Security control of the Stations has been provided. Stations can be locked-down at night to keep the public out while overnight M&R work is performed. All Stations are equipped with man-doors to grant staff (such as cleaning) access once the primary public entrances have been closed.

Sample Organization Diagrams – Station functional plans have been oriented towards the first-time user who is unfamiliar with the OLRT. From point of arrival to departure, public areas are organized simply and intuitively where natural progression of movement, combined with single-point decision-making and long uninterrupted sight lines simplify wayfinding and navigation. Key features incorporated into Station designs include predominant righthand-flow movements with limited cross flows or provision of generous concourse areas where cross flows are unavoidable. Surge areas in front of stairs, escalators, elevators, future fare gates and fare control elements are provided per PSOS requirements.

Table 5.5-2 provides conceptual diagrams (entrances, concourses, passageways, vertical circulation, and platforms) showing how these features have been incorporated into Station designs and explaining key features.

Table 5.5-2 | Sample Functional Design Components within Stations

Location	Functional Diagram
Entrance & Concourse Surface Stations – A distinguishing feature of RTG's Station designs are light boxes: located prominently at the threshold of every Station they function as beacons that make Stations easily distinguishable at night. Typically located to the right, they house two recessed fare machines and accommodate Station information and regulatory signage. Progression of movement follows the sequence of information, ticket purchase, passage through fare control and onwards to vertical circulation. All elevators are located in highly visible locations to support CPTED. Concourses are largely column free. Reverse right hand-flow movements support exiting from Stations. Areas of repose are provided with space for and future fare machines, included.	
Entrance Underground Stations – To optimize space, all ticketing functions are located underground at the concourse level. Thus, Underground Station entrances are configured to support simple and efficient movement from street to concourse. Vertical circulation is organized for right hand-flow movements. The signage beacon is typically located towards the street side of the entrance to maximize visibility.	
Concourse Underground Stations – Fare concourses to Underground Stations accommodate horizontal connections from both north and south. Thus, spaces are planned to permit cross movements in front of fare lines and gate arrays. Similarly, with side-platform configurations, fare-paid concourses have been sized to accommodate some cross-flow movements. All control points, vertical circulation and fare barriers are organized to support right hand-flow movements. Elevators provide access from street to concourse, but require passage into the fare-paid zone before descent to platform level.	
Vertical Circulation – Vertical circulation is organized to support right hand-flow movements. All public stairs are sized to a minimum of 1875 mm which provides three lanes of 625 mm, thereby providing a minimum of two lanes in the predominant flow direction which allows passing. Escalators are generally configured to support right hand-flow upward movements except where consideration of surge zones and relationship to exterior walls might overrule. Surge zones are provided at the top and bottom of all vertical circulation. All public stairs are inclined to 30 degrees to match escalators. Bike runnels are accommodated.	
Passageways – Minimum-width requirements of 4000 mm have been provided on all new horizontal passageways. Existing bridges and underpasses have not been increased since capacities are adequate for anticipated flows. Allowance of a 125 mm shy zone between Passengers and the wall has been discounted in calculating horizontal flow capacity. Right hand-flow assumed in all cases. 90 degree internal corners are typically chamfered to improve sightlines and pedestrian movements.	
Platforms – Surface Stations are sized to a consistent length of 90 m to accommodate a 97 m-long train consist, with doors within the platform length. Minimum platform width of 3.2 m to suit OBC requirements. At high-capacity Stations, platform widths have been increased to accommodate required standing area, and to provide platform-edge zone and one 625 mm circulation aisle to enable Passengers to move along the platform to find a suitable standing space. All platforms have been checked to accommodate the double entraining capacity standing on platform in case of interrupted service. Required space based on reduced LoS E (0.4 m^2 per person) for limited period is consistent with Fruin LoS standards. Thereafter, crowd control measures will be implemented to avoid overcrowding. Underground station platforms sized to meet minimum ultimate platform length of 100 m at Rideau and Downtown West and 120 m at Downtown East	

Crime Prevention through Environmental Design

As demonstrated in the Station functional plans, the core CPTED principles of surveillance, territoriality and ownership, hierarchy of space, prospect and sightlines are evident in our design. Light quality, target hardening and access control measures are less evident but nonetheless will be incorporated during detailed design. Activity support represents an oportunity that can be realized through the Transit Oriented Development program for the line. However, this latter objective will take time to realize and will rely heavily on City and NCC planning processes to encourage complementary uses and scales of development around the Stations to make a positive contribution.

Key CPTED features in RTG's Station design include the following:

- Functional plans are efficient, leading to compact Stations with good sightlines within the public areas. This concentrates Passenger activities and discourages poor behavior.
- Public areas have good sightlines. Extensive use of glass creates transparency and overlook, thereby promoting surveillance. The formulation of three canopy heights communicates hierarchy of space. Eliminating blind spots, reducing 180 degree movements, and chamfering 90 degree corners all promote prospect and sightlines.
- All ancillary areas are locked off and access is reduced to a few doors. In addition, CCTV monitoring of doors and access-control measures monitored through central control will protect against forced entry or unauthorized access to critical operations areas.
- All elevators have been located along the primary paths of travel to provide high visibility to Passengers who must use elevators to access the platform. Elevator cabs have been equipped with CCTV for surveillance. Designated Waiting Areas on each platform and tactile wayfinding system through the Stations help the blind to navigate.
- Lighting quality will be given the utmost attention during detailed design of the Stations. Materials palettes will be selected with light as a consideration to ensure an appropriate level of light is provided to give Passengers a sense of safety.

During detailed design, CPTED audits will be performed and submitted as required by the design submittal process. Any issues raised will be addressed insofar as they relate to Project Co's scope.

Key CPTED issues for further development and exploration with the City are the pedestrain pathways linking local residential neighbourhoods to Bayview and St. Laurent Stations. At Bayview Station for example, the pedestrian pathway linking to the southwest of the Station is secluded from other activities. At night, pedestrians prefer to follow the main road system as opposed to following the proposed pedestrian pathway. At St. Laurent Station, the pedestrian pathway through the tunnel is another remote out-of-sight connection that may be perceived by pedestrians as a hostile environment.

5.5.1.2 Integration of Station Entrances into the Surrounding Urban Context

RTG's approach to integrating Station entrances into their surrounding context is best explained with a fuller description of our four-tier approach to design, which we have used successfully both on the OLRT Project, and on other major transit projects:

- The four-tier methodology has considered firstly the overall macro **transit planning** issues related to ridership capacity, growth demand, intermodal interfaces, connectivity, and placement of Stations in order to better understand the underlying objectives of each Station from a regional perspective.
- Secondly, it has considered the **urban design and contextual fit** issues as they relate to the 'Station hub/precinct' being the area and community the Station is serving.
- Thirdly, the **Station Functional Plan**, as described in **Section 5.5.1.1** which results in Station layout and configuration, is focused primarily on achieving an efficient and safe Passenger environment that also serves the needs of the operator and M&R Team. Within this context, the interface between Station and community is equally important and influences Station placement as well as entrance location and orientation.

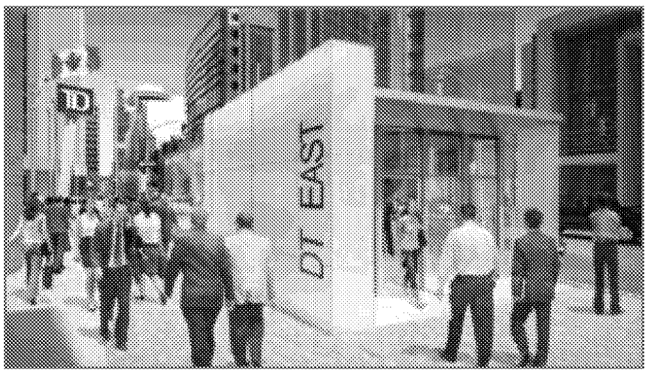
- Finally, the fourth aspect related to **Station Architecture and Technical Design Development**, has considered among other things, the scale, form and architectural aesthetic suitable for each neighbourhood in which a Station is located.

From an urban integration standpoint the Stations can be classified into four groups: Downtown Core Stations; High-Capacity Transfer Stations, Low-Capacity Suburban Stations and Low-Capacity Special Event Stations.

Downtown Core Stations – The four Downtown Stations, comprising Downtown West, Downtown East, Rideau and Campus, are primary destinations during the morning commute. All four Stations have either high to very high ridership. Located within the downtown core and at the University of Ottawa, all Station entrances will be highly integrated within the existing urban context, served primarily by walk on/off ridership, with a proportionately high percentage of cyclists, but with relatively little intermodal transfers from buses, and other modes.

These four Stations can be characterized as City Serving in that their surrounding urban context is mature and developed, and the primary purpose of these Station entrances is to serve a significant existing ridership demand. Our key urban design objectives for the Downtown Core Stations have been as follows:

Figure 5.5-2 | Station Beacon Identification



- **Achieve Station Entrance Legibility** – Because five of the potentially nine entrances may ultimately be incorporated within existing buildings, the challenge for these Stations will be to achieve a clear and distinct legibility for Passengers so that Stations can be easily found amongst the visual clutter and competition for identify that is typical of a dense urban core. RTG's approach to the resolution of these issues has been to develop a system-wide Station beacon identification strategy (see **Figure 5.5-2**).

- **Enhance Pedestrian Realms** – Design of an adequate and high-quality pedestrian realm that provides generous sidewalks to handle the more than 15,000 people per hour who will be distributed into Ottawa's downtown core each weekday morning during the peak. Further definition and exploration of the Queen Street corridor, for example, is an aspect of the design that might be explored more fully with the City after Contract Award.

- **Distribute Entrances Equitably** – A distribution and balance of entrance locations and orientations, considering the downtown core as a whole to distribute Passengers equitably to serve predominant destinations. RTG acknowledges the City's desire to explore alternate Station entrance and cavern locations at Downtown East that may achieve a more equitable distribution, including achieving a passageway connecting into the National Arts Centre (see **Section 5.5.1.11** for details). We acknowledge that some Stations still require Stakeholder consultation and coordination to finalize the Downtown Station designs; for example, Downtown West (with its entrance in Place De Ville), and Rideau Station (with its entrance in Friedman Mall and anticipated connections into the Rideau Centre, plus the provisions for future underground connections into other adjacent developments). RTG has extensive recent and relevant experience resolving these types of issues with the three downtown stations on Canada Line that featured integration into a Class A Heritage building, two major shopping malls and three underground parkades. RTG is cognizant of the Sponsors' interests and risks and is welcome to the challenge of helping the Sponsors find practical and cost-effective solutions that benefit all parties.

High-Capacity Transfer Stations – Beyond the downtown core, there are four higher-capacity intermodal transfer Stations that exhibit moderate and high ridership. Because of the land required to accommodate these transfer facilities, the Stations are generally more remote from their surrounding context and less integrated into their communities. Walking distances to Stations tend to be farther. These Stations comprise Tunney's Pasture (Scenario 1 operations only); Bayview Station (Scenarios 2 and 3) when the O-Train ridership is expanded; Hurdman as the primary transfer point with the southeast BRT Transitway, and Blair Station as western terminus and BRT transfer point.

Our urban design objectives for the High-Capacity Transfer Stations are as follows:

- **Optimize Intermodal Transfers** – At the three BRT Stations, we have secured the perimeter of the BRT bus loop and provided separate dedicated entrances to avoid re-ticketing BRT Passengers. For this Response, RTG has adopted bus plans based on information provided to-date. However, the pedestrian walking distances from bus stop to Station entrance are quite significant at some locations. Based on our work with other transit agencies, during the design development phase RTG would like to explore alternatives that might improve Passenger convenience.

- **Improve Pedestrian and Cyclist Connectivity** – Pedestrian and cyclist connectivity has been resolved at all four Stations and multi-use pathway requirements have been accommodated. At Hurdman, the Station was shifted east to improve alignment of pedestrian and cyclist pathways to the south. At Blair, BRT Passengers have been segregated from cyclists and pedestrians. Resolution of pedestrian connectivity still requires some development and thought. For example at Bayview, the Station's lower main entrance is in a cut, and pathways connecting to it follow secluded routes. While these connections will be used during the day, our experience suggests Passengers will seek more-visible and less-threatening connections at night. Therefore, further exploration during design development is warranted to provide Passengers with better choices at selected Stations.

- **Consider Future Transit-Oriented Development Opportunities** – Early transit-oriented development (TOD) at key Stations offers significant opportunity to expand walk-on ridership and to improve the quality of the pedestrian realm. Introduction of complementary uses combined with increased activity associated with TOD will improve CPTED for Station approaches. At Tunney's Pasture, the Station configuration has been adjusted specifically to balance long-term TOD opportunities and form of development with the preliminary needs of the BRT loop serving the Station. At Hurdman Station, road connections to the east and west of the guideway have been provided and protected as required by the PSOS to support future development to the north (see drawing 5.5.1-HD-102).

Mid- to Low-Capacity Suburban Stations – Lees, St. Laurent and Cyrville Stations are all characterized as low-to-medium ridership Stations. Typically, these Stations are remote from the neighbourhoods they serve. Access to these Stations is commonly compromised by existing infrastructure (e.g. proximity of major highways, road patterns and geographical features) that either land-lock or inhibit proximity and connectivity to these Stations. Although future TOD opportunities around these Stations will, over time, increase ridership and allow for a more integrated urban condition, ridership is unlikely to become greater than low-to-moderate demand.

Our urban design objectives for the Mid- to Low-Capacity Suburban Stations have been as follows:

- **Improve Pedestrian and Cyclist Connectivity** – Improve routing and also carefully consider the CPTED-related aspects of getting to these Stations. As described above, where Stations are served by secluded pathways remote from main roads, Passengers will seek choices and want options to take less-direct routes that are more visible. Review of these connections should continue during design development.

- **Consider Future Transit Oriented Development Opportunities** – New TOD along important pathways to the Stations improves density and ridership and offers opportunities to improve CPTED and raise the pedestrian experience.

- **Refine Station Scale with Respect to Demand** – These Stations have been scaled to better suit the anticipated ridership demand and achieve a more harmonious urban fit. Cyrville, for example, now offers a primary Station entrance on the east side of the road bridge and a smaller secondary entrance on the west, with the fare-paid zone located under the bridge at platform level. Passenger amenity has been preserved, Station scale has been reduced, and Station maintainability has been improved.

Low-Capacity Stations with Special-Event Status – LeBreton and Train Stations are unique in that they currently have very low ridership status, yet each Station will annually host special events that require them to function at a higher level demand during specific periods. Based on our experience managing large crowds associated with special events such as the Vancouver 2010 Winter Olympics, Symphony of Fire (400,000 visitors to the downtown core), and sports venues such as Rogers Arena (18,480 seats and is the host of the Vancouver Canucks), our operating strategy is to provide generous plazas adjacent to Stations to enable queuing outside the Station, combined with controlled entry of Passengers into Stations to avoid overcrowding platforms.

Our urban design objectives of these two Stations have been as follows:

- **Develop Generous Public Plazas and Connections to Hold Event Queuing** – At Train Station, where addition of the Coventry Street Bridge will provide a direct connection to the 10,000 seat baseball stadium, a public plaza has been provided on the south side of the Station entrance. At LeBreton Station, where events such as Blues Fest will attract significant crowds, the approach has been to reconfigure the Station to a centre-platform arrangement and to add an under-platform connection that emerges on the north side adjacent to the aqueduct. This lower Station entrance has been shifted west to achieve a cascading linear public realm that ties into the elevation at the Booth Street Heritage Bridge, and that offers an alternative pathway to the west to connect to the Broad Street Heritage Bridge, which is also on axis with the main entrance to the Blues Fest event site. In addition, the Station is provided with two entrances at the new Booth Street Bridge elevation, and a separate pedestrian stair connecting bridge level to the MUP below provides connectivity without having to pass through the Station. These measures have significantly improved the configuration of LeBreton Station and achieved the important connections desired by the City.
- **Consider Future Transit-Oriented Development Opportunities** – TOD opportunities and protection of future interests have had much greater impact on LeBreton Station than Train. At Train, while significant opportunities exist on the south side of the VIA Station, the development is too remote to influence layout and configuration. At LeBreton Station, the shift to a centre platform will return more than 900 m^2 of land back to developable area, which will improve the scale and form of the development. The top of rail at LeBreton Station has been set to a maximum elevation of 56.33m, consistent with the PSOS requirements.
- **Size Stations for Demand** – As lower-capacity Stations, the functional plans have been optimized to achieve efficiencies and a scale more suited to their daily function. Simultaneously, making provision for urban plazas and orienting these entrances predominantly towards event movements has been incorporated into these Station designs.

RTG's improvements and changes to the Stations have been predominantly as a result of resolving urban design integration issues influenced by short-term and anticipated future land-use pattern changes. With the optimization of the overall Station platform length, now reduced to 90 m (expandable to 100 m) and by scaling Stations to better suit their context, the Stations are now smaller and better integrated.

5.5.1.3 Aesthetic Nature Stations Designs

RTG understands the importance of aesthetics and public image for the OLRT. On a practical and urban design level, light rail is a lynch pin and primary organizing device shaping and contributing to the City's objective of focusing inner-city intensification in transit-based mixed-use centres. Symbolically and architecturally; the system will provide a face to the progressive step the City is making in its commitment to sustainable design, and will help shape the City's brand, expounding Ottawa's core values: pride in its history, and a commitment to sustainable growth, innovation and progressive thinking.

In many respects the OLRT can viewed as one long civic building, with entrances into and out of all the City's core communities. In this capacity the OLRT will act as an ambassador, telling stories literally and subliminally about the capital city, its people and their history, which have shaped the Ottawa we know and admire today.

RTG has sought to create a system with a strong architectural legibility, tempered with thoughtful urban design continuity. Our objective has been to create a brand of public architecture that challenges the way the world views the city and, in so doing, the way it perceives itself. At the same time, RTG has endeavoured to produce architecture which will stand the test of time, respond to a modern transit system's technical requirements, and become a familiar and friendly part of the city's identity.

Our approach to the design of the Stations themselves has been shaped by many factors: conceptual, practical, technical and symbolic. At a conceptual level the design is driven by a desire to create an exceptional Passenger experience, where brand and amenity of Vehicle, Station and public realm are cohesive and complementary. RTG is convinced that if light rail is to be embraced by the travelling public then it must become a "lifestyle" choice. In other words it must have cachet and desirability, so that like Vancouver's Canada Line, where business professionals of the affluent Langara and Oakridge neighbourhoods now choose to leave their expensive vehicles at home in favour of riding the LRT, so too OLRT will become the mode of choice for Ottawa's citizens.

Innumerable adjectives describe good Passenger experience: among them, intuitive, comfortable, humane, safe and accessible. However, from our design experience on other lines, RTG recognizes that success and prestige often revolve around the degree to which the public takes ownership of the Stations, their surroundings and the system as a whole. For this to happen, Station design must meet several criteria; criteria that we believe are integral to our design solution:

- The need to resolve urban design first, and to let the architecture be subordinate to creation of a meaningful "place" with strong connections at all levels to the surrounding context (i.e. resolve the 'Station hub')
- The need to be perceived as public realm, not a proprietary City-owned system
- The need to provide Passengers with an intuitive and safe orientation; in other words, the ability to explain how they work from a distance
- The need to be distinctive in their design yet also friendly and familiar, sharing the DNA of the overall system
- The need to be iconic at a local level, engaging Passengers intellectually and emotionally by telling stories about their own communities literally and symbolically
- The need to be iconic at a national level by offering the citizens of Ottawa, transit users or not, with bragging rights to a stunningly designed world-class transit system

RTG Design Aesthetics Approach

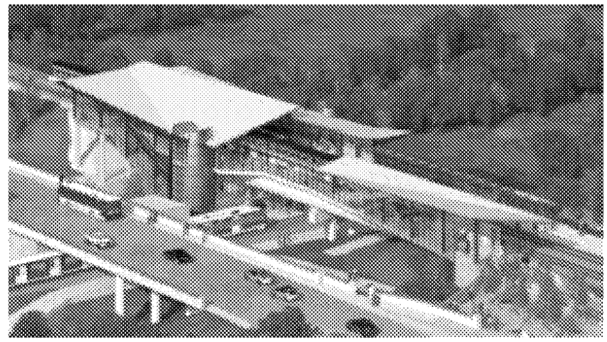
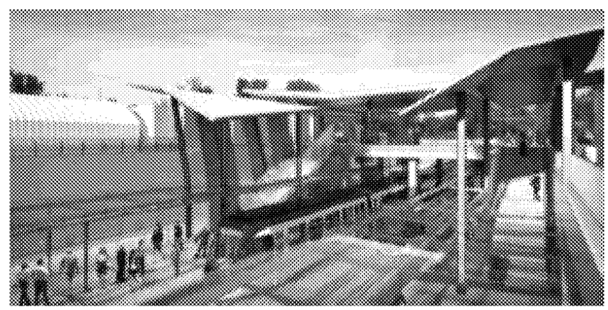
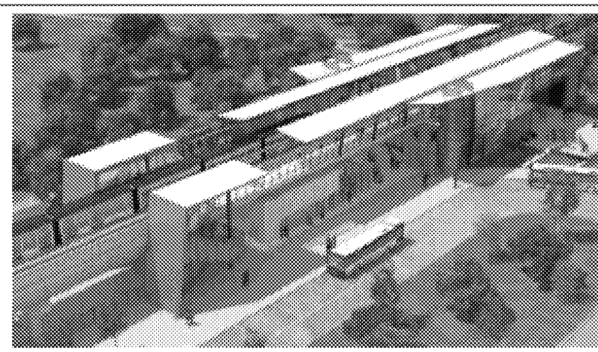
Design approaches to LRT systems can typically be categorized into one of two groups:

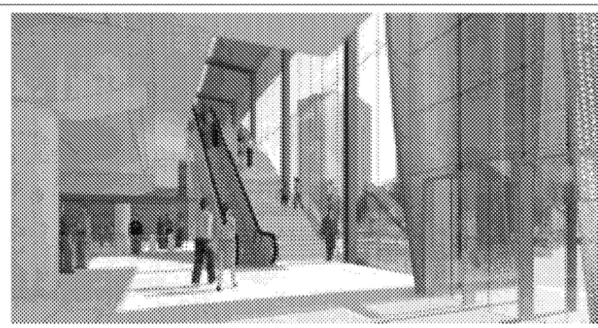
- **The "unified" approach** is characterized by a strong aesthetic language deployed with consistency across the entire suite of Stations. This approach has significant merit with respect to capital and maintenance costs, largely attributable to a high level of standardization. The other benefit is high design legibility achieved through repetition. However, this approach runs the risk of diluting individual Station identity and descending into overall anonymity if the initial concept is not strong. The approach, however, does leave a good legacy in its ability to be easily extended.

- **The "individualized" approach** gives each Station a stand-alone aesthetic, ideally tailored to its context. This approach has merit in providing strong architectural statements giving personality and a unique and high legibility on a station-by-station basis. In general this approach has less merit with respect to capital and maintenance as Stations share little DNA.

With respect to the OLRT, RTG has sought to provide a solution which combines the best characteristics of both approaches: that is, strong legibility and individuality by Station, combined with lower capital and maintenance costs and better legacy through standardization. To do this, RTG has approached Station design through the various components within them. The design concept is a simple one, giving each component (e.g. roofs, elevators, stairs) a strong functional as well as aesthetic design but keeping them the same. By doing this we achieve the benefits of standardization as well as Station individuality and character, taking strong advantage from the very different manner in which these elements are deployed at each venue.

Table 5.5-3 | Description of Primary Station Components that Establish the RTG Design Aesthetic

	Location	Functional Diagram
1	**Roof and Enclosure** – RTG has developed a hierarchy of three roof forms (types A, B and C), combined with an origami concept, that allows subtle manipulation to respond to specific site aspect and contextual needs. The tallest type A roofs designate concourse areas and interstitial areas where multiple pathways and decision points converge. Applied at platform locations, the higher roof form is deployed in areas where exposure to prevailing winds is greatest and where protection across the guideway can be provided to improve Passenger comfort, without conflicting with OCS wires. Type B Station roofs share the same origami conceit as Type A, but are lower and offer slightly improved platform protection without straddling the guideway. Both type A and B roofs are steel constructs, with infill Borer Ash roof panels, and metal cladding along the edges and soffit edge conditons. Finally, the type C roofs with glass roof and steel structure are designed to offer maximum transparency as a counterpoint to the solid material finishes of the previous two roof types. These three roof types have been deployed to meet technical requirements, offer variety of scale and materiality, and to develop and tailor visually pleasing and intriguing compositions for each Station.	 
2	**Landscape** – The Stations and their surrounding public realms set the tone and expectation of the development and character that aspires to define the 'Station hub'. RTG's approach has balanced deployment of hard and soft landscape to reinforce hierarchy of pathways and wayfinding; create acts of place-making, especially at entrance plazas; and to resolve technical objectives such as segregation and separation at BRT bus loops, by using soft landscape and organizational elements that enhance the public realm through visual interest and delight. Indigenous plants and bioswales create natural and sustainable solutions that are easily maintained.	

	Location	Functional Diagram
3	**Entrance Plaza** – The Station plaza is the forecourt, front door, and link between Station and community, and is an extension of the character and values of the Stations and OLRT system as a whole. Careful deployment of soft and hard landscape reinforces pathways, creates areas of repose and waiting, and establishes a pedestrian scale respecting order and organization that reinforces acts of place-making.	
4	**Station Lanterns** –To strengthen the Stations' legibility to the approaching Passenger and to announce the Station entrance locations, RTG has established a concept of 'Station lanterns'. Back-lit light boxes that incorporate recessed ticket vending machines, they add to the iconic legibity of all Stations and establish an effective yet simple wayfinding cue common systemwide, distinctive and easily identifiable even for the first-time OLRT Passenger.	
5	**Elevator Totem** – More than just a shroud to the multiple elevator shafts, its purpose is multi-faceted. Iconic in form and organzational in function, its unique character enforces wayfinding and legibility, contributes to place-making and elevates the OLRT brand. Technically, the shroud offers shade from extreme summer sun, yet preserves a sense of transparency and surveillance. In addition to housing the elevators, it functions at times to visually shield vertical conduit chases between levels, and structural bracing of lateral support systems.	
6	**Public stairs and escalators** – Are the primary public vertical circulation elements, connecting platform to concourse, and by their nature are key wayfinding devices. Inclined at 30 degrees to match stairs and escalators, the tread rise and run provides efficiency of movement and enhanced safety, with features including tactile warning strips and edge nose strips. Typically covered and protected from the elements to provide a good grip underfoot is just one of many considerations. Edge runnels are provided for cleanliness and bicycle movements. Where needed, higher balustrades provide increased wind protection.	

	Location	Functional Diagram
7	**Security Screens** – Station enclosure and containment is both a matter of security control and, most importantly, public safety. Automatic coiling grilles at the threshold of each Station create broad open and inviting public thresholds when open, and security protection at night. Glazed sceens combined with full-height wall panels along edges and perimeters afford safety and weather protection, while preserving openness and transparency.	
8	**Platform Shelters** – At all platforms two partially enclosed waiting areas are provided. Typically located in the middle third of the Station and spaced to meet the 30 m maximum distance between emergency phones, both shelters offer convenience and protection. The primary shelter fitted with on-demand radiant heating is located close to the elevators. Tactile wayfinding tile helps direct the blind. Shelters are fitted with seating, areas for wheelchairs, standing room, information panels and emergency assistance phones. Similar to Calgary's newer Stations, LRT doors are not provided to these areas.	

5.5.1.4 Vertical Circulation within Stations

As described in **Section 5.5.1.2**, elements that form part of the primary public vertical circulation systems within the Stations have been sized to accommodate the morning peak ridership volumes for the Ultimate Demand of 24,000 pphpd. All public stairs have been sized to function at a minimum LoS E, in the operating scenario where one escalator is entirely out of service due to heavy maintenance. This level of service provides a good level of operational redundancy above and beyond PA requirements.

All Stations have the required number of escalators and elevators across the system as specified in PA Schedule 15-5, Section 2.4, with the following variations which reflect RTG's tailored response to the RFP:

- The platform at LeBreton has three escalators serving the platform instead of two. Two escalators serve the bridge-level entrances (one per entrance), and the third serves the lower concourse with the entrance on the north side of the Station.
- Rideau Station has a bank of four elevators for scenario 1 and 2 and five elevators for the ultimate, instead of a single escalator from street level to concourse. This approach has been adopted to minimize construction impacts on the mall and provide reliable service for Passengers (see drawing 5.5.1-RD-105).
- At Train Station, spatial provisions to accommodate a future escalator at each platform have not been provided because the level of service provided by the two elevators exceeds normal morning peak demand. Therefore, in the interests of affordability, RTG has chosen to optimize the Station footprint.

Approach to Vertical Circulation Redundancy in Downtown Stations – For all Stations, escalators have been located and configured to support upward Passenger movement.

Two escalators at each platform level provide a good LoS, and will discharge 200 people per minute per platform during the morning peak, when performing at the manufacturer's rated discharge rates. This volume corresponds to 94, 66 and 113 percent of the required exiting capacity respectively for Downtown West, Downtown East and Rideau Stations, when they are operating at their Ultimate Demand volumes during the morning peak, and at 120, 88 and 150 percent of the required exit capacity needed at the end of Operating Scenario 2. Only at Downtown East Station will it be necessary for some Passengers leaving the platform to use the public stairs.

While the vertical circulation connecting concourse to street will be subject to more bi-directional flow, the addition of new connections to the concourse levels as anticipated at all three Stations will disperse pedestrian activity and reduce demand at primary entrances. With a minimum of two escalators per Station serving any one level, the level of service will be more than adequate.

Elevator levels of service for the three Downtown Stations will also be more than adequate. Elevators serving Downtown West and Downtown East have been configured as pass-through elevators which will improve Passenger amenity and LoS, especially for Passengers in wheelchairs, or pushing strollers or bicycles. They will be able to walk on and walk off the elevators without having to back up to disembark. This small detail is important, especially at the high-capacity Underground Stations where efficiency of pedestrian movement will be more vital to sustaining the high Passenger volumes predicted for these three Stations.

The west entrance to Rideau Station has been configured using a bank of four elevators instead of escalators. Using 4,000 lb traction elevators with a rated capacity of 19 people per cab and an estimated cycle time of 40 seconds provides a capacity of 114 people per minute bi-directionally which is better than a single escalator.

Approach to Vertical Circulation Maintenance and Reliability in all Stations – Specification of escalators and elevators has factored in wear-and-tear from snow, ice and de-salting agents such as sand and grit that will inevitably be tracked in from the outside onto the escalator treads and elevator floors. At all Stations, primary vertical circulation elements have been fully covered to protect escalators from direct snow and rain. Escalators are designed to run 24 hours per day during periods of extreme cold to protect their mechanisms from seizure. Additional features such as block heaters in the truss to maintain minimum operating temperatures have been included.

Escalators will provide features with the intent of achieving high reliability and will be carefully monitered by maintenance through a daily report.

Two types of elevators will be used on the OLRT Project: 2,500 lb hydraulic elevators typically configured in a landscape format will be used in At-Grade Stations except where flow-through movement is required, in which case the elevators will be 4,000 lb portrait format. All elevators where the vertical run is 14 m or greater will be traction elevators operating at 350 fpm.

Porcelain tile on thin set is proposed for elevator cabs to resist the abrasion and wear of sand and grit.

System procurement of the elevators and escalators will ensure consistency and quality of product. While selection of a preferred supplier will be deferred until Contract Award, RTG commits to providing escalators and elevators complaint with the PSOS.

As described in **Section 7.0**, the M&R Entity will contract with the preferred supplier of elevators and escalators and will enter into a long-term contract to maintain equipment at PA-required levels of service availability. This work will include preventive maintenance programs geared toward achieving high levels of service for Passengers throughout the Project Term. As we did on Canada Line, elevators and escalators will have early warning detection systems that will report directly via telephone to the equipment maintainer to give advance notification of emerging technical issues, enabling early intervention and issue resolution.

5.5.1.5 Fire and Life Safety Approach to Stations

RTG code specialists have current and relevant project experience in developing code regimes on major design-build transit projects across Canada, and in working with Ontario Transit Authorities on past and current projects. The scope of this experience includes, for example, SkyTrain Millennium Line, Canada Line, Calgary West Extension, and selected Toronto Transit Commission (TTC) and MetroLinx projects. Three of our Team staff members hold positions on drafting and technical committees for NFPA 130. RTG's code experience is, therefore, directly applicable to transit and is at the forefront of transit code development. This is important because local Provincial and Municipal building codes typically either do not address transit-specific conditions and code philosophies, or do address them but fall behind current transit practice.

RTG Approach of Life Safety Code Requirements

For the OLRT Project, RTG will establish a code committee involving key stakeholders from the Sponsors and Project Co to develop a comprehensive and consistent code approach that will ultimately deliver code documentation and sign-off of the Operating Certificate that will enable the System to be approved and enter operational service.

The Province of Ontario requires that the Ontario Building Code 2006 (OBC) be the governing document for all Stations; however, the PA requires compliance with multiple codes and standards, such as NFPA 130 and the National Building Code 2010 (NBC). Cross-referencing multiple documents causes criteria conflicts that must be ratified in the next phase. Applying design documents not adopted by the Province will require Alternative Solutions to be submitted as part of the detailed design for City approval. The result will be a bridging document that addresses the Code hierarchy and applicable design criteria for the next Project phase.

As an indication of the scale of this issue, on Canada Line the project developed a 'Request for Amendment/Exemption' process and executed 80 RFAEs to address project-specific issues. RTG's expectation is that a similar number of approvals will be needed to obtain all necessary approvals for the OLRT Project. Early mobilization of the code committee and commitment of resources from all member Stakeholder groups forming the committee will be important to ensure timely decision making and approvals to enable timely progression of the design.

RTG's code approach to Station design for the bid phase has been to comply with the most stringent requirements of NFPA 130, NBC and OBC. A good example is the minimum 3.2 m platform-width requirement under OBC versus NFPA 130 requirements which are performance-based and permit narrower platforms where proven by engineering analysis. Thus, for the purpose of the Response, RTG has satisfied the more stringent requirement, but subject to the City's and AHJ approval RTG will seek to explore legitimate Station code optimizations where it benefits the Project.

As described in **Section 5.5.1.14**, RTG has conducted calculations demonstrating all Stations have been sized to meet code requirements related to occupancy separations and rating, platform size, exit capacity and minimum egress evacuation times (see drawing index sheet 5.5.1-DS-100 for passenger flow and platform width drawings for each station)

RTG Approach to Emergency Smoke Evacuation Systems

Four OLRT Stations will be designed and fitted with Emergency Ventilation Systems (EVS): St. Laurent and the three Underground Stations (Downtown West, Downtown East, Rideau). St. Laurent is a stand-alone tunnel segment and has been addressed separately.

The three Downtown Stations are part of the main underground segment and have been designed along traditional ventilation means, adopting a push/pull emergency tunnel ventilation system (see **Section 5.3** for details). RTG's proposed design locates tunnel ventilation fans at track level at both ends of each Station. Jet fans installed near tunnel portals will provide supplemental ventilation in the event of a fire within the daylighting tunnel sections. During normal operation, the LRT is expected to be self-ventilating through the piston effect of the Trains traveling within the System. Draft (blast) relief is provided at the ends of the Stations to control Train-induced air pressures and air flows within public areas in accordance with PA criteria. Emergency ventilation fans can be operated at a reduced capacity during the summer, when the outside ambient temperature is highest and in the event of system congestion when a Train(s) is stopped in the tunnel for an extended period.

RTG will undertake a Subway Environment Simulation (SES) analysis to evaluate and confirm the aerodynamic and thermodynamic behaviour of the underground environment and EVS performance in each of its modes of operation: normal, congested and emergency. Smoke control in the tunnels will be provided through a push/pull response in which fans at one end of the ventilation section operate in supply (push) and those at the opposite end operate in exhaust (pull). To facilitate egress in either direction, the fans will be fully reversible.

If there is a fire within a Station, the EVS fan plant at the incident Station will operate in a pull/pull (all exhaust) response to pull smoke away from public areas of the Station while drawing fresh air in through Station entrances to protect the path of egress. RTG will use Computation Fluid Dynamics (CFD) to analyze Station fires, providing a full understanding of smoke movement within the Stations so that smoke control strategies can be developed in conjunction with a timed egress analysis.

RTG will control EVS operation through a dedicated SCADA system controlled from the Transportation Services Control Centre (TSCC) with a full redundant reporting system installed at the Backup Control Centre (BCC). In addition to providing individual control of EVS equipment, this SCADA system will be preprogrammed with all EVS operating modes. Local control will be available at the fan plant itself, and each Station will also have a Fireman's Control Panel which will allow manual initiation or override of EVS modes. EVS emergency operation will be based on procedures developed during design in collaboration with the City (AHJ, TSCC, first responders) and other key Stakeholders.

Smoke Dispersion - To minimize the risk of smoke recirculation into Station entrances and adjacent buildings, the at-grade location of EVS shaft terminations maximize horizontal separations, while balancing the competing interests that are a condition of the narrow Queen Street corridor. RTG will use computer analysis to evaluate smoke dispersion characteristics at each Station site and, where necessary, to assist in developing mitigation measures. The significant positional constraints imposed by the streetscape at each site may require a collaborative approach with adjacent property owners to address the potential for re-circulation, with one possible resolution being integrated emergency management plans.

Future Platform Screen Doors at Downtown Stations - Future provision requirements to add platform screen doors has been contemplated for the three Stations. Consistent with many other transit lines the assumption is that screen doors will not be full height and will be environmentally separated from the guideway. Based on preliminary analysis and our experience with similar screen door configurations, RTG has determined that additional smoke exhaust systems at platform level will not be required.

Evacuation Time from Stations - Design of the Underground Stations is based on evacuation of the underground platforms within the required four-minute timeframe. Limited exiting availability from Station concourse to grade has required an approach where concourse areas will be treated as points of safety. During detailed design RTG will undertake Computational Fluid Dynamics (CFD) Analysis to prove that Station concourses will remain tenable during the evacuation period which may be longer than the six-minute period in the OBC. Based on our extensive work with Canada Line's eight underground stations and our work on other underground stations, we are confident our Station designs are safe and will meet NFPA requirements.

St. Laurent Station - At St. Laurent Station the existing tunnel ventilation system will be replaced with tunnel ventilation fans that meet NFPA 130 requirements. The current design concept assumes replacement of the fans hung from the ceiling west of the Station, and addition of new ventilation fans located east of the platform, designed to serve both the Station and the tunnel. NFPA 130 requires two independent means of egress from a Station platform. The challenge with St. Laurent is that all existing vertical circulation connects to the concourse bridge which is a single point of failure. To achieve independent egress routes RTG has allowed two protected horizontal pathways discharging to the east, and one to enclose and protect the pedestrian pathway to the southwest. During detailed design, if tenability can be proven for all tunnel and Station emergency scenarios then one or more of the protected routes may be removed. However, until detailed CFD analysis is performed a definitive answer cannot be achieved and the more conservative solution is being carried.

Emergency Ventilation Systems

The OLRT will have emergency ventilation systems throughout its underground portions. These systems will provide a tenable environment for Passengers during evacuation in the event of a fire-and-smoke incident in a tunnel segment or Underground Station. The tunnel ventilation system will also facilitate year-round air circulation to maintain a comfortable environment for Passengers in Stations and onboard Vehicles during both normal and congested operations. Emergency ventilation systems will provide the following:

- A tenable environment along the path of egress from a fire incident at an Underground Station or in the enclosed trainways
- Maintenance of required airflow rates for a minimum of one hour, but not less than the required time of tenability
- Facilitated piston effect in the tunnel to maintain acceptable temperatures, pressures, and air velocities inside the Stations for Passenger comfort
- Capability to reach full operational mode within 180 seconds
- Redundancy to ensure that removing any one fan for maintenance, or the failure of any one fan, will not compromise required tenability
- Capability to provide sufficient airflows in the tunnels to achieve critical velocity at the incident Train with the presence of a stopped non-incident Train in the tunnel segment
- Compliance with NFPA 130-2010

System Configuration

In the event of a tunnel fire, the emergency ventilation system will be designed to operate in a push/pull configuration using fan plants at each end of the Downtown Stations and jet fans at each tunnel portal to provide sufficient airflow to achieve critical velocity in either direction. Each fan plant will consist of two fans connected to a network of shafts and dampers to allow airflow to be directed into the tunnel, or bypassed to permit blast relief of the piston effect. Because the tunnel design does not include a centre wall, both fans and blast shafts at each fan plant will serve both inbound and outbound tunnels.

The number of jet fans at each portal will be chosen to provide the necessary airflow and redundancy in case of a fan failure. The system will be configured to prevent back-layering, to remove smoke and heat emanating from the fire, and to deliver fresh air to evacuating Passengers. The emergency ventilation system will be sized to accommodate the maximum number of trains that could be present in a tunnel segment during a fire incident.

During a Downtown Station fire, the Station's fans will operate in exhaust to maintain tenability in the paths of egress, as specified in NFPA 130. Make-up air will be through the Station entrances and down the vertical circulation to provide fresh air to evacuating Passengers. Four fans will provide the necessary redundancy and reliability. Tenability within the Station will be maintained for a length of time to be agreed with the AHJ during the detail design phase. This length of time, at minimum, will take into consideration travel time to the Station, time to report the fire, time of fan initiation, and time of Passenger evacuation.

A Station fire at St. Laurent Station will be treated similarly, except jet fans will be installed in the tunnels on either side of the Station as there is no space in the existing Station for fan plants. It is expected that there is sufficient volume inside the existing tunnels and Station not to necessitate blast shafts; however, if the SES analysis for this Station proves otherwise, the existing fan plenum at grade can be converted into a blast shaft.

Since the MSF connector tunnel is shorter than one train's length, it is not expected to require a separate tunnel ventilation system. However, a full analysis will be performed by CFD modelling to ensure tenability is maintained inside the tunnel during an evacuation. If necessary, a passive or mechanical ventilation system will be provided.

A detailed smoke dispersion/recirculation study will be performed at each Station to ensure smoke is not re-entrained back into the Station, and to ensure the egress paths of occupants in nearby buildings are not compromised by the Station's emergency ventilation system.

Modes of Operation

Emergency ventilation systems may be configured to suit various operational requirements. Normally, these systems will be configured to ventilate the tunnels and Stations using the piston effect from Train-generated airflows. Should the Station's temperature rise, the emergency ventilation system can be configured to operate in low speed to extract warm air from the public areas of the Station. In the case of congested Train operations or track maintenance, the tunnel ventilation system can be configured to provide push/pull ventilation to the affected tunnel segment. For both normal and congested operations, temperatures will be maintained in the tunnels to a maximum of 5□C above ambient to maintain continued operation of the wayside equipment and the air conditioning equipment onboard the Vehicles.

To facilitate operation of emergency ventilation systems, especially during a fire incident, pre-determined ventilation strategies will be developed for each mode of operation. For Station fire incidents, the emergency mode will be an all-exhaust response, with the Station entrance doors being held open to facilitate evacuation and provide a path for makeup air. For tunnel-fire emergency modes, a push/pull ventilation strategy will be adopted for all tunnel segments involving the fans on either side of the incident segment. As the Vehicle represents the most significant fire source inside the tunnels, smoke detectors will be located on each Vehicle to notify the TSCC Operator of a potential fire incident. Several key decision-making inputs will be made available to the Operator, including location of the incident Train, and the presence and relative position of another Train in the same tunnel segment. Once the Operator has chosen and initiated the appropriate mode of operation for a given scenario, the emergency ventilation control system will be programmed to automatically configure dampers to their correct position and fans to their correct operating speed and direction to provide the necessary ventilation response. Submodes will be programmed into both the tunnel and the Station fire emergency modes to automatically initiate additional fan(s) should one fan fail to start or be out of service.

Fire/life safety protocols will be developed in conjunction with the City, the AHJ, TSCC Operators, and emergency response personnel. These will include a method to evaluate the information provided to the Operator, and a standardized ventilation response for each scenario which is best suited to provide tenability in the path of egress, and to minimize the risk to Passengers not already involved in the incident.

Levels of Control

Emergency ventilation systems will incorporate several levels of control. Generally, the Control Room Operator will control and monitor the system centrally from the Control Centre(s) using the tunnel ventilation control system. During an emergency, the fire department may take local control of the system through emergency ventilation command posts located at each Underground Station and tunnel portal. For maintenance and troubleshooting, control panels will be provided local to the equipment to individually control fans and dampers.

Performance Modelling

The emergency ventilation systems will be analyzed to demonstrate their performance under all the foreseen normal, congested, and emergency scenarios in the OLRT's unique geometry and environment:

- The heat-release rate produced by the combustible load of a fully burdened Vehicle
- The fire growth rate
- Determination of critical velocities
- Station and guideway geometries
- The stack effect inside the tunnels
- Wind pressures at the portals
- A stopped non-incident Train in the same tunnel segment as the incident train
- Small nuisance fires with low heat-release rates
- Smoke movement inside Underground Station before full activation of the emergency ventilation system
- A Passenger evacuation timeline to be approved by the AHJ
- Computational fluid dynamics (CFD) modelling of the emergency ventilation system in Underground Stations to assess tenability within the Station
- Subway environmental simulation (SES) modelling of tunnels in normal, congested, and emergency scenarios to assess temperatures, pressures, normal velocities and critical velocities
- Smoke exhaust re-entrainment/dispersion study at each Underground Station
- Determination of cold flow velocities to be used during testing and commissioning

Equipment Description

Equipment designed to be used during an emergency for smoke control, and exposed to elevated temperatures, will be rated for at least 250□C for one hour per NFPA 130 requirements.

Each fan will be a reversible axial unit with a direct-drive motor, and both inlet and outlet silencers. Station fan housings will be horizontally split for motor removal and equipped with access hatches for ease of maintenance. Blade pitches will be manually adjustable at rest, without removing the propeller from the motor shaft, to vary the fan's volume and pressure characteristics. Fans will be equipped with motor temperature and vibration monitoring, motor anti-condensation heaters, and will be installed on vibration isolating springs designed to meet the seismic parameters in the OBC. In addition, jet fans will be equipped with safety chains to independently fasten the fans to the tunnel roof. The capacity, total pressure rating, and the corresponding horsepower requirements of emergency fans will be functions of the geometries of the tunnels and the related Station, as well as the Vehicle fire size. These parameters will be determined for each fan during detail design, and will be confirmed by CFD and SES modelling. The configuration details for each fan arrangement will be shown in Station and tunnel drawings and will be developed in greater detail as the Project progresses. Additional acoustical lining will be provided inside the shafts as necessary to ensure maximum noise levels are not exceeded.

Bypass and fan-isolation motorized dampers will be provided at each fan plant. They will have parallel blade operation and blade seals, be rated for low leakage, and be structurally capable of withstanding both maximum repetitive and additive piston pressures of moving Trains and emergency airflow velocities. Dampers will be operated by electrical actuators which will spring open or closed upon loss of power to allow an emergency ventilation mode to continue to operate without that damper. Handwheels will be provided for each actuator to allow manual override of the damper's position. Limit switches will be provided at the end of each ship section of damper to provide positive feedback of the damper's position. All damper field wiring will be brought back to a common junction box.

Standardization of equipment will be employed as much as practically possible. Overcurrent protection for all motors, fans and dampers will not depend on thermal properties for operation. Lastly, a reliability analysis will be performed for emergency ventilation systems, as outlined in NFPA 130.

Electrical

Performing a life-safety function, the emergency ventilation system will have specific design requirements to ensure electrical reliability according to NFPA 130 (2010). Motor control and protection, power and control wiring, and manual control panels will be provided.

The emergency ventilation electrical system will be connected to the associated critical-services power supply. The critical-services supply will ensure power is continually available from either of two independent electrical utility supply points. The Station electrical room will house the low-voltage electrical distribution system including automatic transfer switch, switchboard, motor control centres, VFDs, and associated protection relays for the emergency ventilation system.

Emergency ventilation motor control centres, control panels and programmable logic controllers (PLCs) will be provided at Downtown West Station, Downtown East Station, Rideau Station and St. Laurent Station. Portal fans will be powered and monitored from the emergency ventilation equipment room at the nearest Station. Communication between the PLCs and the TSCC and MSF will be through the Communication Transmission System (CTS).

Power and control wiring for emergency ventilation fan motors and related components such as damper actuators will be fire-rated, installed in steel conduit, and rated for continuous operation at an ambient temperature of 250°C for a minimum of one hour. Control or instrument wiring not critical to emergency ventilation system operation may be non-fire-rated.

Manual control panels will be provided at each Station and will consist of relays, push buttons, and indication lights on a mimic background for basic monitoring and individual control of fans and dampers at that Station and adjacent portal where applicable. The control circuit will be designed with electrical interlocks to operate fans without damage. The majority of the control logic of the emergency ventilation system will reside in the PLC, which includes the operating modes. The PLC will control and monitor the emergency ventilation system via the manual control panels.

Emergency ventilation command posts will be provided adjacent to the Firefighters' Command Posts at the portals and Stations. They will enable emergency response personnel to initiate pre-programmed ventilation modes for an emergency fire incident at that Station or the adjacent tunnel segments in case network connection from the TSCC is lost. It will be possible to operate emergency ventilation modes for a given tunnel segment from the emergency ventilation command post located on either side of the incident tunnel segment. Relevant information, such as the location of the incident Train and any non-incident Trains in the tunnel segments, will be displayed at the emergency ventilation command posts to help an operator determine which mode should be initiated. The command posts will be monitored by the PLC for the mode requested by the Emergency Response personnel. The command posts will be provided with a local/remote switch for the Emergency Response personnel to take control from the TSCC; however, the TSCC will still have the capability to monitor the emergency ventilation system.

Testing and Commissioning

Operation of the emergency ventilation systems will be fully verified using a series of tests:

- Factory Acceptance Tests which will include run tests and flow tests as per AMCA 210 for fans, and timed damper operation tests
- Post-Installation Check-Out Tests
- Site Acceptance Tests which will test the performance of each piece of installed equipment individually
- System Integration Tests which will include tunnel and Station airflow measurements to confirm agreement with cold flow predictions, noise measurements, damper leakage tests, and cold smoke tests in both the Stations and tunnels. These will also fully test the emergency ventilation control system and the operation of the modes from all locations: TSCC, MSF, and each emergency ventilation command post.

These will test and validate the performance of the individual pieces of equipment, the emergency ventilation system as a whole, and their integration into the OLRT.

5.5.1.6 Expansion of Stations to Meet Future Demand

At-Grade Station platforms will be built to accommodate Scenarios 1 and 2 (90 m) and designed to be extended to 100 m to accommodate Scenario 3. The initial 90 m platform length will be accommodate a 98 m train, and the full 100 m length platform will accommodate a 108 m long train consist. As explained in **Section 5.5.1.1**, a 3 m surge/queue zone is preserved between the end of platform and near edge of the Vehicle doors. This distance is similar to the Canada Line Station platforms and proven adequate. For the downtown underground stations, the stations will be built to a 100 m platform length to accommodate the ultimate train consist (Please note: Currently the station platform lengths are indicated on the drawings of the downtown underground stations as 120 m which will be refined in during detailed design rpovided the passenger capacity requirements are met).

While the proposed OLRT expansion approach to the vehicles to meet ultimate capacity assumes 108 m long trains and a 100 m platform, as described in **Section 5.4.4.1**, RTG can offer the City alternatives that achieve a 105 second headway but maintain a 90 m platform. These optioins involve slight modifications to the the existing PSOS requirements and have not been assumed in the current design in order to adhere to conformance with the base bid.

A key feature to RTG's approach to Stations is that all primary public circulation stairs have been sized to accommodate the Ultimate Ridership Demand for the peak period during normal operations.

The combined benefit of the RTG approach is that it significantly reduces future invesment needed to expand the system. The only new elements needed to migrate between Scenario 2 ridership of 18,040 pphpd to Scenario 3 ridership of 24,000 pphpd will be the addition of exit stairs at Blair Station, and the potential 10 m platform extensions for most of the At-Grade Stations. The anticipated additional elements and expansion strategies for each Station are listed in **Table 5.5-4.**

Table 5.5-4 | Station Specific Modifications to Meet Ultimate Ridership Demand (24,000 pphpd – Scenario 3)

Station Name	Expansion Provision/Strategy
Tunney's Pasture	Extend platform 10 m; No addition to vertical circulation
Bayview	No expansion required on basis that O-Train double tracked platform is built
LeBreton	Extend platform 10 m; No addition to vertical circulation
Downtown West	No expansion required as providing sizing for ultimate capacity on opening day;
Downtown East	No expansion required as providing sizing for ultimate capacity on opening day;
Rideau	No expansion required as providing sizing for ultimate capacity on opening day;
Campus	Extend platform 10 m; No addition to vertical circulation
Lees	Extend platform 10 m; No addition to vertical circulation
Hurdman	Extend platform 10 m; No addition to vertical circulation
Train	Extend platform 10 m; No addition to vertical circulation
St. Laurent	Extend platform 10 m; No addition to vertical circulation
Cyrville	Extend platform 10 m; No addition to vertical circulation
Blair	Extend platform 10 m; Add 2.7 m width exit underpass stair

In addition to strategies implemented to accommodate system growth at minimal cost to the City, RTG has made provisions to accommodate future platform screen doors at the three underground Stations, up to 10 knockout panels for future underground connections with adjacent developments per PA requirements, and space proofing to accommodate a fare-gate system at each Station.

Provisions for the platform-edge doors include an additional electrical room house equipment controlling automated platform-door operations, with conduit runs connecting to the platform-edge areas, and other power and communications rooms. Consistent with other platform-screen systems, complete environmental separation with the guideway is not contemplated, and as such independent ventilation systems additional to tunnel ventilation will not be necessary.

While the Underground Stations anticipate a total of 10 future underground connections, further coordination during detailed design will prove the feasibility whether all 10 connections can be accommodated.

In accordance with the expansion plan, the MSF building has been designed to be lengthened if the option to adopt the 108 m long train consist is selected by the City. The storage shed will be built to accommodate the initial fleet in Scenario 1, and with foundations constructed for the storage shed for Scenario 2. Provisions are also made for future tracks to be built for the ultimate scenario.

Overall, the RTG solution meets the base obligation to comply with Scenarios 1 and 2. Our designs described above have made every effort to optimize the life cycle of the OLRT infrastructure as it will be eventually handed back to the City after the Maintenance Term.

5.5.1.7 Continuity between Federally Mandated and Non-Federally Mandated Stations

A key feature and benefit of RTG's design approach is that it has achieved a unification and one common brand identity shared across 12 of 13 Stations, common to Federally Mandated and Non-Federally Mandated Stations alike. St. Laurent is the noted exception, because alteration of the existing surface structure is beyond Project Co's mandate and its platform environment is quite different from the Underground Stations.

Continuity has been achieved on multiple levels. Common approaches to function design incorporating right hand-flow principles, along with common organization and sequence of spaces and elements, achieve familiarity in a manner that is more intuitive than it is clearly recognizable. Most observable are the similar and iconic roof forms: the three canopy types that offer a common hierarchy and order applied consistently across Stations. These are reinforced by a common palette of materials across the At-Grade Stations, and the Station entrance identification light beacon.

Another strategy to achieve consistency of products between Stations is system-wide procurement of common elements and subsystems such as elevators and escalators, platform-edge lighting, public lighting, glazing supports, CCTV, speakers, Station furniture, tactile wayfinding tile, platform-edge warning tile, and platform information displays. Common details applied to public stairs, common colour and material palettes also achieve unity and consistency. Our success in this unified approach is exhibited by the Station renderings submitted with this Response (see drawing index 5.5.1-DS-100 for list of renderings for each station).

5.5.1.8 Building Envelope and Weather Protection Approach

As described in **Section 5.5.1.15**, meteorological data gathered at Ottawa International Airport since 1961 provides extensive data describing the weather norms and extremes typical of any given year. Wind in the region is typically light to moderate, with strong winds occuring only 1.8 percent of the time during summer and 6.2 percent of the time during winter. Summer winds are predominantly from the south to the west-northwest quadrant, whereas prevailing winter wind directions are westerly and easterly.

Annual rainfall averages 732 mm with the majority falling between April and October. There are 115 days of rainfall, 25 of which have greater than 10 mm. Rain during winds accounts for 8.6 percent of all winds, primarily with wind speeds classified as low to moderate.

Based on 30-year average snowfall norms provided by Environment Canada, the average annual snowfall in Ottawa totals 236 cm. For the 122 days per year where snow remains on the ground, the average snow depth is 17 cm.

Factors Affecting Building Envelope and Weather Protection

RTG's review of the reference data provided at the Project's outset, combined with our own independent review including micro-climate analysis performed by specialists RWDI (Rowan Williams Davies and Irwin Inc.), concluded that the Stations must balance adequate weather protection and enclosure during winter with openness and moderate shelter for the rest of the year. Capturing natural daylight and allowing it to pentrate Station platform areas is important to enhancing Passengers' experience and should not be jeopardized by entirely covering the guideway and platform and providing limited skylights just to satisfy the winter extremes.

Other important considerations affecting the Stations' envelope designs were also considered:

- **Security and safety protection** – Stations must be secured at night to avoid trespass, since the OLRT will be a 24-hour operation with cleaning, maintenance and testing being performed during non-revenue hours. Keeping intruders out of the system during these periods protects their safety. During operating periods, enclosure and controlled access is a key concept to fare control and revenue generation. A secure Station perimeter satisfies both objectives.
- **CPTED** – Surveillance and overlook are key objectives in today's modern transit systems, needed to create welcoming public environments. CPTED and good design principles encourage use of glass and other transparent materials to create an association between the Station and its adjacent environment.
- **Delight and Durability** – The materials used for Station enclosures (roofs and windscreens) must satisfy transit standards of durability, especially within the 'touch zone' where daily wear-and-tear have the greatest effect. In addition, the palette of materials with their combined assemblies and compositions must establish a quality of public architecture that is befitting the OLRT while still meeting the City's affordability criteria for the Project.
- **Station Capacity and Demand –** OLRT Stations will experience a wide range of ridership demands from high to very low. To achieve the best balance and deployment of the public dollar, lower-capacity Stations can still provide a high degree of Passenger amenity but with a less extensive enclosure.
- **Maintenance Cost and Snow Clearing** – Lifecycle impacts of clearing snow over the long-term operation of the system were also carefully considered as part of the overall maintenance approach.

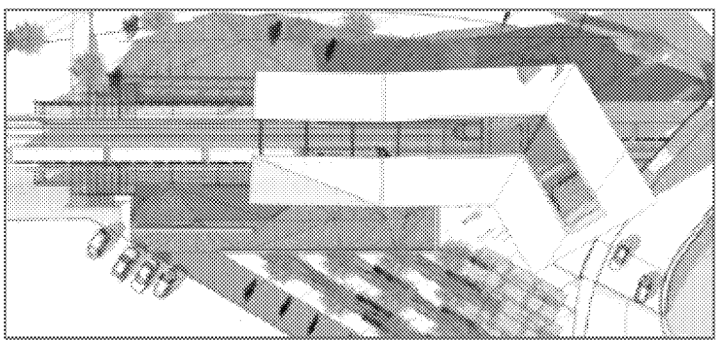
Above and beyond these primary considerations, other tiers of issues factored into the final design approach: preserving tenable environments in long Stations with enclosed roofs; lighting and energy consumption; and balancing the affordability cap against system lifecycle costing.

Approach to Building Envelope and Weather Protection

RTG's approach to Station enclosure design and affording Passenger comfort is to provide fully enclosed Station concourse areas with full roof coverage and windscreens that are virtually full height but that maintain a gap to the roof underside to preserve the Station's open nature and to satisfy key considerations for micro-climate impact (i.e. less vortexing from better pressure balance) and tenability (natural space ventilation). Primary public vertical circulation elements are roof covered. Depending on their location and configuration (centre versus side platform, exterior face versus inside face) they have either full-height or partial-height wind screens. The design intent is to protect these elements from windblown rain and snow under most climatic conditions, except where severe conditions may lead to limited windblown rain or snow landing on these elements. Protecting the concourse and vertical circulation elements leads to at least 50 percent of the Station platform being fully protected from rain and snow, as shown here in the roof plan of Train Station.

At platform level, beyond these protected areas, smaller glazed roof canopies reduce climatic impacts during inclement and more-severe weather, but offer transparency and light at other times. At high-capacity Stations, the entire platform length is covered with canopy, but at lower-capacity Stations, up to 20 percent of the platform may remain uncovered since Passengers at these Stations will not use the full extent of the platform during inclement weather periods.

Approach to Mitigating Prevailing Winds – Extra protection has been afforded at selected areas in Stations where micro-climate analysis indicated areas of increased exposure. As shown in the sample example below of Bayview Station, a more-extensive roof form covering both platform and guideway at the west end of the Station will bear the brunt of westerly winds. At Bayview, this measure was considered appropriate because the raised elevation of the Station relative to the surrounding terrain creates a highly exposed condition needing extra protection.



As described in **Section 5.5.1.15**, the key finding of the micro-climate report was "*the current design of Stations designs provide adequate protection for the various Stations and there are no notable predestrian wind and snow drifting issues*".

Further micro-climate analysis of the Stations will be performed during detailed design and more sophisticated analysis techniques will be used to verify the adequacy of the design. RTG has set aside some contingency to accommodate any futher environmental protection measures deemed necessary.

Approach to On-Demand Radiant Heating – Generally the Designated Waiting Areas (DWAs), one per platform, on-demand radiant heating has been provided within the enclosed areas. All the DWAs are located in the central third of the Station platform length and close to the elevators, to improve convenience for those using the elevator, who most likely will have mobility challenges. The DWAs have full-height glazing, small gaps at the top for natural venting, and doorless entry points to improve mobility. The radiant on-demand heating will emit sufficient heat to increase Passenger comfort on extremely cold days and evenings. The extent to which Passengers use radiant-heat systems in peak periods remains to be shown, since headway times will be just over three minutes, and as demand increases the headway will drop to less than two minutes. We expect that Passenger demand will be greatest during evenings and weekends when the headway is high and Passenger wait times are extended.

5.5.1.9 BRT and Intermodal integration at Stations

RTG's approach to the three BRT bus loops located at Tunney's Pasture, Hurdman and Blair Stations has been first to develop functional layouts consistent with the information supplied by the sponsors and, second, to achieve bus-to-Station relationships that simplify transfer movements to maximize Passenger convenience while preserving fare system integrity by ensuring segregation from other users. In all three cases these objectives have been accomplished within the designs as shown in bus loop and site plan drawings (see drawing index 5.5.1-DS-100 for list of site plan drawings for each station)

Tunney's Pasture Station – This Station is unique because of its high transfer volume and because of the fundamental change it will undergo once the western LRT extension is built. The expanded bus loop design provided by the Sponsors confirmed RTG's original assessment that the bus loop needed to be extended. As a result of the newer design, RTG reorganized the Station's functional plan to better respond to the predominant Passenger movements between bus loop and Station. While the functional considerations of the bus loop appear resolved, RTG expects to work with the City to critically assess operational issues and assumptions to further examine how BRT drop-off and pick-up functions might be refined to improve functionality for Passengers. Our work with other Canadian transit agencies has successfully used other approaches with bus operations that have concentrated Passenger boarding and drop-off activities at large bus loops which, in turn, has improved Passenger convenience.

Hurdman Station – The challenges at Hurdman Station have been to isolate the bus loop from other pedestrian movements and to accommodate the expanded bus loop. A slight adjustment to the Station's location, combined landscaping to create horizontal separation has successfully segregated BRT Passenger movements from others. BRT Passengers have their own Station entrance oriented through a portal on the west side of the Station's main concourse. A large central waiting area under the Station guideway provides amenity for Passengers, in addition to bus shelters distributed throughout the bus loop. With the new bus loop extension now extended westwards and located over part of the old landfill site, RTG will want to explore options with the City to determined how the loop might be optimized to minimize environmental impacts and reduce the quantity of land fill material to be excavated.

Blair Station – This Station experiences the largest BRT ridership growth over the three operating scenarios, and as such has the largest and most-complex bus loop layout and bus layover area. A long bus platform is needed to accommodate all arriving and departing buses. Again, opportunities to improve BRT operations and thereby reduce the size of bus loop would benefit Passengers and will be investigated at the Preferred Proponent stage.

5.5.1.10 Conversion of Existing Stations and Re-use of Materials

RTG's general approach to conversion of existing Stations is to optimize the design whereby major infrastructure elements can be preserved or rehabilitated where practical, thereby avoiding demolition and replacement. Thereafter, a combination of strategies has been followed based on balancing costs and embodied energy associated with reuse and recycling strategies. For example, where existing concrete platform slabs will be replaced by a new slab, the intent is to rubblize the concrete and use it as a sub-base. Reuse of many existing BRT elements is impractical and these will be disposed of and sent for recycling of the source materials.

The general approach to the renovated Stations is as follows:

Tunney's Pasture – The main emphasis at Tunney's Pasture has been to develop a design that preserves the twin cell box culvert the runs along the trainway. Although terminus Stations are normally centre-platform configurations, a centre-platform here would conflict with the escalator pits with the culvert. Thus, a side-platform Station is preferred. Existing retaining walls will be preserved, while ancillary room walls will be demolished to make room to build larger ancillary spaces needed for the new Station. The top of platform will be raised, and existing concrete slabs will be rubblized and used as sub-ballast for the new Station. Much of the existing structure will be recycled. We will investigate the opportunity to replant or salvage some of the mature trees, but relocating large mature trees is expensive and may not be cost-effective. This will be explored in more detail with the City after Contract Award.

Campus - The existing pedestrian underpass beneath Nicholas Street will be retained, but the remaining section will be demolished to accommodate the increased height requirements for OLRT infrastructure. A new datum for platform level will be established and much of the existing bus shelter will be removed. We can discuss with the City the possibility of reusing the shelters elsewhere in the system, but at this stage we assume that the materials will be recycled.

Lees – There are several challenges at Lees Station. The pre-existing condition of contaminated soils favours solutions that minimize foundation excavation. The tight guideway geometry with transitioning horizontal and vertical curves has resulted in a new alignment throughout the Station. Much of the infrastructure will be demolished and either reused as sub-ballast or recycled off site. The main retaining walls will remain in place and part of the existing ancillary block will be reused. The new MUP along the north side of the Station is seeking to reuse the existing stair, and so this structure will be dedicated to the MUP's use.

St. Laurent – This is perhaps the most complex of the renewals, since much of the structure will remain in place. The existing tunnel ventilation system hung from the roof does not meet NFPA 130 requirements and will be replaced with a new system. Existing ducts and fans have no use on the Project other than to operate as temporary fans to vent the underground during construction. The existing pedestrian bridge will require extensive renovation to the existing steel structure which will be performed as part of the Works. To accommodate the new vehicle floor elevation we propose to modify only the platform, keeping the existing running track at the current elevation. Therefore, it is evident that existing escalators will have to be replaced or shortened and refurbished on site. This option has not been explored with the escalator manufacturer and it is unlikely warranties will be supported. Nonetheless RTG will explore this option further in detailed design.

Cyrville – Cyrville Station will change from side-platform to centre-platform configuration. The existing infrastructure that cannot be reused will be demolished. We plan to retain the exterior shell of the ancillary block and to preserve the existing vertical circulation from Station entrance to the lower level as an open stair to the MUIP.

Blair – Blair is another complex Station where the existing pedestrian bridge and the underpass area beneath the BRT guideway will both be retained. The bridge will undergo renovation and addition. At this time the extent of RTG's scope is assumed to be limited to the area between the two main towers, with linkages to the north and south assumed to remain with the City. Realignment of the Station platform at Blair will profoundly affect the existing geometry, and several existing walls to the underground rooms will be demolished to make space for the new requirements.

5.5.1.11 Potential Connection at the National Arts Centre

RTG confirms we have reviewed Background Information in the Data Room with respect to a potential connection from Downtown East Station to the existing National Arts Centre (NAC) parking tunnel, which is under Queen Street and west of Elgin Street. RTG is willing to meet with the City and NAC representatives to discuss how a pedestrian tunnel can be connected to the Downtown East Station. Although we can provide an order-of-magnitude cost estimate related to the current design, we recommend that the work contemplated to shift Downtown East Station further eastward be explored to a suitable level of design development before presenting potential costs to the NAC. Nevertheless, we remain flexible on this matter and will partner with the City to support its obligations to coordinate and interface with Project Stakeholders.

5.5.1.12 Accessibility Analysis

RTG's Stations and their surrounding public realms that constitute the OLRT Project have been designed to comply with the applicable codes and standards in PA Schedule 15-2, Part 5, section 1.15.a. In accordance with these standards and with international best practices in accessibility, the OLRT will be designed and operated to make the system as a whole accessible for the use and enjoyment of all people to the greatest extent possible (as judged to be practicable within a transportation system context). Project scope and reach extends beyond the Stations and their public realms: interfaces at bus loops with buses, the O-Train and other modes of transportation will all require due consideration.

Station designs do not yet indicate the full range of measures they will incorporate: much of this work will be performed during detailed design. However, to indicate how Station designs will comply with accessibility objectives, the following narrative explains how seven broadly accepted design principles of accessibility have been or will be accommodated.

Principle 1: Equitability (Designs that are useful and marketable to people with a diverse range of abilities) - Station designs accommodate a diverse range of abilities and, conversely, disabilties. Voice announcements at platform levels, within elevators and on Vehicles will accommodate the visually challenged; signage using high-contrast colours, internationally accepted fonts, and wayfinding symbols will assist able-bodied and the hard of hearing. Tactile warning systems and wayfinding tiles are designed to assist those using canes. Double elevators to each platform will afford amenity to a variety of user groups including the elderly, mothers with strollers, and people in wheelchairs. Careful placement of elevators along paths of primary travel will preserve CPTED principles, avoid unwanted segregation and promote equality in use.

Principle 2: Flexibility in Use (Designs that accommodate a wide range of individual preferences and abilities) – Stair handrails and bench seating will offer choice for those who favour one side of their body versus the other. Tactile systems leading to stairs, with tactile floor-warning strips and knurled handrails to assist navigation, will permit the visually impaired to use stairs as an alternative to elevators. All principal public stair systems will be sized to a minimum width of 1875 mm, thereby providing three lanes of effective width, enabling Passengers to pass others on the stairs.

Principle 3: Simple and Intuitive (Designs that are easy to understand regardless of the user's knowledge, familiarity, language or current level of concentration) – Station functional designs follow a common organization and layout of elements designed to simplify and standardize movement patterns. Righthand-rule pedestrian-flow principles have been adopted. Small-scale, compact Stations typically served by a single primary entrance simplify Station navigation. A unique coloured illuminated lightbox strategically located at each Station entrance will easily identify the Station and establish a common identity. Deployment of 'elements fo continuity' thoughout the Stations including wayfinding systems, fare collection, vertical-circulation elements, and common detailing all combine to make Stations intuitive and familiar to the user. Wayfinding signage in English and French will be supported by international symbols for those who do not read either language.

Principle 4: Perceptible Information (Design communicates information to the user effectively regardless of ambient conditions) – Passenger information displays (PIDs) on platforms will advise the arrival time of the next Train. Use of green LEDs on black backgrounds will provide good clarity across a wide range of lighting conditions; non-serif characters for signage and wayfinding will be selected to ensure maximum legibility for Passengers.

Principle 5: Tolerance for Error (Minimize hazards and adverse consequences of accidental poor choices and errors) – Warning hazards along the edge of platforms and at the top of all stairs will be provided to alert Passengers of the dangers associated with stepping into the guideway. Platform end-gates with alarms will deter wandering beyond the end of the platform and guideway-intrusion detection systems will identify if someone unauthorized enters the guideway.

Principle 6: Low Physical Effect (Designed to promote efficiency and Passenger comfort and to minimize fatigue) – Public areas of Stations are designed with clear sightlines of important decision-making points or platform destinations. Single seats near elevators will allow the elderly to rest and wait for the elevator. Designated Waiting Areas at platform level will be located close to elevators to minimize User travel.

Principle 7: Size and Space for Approach and Use (Appropriate size and space allocation for approach, reach, manipulation and use, regardless of body size, posture and mobility) – Just as the Alstom Citadus Vehicles accommodate wheelchairs and strollers, so too do the Stations. Washrooms will be sized to accessibility standards, handrails will be sized to ease grabbing and holding. All emergency phones will be sized to accessibility standards. Door handles will either be lever shaped or "D" shaped for easy opening.

Beyond the requirements of the listed codes, RTG also brings experience in working and consulting with groups representing the disabled community. For example, on Canada Line, a key request from the disabled community through the stakeholder consultation process was the wish not to be left stranded at platform level in an emergency. The problem was that, by code, the elevators were stopped and brought to grade. The Canada Line design team worked with agencies to develop a design solution that kept elevators running continuously during an emergency. The work involved demonstration testing with the Elevator branch to prove system safety. Much to delight of the disabled community, we received final approval for this design change, which represented a first within BC for a transit system.

Although current building codes do not call for areas of refuge on platforms, the notion of leaving disabled Passengers unattended without a safe haven until they are rescued is a matter that needs closer attention. Through the code process, the approach to accommodating the disabled will be much more closely assessed.

5.5.1.13 Net and Gross Floor Area Summary

The gross floor area of the 13 Stations presented in design drawings and summarized in **Table 5.5-5** totals 38,817 m^2, excluding all guideways and areas outside Station footprints. **Drawing Set 5.5** reports individual space requirements on a Station-by-Station basis with summaries reported floor-by-floor.

Table 5.5-5 | Station Floor Area Summary Chart

Station Name	Gross Area (m^2)	Concourse Net Area (m^2)	Platform Net Area (m^2)
Tunney's Pasture	2,969	1,099	1,669
Bayview	2,004	960	906
LeBreton	2,274	675	829
Downtown West	4,681	2,898	1,407
Downtown East	3,524	1,624	1,445
Rideau	5,941	3,393	2,548
Campus	2,039	622	1,127
Lees	1,684	585	1,071
Hurdman	2,011	1,050	960
Train	2,180	362	1,145
St. Laurent	5,524	52	2,804
Cyrville	1,384	107	965
Blair	2,602	885	728

5.5.1.14 Preliminary Code Analysis of Stations

RTG's specialist transit fire and life safety design consultants, Sereca, prepared two code reports as part of the development of our proposal submission. The first report addressed the three Underground Stations (Downtown West, Downtown East, and Rideau) as well as St. Laurent Station, and the second report covered the rest of At-Grade Stations. Each code report consolidated the issues common to each Station group. These code reports addressed the following:

- Applicable fire and life safety code and standards for the Stations
- Fire and life safety concepts, analyses and results related to the current designs
- Aspects of current designs needing further ratification, potentially supported by more technical analysis (e.g. Computational Fluid Dynamic (CFD) modelling) during the detailed design phase

Section 5.5.1.5 discusses our code approach and the impact of code requirements on Station design.

General Fire and Life Safety Provisions including Separation Ratings

All Stations will be classified as Group A, Division 2 occupancy (Assembly) which is consistent with OBC and NBC classifications. Subsidiary areas such as the ancillary blocks housing electrical and mechanical equipment are considered F-2 and F-3, and any retail or leased areas in Stations will be considered Group D or E and will be provided the appropriate fire resistance ratings.

The At-Grade Stations have been treated as 'Open Classification' Stations and as such do not require mechanical support systems for ventilation. Where large concourses enclose the trainway there may be a need to perform technical analysis during detailed design to demonstrate compliance with this code requirement. RTG has worked to reduce the bridges and concourses covering the platform and trainway specifically to preserve the 'Open Classification' of Stations and is confident the Stations will keep their Open Classification through the detailed design process.

Structural Fire Resistance construction of At-Grade Stations will comply with the requirements of OBC sentence 3.13.2.1(6). NBC requirements would require a 45-minute fire resistance rating for all supporting members. We recommend that an Alternative Solution be pursued, using OBC 3.13 construction requirements for Federally Mandated Stations.

Interior finishes and ceiling finishes in Stations will comply with Table 3.1.13.2 of OBC and NBC and NFPA130 section 5.9 for an enclosed Station. Interior floor finish materials will be non-combustible and have a critical radiant heat flux not less than 0.8W/cm^2 when tested to ASTM E 648.

Station compartmentalization is based on the concept that public areas form part of the means of egress and that non-public areas will be fire separated from the egress route. Compartmentalization and separation requirements are provided in the reports.

Station Platform Sizing

Applicable codes do not establish criteria for minimum platform size because Passengers are assumed to be walking and in the process of leaving the platform. Thus, emphasis is on the exit capacity of vertical circulation elements and the time taken to evacuate the platform.

For the three design scenarios we have checked platform sizing and capacity based on LoS requirements related to peak operational demands. This approach has followed a similar rationale to building codes, using 'peak within the peak' factors to assess the maximum platform entraining load, and then to confirm that the platform has adequate space to accommodate Passengers based on 0.8/m^2 per person spacing as defined in the PA. In determining the net platform area, we have included the following factors:

- Area deductions have excluded all vertical circulation elements, their surge areas and other areas or spaces on the platforms that would not form part of the standing space.
- A movement aisle width of 625 mm along the entire platform length has been assumed to enable Passengers to move along platforms at periods of peak density on the platform.

Based on these parameters, all Station platforms have been checked to confirm their capacity. For all three operating scenarios, At-Grade Stations are assumed to be 90 m long (expandable to 100 m), whereas the three Underground Stations will be built with platforms 100 m long (see **Table 5.5-6**).

Table 5.5-6 | Station Platform Sizing

Station Name	Peak Platform Occupancy (people)	Required Net Platform Area (m^2)	Platform Area Provided (m^2)
Tunney's Pasture	9930	534	515
Bayview	4870	167	197
LeBreton	1430	49	58
Downtown West	4380	150	177
Downtown East	5990	206	242
Rideau	3510	120	142
Campus	2160	74	87
Lees	560	19	23
Hurdman	3900	134	157
Train	150	5	6

Station Name	Peak Platform Occupancy (people)	Required Net Platform Area (m^2)	Platform Area Provided (m^2)
St. Laurent	1200	41	49
Cyrville	520	18	21
Blair	12160	417	490

Station Egress Capacities and Evacuation Times

Exit requirements were calculated based on both OBC and NFPA 130 methodologies which are virtually identical and in accordance with PA requirements. As shown in **Table 5.5-7**, all Stations meet platform egress capacity requirements for Scenarios 2 and 3 under the initial build-out of the system, except for Bayview, Lees and Cyrville Stations where future exiting capacity will be provided as part of the OLRT's expansion measures (see **Section 5.5.1.6**).

Table 5.5-7 | Station Egress Capacities and Evacuation Times

Station Name	Emergency Occupancy (people)	Scenarios 1 and 2		Scenario 3	
		Req'd egress width (m)	Req'd egress width (m)	Req'd egress width (m)	Provided egress width (m)
Tunney's Pasture	1,434	5.65	3.39	4.44	5.90
Bayview	1,365	2.89	4.66	6.21	5.52
LeBreton	610	6.95	6.51	8.19	8.73
Downtown West	898	3.39	3.63	4.34	5.00
Downtown East	890	3.40	3.27	4.30	5.00
Rideau	1012	3.98	3.52	4.89	5.00
Campus	856	4.34	4.23	5.59	5.65
Lees	860	4.34	4.22	5.58	5.142
Hurdman	1197	4.84	4.24	5.44	5.45
Train	809	3.79	3.80	5.06	5.09
St. Laurent	942	3.53	3.40	4.53	4.80
Cyrville	821	5.08	4.79	6.2	5.08
Blair	1119	5.98	5.79	6.73	8.70

5.1.15 Micro-Climate Study of Each Station

RTG engaged Rowan Williams Davies and Irwin Inc. (RWDI) to study micro-climates at nine of the At-Grade Stations. St. Laurent and the three Underground Stations were considered protected and, therefore, were excluded.

Founded in 1972 and based in Guelph, RWDI is Canada's foremost environmental analysis and simulation modelling firm. Working on a broad range of infrastructure projects and advising municipalities across Ontario, the company has established a high level of expertise and knowledge specific to Ottawa's climatic profile. The OLRT Project has drawn on this knowledge and RWDI's environmental simulation and analysis software to obtain a reasonably reliable assessment and prediction of Station environmental performance. The qualitative report evaluated pedestrian wind comfort, snow drifting, rain infiltration, and other micro-climate conditions around each of the nine Stations studied. The study identified necessary conceptual mitigation measures and features to control micro-climate impacts, based on the following inputs:

- Review of regional long-term meteorological data
- Previous wind and snow studies undertaken by RWDI, in the Ottawa region
- RWDI engineering judgement and knowledge of wind flows around buildings
- RDWI experience of wind tunnels of a broad range of building projects
- RWDI's proprietary software (Windestimator) for estimating the potential wind conditions around generalized building forms

Appendix 5.5.1 contains RWDI's detailed report in its final version for the bid phase, the result of a highly interactive process between design and micro-climate teams. The current Station configurations and the extent of their Type A, Type B and Type C roofs (see **Section 5.5.1.3**) is, in part, a result of feedback received from the micro-climate analysis team. Highlights and key findings of the report are included in this section.

- RTG's current designs adequately protect the various Stations from pedestrian wind and snow drifting issues.
- The Stations have limited influence on the surrounding micro-climate due to their short stature.
- Station designs incorporate several wind and snow control features that will protect pedestrians from strong winds, drifting snow and rain (e.g. large canopies, porous wind screens and tall parapet walls).
- Some Stations feature raised or elevated platforms where pedestrians will be exposed to higher-than-normal wind speeds. At these locations, solid wind screens taller than pedestrians will be provided.
- Most Stations should experience average drifiting and snow accumulations. Hence current snow-removal practices for the BRT system should be sufficient. To reduce snow-removal frequency and cost, we have identified features to collect snow before it reaches pedestrian-frequented areas and will explore these in detailed design.
- Tall vertical structures and large canopies will minimize rain infiltration onto platforms as rain is combined with wind less than 10 percent of the time it rains.

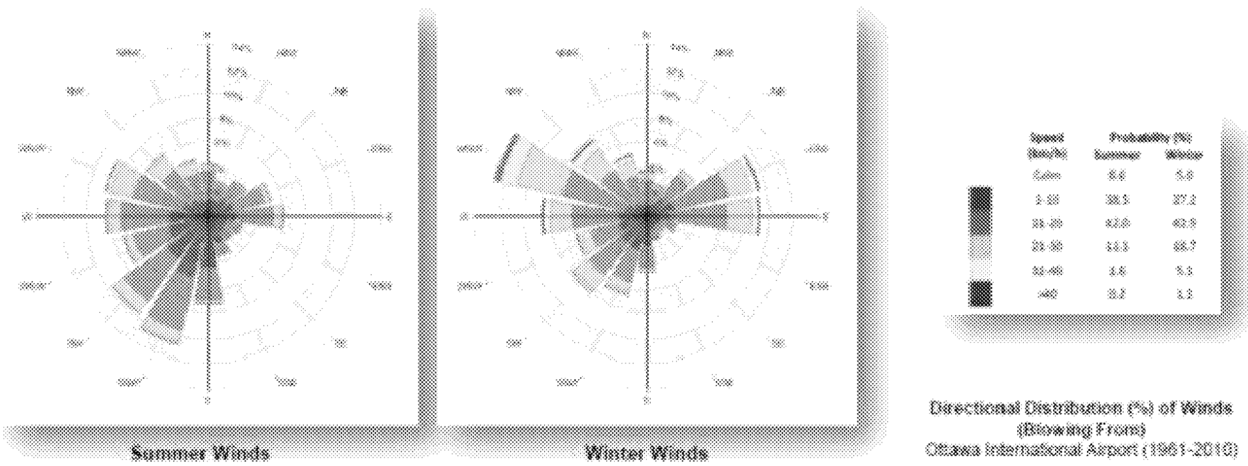
Inputs and Performance Criteria

The analysis considered meteorological data comprising wind, rain and snow drifting.

Wind Climate - Metereological data from Ottawa International Airport from 1961 to 2010 was used as our reference for regional wind conditions. **Figure 5.5-3** shows distribution of wind frequency for summer (May to October) and winter (November to April). During the summer, winds are predominantly from the south to the west-northwest quadrant; during the winter winds are mostly westerly and easterly.

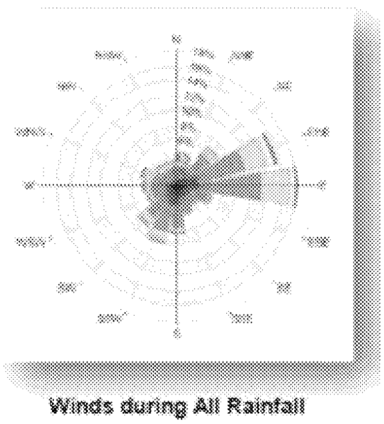
Strong winds with a mean speed greater than 30 km/h measured at the airport occur for 1.8 percent and 6.2 percent of summer and winter, respectively. The west-northwest, west, east and east-northeast winds are prevalent throughout the year. In winter, winds from northwest to north can be sources of uncomfortable and severe wind conditions, depending on site exposure and Station design.

Figure 5.5-3 | Principal Direction and Strength of Winds: Summer and Winter



Rainfall. Metereological data from Ottawa International Airport for 1961 to 2010 was also used as our reference for rain conditions. Annual rainfall volume averages 732 mm with most rain falling between April and October. There are 115 days a year with rainfall, 25 of which have a rainfall greater than 10 mm. As shown in **Figure 5.5-4**, rain during winds accounts for 8.6 percent of all winds and primarily with wind speeds of 30km/h or less.

Figure 5.5-3 | Principal Direction and Strength of Winds: Summer and Winter



% Of Overall: 3.9% Calm — Percentage of Rain over All Winds: 8.6%

Wind Speed (km/h)	Overall Probability (%) All Rains	Light Rains	Moderate Rains	Heavy Rains
1-10	25.91%	24.85%	0.79%	0.26%
11-20	47.21%	45.06%	1.74%	0.41%
21-30	18.04%	16.94%	0.86%	0.24%
31-40	4.04%	3.73%	0.22%	0.09%
>40	0.87%	0.74%	0.08%	0.05%

Directional Distribution (%) of Winds (Blowing From)
Ottawa International Airport (1961-2010)

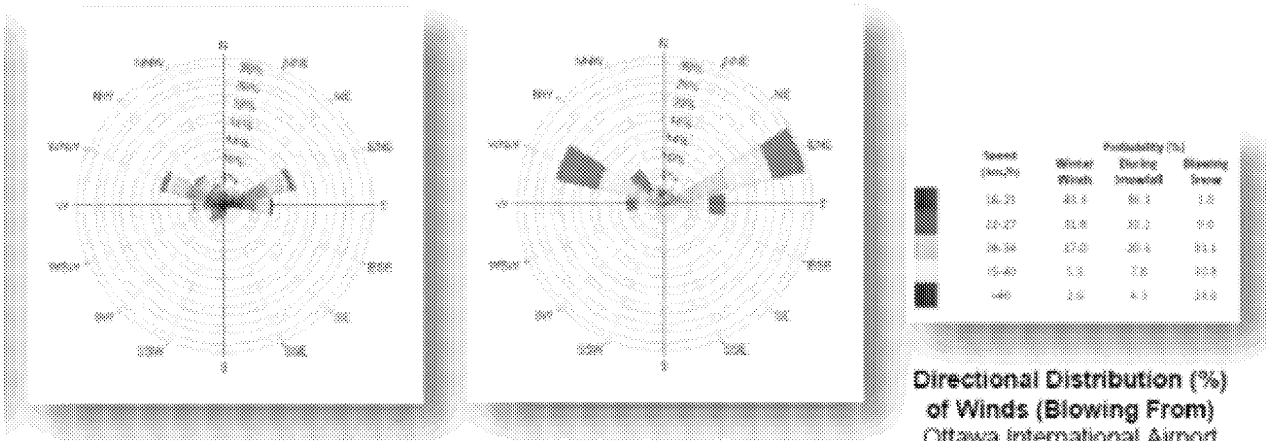
For all types of rainfall, winds are primarily from the east and east-northeast, with secondary winds from the southwest quadrant. Similar wind direction is observed during light rainfall (≤ 2.5 mm/hr). For moderate rainfall, winds are still primarily from east and east-northeast, with secondary winds from southerly directions.

Snowdrifting. Based on 30-year data provided by Environment Canada, the average annual snowfall in Ottawa is 236 cm. Of the 122 days/year (on average) that snow remains on the ground between November and April, the average depth of snow is 17 cm.

Snowdrifting begins to occur when winds exceed 15 km/h. In the Ottawa region, winds great enough to cause snowdrifting occur less than 20 percent of the time in winter. The 15 km/h wind speed is measured at the Airport's anemometer, which is on a mast 10 m above the ground. Winter winds with blowing snow representing higher wind speeds are often associated with storm events and significant drifting.

Review of winter winds greater than 15 km/h indicates that the west-northwest, east, northeast, west and east-northeast are most prevalent (see **Table 5.5-4**). For winds greater than 15 km/h combined with snowfall, (see lower left wind rose), east-northeast and west-northwest and east winds are prevalent. For appraisal of the Stations, winds from the west-northwest, east-northeast, west and east are the most important.

Figure 5.5-4 | Principal Direction and Strength of Winds: Summer and Winter



Explanation of Criteria

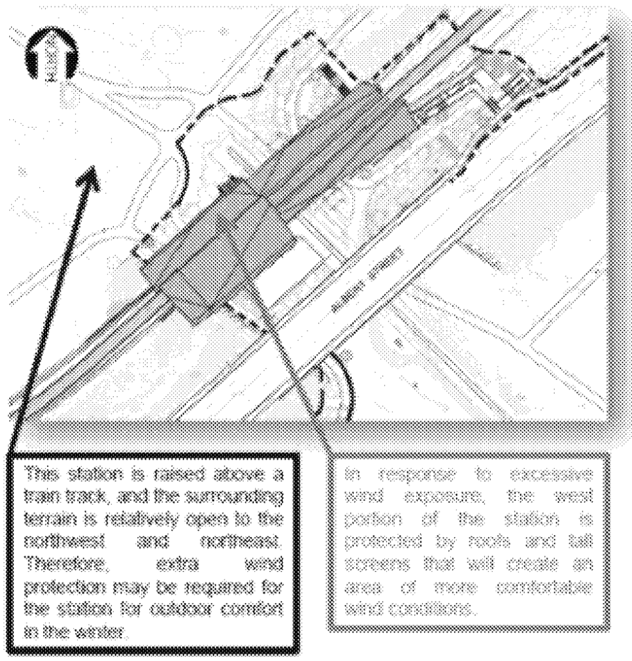
Pedestrian Wind Criteria. The wind criteria described below have been developed since 1974 through RWDI's research and consulting practice. These criteria have been widely accepted by municipal authorities and by the building design and city planning communities in the City of Ottawa:

- **Sitting** - Calm and light breezes desired for outdoor seating areas where one can read a paper without having it blown away
- **Standing** - Gentle breezes suitable for main building entrances, Station platforms and bus transit stops
- **Strolling** - Moderate winds that would be appropriate for window shopping and strolling along a downtown street, plaza or park
- **Walking** - Relative high speeds that can be tolerated if one's objective is to walk, run or cycle without lingering

Wind conditions are considered suitable for sitting, standing or walking if wind speeds are less than the prescribed limit at least four out of five days. An 'uncomfortable' designation means that wind speeds exceed the walking criterion more than one day in five. For context, Ottawa's wind conditions as defined above are generally suitable for 'standing' in the summer and 'walking' in the winter. For the purpose of this assessment, we consider these wind conditions to be 'average'. As standing conditions are considered appropriate for pedestrians waiting on platforms, wind conditions in the summer are generally anticipated to be appropriate. In the winter, the inclusion of wind screens and other mitigation features will provide shelter from strong prevailing winds.

Sample Station Extract – LeBreton Station

We performed a detailed review and analysis for each Station. All Station site plans are shown in their true site orientation and thus the meterological data roses are applicable as described above. **Figures 5.5-5 and 5.5-6** show extracts from Bayview Station's analysis.



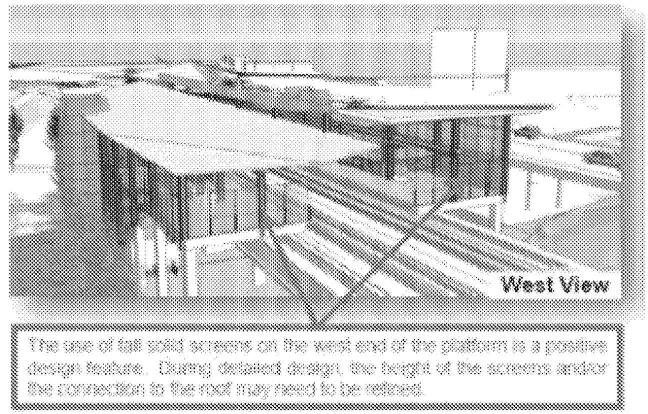


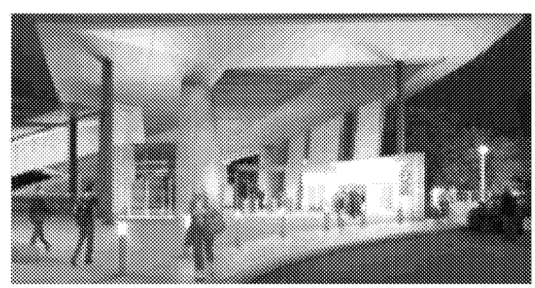
Figure 5.5-3 (above) | Typical micro-climate observations related to the Bayview Station Design

Figure 5.5-4 (left) | Micro-climate context analysis of Bayview Station indicating positive attributes and issues to be considered

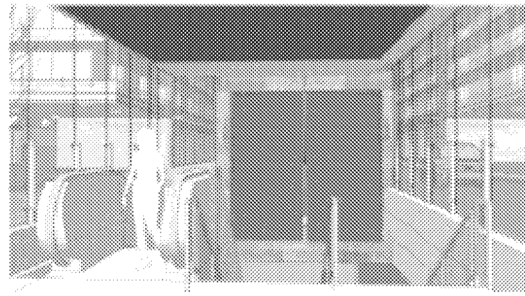
5.5.1.16 Utilization of Borer Ash Wood in Stations

To add warmth and material vesatility, RTG intends to use the City-provided Borer Ash wood throughout the Stations and public realm, evoking an architectural regionalism rooted in Ottawa's association with the lumber industry. We have used wood extensively in North American rapid transit systems; for example, our code and structural teams worked on Vancouver's Millennium Line and Canada Line. Their extensive portfolios, combined with our local Ottawa and Ontario architects, offer proven expertise and project experience to know where and how the Borer Ash wood can be applied effectively. Our approach adopts three strategies or areas of use within the OLRT system.

Wood in At-Grade Stations – We will staple, tie and glue 2" x 4" Borer Ash sections to form prefabricated, modular wood infill soffit panels under roof types A and B. Panels no wider than 8 feet (2.45 m) will be formed using wood pieces 3 ft. to 8 ft. long, which will use much of the available wood stock.



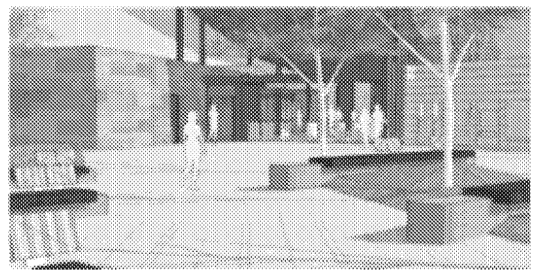
Wood in Underground Stations – Our experience on other projects and the position of our code authority (a full member of NFPA 130 Technical Committee for more than 20 years) is to limit wood to Station entrances; that is, it will not be used in Underground Station concourses or on platforms exposed to a primary fire source. Underground Stations are confined spaces serving thousands of people at any one time and are, therefore, intended to be non-combustible construction. Our design uses wood at Underground Station entrances in limited fashion for aesthetic architectural continuity. Note that wood colour finishes in the underground stations are non-combustible.

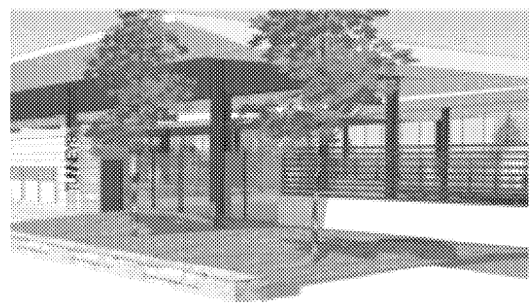


Wood in the Landscape – Using wood to create bench seating and vertical porous screening are two applications developed in our design strategy.

Wood slats for bench seats use shorter pieces of wood. Assembled in modular sections that can be easily removed and replaced as necessary for refinishing and repair, they will be part of the detailed design.

Using the wood in vertical screens designed to be porous forms part of our overall micro-climate management strategy since porosity reduces eddying and vortexing.





The total wood to be used for all stations is approximately 5,900 m^2, which, depending on how the sections are laid out, could result in approximately 330,000 linear bored feet of wood. Without an inventory of wood lengths it is difficult to predict wastage, but our calculations include a 30 percent wastage factor to allow for off-cuts too short to use, and for product with notches or other defects that might affect uniformity of the panels' appearance. The use of wood will be optimized in detailed design, and will be a feature of the sustainability of the stations. Wood needed to make repairs and replace wood in applications subjected to abuse has not yet been factored in and will be discussed in greater detail with the City.

5.5.1.17 Architectural Drawings and Renderings

In accordance with RFP Schedule 3-1, RTG has prepared architectural drawings and renderings depicting the layout, configuration, scale and imagery of the Stations. Common details have been prepared on a Project-wide approach and referenced to Stations. **Drawing Set 5.5.1** provides the architectural drawings.

5.5.2 STRUCTURAL DESIGN

5.5.4.1 Proposed Structural System

Structural framing systems were developed in partnership with the architectural, mechanical, electrical and civil disciplines. Our objective is to create a system that provides the strength, safety and serviceability that the Project needs and that also expresses the Stations' various features. Station structures will comprise a mix of structural steel and concrete framing, interacting to form the gravity and lateral support system for the structure.

Design Criteria & Applicable Standards

- Ontario Building Code, 2006 Edition
- National Building Code, Canada 2005 Edition
- Canadian Standards Association CAN3-S16-01 - Limit States Design of Steel Structures
- Canadian Standards Association A23.3-04 - Design of Concrete Structures
- CSA A23.1/A23.2-04 - Concrete Materials and Methods of Concrete Construction/Methods of Testing for Concrete

In addition to the loading required by the various building codes and standards noted above, the structural design team also incorporated PA requirements for gravity loading, deflections and vibrations.

5.5.4.2 Structural Design Brief

Outline Specifications & Drawings/Sketches

This section describes RTG's approach to structural design and the outline specifications applicable to the OLRT Project. **Drawing Set 5.5.2** provides drawings of the Stations.

Foundation, Floor, Roof & Structural Framing Systems

Foundation design takes into account applicable gravity and lateral loading, frost damage mitigation, and deflection and vibration control. The soil profile for each site requires different foundation systems. Where existing soil profile and design load conditions allow, we have used concrete spread footings. Where fill or other poor soil conditions are present, we have used deep foundation systems to transfer applicable loads into the native soils.

At the lowest level of the Station, typically the platform level, we will use a 125 mm normal-weight concrete slab on grade. At the elevated level, typically the concourse level, a reinforced-concrete slab spanning concrete beams and columns will resist applicable loads. At the uppermost roof level, we propose structural steel framing. This framing will be supported by steel columns that post off the concrete slab. In multiple locations, the concrete slab and/or beam below has been designed to act as a "transfer" member since column locations do not align. Using concrete at the heavily occupied floors provides exceptional durability as well as a clean, finished appearance. Using structural steel for the roof levels allows for the long spans, sloping surfaces and thin roof-edge profiles to suit the architectural intent.

Lateral Load Resisting System

For the lateral load resisting system of the Station structures we propose a mix of steel cross-bracing in elevator shafts, cantilevered steel columns, steel-moment frames, and concrete shear walls. The decking at the roof and the concrete slab for the concourse serve as the diaphragm that distributes lateral loads to each Stations' individual systems. At each Station, the lateral system was selected based on the overall architectural design.

Design Dead & Live Loads for all Areas

Table 5.5-8 shows typical loads applicable to the design of all OLRT Stations. All loads have been determined in accordance with the design criteria and applicable codes.

Table 5.5-8 | Design Loads for All Areas

Load	Concourse	Platform	Roof
Dead Load	Finishes and suspended mechanical, electrical, lighting 1.25 kPa	Finishes 1.00 kPa	Roofing system and suspended mechanical, electrical, lighting 0.60 kPa
Live Load	Typical floor 4.8 kPa	Typical floor 7.2 kPa	Snow load (Ss=2.4, Sr=0.4) 2.32 kPa

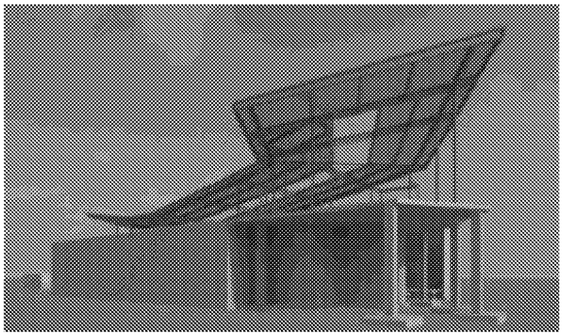


Figure 5.5-5 | Train Station: Entrance View

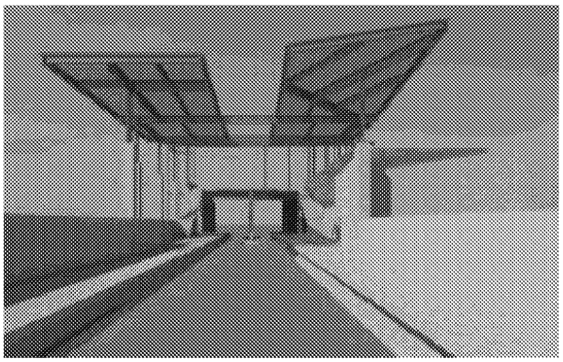


Figure 5.5-6 | Train Station: Platform View

Design or Specification Measures to Meet Serviceability Criteria

RTG's structural analysis of the concourse, platform, and roof levels , as illustrated in Figures 5.5-5 and 5.5-6 incorporates code-recommended live and total load deflection criteria. Depending on the Station, both platform and concourse levels use a suspended floor structure. These levels are occupied by the public, and include floor and soffit finishes. In all cases, where structures are supporting finishes susceptible to cracking, additional measures such as beams or thickened slabs have been implemented.

Similarly, where structural systems are designed to support lateral loads, code-recommended lateral drift and deflection criteria due to seismic and/or wind loading have been incorporated. Structural analysis models were developed that allowed the Team to review lateral deflections at various levels and points across the floor/roof areas. In general, the lateral force resisting system uses moment frames, which provide the necessary strength and stiffness, while maintaining the open floor arrangement that is key to unimpeded views and unobstructed Passenger movements.

Column Spacing & Layout

The superstructure is split into two structures: concourse and roof. In general, concourse framing is supported by concrete columns. The structural team developed a column grid spacing of 7.5 m, with columns running along the track. In the opposite direction, columns have been arranged to provide adequate clearance for proper Passenger and Train flow. For roof framing, the 7.5 m spacing continues up to the roof structure. Additional columns have been added as necessary to adequately support the roof structure as well as glass enclosures, railings and other miscellaneous items.

5.5.4.3 Modified/Retained Stations

At select Stations, components of the existing structure are to remain in the new structure, integrated into the Station's overall design. A review of these structures is key to determining their adequacy for continued use and operations.

Structural Adequacy of Existing Structure

The age and condition of existing structures varies from Station to Station. For components that are to be preserved, we will perform both analytical and physical testing through the various design stages to determine structural adequacy. During the RFP phase, we reviewed existing documents to determine the types of structural systems that are now in place: foundations, slabs on grade, suspended structural floors and roofs. These documents typically noted the loading allowances used to design the original structural system. In some cases a review of this loading compared to the proposed loading confirmed the adequacy of the existing structure. In other instances, initial structural analysis of selected areas confirmed adequacy.

Verification that Existing Structure Meets Current OBC Requirements

The design and construction dates of existing structures vary, and therefore the building codes in effect also varied. As the building code evolves, existing structures that are supporting new load conditions require review to determine conformance with the current code. This review involves both analytical and physical testing, depending on the condition of the structure, the level of existing information available, and its intended use in the new facility.

For example, if existing foundations are intended to be preserved and reused in the new Station, we will perform load rundowns from both gravity and lateral loads, using current building code requirements. Resulting loads will be applied to the foundations and analyzed to determine required strength and serviceability. This analysis will determine whether existing foundations meet current code requirements or require strengthening to safely support the imposed loads.

Proposed Strengthening Measures

Where existing structural systems require strengthening, such as foundations, the Team has reviewed design alternatives to determine the optimal solution. Using the foundation example, some Stations are constructed alongside existing guideways, a portion of which are to be retained. Given that the total imposed loading of the proposed Station exceeds that of the existing, it is clear that additional foundations are required.

Bayview Station, for example, uses existing foundations that consist of driven-steel piles and a reinforced-concrete pile cap. Where additional foundation strength is required, similar steel piles will be installed adjacent to the existing, and reinforced-concrete pile caps will be constructed adjacent to or integrated into the existing caps. This will ensure that the existing and new systems are compatible, both in resisting imposed loads and with respect to relative settlement.

5.5.4.4 Lateral Load Resisting System

Capability to Resist Live Loads & Seismic Loads

The lateral load systems described above have been designed to accommodate the lateral loading noted below.

Wind Loads

We determined wind loads in accordance with the OBC. Structural wind loads are based on the 1/50 average hourly wind pressure, with cladding wind loads based on the 1/10 average hourly wind pressure. Design parameters are as noted below:

- q = 0.41 kPa (1/50), 0.30 kPa (1/10)
- Ce = 0.7
- Cgi = 2.00, per the users' guide to the 2005 NBCC structural commentaries
- CpCg = per the users' guide to the 2005 NBCC structural commentaries
- Cpi = +/- 0.7 per the users' guide to the 2005 NBCC structural commentaries
- Iwi = 1.0, wind importance factor, category normal.

Seismic Loads

Seismic load parameters are outlined in the Supplement to the NBC. The parameters used to represent seismic hazard are the 5 percent damped horizontal spectral acceleration values for 0.2, 0.5, 1.0 and 2.0 second periods and the horizontal Peak Ground Acceleration value that has a 2 percent probability of being exceeded in 50 years.

For Ottawa, the seismic data as per NBCC 2005 is as follows.

- Sa (0.2) = 0.660
- Sa (0.5) = 0.320
- Sa (1.0) = 0.130
- Sa (2.0) = 0.044
- PGA = 0.420

In the design formula for minimum lateral earthquake force, we will use the following values in designing the lateral load resisting system:

- V =S(Ta)x Mv x Ie x W / (Rd x Ro)
- Sa(Ta) = Fv Sa (0.5) for Ta = 0.5 sec (spectral acceleration values)
- Fv = 1 (Velocity-based site coefficient)
- Mv = 1.0 (Higher Mode factor corresponding to braced frame structure)
- Ie = 1.0 (Importance factor)

- Rd = 1.5 (Ductility-related force-modification factor)
- Ro = 1.3 (Over-strength-related force-modification factor)

5.5.4.5 STRUCTURAL DRAWINGS

Drawing Set 5.5.2 provides structural framing plans (1:200) and structural foundation plans (1:200).

5.5.5 MECHANICAL DESIGN

5.5.5.1 Mechanical Systems

Mechanical design will comply with required codes and standards and meet the requirements of the Output Specifications as outlined in the sections below.

5.5.5.2 Facilities Management Systems: BAS and BMS

System Overview

To fully monitor each Station, maintain an acceptable Passenger environment, and provide controlled environments for deployed technical equipment, two systems will be deployed alongside each other to make a complete Facilities Management System (FMS): a Building Automation System (BAS) and a Building Management System (BMS). Each system is essentially a collection of facilities to provide the required functionality.

The **BAS** will be deployed to each Station to monitor and control Station mechanical and electrical facilities that have some automation:

- Heating, ventilation and air conditioning (HVAC)
- Computer room air conditioning (CRAC)
- Station lighting
- Tunnel ventilation

Each system will be built around an open protocol (BAC-Net) LAN to interconnect all devices in the Station and to interface to the SCADA connection for onward connectivity to the TSCC and MSF. At each Station, a workstation will be provided to enable local monitoring and control of the system and associated plant.

The **BMS** will be deployed to monitor all non-automated Station facilities for normal/abnormal operation and to allow oversight of Station mechanical and electrical items and devices:

- Doors
- Fire Detection and Alarm System (FDAS)
- Station and tunnel sump levels
- Operational room temperatures
- Vandal/tamper alarms
- Equipment in adjacent tunnels such as sumps, and standpipe

We expect that the BMS will monitor some elements controlled by the BAS, thus providing a level of redundancy over critical plant monitoring. These two FMS facilities will report to the Station SCADA RTU from where their information will be sent to the TSCC (operational monitoring) and the MSF (alarm/failure management) for display to Control Room Staff.

BAS

HVAC – Room thermostats will control heating and cooling to maintain the specified temperature range of each room. A sensor in the outdoor intake shaft will determine when economizer cooling is used instead of mechanical cooling. Direct digital controls and a series of motorized dampers will control this system. Where unit heaters are provided, electrical interlocks will ensure heating and cooling by ventilation do not occur simultaneously. We will provide a separate CRAC system, capable of being remotely controlled.

Station Lighting – For Station lighting, the BAS will provide facility-level control of interior and exterior lights in functional (e.g. platform, concourse, ancillary) or operational (e.g. all Passenger areas, all non-Passenger areas) configurations. Such lighting control will allow illumination to be determined remotely (TSCC staff via SCADA), locally (OC Transport staff on site) or automatically (local photocells), with each being determined by lighting type, function and location.

Tunnel Ventilation – We note the requirement for tunnel ventilation to be part of the BAS and for the control network to be UUKL-864 listed. We would welcome the opportunity to discuss this further as we do not believe this is the best approach to achieving the control and operation of this life-safety critical function. We believe it more appropriate to build a discrete TVS system based around redundant, high-availability controllers with redundant I/O and meeting SIL-2 as a minimum. Furthermore, the controls for tunnel ventilation systems typically prove to be too complex for a standard BAS. Our proposed system would be independently linked to the main OLRT SCADA system and would interface directly into local FDAS systems and local control panels for emergency personnel use. Lastly, we recommend not operating the tunnel ventilation system automatically based on smoke detection and/or sprinkler system activation as neither smoke detectors nor sprinklers are provided in public areas of the Station.

BMS

Door Monitoring – Doors are monitored in conjunction with the Intrusion Access Control (IAC) system, with monitoring of door status (open/closed) through the BMS providing an independent and redundant path. This is especially important for Station public-area security (break-ins/vandalism) and technical room security (unauthorized entry must be detected).

Fire Detection and Alarm System (FDAS) – The FDAS will be a self-contained unit. However, it is important that key alarms are picked up and transmitted to the control centres (TSCC and MSF) for remote monitoring and response. Alarms received will include the Station Fire Alarm or sprinkler system being active, and standpipe valves being operated.

Station and Tunnel Sumps – Station sumps will be configured with a two-pump arrangement (duty/standby or duty/duty assist) with level monitoring achieved via float switches or pressure transducers. The control of operation will use a packaged discrete controller interfacing into the overall BMS network.

Vandal/Tamper Alarms – Fare equipment, such as ticket vending machines, is a target for vandalism (to break/disable) and tamper (robbery). Such machines will be monitored (e.g. for tipping), with alarms routed to TSCC for response by Transit Law Personnel.

5.5.5.3 General Design Approach to Mechanical Systems

HVAC

Non-public Station areas will have an environmental control system to control room temperature and humidity for comfort where occupancy is a consideration, or to maintain optimal performance of temperature-sensitive equipment. In the Underground Stations, public areas will normally be ventilated by the piston effect of the moving Trains. In the Underground Stations, the rate of air exchange will be confirmed through an SES analysis of both the initial operating conditions and the future addition of platform-edge doors.

To meet environmental requirements, we will provide air conditioning and heating to ancillary spaces as required. Where practical, systems will be designed for energy conservation and efficiency. For example, free cooling, economizer cycles, and heating integrated with cooling systems will be used where possible. In addition, the BAS will be programmed to operate the HVAC in the most efficient manner possible, taking into account outdoor air conditions but without comprising the reliability or performance of critical electrical equipment in the Station. Smaller ancillary rooms will be cooled using VAV boxes, and heated by duct heaters, unit heaters or cabinet heaters to prevent freezing. Occupied spaces such as lunch rooms and bus supervisor offices will have a similar heating system to maintain comfort levels for operators.

Ceiling-mounted radiant electric heaters will be provided in Designated Waiting Areas (DWAs) as required. All spaces will have outdoor air ventilation.

The HVAC system will be designed so that in an emergency, the failure of any one cooling unit does not cause the electrical equipment serving the tunnel ventilation system to fail due to overheating. In addition, ductwork with motorized fire-smoke dampers will connect to the fire alarm system. These dampers will be arranged such that in the event of a fire in one room, smoke will not be distributed to any other rooms.

Underground Stations will have two ventilation shafts to grade, one to intake outdoor air and the other to discharge exhaust air. The outdoor air intake openings will be positioned to avoid introducing debris and fumes into the Station. Where rooftop units are not viable, heat rejected from condensers will be ducted to the exhaust air shaft to grade. Electrical equipment rooms such as communication rooms and signal rooms will be positively pressurized, whereas rooms such as sump rooms, washrooms, and janitor rooms will be negatively pressurized. To prevent the intake of contaminants such as brake dust into ancillary rooms, all louvers facing public areas at platform level will have filters.

Plumbing & Drainage Systems

Each Station will be designed with two metered incoming cold water lines for domestic and fire water services. Fixtures will be of the low-flow water-conserving type wherever practical. Hot water for fixtures such as lavatories, sinks, eyewashes, and emergency showers will be provided through electric tankless heaters, where practical. Hose bibs and non-freeze wall hydrants will be provided throughout the Station for maintenance activities.

All Station drainage will be gravity-fed to City lines where possible; submersible duplex sump pumps will be provided otherwise. Sump pumps for sanitary and/or storm discharge will be provided if necessary, and will be monitored by the BMS. At Station entrances, foot grilles will provide additional drainage, collecting melted snow and preventing rainwater from being tracked throughout the Station. Track drainage will be intercepted at each Station and sized to accommodate a fire standpipe discharge.

Where susceptible to freezing temperatures, installed piping will be heat-traced and insulated. No plumbing lines and/or fixtures will be located inside electrical rooms except to serve eyewashes and emergency showers within the same room. For ease of maintenance, all lines will have isolation valves, easily accessible cleanouts and valves (where required), and proper identification. To the greatest extent possible, no lines will be embedded in concrete or made of combustible materials (e.g. PVC, ABS, polypropylene) if above ground. All plumbing vents will terminate above headhouse roof level, and will be located away from ventilation intakes to avoid recirculation.

Stations will have a Class III automatic dry standpipe system separate from the tunnel standpipe system, with electric fire pumps where required. For non-electrical ancillary rooms, we will install an automatic dry-pipe sprinkler system, zoned appropriately for the Station's geometry. All siamese connections at grade will be clearly marked to identify the system it serves, and will be located adjacent to the Firefighter's Command Post (FCP) to provide a single response point for the Ottawa Fire Service (OFS).

All Station communications rooms will be equipped with a clean-agent fire-suppression system. We suggest the Novec 1230 clean-agent fire-suppression system instead of the specified HFC-227ea, as the former has a significantly lower environmental impact when discharged into the atmosphere. The standpipe, sprinkler, and clean-agent systems will be monitored by the Station's fire alarm system through valves, gauges, and sensors, providing audible and visual signals at the Station's FCP. Station public and ancillary areas will have ABC-type portable fire extinguishers. Electrical rooms will also be provided with clean agent fire extinguishers, installed at all entries and exits.

RTG will coordinate with the OFS for issues such as primary response locations, hose thread types, and siamese connection labelling and locations.

5.5.5.4 Mechanical Drawings, Diagrams, Product Cuts & Schematics

Mechanical drawings, diagrams, product cuts and schematics are provided in **Drawing Set 5.5.3** and address the following:

- Air handling unit drawings including smoke ventilation systems
- Fire protection system schematics
- Main mechanical equipment schedules
- Mechanical floor plans (1:200)
- System schematics for all major systems

5.5.6 ELECTRICAL DESIGN

This section describes the proposed electrical design for power distribution, emergency power, general purpose receptacles, lighting, fire alarm, and communications for all Underground and At-Grade Stations.

5.5.6.1 Electrical Systems

Power Distribution

Underground Stations - Two incoming feeders from Hydro Ottawa Limited (HOL) will feed utility-owned double-ended 13.2 kV medium-voltage switchgear in the HOL Switchgear Rooms. From there, two feeders will run to the medium-voltage Switchgear Rooms in Downtown West and Rideau Stations. Downtown East Station will be fed at medium voltage from each of Downtown West and Rideau Stations. For redundancy, the loads of all three Downtown Stations will be shared between the utility feeders with an automatic transfer scheme using a tie circuit breaker so that remaining feeders can supply 100% load if one HOL feeder fails. In a main/tie/main arrangement with an automatic transfer, a 600 V double-ended unit substation will be provided in the Station AC Switchgear Room. A 208 V double ended unit substation will provide power to 120 and 208 V loads. To ensure a two-hour fire rating, the main feeder raceways in the tunnel will be embedded in concrete.

At-Grade Stations - One incoming medium-voltage feeder from Hydro Ottawa Limited will feed a utility-owned padmount transformer outside the Station. A main 600 V switchboard connected downstream of the manual transfer switch will be provided in AC Switchgear Room along with 208 V distribution panels.

Emergency Power

An uninterruptible power supply (UPS) will feed the main critical distribution panelboard in the Station emergency power room, which will, in turn, feed emergency panelboards. These emergency panel boards will supply power to tunnel lighting, emergency lighting, blue lights, fire alarm system, fare gate/fare control equipment, Train control and all communication systems. The future platform-edge door equipment will likely be supplied with an integral UPS and this equipment is not included at this time; however, the RTG design will protect space for this future requirement.

For At-Grade Stations, a mobile generator connection box outside the AC Switchgear Room will enable us to power the entire Station from a temporary generator if necessary.

General Purpose Receptacles

All public area receptacles will be ground-fault interruptor (GFI) style with lockable covers. Provided at 30 m intervals, no more than six outlets will be connected to a branch circuit. One GFI receptacle will be provided at Station Sign Boxes and Art Elements as required. One flush-mounted GFI receptacle with a weatherproof lockable box will be provided close to the hose bib.

Lighting

Exterior lighting will be designed for vandal resistance, containing no up-light yet providing suitable illumination to be CPTED compliant. Exterior lighting will typically be light-emitting diode (LED) types, and control will include a maintenance bypass switch located on the facility's external wall for night services.

Interior lighting in public areas will primarily use LEDs as a lighting source, will reinforce intuitive wayfinding, and will display the Station's architecture. For safety, the platform edge and DWAs will be illuminated to a higher level than the remainder of the platform. Photometric modeling of all spaces will confirm that we meet illuminance targets.

For energy efficiency, public area lighting will be timer-controlled, and at-grade entrances will include daylight sensing. In service and utility back-of-house rooms, fluorescent lighting will be controlled by wall switches with occupancy sensing. All lighting control will also be monitored and controlled by the BAS.

Because emergency and exit lighting are life-safety systems, their wiring systems will be protected by using conduit embedded in concrete or Circuit Integrity cable, where mandated by NFPA 130, and they will be supplied by UPS. A blue light at each emergency alarm station will be continuously illuminated and fed from an emergency panel board.

Fire Alarm System

In each Station, a single-stage addressable fire detection and alarm system (FDAS) will be designed, installed and verified to OBC, ULC-S524 and ULC-S537 requirements. Fire detectors will be provided in all non-public Station areas.

Sprinkler-flow switches will monitor sprinkler water flow. Supervisory alarms will be monitored by the fire alarm panel, including low sprinkler-water pressure, sprinkler-supervised valves and low-temperature alarms. Alarms will be annunciated at the fire alarm control panel, with annunciators located as required by the City and firefighters, and at the TSCC where the alarm can be verified and appropriate action taken.

The FDAS wiring system will be protected by using conduit embedded in concrete or Circuit Integrity cable, where mandated by NFPA 130.

Communications

Infrastructure, including outlet boxes, raceway systems and emergency power supplies will be provided for the telephone network, emergency trip system, public telephones, Passenger assistance intercom, radio, SCADA, intrusion detection, CCTV, public address system, Passenger information video, next-vehicle-arrival system, automatic fare-collection system, GPS master clock and train-control signalling. Coordination with each system designer will determine head-end space, cooling and power-supply requirements, as well as device locations and raceway requirements.

5.5.6.2 General Design Approach to Electrical Systems

Redundancy & Emergency Power

RTG's proposed design provides reliability and redundancy that complies with the reference design and NFPA 130 for an acceptable alternate power source (generator or alternate utility feed as appropriate).

Underground Stations - Through a parallel cabinet, a UPS will feed the main critical distribution panel board which will, in turn, feed emergency panel boards. The UPS and associated panelboards in the Station emergency power room will back-up all loads classified as "emergency level 1", since a second utility power source is proposed for the Underground Stations. Emergency panelboards will supply power to tunnel lighting, Station emergency lighting, blue emergency lights, control and communication systems. Tunnel lighting panelboards will be located at the ends of the platform

At the 208 V and 600 V levels, the double-ended unit substation with a main/tie/main arrangement with automatic transfer provides another level of redundancy if one of the two busses fails. Each side of the unit substation 600 V normal power distribution section will feed a UPS that includes a 600-208 V transformer, rectifier, battery, inverter, static bypass switch, and manual bypass switch.

The proposed design provides reliability and redundancy by an automatic transfer at the medium-voltage level that will transfer power from preferred to alternate source if the preferred source is interrupted. RTG has used this on several projects with underground stations; however, we acknowledge that the Authorities Having Jurisdiction must review and approve the design.

At-Grade Stations - With one utility power source, power-source redundancy will be achieved by connecting a mobile generator sized to support all Station loads. To provide back-up power for critical loads, these Stations will use a single UPS with static bypass and external maintenance bypass switch.

5.5.6.3 General Design Approach to Provision of CCTV, PA, Advertising, Signage, Fare Collection, PIDS, Pumps, Etc.

Several installed subsystems will require some form of electrical infrastructure (e.g. conduit, raceways, power supplies) to support the following Station subsystems:

- Central Transmission System (CTS)
- Public Address System (described below)
- Passenger Information Display System (described below)
- CCTV System (described below)
- Telephone and intercom system
- SCADA
- Radio communications
- Intrusion Alarm Control (IAC)
- Train Communications Systems

CCTV

Fixed-facilities-based CCTV will comply with PA Schedule 15-2, Parts 4 and 6 (Articles 6 and 7, respectively), built up from several subsystems (e.g. cameras, power supplies, network devices, video recorders/storage and displays) integrated into one coherent system meeting OLRT security and operational monitoring needs.

To monitor fare collection equipment and other areas that must be covered after CTPED reviews, we will deploy fixed and pan-tilt-zoom (PTZ) cameras at Station entrances, along Station platforms, in Passenger circulation areas covering Designated Waiting Areas (DWAs), and at tunnel entrances. These cameras will be connected to their respective Station equipment using a mix of fibre and copper technologies as determined by their location, distance and application.

The electrical team will support the CCTV system by installing necessary conduit and raceway infrastructure, with UPS backup and interconnection to other systems (e.g. SCADA, CTS Network, TSCC Video Wall). As with other transit projects RTG has completed, the Design Team will integrate camera installation into Station architecture unobtrusively, while maintaining appropriate viewing zones.

Public Address (PA) System

We will install an OLRT public address system in Stations, to provide clear, audible announcements throughout the Stations from both local microphones and the TSCC, supporting both *ad hoc* and pre-recorded broadcasts. Station-based systems will comply with PA Schedule 15-2, Part 4, Article 6, comprising speakers, microphones, ambient-noise monitors, amplifiers and signal processors. Projection speakers will be used on Station platforms and other areas requiring targeted announcements; in-ceiling speakers will be used where drop ceilings are available, providing a flush finish.

The electrical team will support the public address system by installing necessary conduit and raceway infrastructure, with UPS backup and interconnection to other systems (SCADA, CTS network, Central Master Clock, Train Control, and FDAS). As with other transit projects RTG has completed, the Design Team will integrate speaker installation into Station architecture unobtrusively, while maintaining appropriate performance.

Advertising

We will supply electrical infrastructure to support OLRT advertising. RTG understands that an opportunity may exist for advertising revenue, and that much of this equipment is becoming extremely sophisticated, potentially requiring significant power and data infrastructure. PA identification of the advertising program is currently open ended; further definition will be negotiated with the City or a method developed by which RTG's liability can be reasonably limited.

Signage

We will supply electrical infrastructure to support OLRT lit signage. Information and wayfinding is a significant contributor to a successful transit project, supported by appropriate use of lighting in signage (external or internal). Through the design phase, we will collaborate with the City to develop the Project's signage program.

Fare Collection

RTG will supply electrical infrastructure to support fare collection equipment identified in PA Schedule 15-2, Part 4, Article 7, comprising ticket vending machines (TVMs) and validators. No provision is being made at this time for a faregate system other than to provide walker ducts and conduit neeed to implement the system later. It is unclear whether implementation of a Smart Card or fare card system is intended to be enacted during the Construction Period.

PIDS

The Station-based Passenger Information Display System (PIDS) will comply with PA Schedule 15-2, Part 4, Article 6 and will comprise variable text/graphic signage displaying pre-recorded and TSCC/MSF-generated *ad hoc* messages as necessary. Using alphanumeric characters and graphics, PIDS signs installed at each Station will provide travel, operational and emergency information messages to Passengers. The signage will be designed and located to provide maximum visibility to Passengers within Stations and on Trains.

A typical display on the PIDS signs will provide date and time information, destination of the next two or three Trains, and expected arrival times. This Train-travel information may be augmented with *ad hoc* and preprogrammed operational information such as elevator/escalator availability, bus-travel information and weather information, and may also be used for other informational messages such as No Smoking/Littering messages. Additionally, the signs can also display *ad hoc* and prerecorded emergency information and messages related to OLRT operation or other System events.

All PIDS will be double sided and positioned to be easily visible for and from all Station and concourse areas used by Passengers. Use of ADA-compliant colours and legible text fonts will enhance signage usability and visibility.

To achieve this level of functionality, the new PIDS will be integrated with the existing PIDS, as well as the CTS network, Central Master Clock and Train Control. The electrical team will support the PIDS by installing necessary conduit and raceway infrastructure, with UPS backup and adequate structural support of signs.

Pumps

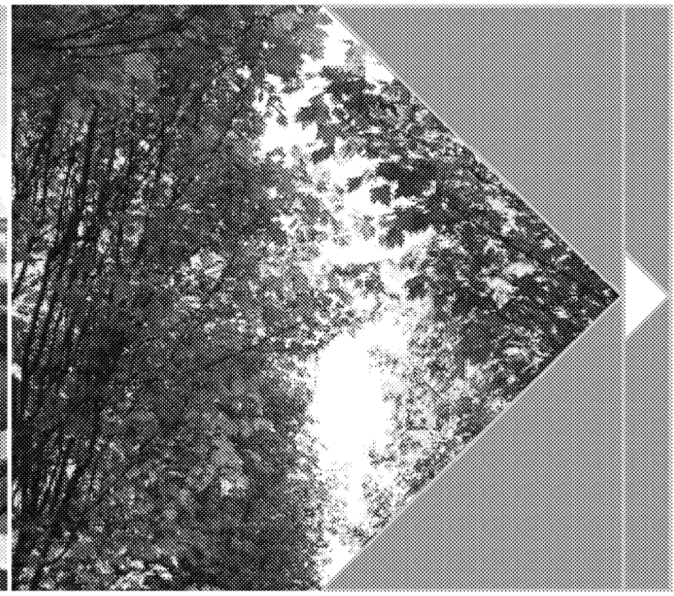
RTG will supply electrical infrastructure to support OLRT mechanical equipment, including pumps and fans: necessary motor control centres, starters, variable frequency drives, and disconnect switches for an efficient, readily maintainable and safe installation. The dual power supplies from HOL meet NFPA 130 criteria (and, by reference, NFPA 70) as a suitable power supply for tunnel ventilation fans and jet fans.

5.5.6.4 Electrical Drawings, Schematics, Product Cuts & Diagrams

Drawing Set 5.5.4 provides electrical drawings, diagrams, product cuts and schematics that illustrate the electrical systems, including power, lighting, life safety and emergency services:

- Layout drawings
- Floor plans (1:200)
- Single line diagrams
- Riser diagrams
- Emergency back-up generator detail location and capacity including UPS
- Single line and schematic diagrams
- Lightning protection and grounding systems
- Fire life safety system block diagram
- Product cuts for primary equipment & light fixtures for public areas

5.6 MSF DeSiGn



RIDEAU TRANSIT GROUP

5.6 MSF DESIGN

For Maintenance and Storage Facility (MSF) design, Rideau Transit Group (RTG) Team members MMM and SNC-Lavalin have taken the lead, drawing on their experience on similar projects such as the Sheppard Maintenance and Storage Facility and the Richmond Operations and Maintenance Centre. As described in this Section, the result is an MSF that meets Project Agreement (PA) requirements, and addresses key City of Ottawa (City) objectives—safety, efficiency, flexibility and expandability, accessibility, and sustainability—all while operating with due regard for the surrounding community.

5.6.1 DESIGN APPROACH

This Section summarizes the approach that guides RTG's MSF design, including the site, systems and building:

- **Safety and Security** - RTG's key design goal is an environment that allows employees to access and perform their work safely and efficiently. By establishing clear divisions between revenue Vehicles, Passenger vehicles, delivery vehicles and specialty maintenance equipment, site design accounts for the safety and security of Drivers, MSF staff, visitors, neighbours and the general public:
    - Private vehicles of OC Transpo drivers and MSF staff are segregated from delivery vehicle and revenue Vehicle movements. The design provides safe and efficient pedestrian access to the MSF Building from parking areas. Barrier-free and visitor parking is also positioned close to the MSF Building entrance.
    - In addition to a secure fence that encloses the MSF site, additional fencing within the site will prevent Drivers, staff and visitors from accessing active track zones. Key functional areas and equipment are isolated from surrounding spaces to ensure ongoing operation during emergencies.
    - Gates along Belfast Road control access to the MSF site: staff parking, loading dock and visitor entrances. A CCTV system and direct sightlines from within the MSF Building will enable site monitoring at key points.
- **Efficient Layout and Work Flow Processes** - RTG's design responds to the required maintenance and operating procedures. Opportunities for improvement have been identified through collaboration with team members operating similar facilities in Canada, Europe and the USA. Our design delivers an efficient work environment that facilitates proper traffic, materials handling, workflow and interdepartmental communication. Yard and shop circulation routes support allocated space and workflows. The design provides unimpeded access to Vehicle sanding and washing, cleaning and inspection, heavy maintenance, wheel truing, maintenance-of-way (MOW) vehicles and storage yards.
- **Site that is Flexible and Expandable** - MSF site design takes into account initial requirements but is also designed to accommodate expansion, with areas designated for future revenue Vehicle storage, paint shop, and MSF Building expansion. The impact of expansion on ongoing operations and maintenance activities has been minimized.
- **Accessibility** - The design complies with local regulations, building codes and standards related to accessibility.

- **Sustainable Design** - Our MSF Building design meets LEED 'Certified' requirements and we will continue to develop LEED sustainability initiatives.
- **Good Neighbour** - RTG's design integrates the MSF site with the various surrounding uses, including residential, light industrial, commercial and retail. We recognize the importance of being a "good neighbour" by minimizing the impact of construction on neighbouring businesses, residences and the natural environment. Our design also recognizes sensitivity to the impact of 24/7 operations on neighbours, especially residences. Noise and vibration will be mitigated with specific engineered solutions and noise barriers. The impact of traffic generated by construction and operations will be minimized, with access and egress routes to and from the site clearly defined. Our goal is to seamlessly integrate the MSF with the local community.

Functional Layout of the Yard and MSF Structures

The proposed layout of the yard and structures accommodates the mainline connection track, the revenue Vehicle storage area, the MSF Building, traction power substation (TPSS), MOW laydown area, loading dock and parking facilities. The MSF site incorporates three key areas:

- Revenue Vehicle Storage Yard
- MSF Building
- Belfast Road Frontage

These areas and their functions are described below.

Revenue Vehicle Storage Yard

The revenue Vehicle storage yard includes the storage track, the interface with the mainline connection track, the TPSS, and the MOW laydown area.

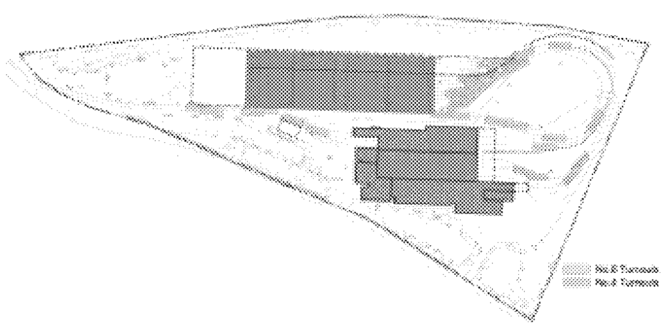


Figure 5.6-1 | Revenue Vehicle Storage Yard Turnout

As shown in **Figure 5.6-1**, access to the MSF site from the mainline is provided by the connection track, which enters at the western end of the yard. Revenue Vehicles exit and enter the site from this position. Crossover tracks near the western edge of the site provide flexibility for Vehicle movements. Loops at the eastern edge allow Vehicles to enter the storage track area and to turn around within the site. The area within the eastern loop is the laydown area for MOW material and equipment.

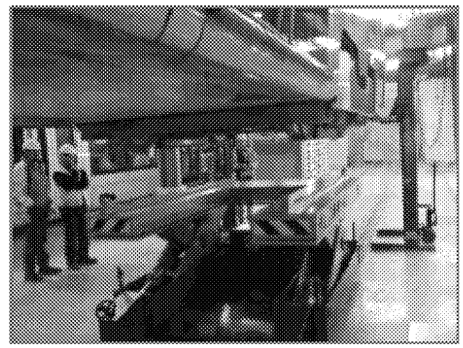
Number 6 turnouts have been provided at the most heavily used positions. Number 4 turnouts have been provided at the Vehicle storage area, as well as those connecting to the wheel lathe and MOW bay. These turnouts were incorporated to ensure that the track layout fit within site limits and to preserve future Vehicle storage requirements. Given the speed limit of trains within the yard, and the frequency of use of these switches, the turnouts incorporated are capable of performing as intended.

RTG has incorporated automatic train control within the MSF site, including the storage tracks, east loop track, sanding and washing, and Vehicle cleaning and inspection tracks. Trains on the heavy maintenance tracks will be manually controlled. We understand the safety implications of the automatic track system, and will provide corresponding designs and procedures to ensure the safety of all potential human interfaces.

To mitigate noise and vibration migration to the residential area, the Vehicle storage yard is bounded to the north by an earth berm and sound wall. The storage yard is designed to accommodate full Train sets. The TPSS is located south of the storage tracks, providing power to the tracks in the MSF yard.

Access to the storage yard for non-revenue vehicles is restricted. In addition to MOW vehicles, sand delivery vehicles and vacuum trucks will, on occasion, require access to this area. MSF staff will supervise the Driver when these vehicles enter the storage yard.

MSF Building



Near the centre of the site, the MSF Building is where Vehicles are transferred, cleaned, inspected and maintained. It supports frequent maintenance activities as well as longer-interval inspection and maintenance operations. Key features and functions of maintenance tracks are described in order within the Maintenance Hall, from north to south:

- **Vehicle sanding and washing** - Vehicles enter from the west, are sanded and washed, and exit to the east. Activities include the following:
  - Daily use, replenishing vehicle sanders as required
  - Exterior Train cleaning using an automatic wash system, frequency per program requirements
- **Vehicle cleaning and inspection tracks** (VCIF 1 and 2) - Vehicle handover occurs on these two tracks, together with a third position immediately north of the MSF Building (run-through track). Driver access to these handover tracks is via a grade separation. At the start of revenue service the Vehicles enter these tracks from the east and depart to the west. At the end of revenue service, the Vehicle movements run opposite. Activities include the following:
  - Perform daily full interior cleaning and inspections
  - Interrogate the train health monitoring systems to identify any faults
  - Inspect critical mechanical and safety systems as recommended by Alstom, the Vehicle manufacturer
  - Perform any required regulatory inspections
  - Correct and repair minor faults identified on each Vehicle during the previous 24 hours of operation
- **Heavy maintenance tracks** (HM 1, 2 and 3) - Vehicles enter and exit the Maintenance Hall from the east. Tracks include intermediate pits adjacent to the Vehicles, deep pits beneath the Vehicles, and raised platforms to access Vehicle roofs. Activities include the following:
  - Monthly, quarterly and annual scheduled maintenance activities:
    - Periodic safety inspections and preventive maintenance work as recommended by Alstom, corrective maintenance necessary to keep the Vehicles in service, and any necessary Vehicle modifications
    - Vehicle systems overhaul at intervals recommended by Alstom and in accordance with PA requirements: includes replacement of worn components including brake systems, trucks, couplers, compressors, electrical equipment, and replacement of car interiors
  - Non-scheduled maintenance activities:
    - Repair of exterior skin, including welding, patching, drilling, reforming exterior, glass replacement
    - Repair or replacement of rolling stock elements including coupler, yoke, bogie (truck) reconstruction, power source, transmission, wheels and interior repairs
- **Wheel Lathe** - Vehicles enter and exit the Maintenance Hall from the east. Vehicle wheel reprofiling will be undertaken when wheels are out of specification using an underfloor wheel lathe located in the wheel lathe track.
- **Maintenance of Way** - MOW vehicles and equipment enter and exit the Maintenance Hall from the east. Activities include the following:
  - Vehicle inspections using the pit

- Ongoing regular servicing and repairs of both light and heavy MOW equipment

South of the Maintenance Hall are the storage, loading dock and maintenance support spaces: storage for parts and equipment, bogie storage, compressor room, TPSS, mechanical/electrical rooms and repair rooms.

Integrated with the Maintenance Hall, the Administration Area meets the needs of City and MSF staff; the latter will manage maintenance services, as well as provide Help Desk support services. The two-storey Administration Area provides the main entrance to the MSF Building, and represents its public face with access from Belfast Road. It includes the yard control centre, the back-up control centre, training and meeting areas, change facilities, washrooms and Driver dispatch room. The Administration Area is organized so that it presents the 'front door' to the MSF for both the public and daily users. To maintain security, all MSF users will arrive through a common entrance and move to their appropriate workspace: the Administration Area, the Maintenance Hall, or the storage yard.

Belfast Road Frontage

The MSF site is bounded on the south by Belfast Road, which is the access point for all non-revenue vehicles. Parking is positioned along this frontage, west of the MSF Building. Loading docks are accessed from Belfast Road, to the east of the MSF Building. The loading dock faces east, to be obscured from view.

Several goals were set and achieved with respect to site design such that access and egress would be clear and logical, provide exceptional safety and security, connect positively to the neighbourhood, meet City standards, and provide a pleasant end-user experience:

- Emergency vehicle access -
  - Direct access to the MSF Building from Belfast Road
  - Fire truck entrance and exit positions established
- Delivery vehicle access -
  - Direct access to the loading dock from Belfast Road
  - Delivery vehicle entrance/exit positions, including access to MOW laydown areas
- Driver and MSF staff access -
  - Direct access to the private-car parking area from Belfast Road at the intersection with Trainyards Drive
  - Private-car entrance/exit positions, including access to the visitor parking areas, established
- Site security, primary and secondary control points, CCTV
- Building entrances
- Pedestrian access
- Future expansion and adaptability

Movement of non-revenue vehicles through the internal road network has been analyzed and is shown in **Figure 5.6-2**.

Work Flow Processes Used to Minimize Train Movements

Within the MSF Building, the Maintenance Hall has been designed for efficient and consistent Train movements. RTG has also reviewed the site and, based on the available yard area, developed an effective track and building layout for scheduled and non-scheduled maintenance activities.

For daily operations, the Train consist will move from the storage track to the Vehicle handover positions via the east loop. The prepared Trains will be transferred to the Drivers for revenue service, departing the site via the mainline connections track. All revenue Vehicles will depart the MSF site in a similar manner.

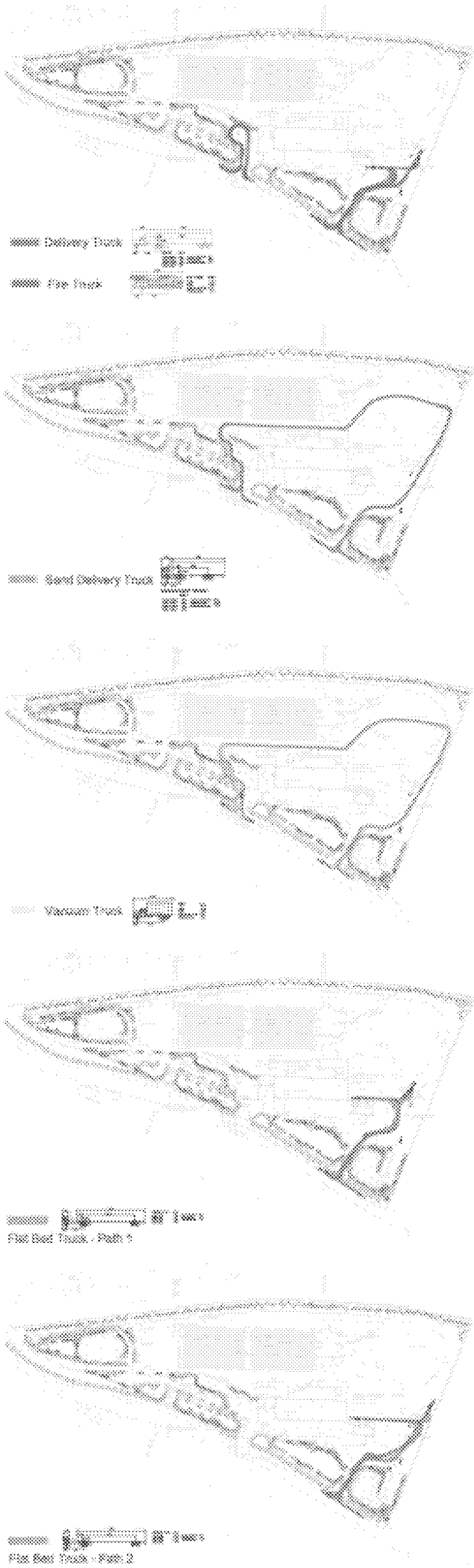


Figure 5.6-2 | Non-Revenue Vehicle Movement

At the end of the cycle, the Trains will return to the site in the opposite direction, entering from the west, with the handover positions remaining the same. The Vehicles will undergo daily cleaning and inspection, and then return to the storage area using the east loop track. This will accomplish routine Train movements without train reversing, while minimizing daily Train movements. Trains requiring sanding and washing will enter the sanding and washing track for these services.

If sanding and washing are required and not accomplished at time of inbound movement, or if more extensive inspection and repairs are necessary, the Trains would return to the Maintenance Hall, either via the run-through track to the north of the Maintenance Hall (sanding/washing), or via the east loop transition track that transfers Train control.

Connection of the MSF Site to the Mainline

The MSF site is south of the mainline, with the connection track running parallel to Belfast Road, south from Tremblay Road. RTG's proposed approach is to design and construct a connection track that occupies a portion of the existing Belfast Road right-of-way. The proposed line crosses under the existing VIA line, using new structure.

Layout of City Spaces within the MSF Site

City spaces are defined in the PSOS: minimum area requirements, adjacencies and functional relationships. To provide these relationships, City spaces have been located on the ground floor of the Administration Area within the MSF Building. Access to these spaces is provided through a controlled entry point off the lobby. Highly visible from the parking areas, the lobby will serve as a reception and a point where the public can be educated in OLRT sustainability and features. On the south side of the lobby, a millwork display case will describe these principles.

Public access beyond the lobby will be restricted and controlled. Training areas are also on the ground floor and will be available to all staff. A future installation of driver training equipment has been provided for.

As shown in **Figure 5.6-3**, individual rooms within the City spaces respect PA-defined adjacencies and relationships and can be controlled independently from Project Co areas. The YCC/BCC and Electronic Equipment/Shared Server room will be designed to post-disaster requirements. Crew dispatch areas are located close to the Vehicle handover area at VCIF 1, VCIF 2 and VCIF 3. Two handover tracks are within the Maintenance Hall while one track is north of the MSF Building. The handover tracks are accessed through a below-grade corridor. The corridor takes Drivers below VCIF 1 and VCIF 2 (automatic tracks) emerging on the north side of VCIF 1 for access to that Train position. The corridor also continues beneath the sanding and washing track and emerges at grade with a view to the outdoor handover track.

BCC Functions

The BCC is inside the YCC on the Administration Area ground floor and enables back-up operations and dispatch area (as per TSCC at 875 Belfast). The following design requirements form part of BCC functions:

- Two Dispatcher Stations to be provided
- Designed to post-disaster standards (structural, mechanical, electrical)
- Triple-redundant HVAC on mission-critical equipment (control centre and data systems room)
- Mission-critical equipment on full emergency back-up electrical (fixed emergency generator system, supported with UPS for two hours)

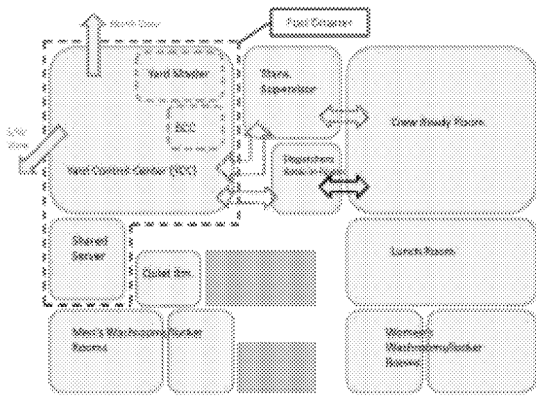


Figure 5.6-3 | Layout of City Spaces within the MSF

Crew Dispatch

The following requirements form part of the Crew Dispatch spaces:

- Under control of Drivers
- Independently controlled from Project Co areas
- Available to both Operations and Drivers
- Located close to LRT handover area and providing convenient access
- Including functional areas such as the following:
  - Dispatcher's Area
  - Management office for Driver
  - Day room for Drivers
  - Storage Areas for Drivers
  - Welfare Facilities Room

Room Data Sheets (Appendix F)

City spaces are inside the Administration Area, which is adjacent to the Maintenance Hall but isolated from sound and vibration. City space room sizes and adjacencies are planned and organized in accordance with PA Schedule 15, Appendix F2. These spaces are described on the architectural floor plan drawings.

5.6.1.1 Site Plan

Package B2 – Design Submission Part 2 – Volume 4 (of 4) provides the architectural drawings, including the site plan.

5.6.1.2 MSF Facilities

Location/Facilities in the MSF Site for Train Consist Transfer between RTG and Drivers

MSF facilities are designed to process Vehicles for daily activity efficiently, as well as to accept Vehicles for more extensive repair and replacement.

Driver parking, the Administration Area and the Maintenance Hall are positioned to ensure ease of transfer of Vehicles from MSF staff to the Drivers. Drivers will enter the site at the Belfast Road and Trainyards Drive entrance, directly to the private-car parking area. Drivers will access the Administration Area, adjacent to the parking area, where they will be able to change, meet with the supervisor and dispatcher, and collect information related to their travel route and Vehicle.

From the Administration Area, Drivers enter the northwest corner of the Maintenance Hall, and receive the Vehicles, either at the two cleaning and inspection tracks, or at the run-through track immediately north. A grade-separated north-south route allows Drivers to pass from one track to the next, without crossing an active track. RTG will inspect all Vehicles comprising a Train consist before they enter revenue service. After inspection, RTG will provide a copy of the checklist to the Driver who, before accepting the Vehicle, will verify that the checklist has been completed and signed by responsible and qualified MSF staff. After the handover, Vehicles exit the MSF yard and enter the connection track.

Upon return to the MSF yard, Drivers will enter the yard and Vehicles will be moved to the same three positions, at which point the Vehicles are returned to MSF staff, and the Drivers return to the Administration Area, reversing their inbound route. At no time is a Driver required to cross an active track. This location is consistent with the desire to minimize Train movements and maintain consistency with daily activities for both MSF staff and Drivers.

Optimization of Handover Process

As illustrated in **Figure 5.6-4**, the handover process is optimized in four ways:

- By maintaining private-car parking, administration and welfare facilities, and handover positions close together
- By maintaining the same Vehicle handover positions from the point of departure to the point of return
- By eliminating the need to cross any active tracks, or to traverse significant sections of the MSF yard
- By facilitating direct communication with Drivers immediately before the Trains depart and immediately after the Trains arrive, by positioning Driver dispatch and yard control rooms close together

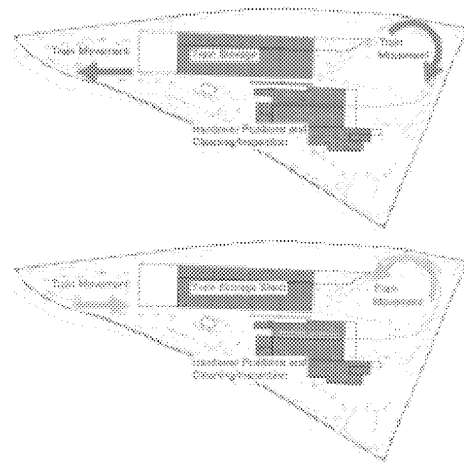


Figure 5.6-4 | Handover Process

5.6.1.3 Ultimate Build-Out Design for the MSF

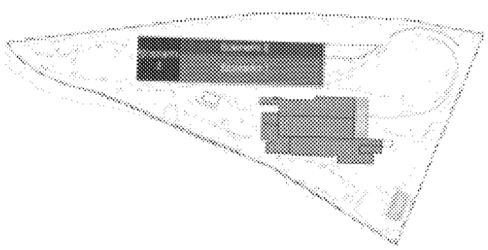


Figure 5.6-5 | Allowing for MSF Expansion

As shown in **Figure 5.6-5**, the MSF site design accounts for immediate needs as well as the planned expansion of the System, including additional revenue Vehicles.

Phased Expansion through Design and Construction

As OLRT ridership expands, the MSF yard must accommodate more revenue Vehicles. RTG has developed Train storage requirements to accommodate three scenarios:

- **Scenario 1** includes the tracks closest to the run-through track as well as the MSF Building.
- **Scenario 2** includes an additional track parallel to, and immediately north of, the Scenario 1 tracks.
- **Scenario 3** extends Scenario 1 and 2 tracks to the west, where space has been reserved. Design and construction of this expanded storage area can be readily accommodated as it does not interfere with existing track or the MSF Building. Additional traction power requirements can also be accommodated within the MSF yard.

The design also accommodates a future painting area. South and east of the MSF Building, additional track can be developed adjacent to the access road, with an area reserved on the site's southeast corner for a two-bay paint building. Expansion of the MSF Building can be accommodated via space provisions to the east, as well as expansion space to the west of the Vehicle cleaning and inspection tracks.

5.6.1.4 Proposed LEED Checklist for MSF Building

RTG is dedicated to developing sustainable facilities and meeting or exceeding committed sustainability goals, and is confident in our ability to design the MSF Building to fully satisfy LEED Canada-NC Certified requirements. Our strategy, described in this section, is to achieve the 40 LEED Certified points and an additional four points to provide a buffer and achieve a high standard of sustainable design. Targeting provisional credits has proven to be an essential component of LEED strategy with a goal of achieving a particular rating.

The integrated approach will use input from all Design Team members. Each LEED credit is discussed and evaluated from a sustainability, feasibility, cost, and benefit perspective. Credits selected under the Certified certification strategy were deemed the most practical and cost-effective sustainable measures to include in the design.

Throughout design development and detailed design, Enermodal, as the LEED consultant, will conduct reviews to ensure all targeted credit and prerequisite requirements are met. During the Construction Period, they will train subcontractors in all Indoor Environmental Quality and Materials and Resources credit requirements, and document building materials and construction waste. Enermodal will also compile the final LEED NC application with all templates and supporting documentation. The application will be submitted to the CaGBC and all supplementary audit materials will be provided. **Table 5.6-1** highlights the specific LEED credits to be targeted.

Table 5.6-1 | LEED Checklist

Targeted LEED Credit	LEED Points	Strategy
SSp1 Erosion and Sedimentation Control	Prereq.	■ ESC measures implemented in accordance with EPA Document EPA 832/R-92-005 will include silt fence around the site, wrapped catch basins, tarping of any stockpiled soil and a gravel strip construction entrance.
SSc1 Site Selection	1	■ The site has been selected and no prohibited requirements apply.
SSc3 Brownfield Development	1	■ The selected site is considered contaminated and will be remediated, as required by the relevant regulatory agency.
SSc4.2 Alternative Transportation: Bicycle Storage & Changing Rooms	1	■ Secure and covered bike racks and showers must be provided for 5% of building occupants. The full-time equivalency (FTE) is still to be determined (TBD). Bike racks will be within 183 m of building (locations TBD). Shower/change-room facilities will be provided in the building.
SSc4.3 Alternative Transportation: Low-Emitting & Fuel-Efficient Vehicles	3	■ Electric plug-in stations will be provided for 3% of total on-site vehicle parking. Locations TBD but will include preferred parking locations.
SSc4.4 Alternative Transportation: Parking Capacity	2	■ Parking capacity will be sized to meet minimum local zoning for the area. In addition, designated parking spaces will be provided for 5% of total vehicle parking. Locations TBD but will include preferred parking locations.
SSc7.2 Heat Island Effect: Roof	1	■ A high solar reflectance roofing material will be used for at least 75% (weighted average) of roof area. A roofing material with an SRI value of 78 and 29 or greater will be specified for low- and high-slope areas, respectively.
WEp1 Water Use Reduction	Prereq.	■ Potable water use will be reduced by more than 35% by installing dual-flush toilets, half-flow urinals, ultra-low-flow faucets with automatic controls, and ultra-low-flow showerheads.
WEc1 Water Efficient Landscaping	4	■ No permanent irrigation system will be installed. Drought-resistant vegetation and a good drainage plan will limit irrigation required by the plantings.
WEc3 Water Use Reduction	3	■ See WEp1
EAp1 Fundamental Commissioning	Prereq.	■ A commissioning agent will review design intent documentation, incorporate commissioning requirements in construction documents, develop a commissioning plan, verify equipment installation, test functional performance, verify training, review O&M manuals and write a commissioning report.

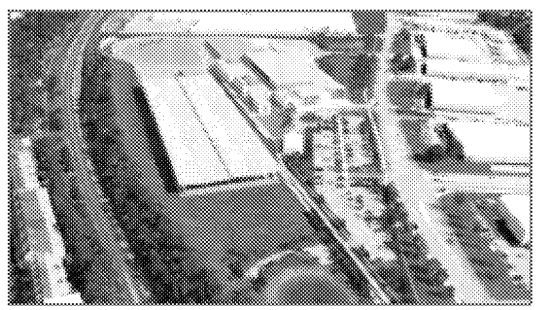
Targeted LEED Credit	LEED Points	Strategy
EAp2 Minimum Energy Performance / EAc1 Optimize Energy Performance	Prereq. /3	■ The points targeted are TBD; however, energy efficiency is an RTG priority. Energy performance will be simulated through an energy model. Baseline energy efficiency measures will include low-e argon windows in thermally improved frames, and occupancy/daylighting sensors. Mechanical equipment will use heat-recovery ventilation, variable-speed pumps/fans and condensing boilers.
EAc3 Enhanced Commissioning	2	■ Engage an independent commissioning authority (from a third-party firm) to design, implement and document a commissioning plan and provide peer review of design and construction documents with additional tasks as specified.
EAp3 Fundamental Refrigerant Management / EAc4 Enhanced Refrigerant Management	Prereq. /2	■ The proposed mechanical system design will not incorporate CFCs, halons, or HCFCS. The design will select refrigerants that minimize emission of compounds that contribute to ozone depletion and global climate change.
EAc5 Measurement and Verification	3	■ Engage an M&V consultant to develop a plan consistent with Option D or B as specified in IPMVP Volume III. The M&V period will cover 1-year post-occupancy.
MRp1 Storage & Collection of Recyclables	Prereq.	■ The MSF Building will include a recycling area and receptacles to facilitate recycling/collection of paper, corrugated cardboard, glass, metal and plastic.
MRc2 Construction Waste Management	2	■ RTG's Construction Waste Management Plan will divert at least 75% of construction waste from the landfill by separating materials on-site, upstream of receiving facilities, or by using a receiving facility offering off-site sorting services.
MRc4 Recycled Content	1	■ Enermodal will work with Design Team and subcontractors to select materials with recycled content. Calculations are based on materials cost, so we will target high-cost materials (e.g. asphalt, concrete, steel, drywall, and mineral wool insulation).
MRc5 Regional Materials	1	■ Enermodal will work with the Design Team to source materials classified by LEED as regional. Calculations are based on materials cost, so we will target high-cost materials (e.g. asphalt, concrete, steel, drywall, and mineral wool insulation).
EQp1 Minimum IAQ Performance	Prereq.	■ The mechanical designer will ensure that the MSF Building design complies with ASHRAE 62-2007 for ventilation.
EQp2 Environmental Tobacco Smoke Control	Prereq.	■ Smoking will be prohibited inside the MSF Building.
EQc3.1 Construction IAQ Management Plan: During Construction	1	■ An IAQ Management Plan to SMACNA standards will protect building materials and ductwork from contamination. Enermodal's subcontractor workshop will review SMACNA principles and documentation needed for the credit. The plan will include strategies in HVAC protection, isolated work areas, protection of materials, work scheduling, and housekeeping.
EQc3.2 Construction IAQ Management Plan: Before Occupancy	1	■ Building flushout or baseline IAQ testing will be conducted prior to occupancy.
EQc4 Low-emitting Materials	4	■ Low-emitting materials will be specified to avoid negative effects on human health. Adhesives, sealants, paints, coatings, carpets/flooring and composite wood specified will be low-emitting per LEED standards. Enermodal will review

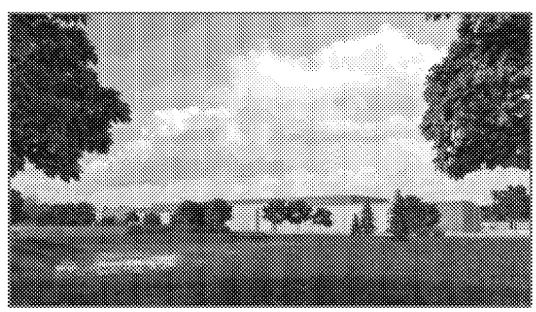
Targeted LEED Credit	LEED Points	Strategy
		design documents to ensure that specified products meet the credit requirements. We will implement specifications that indicate VOC limits of adhesive, sealant, paint and coating products, carpet and composite wood requirements. During construction, products will be monitored for compliance. MSDS for all paints, adhesives, sealants, coatings, carpets/flooring, and urea-formaldehyde-free wood will be collected to document credit compliance.
EQc6 Controllability of Systems	2	■ Building systems will be designed to provide individual lighting and comfort controls to the occupants.
EQc7 Thermal Comfort	2	■ HVAC system design will comply with ASHRAE Standard 55-2004 for thermal comfort conditions and must dehumidify the space to maintain ASHRAE comfort conditions. The design will also incorporate a building control system to monitor thermal comfort conditions in space.
IDc1-5	TBD	■ Innovation credits reward design teams and projects for exceeding LEED® Green Building Rating System expectations and requirements and encourage innovative ideas not specifically addressed by the LEED® Green Building Rating System. Innovation points will be identified as the design develops.

**This scorecard is intended to serve as a benchmarking tool to assess potential LEED Canada 2009 performance. It does not confirm a LEED rating nor guarantee credit compliance. This document is the sole property of Enermodal and is only to be used for the project listed above. This document is not to be used in any other capacity without the express consent of Enermodal Engineering.*

5.6.2 GENERAL ARCHITECTURAL DESCRIPTION

Architectural design follows the same approach to the overall MSF design, including safety/security, efficient layouts, flexible/expandable space, accessibility, and sustainability.





5.6.2.1 General Architectural Design Description

Overall Facility Design, Function & Technical Requirements

The MSF site plan is designed to meet the following Project requirements:

- Design to existing parcel
- Facilitate pedestrian movement to/from Belfast Road
- Provide parking for 50 City staff
- Provide a safe handover location (RTG to Drivers)
- Provide a recognizable entrance/exit (no passing through industrial areas)
- Provide appropriate site security and fencing
- Protect future expansion or build-out requirements
  - Operating scenarios
  - Future paint shop

The MSF site also meets City Site Plan Approval Requirements (final details to be resolved) as follows:

- As of Right Zoning: IG3
- Permitted Use: Light Industrial & Maintenance Facility for Rapid Transit Network
- Maximum Lot Coverage: 65 percent
- Setbacks: 3 m
- Floor Space Index: 2
- Maximum Building Height: 22 m
- Minimum Landscaped area: 3 m
- Minimum Parking Spaces: 93 required, 146 provided (@ 0.8/100 m^2 GFA)
- Minimum Loading Spaces: 2 standard sizes and 1 over-sized loading space
- Gross Floor Area (Municipal): 11,540 m^2
- Continuity of Bike/Pedestrian Path
- Alignment of MSF Access with Trainyards Drive

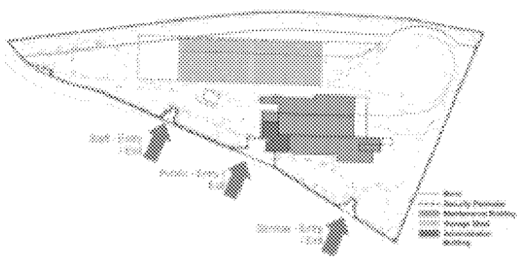


Figure 5.6-6A | Major Entries / Exits

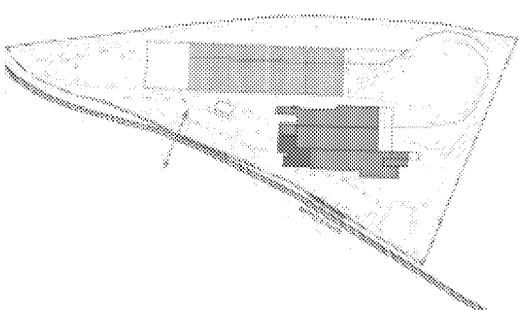


Figure 5.6-6B | Pedestrian / Bicycle Path

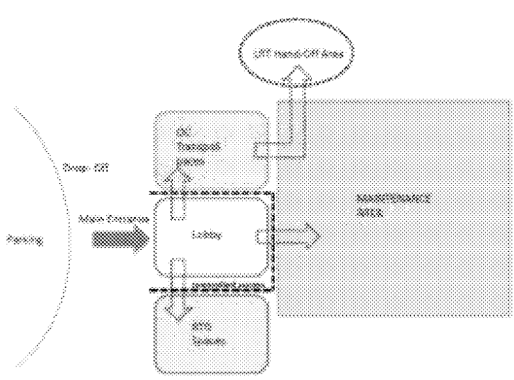


Figure 5.6-7 | Overall MSF Design

Site Access Plan

Figure 5.6-6A shows the site's security perimeter and main access points. The public entrance also provides access to the Drivers' shuttle lay-by, adjacent to the main entry and to the fire access route. The turn circle will accommodate the fire trucks' turning radii. To facilitate vehicular traffic flow and a potential future traffic signal, the staff entrance/exit is aligned with Trainyards Drive. Pedestrian routes along Belfast Road will be contiguous with existing sidewalks along the north side of Belfast Road. The bicycle path will be an on-road system designed into the existing pavement right-of-way as shown in **Figure 5.6-6B**.

Overall Facility Design, Function & Technical Requirements

As shown in **Figure 5.6-7**, the design places the MSF Building close to the parking area. The lobby serves as the point of entry for MSF staff, City staff and the public.

5.6.2.2 Materials & Finishes

Building Image

Package B2 – Design Submission Part 2 – Volume 4 (of 4) provides architectural drawings including exterior elevations and renderings that describe the building finishes.

Selection & Use of Materials/Finishes

Activities within the MSF Building range from administration and reception areas to heavy maintenance and repairs. Drawing on our combined experience as designers and operators of maintenance facilities, we selected materials and finishes to meet the following criteria:

- Durability
- Maintainability

- Common aesthetic
- In accordance with industrial type structures
- Site signage to promote wayfinding and key building identification
  - Operational signage – as required
  - Interior signage to rooms and spaces

5.6.2.3 Lifecycle Analysis

To align the MSF Building's lifecycle program to reasonable expectations for asset life and facility use, our Maintenance and Rehabilitation (M&R) Team has applied industry standards, benchmark data and our experience. To time-phase a program that will maintain key operational requirements, we have applied this information to the MSF Building's operating parameters, considering the need to minimize disruption and to support maintenance activities.

RTG carefully considered the lifecycle of all MSF Building components. Design inputs require careful specification of materials and equipment as well as a proactive maintenance and replacement plan. Our M&R Team played a critical role throughout the design process. Their experience running similar facilities provided valuable insight to the architectural and engineering design teams. Areas reviewed included the following:

- Building envelope and exterior finishes
- Vertical transportation
- Cooling equipment
- Other maintenance equipment
- Interior finishes
- Heat generation equipment
- Specialty maintenance equipment

Table 5.6-2 summarizes RTG's approach to the lifecycle program.

Table 5.6-2 | Lifecycle Approach to Major Building Components

Component & Expected Life	Description
Building Envelope >30 years	The preventive maintenance regime will ensure that the MSF Building envelope life exceeds 30 years and the concession period, if maintained to the same degree.
Interior Finishes 10 years	Starting with the BOMA standard, we will apply our building management experience to determine the optimal time for replacement/refurbishment of interior finishes. This will include a rolling painting program and touch-up maintenance to keep the MSF Building looking fresh and clean, projecting a positive image to all users; and periodic replacement of flooring and special features. The design of hardwearing finishes for flooring will prolong the life of interior finishes in public spaces where the highest traffic will occur.
Vertical Transportation (Elevators) 20 years	Elevators can be maintained to operate effectively beyond the 30-year concession, although we expect to conduct major refurbishment programs (e.g. cab upgrades, controls upgrades, replacement of hoist cables). Units will be safety tested and inspected by the Technical Safety and Standards Authority (TSSA) annually; licensing will be displayed in the cab per code. Annual tests will augment preventive maintenance programs by licensed elevator management subcontractors (usually the original installer or manufacturer's representative). We have planned major refurbishment (25%) after 20 yrs.
HVAC Systems Varies	HVAC equipment will typically be subject to the manufacturer's suggested operations regime, which includes scheduled and predictive maintenance to prolong system life. During the 30-year concession, each system will be subject to major overhaul and replacement of burners, filters, and controls. After each replacement schedule, systems will be re-commissioned to achieve their full lifecycle beyond the concession period completion date. Indoor air quality and flue gas emissions will be monitored to ensure equipment is meeting or exceeding accepted commissioning levels.
Chillers and Heat Exchangers 20 years	As with heat generation equipment, refrigeration equipment will undergo major refurbishment during the concession period which will enable it to function well beyond this time. The shell and non-moving parts will enjoy extended life through well-monitored water treatment programs. This will restrict refurbishment to compressors, pumps and upgraded control systems.

Component & Expected Life	Description
Specialty Maintenance Equipment - Refurbish after 10 years	Most specialty equipment manufacturers provide equipment that will surpass a 25-year life. With continuous minor maintenance (e.g. lubrication), potential problems can be caught and corrected before major breakdowns occur. We plan to refurbish approximately 25% of specialty equipment after 10 years.

5.6.2.4 Life Safety Code Analysis

Contract requirements for fire protection and life safety for MSF design include the following:

- RFP Schedule 3, Part 1.B., Section 5.6 MSF Design, Code Analysis.
- PA Schedule 15-2, Part 6, Article 2, Section 2.3 Building Code Analysis

Applicable Codes and Authority Having Jurisdiction

The applicable building code for this Project is the 2006 edition of the Ontario Building Code (OBC). The applicable fire code is the 2007 edition of the Ontario Fire Code (OFC). The City is the Authority Having Jurisdiction (AHJ).

The Building Code Matrix, included on the architectural drawings in **Package B2 – Design Submission Part 2 – Volume 4 (of 4)**, lists general provisions for compliance with the OBC. Requirements that warrant interpretation, as well as requirements to be addressed as alternative solutions as permitted by OBC Article 1.2.1.1., are further detailed in this narrative.

Building Code Analysis

Fire Separations

Fire separation of rooms and spaces in the MSF Building will be as follows:

1. **Floor assemblies** – Based on OBC Article 3.2.2.67, floor assemblies will be required to be constructed as fire separations having a two-hour fire-resistance rating, except as described in **Item 5**.

2. **Exits** – Based on OBC Article 3.2.2.67, for floor assemblies to have a two-hour fire-resistance rating in accordance with OBC Sentence 3.4.4.1(1), exit stairs serving the second storey of the Administration Area will be separated from the remainder of the MSF Building by a fire separation having a two-hour fire-resistance rating.

3. **Exit Exposure Protection** – In accordance with OBC Sentence 3.2.3.13(1) and (3), for exit stairs serving the second storey of the Administration Area, at the point where those exits discharge to the exterior at grade, the walls at right angles to the exit door will either be constructed with no unprotected openings, or the openings will be protected in accordance with OBC Sentence 3.2.3.13(4).

4. **Corridors** – Most corridors within the MSF Building will be considered as corridors within a suite, which do not require fire separation from adjacent floor areas. An exception will be the exit corridor along gridline Ag serving the MSF Building, which will require separation from the remainder of the MSF Building as stipulated in **Item 2** for exits.

5. **Interconnected Floor Space** – An interconnection between the first and second storey in the lobby of the MSF Building is indicated in the proposed design and is permitted without fire separation or additional protection in accordance with the provisions of OBC Sentence 3.2.8.2(6).

6. **Fire separation of elevators and elevator machine rooms** – The elevator proposed for the Administration Area will contain the elevator machinery within the elevator shaft. Therefore, in accordance with OBC Sentence 3.5.3.1(2), the elevator shaft will require separation from adjacent floor areas by a fire separation having a fire-resistance rating of at least 1.5 hours.

7. **Major Occupancy Separation** – The MSF Building will contain both Group F, Division 2 and Group D major occupancies. OBC Sentence 3.1.3.1(1) referring to Table 3.1.3.1 does not stipulate fire separation between major occupancies having those classifications. However, refer to **Item 9** below regarding separation of repair garages.

8. **Suite Separation** – The MSF will be operated and occupied by a single tenant; therefore, the requirements of OBC Article 3.3.1.1 for fire separation between suites are not applicable.

9. **Repair Garage Separation** – In accordance with OBC Sentence 3.3.5.5(1), a repair garage and ancillary spaces serving the repair garage are required to be separated from other occupancies by a fire separation having a two-hour fire-resistance rating. For the Maintenance Hall, all occupancies south of the vehicle repair bays will be considered to be associated with the Maintenance Hall function; therefore, the required fire separation will be provided between the Administration Area and the remainder of the MSF Building.

10. **Fire Pumps** – The fire pump to be installed in the MSF Building is not expected to have a rated net head pressure greater than 280 kPa; therefore, the requirements of OBC Sentence 3.2.5.19(1) for fire or physical separation will not be considered applicable.

11. **Janitor's Rooms** – In accordance with OBC Sentence 3.3.1.20(3), janitor's rooms will be separated from the remainder of the MSF Building by a fire separation not required to have a fire-resistance rating.

12. **Service Rooms** – Except as stipulated in OBC Subsection 3.6.2, fire separation is not required for most service rooms in sprinklered buildings. For the MSF Building, fire separations will be provided for the following service rooms:

    a. **Electrical Rooms** – Two-hour fire separations will be provided around the unsprinklered electrical rooms listed under *Automatic Sprinkler Systems* below based on the provisions of NFPA 13-2007.

    b. **Electronic Equipment Rooms** – As described in *Clean Agent Systems in Lieu of Sprinklering* below, a fire separation not required to have a fire-resistance rating will be provided around rooms protected by automatic clean-agent fire-suppression systems.

    c. **Combustible Refuse Storage Rooms** – In accordance with OBC Sentence 3.6.2.5(1), rooms used for storing combustible refuse will be separated from the remainder of the MSF Building by a fire separation not required to have a fire-resistance rating.

13. **Vertical Service Shafts [OBC Sentence 3.6.3.1(1)]** – Based on the requirement for two-hour floor assemblies in the building, a one-hour fire separation will be provided between service shafts and the remainder of the storey.

14. **Hazardous Substances, Equipment and Processes** – OBC Article 3.3.1.2 refers to the Ontario and National Fire Codes regarding storage, handling and use of hazardous substances. As a minimum, it is anticipated that a two-hour fire separation will be required for the Train Wash Facility Storage Room and the Chemical Room.

Number and Location of Exits

For purposes of evaluating number and location of exit routes, the MSF Building can be divided into two main areas—i.e., the Administration Area and the Maintenance Hall. The proposed design for the Administration Area complies with the applicable requirements of the OBC for provision of egress and exit routes.

For the Maintenance Hall, given that the geometry of the MSF Building is based on the configuration of the Train consist, it is not possible to achieve compliance with the requirements of OBC Sentence 3.3.1.6(1) and Subsection 3.4.2 for a maximum travel distance of 45 m to a point of egress from the floor area. Therefore, requirements for the number and location of egress routes from the Maintenance Hall will be addressed as an alternative solution, based on the following factors: low occupant load, occupants familiar with their surroundings, timed-exit analysis to demonstrate exiting within the time implied in the prescriptive requirements of the OBC. Refer also to further discussion below related to work platforms and pits.

Barrier-Free Design (OBC 3.8)

The MSF Building will comply with the applicable requirements of OBC Section 3.8 for barrier-free design with the exception of work platforms and pits in the Maintenance Hall.

Fire Alarm and Detection (OBC 3.2.4)

Based on configuration and use of the MSF Building, a fire alarm system would not be required in accordance with the provisions of OBC Article 3.2.4.1. However, in accordance with contract requirements, a fire alarm system will be provided, designed per the requirements listed in *Article 5 Electrical Design Criteria, Section 5.4 Functional Requirements, Clause (g) Fire Alarm, Item (i)* of PA Schedule 15-2, Part 6 (RFP Version 4.0).

Additionally, in accordance with NFPA 130, a Proprietary Supervising Station Alarm System is required for rapid transit systems. Considering the role of the BCC, it is proposed that a two-stage system be provided and that the capability to control and supervise fire alarm systems throughout all OLRT facilities be provided at the YCC/BCC.

Provisions for Fire Suppression

Automatic Sprinkler Systems (OBC 3.2.5.13 to 3.2.5.15)

The MSF Building is required to be sprinklered throughout based on application of OBC Article 3.2.2.67. In accordance with OBC Article 3.2.5.13, the design, construction, installation and testing of the system will comply with the 2007 edition of NFPA 13 *Installation of Sprinkler Systems* and with modifications to those requirements listed throughout OBC Subsection 3.2.5. A proposed exception is for rooms protected by automatic clean-agent fire-suppression systems as described below.

As permitted by NFPA 13-2007, Section 8.15.10.3, sprinklering will not be provided in electrical rooms where: the room is dedicated to electrical equipment only, only dry-type electrical equipment is used, equipment is installed in a two-hour fire-rated enclosure including protection for penetrations, and the room is not used for combustible storage. This exemption will be considered applicable to the following rooms within the MSF Building (refer also to discussion regarding fire separations): TPSS, High Voltage A, High Voltage B, and HOL high voltage.

Clean-Agent Systems in Lieu of Sprinklering

Some rooms within the MSF Building will contain critical equipment that could be damaged by the discharge of sprinklers. Furthermore, the PA stipulates that a clean-agent system be provided in specific rooms of the BCC *(PA Schedule 15-2 Part 6, Article 4, Section 4.2, Clause (d)(ii) A.i. (RFP Version 4.0))*.

An alternative solution to the requirements of OBC Clause 3.2.2.67(2)(a) and OBC Sentence 3.2.5.13(1) to permit certain rooms to be protected by automatic clean-agent fire-suppression systems in lieu of sprinklering is proposed, based on the use of listed systems and a requirement that such rooms be separated from the remainder of the MSF Building by a fire separation not required to have a fire-resistance rating. The use of clean agent is proposed in the following rooms (refer also to discussion regarding fire separations): YCC/BCC, electronic equipment and shared server room, data room, and switch control room.

As stipulated in the PA, the clean-agent systems will use inergen gas, and the selected supplier will be capable of 24/7 response to an emergency situation within two hours *(PA Schedule 15-2 Part 6, Article 4, Section 4.2, Clauses (d)(iii) A.i. and ii (RFP Version 4.0))*.

Standpipe Systems (OBC 3.2.9.)

The PA stipulates that a Class III wet standpipe system be provided in the BCC as back-up to clean-agent fire suppression *(PA Schedule 15-2 Part 6, Article 4, Section 4.2, Clause (d)(ii) A.i. (RFP Version 4.0))*. However, in accordance with OBC Article 3.2.9.1, a standpipe system is not required in the MSF Building based on its use and configuration. We propose that standpipe coverage for the BCC is not warranted based on the following considerations: fire extinguishers will be located throughout the MSF Building as required by the Fire Code; the BCC will be located on the ground floor and close to the designated fire department access; and if additional fire suppression is required, the fire department will be capable of supplying hose coverage from a fire department pumper vehicle located near the fire department access.

Special Consideration

Back-Up Control Centre

The BCC must be 'post-disaster survivable', in accordance with PA, Schedule 15-2, Part 6, and Schedule 15-1, Article 1.

The OBC does not define or refer to an Essential Services Code and includes only the following prescriptive requirements related to Post-Disaster Buildings:

- Sentence 1.1.2.2(2) stipulates that Part 4 of Division B applies to post-disaster buildings, which is related to the structural system of the building, or part of the building.
- Section 1.4 defines a post-disaster building as "a building that is essential to the provision of services in the event of a disaster" including "control centers for land transportation".
- From OBC Sentence 4.1.2.1(3), "For the purpose of determining specified loads S, W or E in Subsections 4.1.6 to 4.1.8, buildings shall be assigned an Importance Category based on intended use and occupancy, in accordance with Table 4.1.2.1.B."
- OBC Subsections 4.1.6 through 4.1.8 stipulate structural design requirements to resist live loads due to use and occupancy, wind loads, and earthquake loads and effects.

OBC Article 4.1.8.14 allows post-disaster buildings to be structurally connected or separated from adjacent buildings or parts of buildings. Guidance for life safety HVAC systems in post-disaster buildings is also provided in Appendix A-6.2.1.3. This section suggests that mechanical equipment may be an important component of post-disaster life safety systems and, in such cases, will require close coordination between the mechanical and structural designers.

Based on the above, the proposed design will incorporate the following features:

- **Structure** - OBC Part 4 structural requirements related to post-disaster facilities will be applied to the Administration Area containing the YCC/BCC, which will be fire separated from the remainder of the MSF Building as explained elsewhere in this analysis.
- **Systems** - The PA stipulates that BCC design should include redundancy for HVAC and emergency power related to 'mission-critical' systems and equipment. All associated critical life-safety systems in the BCC will be separated and be capable of operating independently of the Maintenance Hall (e.g. exits, ventilation, electrical systems, sprinkler zoning and design, fire alarm).

Work Platforms

- **Fire Resistance** – The Maintenance Hall will include work platforms used for servicing the upper portion of a Train car. In accordance with OBC 3.2.1.1(3), the platforms are not considered as storeys; therefore, the required fire-resistance rating will be determined based on requirements for mezzanines which, in accordance with OBC Article 3.2.2.67, require a one-hour fire-resistance rating.

  An exemption from requirements for fire-resistance rating may be reasonable on an alternative solutions basis considering the provisions of OBC Sentences 3.2.1.1(6) and (7), which exempts platforms and catwalks from consideration as floor assemblies or mezzanines provided: they are not used for storage, they are constructed of non-combustible materials, and the occupant load on any one platform is not more than four persons.

  Additionally, in accordance with OBC Clause 3.2.2.3(1)(e), the stairways serving those platforms will not require a fire-resistance rating provided they are constructed of steel and are not part of the structural frame of the MSF Building.

- **Arrangement of Egress Routes** – As explained above, the requirements of the OBC for number and location of egress routes in the Maintenance Hall will be addressed on an alternative solutions basis. Similarly, given the configuration and operational requirements for the floor area under the work platforms, it will be necessary to address number and location of egress routes from the work platforms on an alternative solutions basis.

Pits

- **Protection around Floor Openings** – OBC Sentences 3.3.5.4(6) and 3.3.5.8(1) require curbs around floor openings in garages and Group F occupancies. It is anticipated that there will be a need to develop an alternative solution approach to compliance with those requirements for the pit openings.
- **Arrangement of Egress Routes** – The OBC does not specifically address pits. Assuming that the pits will be configured as individual depressions in the floor of the Maintenance Hall, the pits will be considered as part of the Maintenance Hall floor area and analogous to mezzanines (i.e. a depressed mezzanine) for purposes of determining requirements for egress on an alternative solutions basis, as described below. If an alternative configuration is considered (e.g. a depressed floor area underneath a suspended floor slab with access between the pits), the following interpretations will require re-evaluation.

  As discussed above, OBC requirements for number and location of egress routes in the Maintenance Hall will be addressed on an alternative solutions basis. Similarly, given the configuration and operational requirements for the pit areas, it will be necessary to address number and location of egress routes from the pits on an alternative solutions basis.

Alternative Solutions Summary

The previous sections of this code analysis identify issues associated with design of the MSF Building that may not comply with OBC Part B requirements and may, therefore, need to be addressed as alternative solutions. Those issues include:

- Clean-agent fire-suppression systems in lieu of automatic sprinklering
- Location of exits for Vehicle maintenance floor areas (the Maintenance Hall)
- Fire-resistance rating and location of egress and exit routes for work platforms
- Protection around floor openings and means of egress for pits

5.6.2.5 Environmental Considerations

Noise and Vibration Mitigation Techniques

MSF operation will produce noise and vibration and may affect land use surrounding the MSF and along the connection to the mainline. We anticipate that the main sources of vibration and noise will be Vehicle movement, mechanical equipment, electrical substation, maintenance activities and the emergency generator. The most sensitive receptors are residences to the north, approximately 45 m from the MSF yard and approximately 15 m east of the connection line.

To minimize noise and vibration, Vehicles will be equipped with resilient wheels, have a soft primary suspension and run on continuous welded rail on concrete tie and ballast in the storage tracks. Ground-borne noise and vibration levels will be assessed at sensitive receptors, with a generalized prediction method (as per PA Schedule 17, Section 8.3b). The predicted ground-borne level will be compared to the vibration criteria (PA Schedule 17, Section 8). We anticipate that Vehicle ground-borne vibration levels will be lower than the criteria.

To control structure-borne vibration into the MSF Building and ground-borne vibration to sensitive receptors, we will mount mechanical, electrical and HVAC equipment on vibration isolators as per ASHRAE2 recommendations. The emergency generator will be located far from the sensitive receptors, south of the MSF Building.

Noise levels will be assessed at the sensitive receptors, based on the Vehicle and the equipment (mechanical, electrical, HVAC) emission levels from suppliers. The predicted noise level will be compared to the noise criteria (PA Schedule 17, Section 8 and MOE NPC-2053). We anticipate that noise levels will be higher than the criteria and, therefore, propose the following noise mitigation measures:

- Build a 4.5 m-high noise barrier along the north property limits of the MSF site, composed of an earth berm and localized wall sections at the northeast loop track. Wall height and length will be optimized during final design.
- Conduct maintenance activities, including replacement and repair activities, indoors. The MSF Building will have a minimal STC-324 rating. Close doors when feasible.
- Mitigate wheel noise by implementing speed restrictions via the CTBC system at specific locations within the MSF and/or at specific times of the day.
- Locate HVAC equipment as far south as possible, and specify low-noise equipment. Avoid intake, exhaust and openings on the MSF Building's north wall and orient them away from the north sensitive receptors. Install intake, exhaust silencers and barriers around equipment as required to meet criteria.
- Locate the emergency generator south of the MSF Building, within a low-noise enclosure, using an air-intake silencer and exhaust silencer to meet decibel-at-distance criteria. Test generators during the day.
- Locate the Train turnaround on the MSF site's northeast corner, immediately south of the noise barrier. Control wheel squeal with resilient wheels and attenuate it with the noise barrier. Consider rail lubrication should wheel squeal occur.
- Test warning horns and bells, when required, inside the MSF Building

Light Trespass Mitigation Techniques

The MSF site will include exterior lighting at the MSF Building, parking, loading and train storage areas. Site lighting is designed to meet the required exterior lighting levels while keeping light dispersion to within the site limits.

5.6.2.6 Net and Gross Floor Area Summary

Package B2 – Design Submission Part 2 – Volume 4 (of 4) provides architectural drawings, including floor area summaries.

5.6.2.7 Architectural Drawings

Package B2 – Design Submission Part 2 – Volume 4 (of 4) provides architectural drawings.

5.6.3 STRUCTURAL DESIGN

The intent of structural design in general is to satisfy the requirements of facility operators and end users. For the MSF, the structural form is driven by maintenance operations and activities. The superstructure design, therefore, will account for the large open plan of the Maintenance Hall, the support of the rails within pits, as well as for the vertical clearances for Trains and platforms. The Administrative Area will be framed similar to other low-rise facilities, with columns spaced at a regular grid, allowing for vertical access points and with proper clearances for building services. Lateral loading will be resisted through combinations of vertical braced bays and moment frames. Isolation of post-disaster sections of the MSF Building will be accommodated through the use of movement joints and independent framing systems.

Applicable Codes and Standards

The following codes and reports are used in the design of this Project:

- Ontario Building Code, 2006 Edition (OBC)
- National Building Code, Canada 2010 Edition (NBC)
- Geotechnical design criteria, Golder Associates report dated October 24, 2011 and geotechnical memos from Thurber
- All applicable materials codes

Lateral Loads, Gravity Loads, Vertical Deflection, & Lateral Deflections/Interstorey Drift Criteria

All loads have been determined in accordance with the NBC, including lateral loads due to wind and seismic events, as well as gravity loads from finishes, equipment and varying occupancies.

The structural systems are design to meet established deflection criteria for lateral loads and vertical loads, including specialty equipment such as overhead cranes.

5.6.3.1 Proposed Structural Framing System including Foundation Design

The MSF Building foundations consist mainly of shallow spread footings on properly compacted engineered fill, glacial till, or sound rock, depending on the location and depth of the local pits and/or footings. Since the spread footings and pits are to be founded on the glacial till which is generally 2 m below the finished floor elevation, most foundations will be approximately 2 m deep which also satisfies the perimeter foundation frost depth requirement of 1.8 m. The founding elevations of footings in the vicinity of service pits will be dictated by the local pit depths. The typical perimeter foundation consists of strip footings with foundation (knee) walls to support the perimeter cladding. The footings are typically founded at approximately 2000 mm below the exterior grade, insulated, or drained for proper frost protection.

The Maintenance Hall requires several pits for servicing Vehicles. The pits vary in depth and, therefore, there are several steps in the ground floor slab. The typical foundation wall that forms the step in the pit is similar to the exterior footing and wall assembly.

Ground Floor

The ground floor supports several activities. For all areas, the ground floor is constructed using a concrete slab on grade, with slab thickness and reinforcement depending on use and occupancy.

Second Floor

The second floor of the Administration Area consists of an office floor. The 64 mm concrete slab on 76 mm composite steel deck is supported by structural steel beams and girders.

The Maintenance Hall has varying roof heights, due to various clearances in the work areas below, with the overhead crane typically dictating the roof levels. All roof framing consists of steel deck, supported by open web steel joists on steel girders, depending on the clear span requirements. The loading on the roof varies due to snow piling at steps in roofs and mechanical units.

Crane Supports

The Maintenance Hall supports several repair and replacement activities. Crane(s) and monorail(s) as well as other equipment are supported by the primary building structure, with various load capacities and travel lengths. In addition to the steel beams and steel bracket column connections, the crane rail beams will use bearings, stops and secondary beams for support.

Cladding and Partition Support

The building cladding options include precast, metal panel and glazing. Due to the various horizontal bands of cladding, as well as large openings for doors and windows, additional horizontal structural steel sections are required to provide cladding support.

Lateral Force Resisting Systems

The building lateral system will incorporate braced frame and moment frame structures. These systems resist wind and earthquake loads, as well as lateral loads imposed by the overhead cranes. The steel roof deck provides the diaphragm that distributes lateral loads to either the braced or moment frames. To transfer the lateral loads, HSS steel filler sections are required to bridge the gap between the steel deck and the steel beams that are created by the joist shoes.

The areas supporting post-disaster facilities will be structurally isolated from the remaining structures, and designed with an independent lateral force resisting system.

5.6.4 MECHANICAL DESIGN

HVAC, plumbing, drainage, fire protection and building automation systems (BAS) will be provided to serve the Administration Area and Maintenance Hall. In addition, lubritorium, compressed air, vehicle tailpipe exhaust and gas detection systems will be provided to the Maintenance Hall. Mechanical system provisions will be designed to suit the LRT operation, maintenance activities and vehicle service requirements. The MSF Building will be designed for LEED Certified status.

5.6.4.1 General Approach to Mechanical Systems

Mechanical design will conform to the general requirements of the RFP drawings, documents and addenda thereto, and will comply with the following codes and standards:

- Ontario Building Code, 2006 Edition (OBC)
- Ontario Fire Code (OFC) 2007
- NFPA 14 Standard, 2010 Edition
- NFPA 2001 Standard, 2012 Edition
- National Building Code, Canada 2010 Edition (NBC)
- NFPA 13 Standard, 2010 Edition
- NFPA 20 Standard, 2010 Edition
- ASHRAE Handbooks and Standards

The scope of mechanical work includes the following:

- HVAC system
- Service piping system
- Building management system (BAS)
- Plumbing and drainage system
- Fire protection system

HVAC

The MSF Building will be equipped with various HVAC equipment including roof-mounted energy recovery units (ERUs), roof-mounted exhaust fans, rooftop air handling units (RTUs), split AC units, split heat pump units, fan heaters, radiant heaters, heat recovery ventilators, a standalone heating plant, complete with their associated supply and exhaust air ductwork, piping and accessories.

Heavy Maintenance and VCIF

- The heavy maintenance and VCIF bays will be served by two ERUs on the building low roof, in conjunction with the high-efficiency gas-fired unit heaters. Each ERU system will be equipped with supply and exhaust Variable Frequency Drive (VFD) fans, filter sections, energy recovery module and an indirect gas-fired heating module . The energy recovery module will be of heat-pipe configuration to minimize cross-air contamination. The unit will constantly monitor and recover available energy from exhaust air and transfer it to incoming outdoor air. Filters in the outdoor air-intake stream will provide proper filtration to the fresh air.
- A gas-detection system will be provided in the space to facilitate reduced supply air for energy saving.
- Ventilation of inspection pits will be provided via continuous exhaust at low level of the pits during occupied mode.

Trainwash, Sanding and Wheel Lathe

- Two roof-mounted ERUs, in combination with high-efficiency gas-fired unit heaters, will be provided to serve the spaces. One ERU will serve the trainwash and sanding bay, and the other serves the wheel lathe area. Each ERU will be equipped with supply and exhaust VFD fans, filter sections, energy recovery module and an indirect gas-fired heating module. The energy recovery module will be of heat-pipe configuration to minimize cross air contamination. The unit will constantly monitor and recover available energy from exhausted air and transfer it to incoming outdoor air for energy saving. Filters in the outdoor air-intake stream will provide proper filtration to the fresh air.

Administration Area and Drivers Dispatch and Handover

- The two-storey Administration Area will be served by a package RTU: a Variable Air Volume (VAV) unit consisting of a supply fan, filter, indirect gas-fired heating module and electric DX cooling section. The RTU supply fan will be equipped with VFD to suit various load demands. The return fan will also be equipped with VFD to interface with the supply fan. The unit's economizer will provide 100% free-cooling. Room-temperature sensors will control the associated VAV boxes through the BAS to meet the room-temperature requirement. CO_2 sensors will be installed in high-occupancy spaces for demand-controlled ventilation. Perimeter zones will be provided with hydronic perimeter heaters, and a steam humidifier will maintain the space design humidity level during heating season.

Heavy Storage and Light Storage

- Heavy storage and light storage will be served by respective hydronic unit heaters and ventilation exhaust fans. Make-up air to the space will be supplied through exterior wall louvres.

Maintenance-of-Way (MOW)

- An independent mechanical system will be provided to serve the MOW space. The system will include a gas-heated ERU equipped with heat-pipe heat-recovery unit, and VFD supply and exhaust fans. The space will also be provided with vehicle tailpipe exhaust system, high-efficiency gas-fired unit heaters, gas detection system, and the associated supply and exhaust ductwork. The ERU will interlock with the gas-detection system and the tailpipe exhaust system to ensure proper outdoor air and ventilation is being achieved within the space.

Traction Power Substation (TPSS), High Voltage Rooms, Bell Room and Mechanical Rooms

- Rooms will be served by dedicated electric or hydronic unit heaters and ventilation exhaust fans. Make-up air to the space will be supplied through exterior wall louvres.

Shared Server/Electronic Equipment Room and Switch Control Room

- The Shared Server and Electronic Equipment Room will be served by three RTUs on a "one duty and two standby" arrangement. The Switch Control Room will be served by a dedicated rooftop unit. Each RTU will be constant-volume type and consist of a supply fan, air filter, indirect gas-fired heating module, electric DX cooling section and free-cooling economizer.

Yard Control Centre (YCC)/Backup Control Centre (BCC)/

- The YCC/BCC will be served by three RTUs on a "one duty and two standby" arrangement. Each RTU will be constant-volume type and consist of a supply fan, air filter, indirect gas fired heating module, electric DX cooling section and free-cooling economizer.

Signal Equipment Room, Battery Room, Data Rooms, Plant Offices, and UPS Room

- A dedicated split-type air conditioning/heat pump system with indoor evaporating units and respective roof mounted condensing unit will be provided to serve these rooms. Outdoor air will be supplied to every room in compliance with ASHRAE standards.

Mechanical Room, Electrical Room, Compressor Room, Recycling Room, Battery Room, Bogie Room, and Chemical Room

- A dedicated exhaust ventilation systems and hydronic unit heaters will be provided to the space.
- An explosion-proof electric unit heater and hydrogen-detection system will be specified for the Battery Room.

Loading Dock

- High-efficiency gas-fired unit heaters will be provided to the space.

Locker Rooms and Washrooms

- A dedicated exhaust system with Energy Recovery Ventilator will be provided to serve these rooms, in addition to supplementary heating from hydronic cabinet fan heaters.

To optimize mechanical system performance, equipment design will be complemented by enhanced building architectural features which include better insulation for walls and roof (with higher R-value insulation), and window glazing with increased thermal resistance (reduced U-values).

Plumbing and Drainage Systems

A domestic cold- and hot-water system will provide water services for the entire MSF Building. An incoming watermain equipped with a main shut-off valve, meter and backflow preventer will deliver domestic cold water to all plumbing fixtures via a piping distribution system. High-efficiency gas-fired water heaters will provide domestic hot water. The long runs of domestic hot water piping will be complemented by recirculation piping equipped with a hot-water recirculation pump.

Plumbing fixtures will use low-flow type, including touchless lavatory faucets in office and metering faucets in plant, reduced-flow showerheads, and low-flow toilets and urinals. These plumbing fixtures will increase water-use efficiency and achieve associated LEED credits. Interior hose bibs will serve the pits and platforms; and non-freeze type exterior wall hydrants will serve the MSF Building exterior.

A sanitary drainage system will serve plumbing fixtures, floor drains, trench drains, and pits. The proposed sanitary drainage system will be a gravity type and will discharge to the outdoor sewage system. Drainage from the Heavy Maintenance, VCIF and MOW areas will be collected and connected to an oil interceptor prior to discharging into the MSF Building's sanitary drainage system. A dedicated interceptor will be provided to the Chemical Room drain. A sump pit with submersible pump will be provided for drains in the pits or tunnel if a gravity drain is not feasible.

The storm drainage system will collect rain water from the roof and discharge it to the outdoor storm sewage system through the indoor underground storm drainage piping. The roof will use flow-control drains to store stormwater per stormwater management requirements.

A gas-distribution system will supply natural gas to all gas-fired equipment in the entire MSF, including the gas-heated switches on the rail tracks.

Service Piping Systems

The service piping systems will include compressed-air system, lube-oil storage and a distribution/dispensing system.

The compressed-air system will consist of an air compressor, refrigerated air dryer and air receiver located in the air compressor room. The compressed air piping distribution system will come complete with the air stations required to serve the MOW, Heavy Maintenance, VCIF, Trainwash, Sanding, and Electronic Shop.

The lube oil storage and distribution system will consist of an above-ground engine oil tank, windshield fluid tank and waste oil tank, diaphragm pumps, hose reels and piping, lube oil storage drums, and mobile grease dispensing units.

Fire Protection Systems

The majority of the MSF Building will be protected by a sprinkler system and standpipe system designed in accordance with NFPA standards and the applicable codes. Hazard classifications for various areas will comply with applicable codes and standards. An incoming watermain with a backflow preventer, supervision valves, flow switches, fire pumps (if required) and control valves will provide the water flow and pressure required for the sprinkler and standpipe systems. Dry standpipe and sprinkler systems will be provided in areas subject to freezing. Sprinkler and standpipe systems will integrate with the fire alarm system to protect the entire MSF Building. Each system will have a fire department siamese connection located within 45 m of an exterior fire hydrant.

A fire suppression system (clean agent) and pre-action sprinkler system will be provided to the YCC/BCC Control Centre and the Shared Server/Electronic Equipment Room. Fire extinguishers will be installed throughout the MSF Building per NFPA 10 and Fire Code requirements.

Building Automation System (BAS)

Through equipment monitoring and control, as well as energy management, a direct digital control (DDC) BAS will achieve a high level of occupant comfort and a healthy and productive environment throughout the MSF Building.

BAS design and installation will allow monitoring and operation from a single location. To facilitate maintenance, access points to the BAS will be provided throughout the MSF Building. The BAS will control HVAC systems to maintain the space temperature, humidity and air quality through temperature sensors in each room, and humidity sensors and CO_2 sensors in some critical areas. To manage utility costs, the BAS will measure the consumption of electrical power, natural gas and domestic cold water, as well as the energy efficiency of HVAC equipment.

The BAS will monitor critical alarms for the main building systems and the life safety systems, and be compatible with the OLRT SCADA system.

5.6.4.2 Main Mechanical Equipment Schedules

Mechanical equipment schedules are provided in **Tables 5.6-3 through 5.6-7** below.

Table 5.6-3 | Roof Top Units

Tag No.	Area Served	Location	Supply Fan Air Flow (L/s)	Gas Heating Input (kW)	Elec. Cooling (kW)	VFD
RTU-1	Office	Roof	5899	105.5	105.5	Yes
RTU-2	Electrical Shop	Roof	755	19.1	14.1	No
RTU-3	Electronic Shop	Roof	944	19.1	17.6	No
RTU-4	Switch Control	Roof	378	19.1	7.0	No
RTU-5	Electronic Equipment/Shared Server	Roof	944	19.1	17.6	No
RTU-6	Electronic Equipment/Shared Server	Roof	944	19.1	17.6	No
RTU-7	Electronic Equipment/Shared Server	Roof	944	19.1	17.6	No
RTU-8	YCC/BCC	Roof	566	19.1	10.6	No
RTU-9	YCC/BCC	Roof	566	19.1	10.6	No
RTU-10	YCC/BCC	Roof	566	19.1	10.6	No

Table 5.6-4 | Energy Recovery Units

Tag No.	Area Served	Location	Supply Fan Air Flow (L/s)	Exhaust Fan Air Flow (L/s)	Gas Heating Input (kW)	VFD
ERU-1	Maintenance Hall	Roof	10950	10950	897.0	Yes
ERU-2	Maintenance Hall	Roof	10950	10950	897.0	Yes

Tag No.	Area Served	Location	Supply Fan Air Flow (L/s)	Exhaust Fan Air Flow (L/s)	Gas Heating Input (kW)	VFD
ERU-3	Sanding and Trainwash	Roof	2360	2360	182.3	Yes
ERU-4	Wheel lathe	Roof	2925	2925	217.0	Yes
ERU-5	MOW	Roof	2360	2360	182.3	Yes

Table 5.6-5 | Air Conditioning Units

Tag No.	Area Served	Indoor Unit Location	Outdoor Unit Location	Indoor Unit Type	Supply Fan Air Flow (L/s)	Elec. DX Cooling (kW)
AC-1	Data (West)	Data (West)	Roof	Wall Mounted	500	8.8
AC-2	UPS Room	UPS Room	Roof	Wall Mounted	335	7.0
AC-3	Elevator M. Room	Elevator M. Room	Roof	Wall Mounted	335	5.3
AC-4	Data (East)	Data (East)	Roof	Wall Mounted	335	5.3
AC-5	Battery Room	Battery M. Room	Roof	Wall Mounted	335	5.3
AC-6	Signal Equip. Room	Signal Equip. Room	Roof	Wall Mounted	335	7.0
AC-7	Office (East)	Office (East)	Roof	Wall Mounted	212	3.5
AC-8	Pick-up (East)	Pick-up (East)	Roof	Wall Mounted	212	3.5

Table 5.6-6 | Boilers

Tag No.	Area Served	Location	Gas Output (kW)	Boiler Efficiency	Water Supply Temp (°C)	Water Return Temp (°C)
B-1	Office, Service Rooms and Storage	Sprinkler/Mech Room	154.7	92	48.9	37.8
B-2	Office, Service Rooms and Storage	Sprinkler/Mech Room	154.7	92	48.9	37.8

Table 5.6-7 | Domestic Hot Water Tanks

Tag No.	Area Served	Location	Gas Input (kW)	Boiler Efficiency %	Storage Capacity (L)	Recovery at 100 F Rise (LPH)
DHT-1	Office, Service Rooms	Sprinkler/Mech Room	88.0	96	492	1321
DHT-2	Office, Service Rooms	Sprinkler/Mech Room	88.0	96	492	1321

5.6.5 ELECTRICAL DESIGN

5.6.5.1 General Design Approach to Electrical Systems

Electrical design will conform to the general requirements of the RFP drawings, documents and addenda thereto, and will comply with the Ontario Building Code (OBC), Ontario Fire Code (OFC), Ontario Electrical Safety Code (OESC), and other applicable regulations.

The electrical utility will be supplied by two Hydro Ottawa Limited substations, providing three circuits at a voltage of 13.2kV in looped configuration. These circuits will be extended across Belfast Road, using post-disaster, seismic-rated duct banks to three high-voltage substations located around the MSF. The two track power substations will supply the yard and track located inside the MSF Building. The remaining substation will supply other MSF Building functions and equipment including the BCC. Power will be distributed around the site at 600V as the main distribution voltage.

Redundancy & Emergency Power (YCC/BCC)

The BCC will be supplied by an 875 kVA, 600 V emergency generator, providing four hours of backup power at 100% load. The selected generator location segregates the backup emergency system from areas which are not seismically rated for post-disaster survivability, increasing the reliability of the emergency backup power system in a disaster. The emergency generator will feed three automatic transfer switches, separating life-safety equipment, fire pump, and emergency loads as per OESC. A mobile generator connection box will be provided in the event of required maintenance activities on the on-site stand-by generator. The emergency load ATS will feed a 600 V emergency switchboard, which in turn will feed a 250 kVA, 600 V back up UPS. The UPS will provide 15 minutes of battery backup time to the BCC and other UPS required loads. The remaining time is provided by the generator, totalling a minimum 2 hours for the YCC/BCC.

Equipment Selection

The equipment cut sheets including the generator, UPS and light fixtures are included in **Package B2 – Design Submission Part 2 – Volume 4 (of 4)**. A summary of the key electrical equipment is noted below:

- Main high voltage transformer will be a 3 MVA 13.2 kV-600 V/347 V 3 ph 4-wire dry-type pad-mounted transformer
- Main 4000 A, 600 V/347 V 3 ph 4-wire switchgear for distribution with spare for future paint shop
- Draw-out type main and feeder breakers in main 600 V switchboard
- Distribution to 600 V switchboards, distribution panels, track switch heater panels, and emergency distribution panel (see section for emergency power and UPS units)
- 600-120/208 V distribution transformers, 600/347 V and 120/208 V panelboards as required
- 875 kVA, 600 V emergency generator
  - Communication equipment
  - Telephone systems
  - Data and communication racks
  - Yard dispatchers' equipment
  - UPS room exhaust fans
  - Radio communication
  - Intercom system
  - Emergency egress lighting
  - CCTV system
  - Security access systems
  - Public address systems

- 250 kVA 600 V UPS providing 15 minutes of back-up time
- 2x 120/208 V UPSs providing 4 and 24 hours of back-up time for respective systems
- Transient Voltage Surge Suppression (TVSS) in switchboards, panelboards
- Light Fixtures
  - Maintenance and Repair garage area:
    - Ceiling-mounted – enclosed high-bay IP67 T5 luminaires, and/or watertight linear fluorescent fixtures complete with high-impact acrylic lens and fibreglass housing with SS latches
  - Open-ceiling storage and electrical/mechanical spaces:

    - Open-type industrial linear fluorescent fixtures with wire guard
  - Office space with suspended ceiling:
    - Linear fluorescent fixtures
  - Hazardous locations:
    - Enclosed Class 1 Div 1 linear fluorescent fixtures
  - Linear fluorescent luminaires with energy efficient rapid start electronic ballasts of BF 0.88 or programmed rapid start ballasts
  - T8, T5HO, and T5 linear fluorescent lamps, average 30,000 hrs
  - LED Light Fixtures
  - Emergency and exit lighting to meet OBC requirements
- Lighting Control
  - Centralized LV control system
  - Networked lighting control panels with touchscreen graphical user interface, programmable relays
  - Network communication module programmable through built-in web server
  - Integration with LonWorks, BACnet and Modbus standards
  - Switching stations
  - Occupancy sensors
  - Automatic daylight sensors (where applicable)

5.6.5.2 General Design Approach to Provision of CCTV, PA, Data/Communications Systems

CCTV

Fixed facilities-based CCTV will comply with PA Schedule 15-2 operational and performance requirements (Part 4, Article 6; Part 6, Article 7) and will be built up from several sub-systems (i.e. cameras, power supplies, network devices, video recorders/storage and displays) integrated into one coherent system providing OLRT security and operational monitoring needs.

Fixed and pan-tilt-zoom (PTZ) cameras will be deployed in the yard, at building entrances, in major circulation areas, and at other areas that must be covered following CTPED and security reviews. These cameras will be connected to head-end equipment using a mix of fibre and copper technologies as determined by their location, distance and application.

The electrical scope of work will support the CCTV system by installing necessary conduit and raceway infrastructure, with UPS power backup and interconnections to other systems (SCADA, CTS Network, TSCC Video Wall).

Public Address (PA)

The MSF system will comply with Part 6, Article 7 requirements; it will comprise speakers, microphones, amplifiers and signal processors in each operational building with microphone facilities available at the TSCC and MSF as necessary.

The system will provide clear, audible announcements throughout the Stations and MSF from both local microphones and the Control Centres (TSCC/YCC/BCC) with both ad-hoc and pre-recorded message broadcasts being supported.

Exterior Lighting

The lighting summary below outlines the luminaire types used to obtain required lighting and uniformity levels as required by the reference design. The proposed layout also meets LEED standards for Sustainable Sites Credit 8.

Yard lighting will consist of LED lighting heads on 40 foot (12 m) poles, with two, three, or four heads per pole as required to meet illumination levels. Lighting poles will also support CCTV cameras and PA speakers as required. Perimeter lighting on the MSF Building will consist of LED wall-mounted fixtures similar to the yard lighting heads, but in a lower wattage. All exterior lighting will be photo-controlled via a low-voltage, relay-control system.

To meet full cut-off classification, fixtures will be mounted at 00 when horizontal.

Data/Communications Systems

The MSF Building will house the main communications system for the OLRT. The Central Transmission System (CTS) links the control centres, the transit Passenger Stations and the sub-stations. The CTS provides the transmission medium for all internal operation-related communication systems (i.e. SCADA, PA, Telephony and CCTV) and external systems (i.e. Train Control and Fare Collection). **Section 5.4** provides a detailed description of control centres, key subsystems, and related communication design.

5.6.5.2 Proposed tie-in to OC Transpo at 875 Belfast Road

The CTS links the three control centres including the Belfast Road Transit System Control Centre (TSCC) at 875 Belfast Road, and the Yard Control Centre (YCC)/Back-up Control Centre (BCC) at the MSF. A pair of duct banks will be provided along the Belfast Road right-of-way to provide a fixed connection between the TSCC and the MSF. These two duct banks (the second duct bank providing redundancy), will house the primary fibre connection between these two critical facilities. Additional information on this tie-in is included in **Section 5.4**.

5.6.5.3 Electrical Drawings, Schematics, Product Cuts & Diagrams

Package B2 – Design Submission Part 2 – Volume 4 (of 4)provides electrical drawings, diagrams, product cut sheets and schematics that illustrate the electrical systems, including power, lighting, life safety and emergency services:

- Single line diagrams
- Preliminary sizing of equipment and feeders
- Electrical distribution
- Emergency and critical power systems including electrical demand load calculations
- Emergency back-up generator detail location and capacity

5.6.6 SHOP EQUIPMENT

Shop equipment has been selected to ensure ease of maintenance and efficient handling of Vehicles and/or Train consist. Outlines of the proposed fixed and auxiliary machinery are provided in **Tables 5.6-8 and 5.6-9**.

5.6.6.1 Proposed Shop Equipment List

Table 5.6-8 | Maintenance Equipment – Fixed Machinery

Maintenance Equipment – Fixed Machinery			
Machine	**Location**	**Machine**	**Location**
LRV Wash Machine	East end of Sanding & Wash track	Truck Turntables	Bogie Repair Area adjacent to HM3
Sanding System	West end of Sanding & Wash track	Truck Drop Pit	HM3 and support track (not system connected)
Wheel Lathe	Wheel lathe track and bay	Repair Tables	Various
Over Head Cranes	Maintenance Hall – over HM1, HM2, HM3	Lubrication System	Various delivery points
Jib Cranes	Bogie Repair Area	Compressed Air System	Various delivery points
Truck Repair Hoist	Bogie Repair Area		

Table 5.6-9 | Maintenance Equipment – Auxiliary Machinery

Maintenance Equipment – Auxiliary Machinery			
Machine	**Location**	**Machine**	**Location**
Steam Cleaner	Bogie Repair Area	Grinders/Buffers	Windows extracting system
Battery Charging System	Battery Storage Room	30-ton press	Various work centres in HM
Fork Lift Truck(s)	Various	Grease and Oil storage facilities	Heavy Maintenance Hall
Mobile rail car mover	Various	Lorry(s)	Mobile
Stairs for train Access	Various as required	Shock Absorber Testing System	Heavy Maintenance Hall
Storage Shelves and Units	Stores Department and work centres	Laser Wheel Profile Metre	Wheel Lathe Bay
Drill Presses	Various work centres in HM	Windows extracting system	Various

5.6.7 SECURITY & COMMUNICATIONS

5.6.7.1 Perimeter Security System & Proposed Access Points

Site security will use both a primary and secondary system, enabling the end user to restrict access to the MSF under several scenarios.

Primary Security

Primary security will include full perimeter security around the MSF site comprising fencing and CCTV monitoring systems along with controlled access points through the perimeter.

Fencing along the site's boundaries will be strategically placed for maximum benefit, and be protected by a mix of fibre-optic sensor, fence-line security, and video analytical CCTV cameras. The fibre-optic fence-line security will detect any attempted break-ins (e.g. by an intruder cutting the fence), identify the area of the attempt and report it to the Yard Intrusion & Access Control (IAC) system. The IAC system will link to the CCTV to trigger the Yard PTZ cameras to swing to the identified area of intrusions, will cause the image from the appropriate camera to be automatically driven to the overview video wall, and will generate a SCADA alarm to alert YCC staff to the event. As a back-up measure, cameras with video analytical capability for intrusion detection will be located looking at spots that have been identified, following the threat and vulnerability analysis, as potentially more likely to see intrusion attempts. Any event detected by these cameras will be driven to the CCTV screens of the YCC and alarmed to the operator.

To comply with privacy legislation, the CCTV system for intrusion detection and monitoring will be signed, facing outwards, on the perimeter fencing.

The following physical boundaries will be provided:

- 4.3 m-high acoustic wall/berm wall with chain link fence and barbed wire along the VIA Rail line
- 1.8 m-high chain link fence with barbed wire along Belfast Road and the PepsiCo Yard

The MSF yard and external areas of the MSF Building will be part of the overall MSF Public Address system which, while complying with requirements (e.g. addressing acoustic requirements), will also allow YCC operators to make announcements in response to any intrusion attempts.

Primary control points will be provided through the perimeter fence consisting of sliding gates; card reader/gate arms are provided at the following locations:

- At vehicle entrance to visitor parking and main entrance

- At employee parking entrance from Belfast Road (card reader/gate arms)
- At truck entrance to loading dock, maintenance of way area

All access through these points will require cards that are recognized by the MSF IAC system. Access for those persons without valid access cards will be via intercom to the YCC from where YCC staff can open the gate remotely. All access through these gates will be monitored via CCTV and all movements by vehicles and persons entering will be monitored on CCTV at the YCC. For compliance with Freedom of Information and Privacy Act provisions all persons entering the MSF site via these access points will be made aware that they are being monitored and recorded on CCTV.

All vehicle entry and exits will be protected by vehicle inductive loops: on entrances to prevent gates closing on vehicles, and on exits to auto-open gates and to prevent closure on stopped vehicles.

Secondary Security

We will restrict access to the automatic yard area by installing security fencing between the automatic track and the manual track, running east to west, through the MSF site.

At any point where a road or pedestrian pathway is provided across tracks, whether manual or automatic, a controlled crossing will be installed. For vehicles this will be a level crossing, controlled with barriers, and requiring vehicle drivers to dismount from their vehicle, contact the YCC via intercom and then request and receive clearance to cross the tracks. YCC will control the barriers that allow movement over these tracks and the vehicle operator will be required to inform the YCC that he has successfully cleared the crossing. For foot crossings, the pedestrian will need to contact YCC, ask and receive clearance to cross, and then inform YCC that they have successfully reached the other side. In both cases, YCC will protect against conflicting Train movements while a crossing is in use.

Secondary Control Points are provided at the following locations along the secondary security fence:

- At entrance to automatic yard adjacent to the TPSS
- At northeast corner of the MSF site, the entrance to the MOW laydown area

As with primary access locations, CCTV cameras will monitor the crossing and provide an image of the crossing user while at the intercoms.

5.6.7.2 Other Planned Security Systems

Building Security

Building security comprises three main components:

- Intrusion and Access Control (IAC) System
- Video Surveillance System (CCTV) at strategic points
- Primary Security Line (PSL) through building

Intrusion and Access Control System: IAC system technology will be deployed to protect areas of the MSF Building by restricting access to technical and other controlled access areas through the use of card readers and programmed access cards connected to a centralized Door Control system which will release magnetic locks or electric strikes as appropriate.

To detect and monitor unauthorized entry across MSF Building, perimeter points devices such as door position switches, motion detectors, and lead foil tape will be used; should any of these systems determine entry has been made into an unauthorized area, the IAC will generate an alarm to YCC staff allowing them to coordinate an appropriate response.

Video Surveillance System (CCTV) at Strategic Points: The use of video surveillance (CCTV) cameras throughout the MSF Building and yard will enable YCC staff to monitor and investigate any intrusions without exposing themselves to unnecessary dangers. The CCTV system will be part of the overall OLRT system allowing monitoring and video capture of intrusions to be undertaken in the same way as Station and guideway intrusions.

Primary Security Line (PSL) through MSF Building: A primary security line is provided through the MSF Building such that there is a defined public space upon entry to the MSF Building with all spaces behind the PSL secure. Protection measures that comprise the primary security line include the following:

- Monitoring door status (DC) – monitors open/closed status
- Intercom (IC) – provides two-way communication to a specific point
- Card reader (CR) – provides controlled access through a given point

Door contacts, intercoms, and card readers will be incorporated throughout the MSF Building as required to ensure the safety and security of the staff and end users.

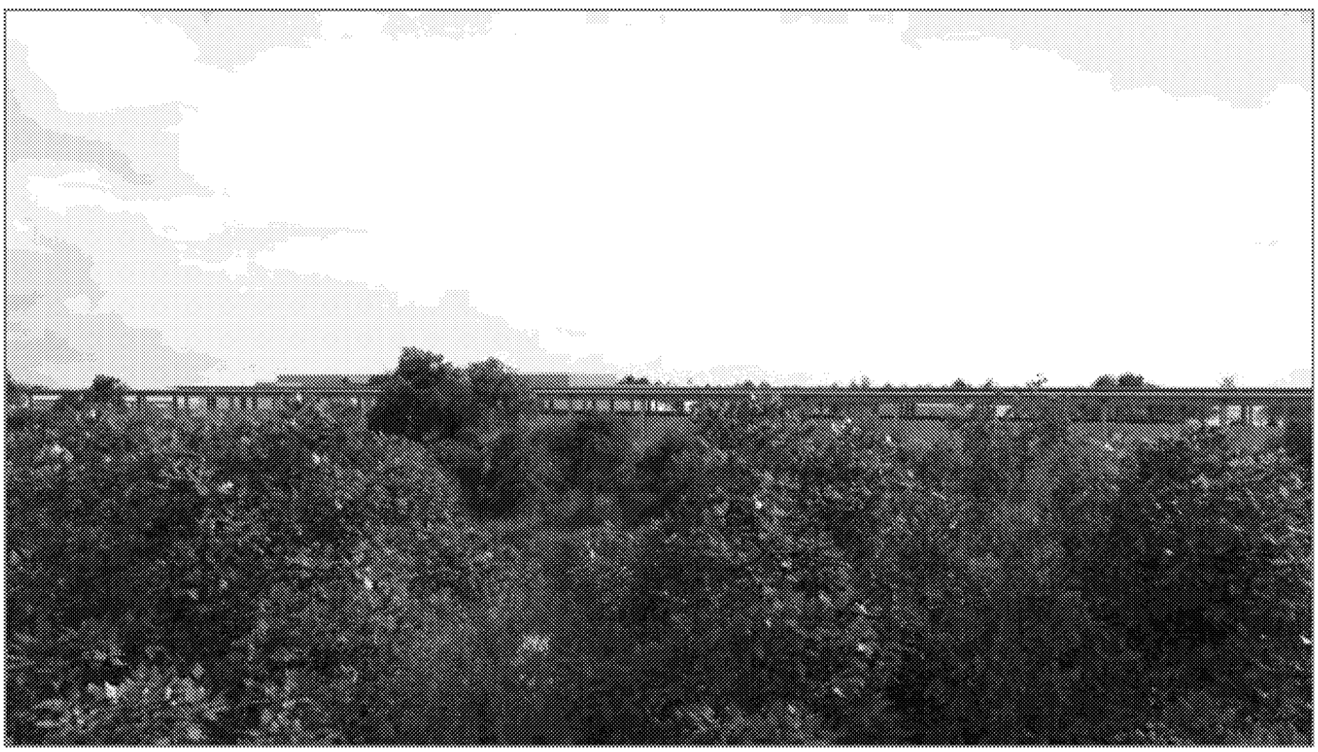
5.6.7.3 Communications

The MSF Building and yard will form part of the overall OLRT system and, accordingly, their communication systems will be part of the integrated OLRT communication systems.

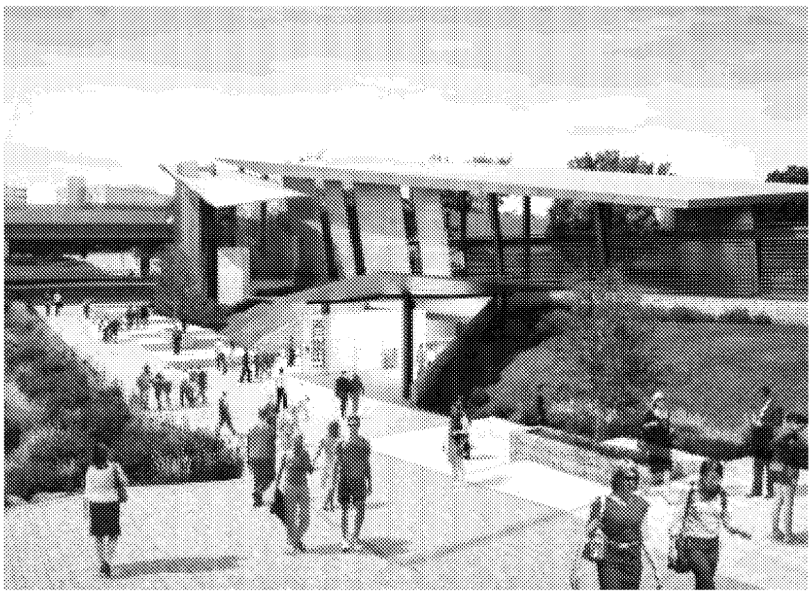
All telephones within the MSF Building and yard will connect to the main MSF PABX, enabling land-line communication between MSF staff, YCC operators and other authorized persons within the site, such as OC Transpo drivers and staff. To provide service between OC Transpo staff at the TSCC and staff at the MSF, the MSF and TSS PABX telephone switches will be connected over the CTS (see elsewhere) enabling staff to make internal extension calls to each other.

External land-lines, via TelCo lines will be provided to talk to other agencies involved in the successful operation of the line (e.g. Ottawa Police Service, Ottawa Fire Services) as well as for normal RTG business purposes.

Other communication systems, being the same as those used on the main line, are discussed elsewhere in this Response.



5.7 CoNSULTATioN pLAn



RIDEAU TRANSIT GROUP

5.7 CONSULTATION PLAN

RTG recognizes the City of Ottawa has led the public consultation program through the Conceptual and Preliminary engineering phases and will continue to do so through final design, construction and through Revenue Service. In this regard it is seeking a Project Partner who can demonstrate it understands the issues, has the relevant Canadian and LRT project experience to put together a comprehensive Consultation and Communications Plan, and can prove it is committed to deliver the organization, resources, experienced project personnel and project funding to support the City in meeting its obligations under Schedules 17 and 18 of the Project Agreement. Moreover the City's expectation is to work with a partner to support the City in elevating the OLRT project to a compelling public communications and consultation success story.

In response, through **Section 5.7.1**, RTG has outlined the key elements it sees essential to the Consultation Plan, categorised and classified the scale, type and number of consultation meetings, and identified key issues, challenges, opportunites and approaches to working with the project stakeholders including the City itself. **Section 5.7.2**, describes RTG's commitment to the City to support the Consultation Plan with precise details as evidence to its commitment to the OLRT project.

5.7.1 PRELIMINARY CONSULTATION PLAN

RTG's Preliminary Consultation Plan is founded upon it's detailed understanding of the significant input that has already been received on this project from City advisors, key stakeholders and the public, and on its proposed design and construction methodology, as thoroughly scrutinized during the development of its RFP response. As a result, our solution is tailored to the unique characteristics of the OLRT project, and gives full consideration of the City, NCC, the public and vested stakeholder interests including affected businesses and property owners and relevant authorities.

Our plan draws upon the experience and associated expertise of RTG member companies, who have led and supported significant large scale rapid transit infrastructure project programs across Canada including:

- Vancouver's Canada Line Rapid Transit Project
- Calgary West LRT Project
- Edmonton North LRT Project
- York Region's vivaNext BRT Program
- Mississauga's Hurontario-Main LRT Project

The knowledge and expertise RTG brings to the OLRT project is deep in its understanding of both the specific features of the project and of lessons learned from other Canadian transit infrastructure projects. This unique advantage, combined with the strength of our consultation team, our design and construction methodology and our commitment to partnership with the City, establishes RTG as a strong proponent candidate.

5.7.1.1 Understanding the Issues and Strategic Approach

The launching point of RTG's public consultation plan will evolve from the two key environmental assessments (federal and provincial) completed to date. Most recently the CEAA Final Screening Report received its Decision Statement taken on July 13, 2012 whereby it was determined the Project is not likely to cause significant adverse environmental effects, and as such no follow up is needed. Both the Federal and Provincial processes have performed extensive consultation so far, including through the Federal Process consultation with the National Capital Commission (NCC). Future consultation contemplated for the project, and as documented in the CEAA report, anticipates the Contractor will partner to support the City in delivering communications and public consultation activities that will:

- Maintain transit ridership during construction, and maintain transit user satisfaction;
- Communicate traffic/transit changes to the public;
- Enhance opportunities for open, transparent, effective and pro-active communications with the public;
- Recognize the contribution of the parties in the Project Agreement; and
- Foster and maintain positive and constructive relationships with the public including communities and businesses that maybe affected by construction activities

The Fixed Points – As the Project moves forward through the Design and Construction phases the consultation program will narrow and the role of communications will expand. In this regard, the 'Fixed Points" that will define the processes and scope of consultation are as follows:

- The project schedule, completion dates and budget for the project are determined
- Vehicle and train control technology is determined
- Alignment for the main line is fixed
- Station locations and designs are substantially determined
- The Maintenance and Storage Facility is defined
- Temporary BRT traffic diversions for the construction period are substantially determined

Opportunities for public communication and consultation – Despite the advanced state of the project design there are still significant elements of the project to finalize, and opportunities for public input and engagement. In branding the vehicle there is opportunity to invite public opinion on the selection of the vehicle's livery. Similarly, opportunities for public and community engagement exist with asking the public for input related to themes for station art concepts. Our experience from past public consultations where we have deliberately targeted the public for key thoughts around specific subject matter, has demonstrated the process to be successful whereby new thoughts and ideas tied to community and history have stimulated the development of art concepts and acts of storytelling.

THE POWER OF DIALOGUE

On Canada Line, a two stage process of consultation was conducted, involving a representative from each of the major local disabilities groups. Through a two phase process we showed the system design and invited input. We were clear ahead of time what subject areas were available for input and discussion and which areas were off limits.

As a result of the dialogue - a key concern that came to the surface was the fear of being trapped in underground stations at a time of emergency. Under existing provincial regulations all elevators had to be stopped in case of an emergency. RTG representatives took the issue on board and worked with the Provincial Elevating Authority, Fire Department and code officials to obtain approval to keep elevators operational during emergencies, and thereby facilitate 'self-rescue'.

The initiative took considerable effort to achieve, but was accomplished. The commitment made by the project earned significant good will from the local disabled community because it was an issue they had previously championed but were unable to get a decision in their favour.

As illustrated in the Power of Dialogue box above, engagement of Special Interest Groups, such as the disabled community, to provide input to the system design, especially as it pertains to the design of the vehicle interior and the public areas of the stations, are key opportunities for engagement.

The construction work plan will stimulate extensive public interest. Consultation on matters related to minimizing disruption to the public, businesses and properties owners will be a key interest during the construction phase.

Formulating a Coordinated Approach – Development of the OLRT Project Communications Plans will be dovetailed with the project schedule and execution plan. The nature of the consultations, the meetings, and events, must be coordinated with the evolution of the design as it moves from Design Development through to Final Design, Construction, Testing and Commissioning, and finally into Revenue Service.

5.7.1.2 Consultation Principles

RTG's approach to consultation is designed to meet or exceed PA requirements. Understanding and effectively engaging with various Stakeholders and the public will be pivotal to Project success. As part of our Consultation Plan submission after Financial Close, we will provide an Outreach Matrix that outlines the plan to meet with Stakeholders and the public, and the timing, methods and tools to be used.

Objectives

Our approach to design consultation is driven by the following objectives:

- **Building** and maintaining strong internal and external communication networks to facilitate the timely and accurate exchange of design and construction-related information
- **Supporting** the City in providing clear, consistent and accessible design, construction and traffic management information for Stakeholders and the public
- **Engaging** with Stakeholders (including news and traffic media support) and the public to foster greater understanding of finite issues, to plan for and reasonably minimize construction inconvenience, and to maintain trusting relationships throughout the Project
- **Providing** opportunities for non-structured yet important feedback through communications channels outside formal consultation programs
- **Delivering** programs (in both lead and support roles) on-time and on-budget.
- **Reporting** on our progress and fully supporting the City to keep Stakeholders and the public informed, engaged, and confident

Principles

Consistent with our overall approach to partnering, integration, communication and consultation, several guiding principles will support RTG's consultation objectives:

- **Client and customer focus** – Keeping in mind the needs, preferences and behaviours of the people who are affected by the OLRT and applying a best-practice approach
- **Transparent, timely two-way communication** – Identifying design elements open to consultation proactively and transparently, while incorporating ideas and input to maximize results
- **Emphasis on benefits to the community** – Maintaining the public interest in all that we do, and continually promoting the OLRT benefits along the corridor
- **Reliable planning and implementation** – Using proactive look-ahead, meetings and on-the-ground progress reports
- **Broad solutions, local outreach** – Supporting the City with a corridor-wide focus, while continually communicating at the neighborhood level
- **Focus on listening and inclusiveness** – Emphasizing that our team is here to listen, while demonstrating forward movement with clear understanding of what is important to each community/

Working with the City, RTG will assist the City in developing responses to public and stakekolders input during consultations. The following four categories of input will be recommended:

- Input that has already been incorporated into the design
- Input that has reasonable merit that can be considered within the Project scope, schedule and budget, and that RTG can incorporate into design and construction management plans (includes environmental and traffic/transit management)
- Input that would lead to significant changes to design or construction management plans, and which is not possible to achieve within the Project scope, schedule and budget (unless the City supports the change)
- Input that is out of Project scope or that our team is not able to address, possibly forwarded to another City initiative or relevant authority for consideration (consistent with communication protocols established with the City)

RTG will maintain a highly accountable support role consultation structure with the City, and outline how RTG design and construction leads will interface with the City's Project Management personnel. RTG's Environmental and Sustainability Director will lead consultations with the City, key Stakeholders, municipalities and regulatory authorities regarding compliance with the Environmental Management Plan. This same regulatory and technical interface required under the Traffic/Transit Management and Utility coordination functions will be led by the DBJV Traffic Manager and Construction Manager, with guidance and support from our RTG Communications Director and Manager. These regulatory and non-regulatory (design and technical) consultations will be undertaken in parallel with any general public consultations regarding environmental and traffic/transit management. RTG also has extensive experience with Environmental Assessment (EA) processes, permits, consultations, EA amendments and regulatory consultations. We will adhere to PA Schedule 17 requirements and comply with all environmental approvals, standards, regulations, guidelines, policies, practices, and Environmental Laws applicable to the Project.

5.7.1.3 Types and Number of Consultation Meetings

RTG understands the importance of informing and engaging key Stakeholders and the public in distinct communities, affected by the Project to varying degrees. Throughout the Design and Construction Phases, RTG will attend meetings, workshops, Council/Committee meetings, Open Houses and events to fully coordinate with and support the City.

The number, scale and scope of these meetings, and the type of consultation is driven by audience, format, and purpose. In **Table 5.7.1**, RTG has classified broadly the main categories and types of meetings it anticipates for the project based on its experience, lessons learned applied to the OLRT project. These numbers of meetings are preliminary at this stage and will be verified with the detailed development of the Public Consultation Plan as it is advanced with City staff.

Table 5.7-1 | Information Meetings and Consultation Sessions

Meeting Classification	Small Group Format (2 to 20 people)	Medium Group Format (15 to 50)	Large Group Format (40 plus people)
Public information Sessions **Purpose:** To provide project information to the general public; **Consultation Opportunity:** General in nature, gather comments and feedback	**Small Group Outreach**: Focussed on individuals or small groups, these meetings are held to address project issues of specific interest to the interested parties **Number**: Continuous	**Roundhouse Meetings**: Medium format targeted at smaller interest groups, e.g. strata group, small business group etc. Objective to share project information and gather feedback; discuss issues **Number:** 10 - 20	**Public Open Houses**; large format sessions; held in public halls etc. Objective to communicate project information and allow public opportunity to comment **Number:** 6 - 10

Meeting Classification	Small Group Format (2 to 20 people)	Medium Group Format (15 to 50)	Large Group Format (40 plus people)
Project Education Initiatives and information sharing: **Purpose:** To educate the general public about the project **Consultation Opportunity:** Primarily focus is information dissemination and education	**Storefront Outreach**: Focussed on the individual and casually interested, where members of the public can drop in to ask questions or raise specific issues **Number**: Continuous	**Classroom Sessions**: Medium format similar to school sessions aimed at educating small groups such as children; small interest groups etc. Informal in nature **Number:** 20 - 40	**Seminar Presentations & Mall Displays**; large format sessions; held in lecture halls and malls. Lectures to target audiences e.g. students & professionals; mall displays to general public **Number:** 20 plus
Focus Group Meetings: **Purpose:** Working with stakeholders, Special Interest Groups (SIG), Agencies and Partners to address project specific issues with intent to advance project design **Consultation**: Interactive	**Technical Meetings:** Small group working and coordination sessions aimed at resolving project specific issues. Consultation and dialogue is detailed **Number**: 100 plus	**Workshops & Charettes:** Medium format - working with SIGs with special focus to address project interests: e.g. Disabled Community consultation **Number:** 6 - 10	**Partnering Sessions:** large format with key stakeholders Good for envisioning and partnering, to develop teamwork and shared vision **Number:** 1
Project Reporting: **Purpose:** Working with stakeholders with specific project interests and Special Interest Groups (SIG) **Consultation:** Strategic	**Partner Reporting**: Smaller boards or groups within partners and agencies to provide updates on project status or on key project issues **Number:** 20 - 30	**Board Presentations:** Typically to agencies & boards, providing update on project status, or seeking regulatory approvals **Number:** 10 – 20	**Public Reporting:** large format such as reporting to Council, project progress **Number:** 1 (annually)
Construction Outreach: **Purpose:** Working with stakeholders & Special Interest Groups (SIG) with specific interest regarding construction **Consultation:** interactive, with intent to identify issues & find solutions	**Construction Small Group Outreach**: Focussed on individuals or small groups, these meetings are held to address specific construction issues and find solutions. **Number**: 20 – 50 plus	**Construction Roundhouse Meetings**: Medium format targeted at smaller interest groups Objective to share project information and discuss issues **Number:** 6 - 10	**Construction Open Houses:** large format sessions; held in public halls etc. Objective to communicate project information and allow public opportunity to comment **Number:** 6 - 10

5.7.2 KEY ISSUES/CHALLENGES/OPPORTUNITIES & CONSULTATION APPROACH

RTG understands that the issues, approach, key messages, strategic approach and implemention will be dynamic as Design and Construction proceed. Working with the City, RTG will plan for this and develop a strategy to prevent, address and mitigate issues and concerns that are likely to arise. Our approach will be tailored to the interests of the particular stake holder groups including NCC and Regulatory Authorities, the public, affected businesses and properties. As part of RTG's outline plan we have identified the particular interests and issues, challenges and opportunities these groups are likely to share, and indicated these in the following tables. See **Tables 5.7-2 to 5.7-6**

Table 5.7-2 | Key Issues, Challenges, Opportunities and Approach to Working with the City

The City - The primary City objective is to deliver a highly successful project befitting the National Capital. Under scrutiny of public opinion and the watchful eye of Federal and Provincial elected officials it must be seen to effectively manage the process by delivering on time and on budget, a sustainable transit system with strong iconic identity that fully meets the City's stated project goals.

Issues / Interests	Challenges / Opportunities	RTG Approach
Managing the relationship with the Preferred Proponent through the entire project, to ensure a successful project outcome in all respects.	▪ There remains substantial work ahead for Project Co and the City to undertake. Selection as Preferred Proponent will herald a new phase to the project's implementation where both teams can work in partnership to fulfill a common goal. ▪ While RTG has extensive transit public consultation experience, the City knows the Ottawa political context, primary interests & concerns of its key stakeholders. Project Co & the City will jointly develop an effective communications & consultation plan that provides continuity to the work performed to date & specific to the project's implementation phase	▪ RTG's Project Plan relies on providing a highly qualified team with extensive transit and technical experience needed to deliver the project & assist the City with key decisions ahead. ▪ Most City consultation will be technically based. A regime of joint meetings & working groups will be agreed to effectively organize & coordinate resources consistent with the project Work Plan. ▪ Based on the known 'Fixed Points', RTG & the City will tailor the consult-action plan to manage stakeholder expectation while still being responsive to their interests.
Maintaining good Provincial and Federal Relationships by considering and accommodating where appropriate their interests and requests (being mindful of the substantial financial contribution from both levels of government)	▪ Provide opportunities to celebrate key milestone events with political representatives present. ▪ Project Co to provide City information upon demand to meet reporting requirements &respond to questions from elected officials. ▪ Anticipate and plan for any public opposition to be mobilized through political representatives. ▪ Being the National Capital residents are highly informed and politically savvy. Project Co and the City must work smartly together to resolve issues quickly and avoid escalation.	▪ Project Co has planned seven major events (ground breaking; start of tunnel construction; end of tunnel construction; vehicle unveiling; first train trip; opening the line, 150 yr anniversary), with approximately 10 other events with political participation opportunities. ▪ Project Co will provide 24/7 access to a core public relations team of 4 people, who will have immediate access to project leadership and can respond promptly to emerging issues. Project Co will work in support to the City with the City providing the direct political and agency interface lead.
Preserving and growing BRT ridership during construction and growing ridership during operations	▪ The City not only wants to preserve BRT ridership through construction but grow it. ▪ BRT ridership is a captive audience that should be engaged.	▪ Develop BRT ridership outreach program with the City to keep BRT riders informed ▪ Provide monitoring of transit user's behaviour patterns. Use feedback to inform communications strategies.

Issues / Interests	Challenges / Opportunities	RTG Approach
Minimizing disruption to the public and businesses during construction	■ The City must be seen to advocate support of local business interests ■ Business interests relate to preserving access, making delivering and preserving parking for customers ■ Christmas retail period is vital and must be respected ■ Opportunities exist to minimize and coordinate utility shut downs impacting stakeholders. ■ Other Ottawa special events planning (Winterlude, Tulip Festival). ■ Business of the capital must be preserved during construction	■ RTG's underground construction substantially reduces disruption, and is a positive message that should be promoted. ■ RTG will work with Business Associations to listen and learn of the specific issues unique to Ottawa, and work with them to find solutions. ■ Provide pre-construction information. Meet local stakeholders to keep them informed. Meet one-on-one to address specific issues.
Executing the project in accordance with best practices, by following regulatory approval processes and protocols	■ Follow CEAA requirements and commitments to obtain all permits. ■ Meet other Regulatory requirements as needed (see NCC below) ■ Develop the Regulatory Framework to approve the project and operate the system. This significant issue is both an opportunity and a major work task for the project	■ Project Co is committed & organised to fulfill the CEAA requirements.(table 4.2.3) ■ RTG is the only non-transit entity to have successfully obtained LRT Operating Permit in Canada. It understands the issues & has the expertise to help the City. ■ Seek advice from Transport Canada as appropriate on the Regulatory Framework
Maintain and grow strong public support for the project, by implementing an effective public consultation and communications project program that includes outreach to schools and institutions.	■ The public will want to see the Preferred Proponent's proposed design and also will expect to see the final designs. ■ Project Co and the City will have an opportunity to make full use of social media tools at its disposal to keep the public informed and stay ahead on key and emerging issues. ■ Education, through school outreach and community programs is an effective means to stimulate excitement and change attitudes to grow ridership.	■ Project Co. is committed to supporting public open houses as part of the consultation plan (See below for details) ■ Project Co will provide a project vehicle with one staff member dedicated to education outreach program (schools, malls, community centres etc.) to build ground level project support and interest in the OLRT. ■ Senior technical staff members will make presentations to local chapters of professional bodies, universities and key public meetings to support the education program.

Table 5.7-3 | Key Issues, Challenges, Opportunities and Approach to Working with the NCC

NCC – With a mandate to safeguard the Capital's National Treasures and sites of great prestige, combined with aspirations to accommodate projects showcasing the City of Ottawa, the OLRT project is of the scale and complexity to warrant the NCC's utmost attention. As stated in its endorsement letter of February 6th, 2012, the NCC has for the benefit of the Proponents defined its expectations in terms of project approval process and it's stated Capital Interests.

Issues / Interests	Challenges / Opportunities	RTG Approach
Compliance with federal legislative and regulatory framework (CEAA, National Capital Act)	■ CEAA Final Screening Report supports the OLRT project. ■ NCC will publish its list of conditions, deletions & additions following 60% DD submission from the City.	■ RTG will meet the requirements of the CEAA Final Screening Report ■ RTG has submitted a compliant bid and will meet the NCC requirements, consistent with the RFP.
Respect of founding elements of the Capital including natural and cultural landscapes, the Parkway network, historic sites & National symbols.	■ RTG must demonstrate how it intends to preserve these interests and restore the City to an improved state as anticipated under the PA.	■ RTG's method of construction minimizes impact & disruption. ■ RTG is committed to preserving affected National symbols.
Quality of planning, design & execution for all project elements, reflecting best practices in urban design, architecture, landscape architecture sustainability, universal accessibility and conservation	■ Through the DPM process RTG has received verbal NCC approval, but further dialog is planned to finalize design.	■ RTG's solutions are founded on a rigorous and holistic design process. It is committed to continued dialog and partnership with NCC & City staff to reach amicable solutions.
Seamless integration into the transportations and communications network	■ Intermodal connectivity is a primary ridership planning & design issue ■ Passengers seek on-time information	■ RTG's designs have refined BRT to LRT and O-Train to LRT interfaces. Further dialog will help finalize design
Experiential quality and efficiency of the system	■ OLRT is committed to enriching the cultural and social experience per stated NCC Capital Interests	■ RTG upholds enhancing the entire passenger experience from door to door as a means to encourage use.
Adherence to planning principles that secure potential for Transit Oriented Development (TOD) on NCC Lands	■ Adjacent TOD opportunities have been identified at Tunney's Pasture, Bayview, LeBreton, Hurdman and Cyrville stations	■ RTG will work with NCC staff to reconfirm linkages with TOD sites, and other objectives to secure future TOD opportunities.
Minimizing the impact of construction on the overall Capital Experience to the degree practical and reasonable	■ The business of Government must continue through construction. The City cannot afford major disruption. RTG must demonstrate its commitment to meet this requirement.	■ RTG staff will partner with the City & RA's execute the construction plan taking into account key Capital interests and uphold the principle of 'Open for Business'.
Continue to foster a collaborative working relationship with the City and its selected Proponent with regard to the OLRT	■ OLRT is a significant project to the City of Ottawa and represents an opportunity for collaboration and teamwork to deliver a project that will showcase the City and make its residents and politicians proud	■ RTG understands the National significance of this project, and is fully committed to partnering with the City to support the NCC's stated Capital Interests and make the OLRT an overwhelming success.

Table 5.7-4 | Key Issues, challenges, opportunities and approach to working with the public

The public – Comprising the general public, the current BRT and future LRT riders, Special Interest Groups (SIG's) and community organizations: all have a vested interest in a successful implementation of the OLRT project. Announcement of the Preferred Proponent will stimulate renewed interest as the project shifts from a vision of the future onto a new reality. The public will want information to understand the refined definition of the project, its impact on them and the timelines for completion. There will be pressures for refinement and accommodation, and where legitimate these interests must be given due consideration.

Issues / Interests	Challenges / Opportunities	RTG Approach
The general public will want to be kept up dated on the project. They expect to see the Preferred Proponent's design, the vehicle, stations and understand the construction program.	■ The Final CEAA screening report places expectation on Project Co. to "enhance opportunities for open, transparent, effective and pro-active communications with the public' ■ Public consultation creates opportunity to generate support.	■ RTG is committed to supporting two rounds of public open houses through the design process. ■ RTG will develop a comprehensive plan in conjunction with the City based on its experience of four recent major Canadian transit projects.
The public may still be expecting to have some input to the final design of the OLRT. The level of expectation will largely depend upon the expectations set during Preliminary Engineering	■ Much of the project is already fixed but opportunities to engage public involvement exist that will encourage participation & project support	■ RTG will bring forward suggestions and opportunities to the City for consideration as part of the detailed public consultation plan.
Construction impacts in terms disrupting travel around the city, will be of interest to the general population and businesses within the Ottawa area	■ Traffic advisories and updates will be expected to keep the public informed ■ Business groups and associations will want to know their options.	■ RTG is committed to a public communications plan involving social media & tools geared to keeping the public informed and up to date. (See Section 6.2)
BRT riders will want to understand the impacts upon BRT service and the impact on their daily commutes	■ Outreach to the BRT community to maintain ridership & commitment to public transit is a key objective.	■ An outreach program tailored to BRT users and their interests will be developed with City staff.
Special Interest Groups (SIG's) and advocacy groups will want assurance the interests of their members are being given due consideration	■ Key SIG such as the disabilities and cycling communities will require tailored consultation programs ■ Other SIG with peripheral interests offer opportunity to expand public support while listening of their issues	■ RTG has successfully managed disabilities SIG consultation on major transit projects. ■ RTG will provide technical support to respond to all SIG's.
Community Groups directly affected by construction will have special interest in the project and will want to discuss precise details to assess impact on them.	■ Where there are legitimate interests the project must give due consideration & find solutions ■ Major underground construction may cause some settlement & damage. These issues whether legitimate or not must be handled delicately, professionally & efficiently	■ Construction outreach to local residents and business is proposed. ■ RTG is committed to ethical business practices & fair compensation if there is damage to property. RTG will undertake an extensive precondition and building monitoring survey to help reduce these types of risks.

Issues / Interests	Challenges / Opportunities	RTG Approach
First Nations	▪ Opportunity for employment and for First Nations imagery and art at LeBreton Station. ▪ Consult on archaeological discoveries	▪ One-on-One outreach with First Nations leaders at the earliest opportunity (led by the Environmental Director with support from the Communications team) especially for the LeBreton area.

Table 5.7-5 | Key Issues, Challenges, Opportunities and Approach to Working with Affected Stakeholders

Affected Businesses and Properties – Where the new OLRT will directly impact and modify business and property interests in the long term, the requirement to reach mutually acceptable terms will be commercially and legally based and will require extensive coordination and co-operation between all affected parties. Where business and property interests are limited to the construction period, focus will be on reducing construction impacts to acceptable levels so that commercial interests can be sustained through the period of construction, and business can return to normal.		
Issues / Interests	**Challenges / Opportunities**	**RTG Approach**
The City has to reach agreement with property owners where u/g station entrances are located on their lands. The owners will require full disclosure of designs in order to finalize legal and commercial agreements.	▪ The RFP procurement process does not facilitate direct consultation with property owners. The consultation needed to advance design to a stage whereby legal and commercial agreements can be reached must be performed after Preferred Proponent	▪ RTG supported similar Agreements for three u/g stations on Canada Line, connecting to u/g shopping malls and a Class A historic building. It understands the complexities & nuances of these negotiations & will support the City in completing the Agreements.
Property owners along the alignment especially within the underground segment will be interested in tunnel construction negatively impacting their buildings. It will be incumbent on Project Co to demonstrate construction impacts will be negligible.	▪ Underground construction is inherently a complex construction activity, and some localised limited settlement is inevitable. Consultation with property owners along the tunnel alignment will be necessary.	▪ RTG is committed to providing a combination of group information and consultation sessions with property owners. Where there are special interests specific in nature, it will contribute specialised resources to help explain solutions and answer technical questions.
The interests of business will be represented both individually and collectively by business associations who will lobby for the members interests, especially with respect to construction disruption. They will want to work with the City and Project to identify and resolve issues	▪ Business Associations offer opportunity to crystallize the needs of its members and can help the City and Project Co. develop an effective and coordinate approach to sharing information and addressing concerns	▪ RTG with the City and as part of the Communications Plan will reach out to engage the local Business Associations, hold regular reporting sessions with them. Business associations/interests include Downtown Coalition, Rideau Street BIA, Bank Street BIA, Ottawa Gatineau Hotel Association, Viking Rideau Corporation and Hudson's Bay Company.

Issues / Interests	Challenges / Opportunities	RTG Approach
Businesses sensitive to the changes brought about by introduction of the OLRT will want assurances they will not suffer long term harmful impacts to their business (e.g. CBC is sensitive to noise & vibration transmission).	▪ Special consideration and consultation must be given to businesses and institutions with special interests. For example the CBC, University of Ottawa and National Arts Centre and the National Research Council and various national embassies (such as the US Embassy).	▪ RTG is committed to supporting the City in convening one on one meeting addressing the technical concerns of these groups and providing the necessary technical information need to address their concerns. RTG's design already makes special provision to mitigate noise and vibration transmission in front of the CBC and technical consultation with RTG's experts is considered part of its obligation to the project.

The interests, issues, challenges and opportunities and approach with other Regulatory Authorities are similar in nature to those of the NCC and City. RTG will develop and expand its approach in similar fashion as exhibited in the tables above.

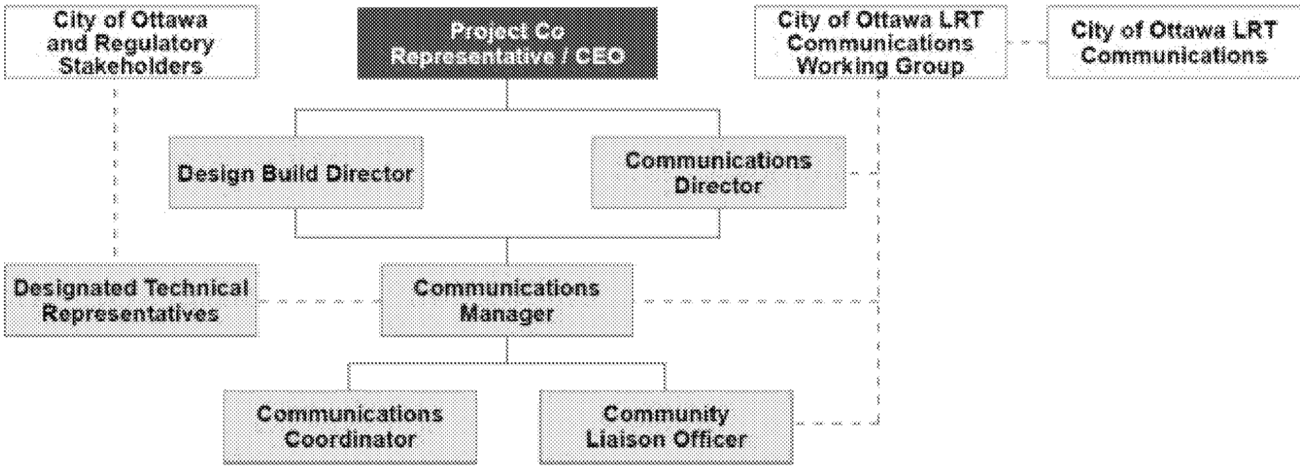
5.7.3 RTG'S OLRT APPROACH & SUPPORTING THE CITY

RTG would like to demonstrate it's commitment to the City in supporting the Project's Consultation Program by describing how it has organized its resources to support the program, the number and quality of resources it will commit, and the scope of work covered within the budget. In preparing its commitment to the project and what it has included in its base services RTG has made certain assumptions about the roles, responsibilities and resourcing the City has committed to provide. RTG will work with the City to develop and implement the Design and Construction Communications and Consultation Plan within 30 days after Financial Close. The equivilant plan for Maintenance will be delivered no later than 30 days prior to the Required Revenue Service Availability Date.

5.7.3.1 Approach to Public and Stakeholder Engagement

The members of RTG have completed the only P3 transit project in Canada to date. In total, our team has more than 12 (twelve) P3 projects currently underway across the nation. This collective experience has provided our Project team, from both the engineering and consultation side, with the depth and understanding needed to structure and manage a coordinated Design and Consultation Plan. RTG's approach to public consultation on large rapid transit infrastructure projects recognizes the consultation team and technical teams must work in unison. The role of the consultation team is to be the public face of the project and provide accessible points of contact to initiate and sustain engagement with stakeholders. Strategic use of senior technical resources is essential in dealing with regulatory agencies, advancing important design and construction issues with key stakeholders and presenting the 'professional' face of the project. **Team Structure and Organization – Figure 5.7-1** shows how our Communications and Consultation team is organized. RTG has two primary levels of organization within its corporate structure, and it has assigned roles and responsbilties based upon which group is best positioned to manage the work. Project Co. as the leader of RTG, will provide the Communications Director who will hold the primary responsibility for setting policy, confirming compliance, setting direction and maintaining the overview of RTG's support to the City's Consultation and Communications Program. The DBJV will provide the main day-to-day consultation and communications management and support during the project execution phase. It will provide a communications manager and two support staff. The Communications Manager will interface directly with the City of Ottawa Communications Working Group, and will also act as the main point of contact with the Technical Team. The technical consultation which involves working with regulatory authorities, engineering and construction coordination with the City and other agencies will be led by the DBJV, the Design-Build Director, Design and Construction Managers and their respective leads.

Figure 5.7-1 | Organization Chart of the RTG Communications and Consultation Team



While the DBJV will take the primary RTG execution role during the design and construction phase, responsibility will shift to the Maintenance Team during the revenue service period. RTG maintenance staff responsible for communications and consultation will be engaged at the appropriate stage to ensure a smooth transition between the DBJV and Maintenance.

Scope of Work included within budget –RTG will be compliant with the scope of Project Co as defined in Schedule 18. Given our understanding of the advanced state of the project, and the regulatory approval process, we have made allowances for the public Consultation Program as follows:

- **Public Open Houses** – we have provided for two rounds of public open houses, with three events at different locations in each round. The first round of Open Houses will take place after project award and will present the RTG solution to the public. We believe this is necessary as part of fulfilling the CEAA process and is consistent with Canada Line's public consultation approach. The second round of open houses will be held at the end of Design Development, once the designs are finalised. The purpose of these open houses will be to conclude the design phase of consultation by showcasing the final design solutions.
- **Other Large Format Consultation Sessions** – As per table 5.7-1, RTG has allowed for 30 - 45 large format events where in many circumstances it will be necessary to pay to book halls, or large meetings rooms at public venues. Within this allowance 50% of the venues are assumed to be lecture theatre and mall type presentations where booking fees are minimal or zero.
- **Outside Public Events** – RTG has allowed for seven major celebratory events during the course of construction. These include ground breaking, start of construction, end of tunnel construction, vehicle unveiling, first training trip; opening the line; and access to Rideau station for the sesquicentennial related event).
- **Number of other Consultation Meetings** – As per table 5.7-1, RTG has allowed for between 200 to 400 small and medium format consultation meetings, with the bulk being held at RTG, City or Stakeholder venues. An allowance for up to 40 medium format venues has been budgeted.
- **Contact Database Tracking Software** – RTG will implement and use a contract database tracking software to track all inquiries, follow up and complaints received, which will be used to provide reporting out of communications and consultation activities.

5.7.3.2 Provide Information for Use in Public Materials

To help Stakeholders and the public to understand each Project phase and the anticipated impacts, RTG will provide the City with images and bilingual narrative (English and French) that support consultation and communication including:

Consultation Resources and Support Material

RTG has extensive experience in the preparation and implementation of design consultation forums, including providing illustrations and narratives that create shared understanding and excitement about the future. Together with the City, we will collaborate on presentation material and key messaging, where and when design renderings are used. In our support role, it is our understanding that the City will prepare and publish all consultation invitations, undertake print and online advertising, and handle all media relations.

RTG will provide the following consultation support resources and material:

- Detailed Design illustration drawings for City/NCC meetings, regulatory meetings, and other key stakeholder meetings
- Detailed Design illustrations for the City's public display boards, printed and online materials
- Narrative text to coincide with illustrations
- Narrative text describing what is open to consultation versus fixed design elements, and design consultation questions to help guide key decisions
- Narrative to support other City consultation communiqués, such as Briefing Note Bulletins, Fact Sheet and Design Workbook/Discussion Guides.
- Assistance with the Detailed Design Consultation Summary Report.
- Supporting and attending Stakeholder and public meetings, and recommending the establishment of additional and relevant Committees. This includes providing timely and accurate design, construction and traffic management information, promptly responding to construction and traffic management feedback, and facilitating high-level Project and non-project related inquires to other agencies. RTG will also integrate with appropriate site and community offices (or 'storefronts') along the corridor.
- Supporting and attending media relations activities and events. We recognize the critical role of mainstream media, social media, bloggers, and other networks and how their messaging shapes public opinion prior to and during consultation events. We will provide the City with key milestone media event opportunity information, such as tunnel and guideway milestones and access; tunnel and station sneak peak opportunities, and more. All event opportunities are subject to rigorous safety requirements and will be discussed with the City.
- It is our understanding that RTG's public information support materials, such as renderings and narrative for display panels, handouts, and feedback forms are to be provided by RTG in French and English.

RTG will also provide traffic and transit management information to the City in its consultation forums, along with preliminary Construction and Environmental information. RTG will also collaborate with OC Transpo to integrate preliminary Operations information along with RTG's preliminary Maintenance information.

5.7.3.3 Complaints Management and Dispute Resolution

RTG will establish a trusting, open and transparent network for positive two-way communication, particularly during challenging times on the Project. We understand the benefits of engaging internal and external Stakeholders, and the broader public, early on and throughout the Project. We will apply our lessons learned to minimize the effects of the Project, using consultation as an effective tool. RTG takes a proactive approach to minimizing issues and managing conflict in order to achieve successful outcomes. This stems from our strong internal working relationships, which allow Communications to be at the forefront of planning and implementation decisions. The City, too, will become part of our strong internal network to support our 'No Surprises' rule as we strive to maximize predictability and minimize negative effects of the Project. In our view, one call to an elected official, at any level, to complain about the Project, is one too many.

COMMITMENT TO DUE PROCESS

On Canada Line the Proponent followed the Sponsors requirement and moved the entire station box and entrance to a community valued public plaza in a highly constrained downtown neighbourhood.

As the project advanced into the initial round of public consultation, the project faced fierce local opposition because the new station location and entrance would result in significant disruption and access during construction, although the technical solution and long term benefits to the community were superior. Project staff listened to the public's issues and concerns and committed to a program of due process. In six weeks, two rounds of workshops & many additional small group meetings were held with community representatives to inform and consult on the opitons.

Final assessment concluded the proponent's solution offered the best integration & overall value. Staff continued to work with the most vocal strata & business groups, where property agreements were needed to enable the station entrance to be constructed through an underground parkade. The project paid for CPTED studies and fire alarm modifications to accommodate the new works. The tone of public discourse changed positively as the project demonstrated its commitment to open honest dialogue and due process.

5.7.3.4 Capitalizing on Project Personnel Capabilities to Implement the Consultation Plan

Having led and supported significant rapid transit communication and consultation programs across Canada, RTG truly understands the implications of high profile, environmentally and socially sustainable LRT projects. More specifically, from high-level to street level, we have a superior understanding of the critical role that strategic communication and consultation plays -- in parallel to the design and construction streams -- to achieve a successful Project.

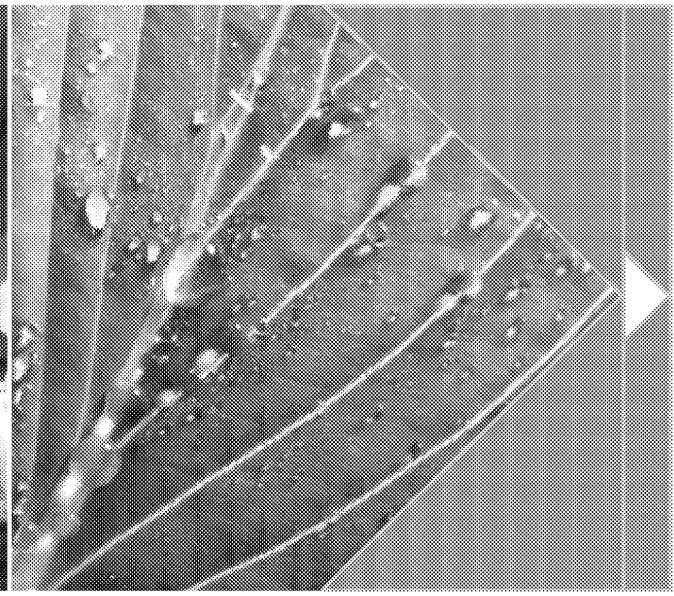
Although led by our Communications Director, the RTG senior management team has been directly involved with these signficant LRT Project consultations. We are an integrated unit and have unparralled, collective experience in strategically planning and implementing LRT communication and consultation programs. The trust and respect that we have developed within RTG is exceptional, enabling us to work together though specific LRT design and construction challenges. RTG also attracts high-calibre, local communicators who we align with our senior management so key design and construction decisions are considered with a solid understanding of the community and political implications. Communications must always be "out front and ahead" of each Project stage, and we know precisely how our collaboration helps to maximize success.

Availability of Design and Construction Staff

RTG will make senior design and construction technical leads available for all large format public consultation meeting, with an appropriate level of attendance needed for the event based upon technical content and format of the meeting (see **Table 5.7-1** for types of meetings). Technical staff will lead the consultations that are technical in nature, including Special Interest Group meeting with the Disabled Community where technical staff need to be on hand. In general RTG will provide the resources needed to get the job done, but with an understanding that the technical team must be somewhat protected to ensure their focus in on executing the project. Striking the right balance varies from project to project, and as part of the Consultation Plans Development it is assumed RTG and the City will arrive at an appropriate agreement.

The RTG team has decades of experience planning and delivering timely and transparent consultation programs and we understand the consequences of decisions that do not incorporate input at key decision points. RTG has a host of 'LRT lessons learned' that we will apply to minimze the implications of the OLRT Project. Our breadth and depth of rapid transit communication and consultation expertise sets us apart due to our commitment to excellence, our applied expertise, and our technical understanding.

5.8 OUTPUT SPECIFICATIONS ASSUMPTIONS AND VARIANCE ANALYSIS



RIDEAU TRANSIT GROUP

5.8 SELF-REPORTING OUTPUT SPECIFICATIONS CHECKLIST

Item	PA Schedule 15 Reference Section	Specific Requirement	Assumption/Rationale for Variance
System-wide			
1	15-1, Reference Documents in Schedule 15	Canadian Transport Agency Code of Practice	It is our understanding that the requirements under Canadian Transport Agency Code of Practice are more suited to heavy rail applications. Given the late release of this requirement, RTG has not had the opportunity to fully understand the compliance conditions. Notwithstanding, RTG intends to work with the Sponsors and the Canadian Transit Agency to tailor the requirements to LRT applications with respect to the OLRT project.
Guideway and Trackwork			
2	15-2 Part 2 Article 2 Subsection 2.1 (a) (i)	The horizontal Track Alignment shall be designed in accordance with the requirements of Schedule 15 – Output Specifications, and shall be such that all of the Works is contained within the OLRT Lands.	At Lebreton and Blair, optimization has led to short portions of the alignment to encroach outside the LRT Lands.
3	15-2 Part 2 Article 2 Subsection 2.3 (d)	A minimum tangent length of 20m shall be inserted between the back to back switch points where the turnout arrangement may entail a reverse movement through turnouts.	This is currently not met at the future pocket track east of Hurdman due to geometric constraints. Will be revisited during detailed design
4	15-2 Part 2 Article 3 Subsection 3.1 (a) (i)	The Design and Construction of trackwork shall be in accordance with the criteria contained in this Article, and all standards, regulations, policies, Applicable Law, guidelines or practices applicable to the Project, including but not limited to each of	The design and construction of the trackwork will comply with all criteria relevant to the OLRT project

Item	PA Schedule 15 Reference Section	Specific Requirement	Assumption/Rationale for Variance
		the following Reference Documents. If the event of a conflict between the criteria, commitments or requirements contained within one document when compared with another, the more stringent shall apply: A. Requirements of this Article; B. AREMA Track Standards, or equivalent; and C. The criteria in TCRP Report 57.	
5	15-2 Part 2 Article 3 Subsection 3.4 (d) (iv) B.	Restrain the rail movement during rail break incidents limiting the rail break gap to 50mm;	Difficult to achieve given the severe temperature range in the Ottawa Region. Propose a maximum rail gap of 100 mm.
6	15-2 Part 6 Article 6 Subsection 6.6 (b) (i) A.	Provide minimum #6 turnouts within the yard	Providing some #4 switches in less travelled areas
Above-Ground Stations			
7	15-2 Part 1 Article 17 Subsection 17.5 (a) (iv) B. iii.	Where a MUP is adjacent to an existing or a proposed vertical constructed surface or element such as a building, guardrail, retaining wall, fence, etc., a 0.5 m "buffer" space shall be provided from the existing constructed surface in addition to the width of the MUP.	In some places, existing clearance is inadequate to accommodate a buffer space
Maintenance and Storage Facility			
8	15-2 Part 6 Article 1 Subsection 1.3 (a) (vii)	Management shall, to the fullest extent possible, be positioned with a view of maintenance and Equipment operations;	This requirement has not been incorporated in the RTG design for the following reasons: -The maintenance and equipment operations must be conducted in controlled environments, as such having excessive sky lights could affect the HVAC and the lighting of the area -In our experience, having full views of the maintenance and equipment operations area could create a hostile environment between operations staff and management as the action of having constant supervision could be perceived negatively by staff.

Item	PA Schedule 15 Reference Section	Specific Requirement	Assumption/Rationale for Variance
Tunnel and Underground Stations			
9	15-2 Part 1 Article 20 Subsection 20.4 (a) (i)	Adjacent Structure Verification Study: A. Confirm information related to Existing Adjacent Structure locations, dimensions, elevations, foundations, structural details, materials, and other information necessary to complete a deformation analysis of the Structures. Perform field surveys, utility locates, and foundation test pits as needed.	It may be difficult to confirm information on adjacent structures based on available information and site inspection; further dialogue with adjacent property owners would be necessary and can be coordinated as part of Consultation Plan
10	15-2 Part 5 Article 2 Subsection 2.6 (c)(ii) A.	Roof Design features shall include, but are not limited to the following: A. Skylights to allow natural daylight to reach the Platform surface.	The skylight feature does not provide the intended purpose of additional light to the platform in the underground stations, especially as stations are located under the street right-of-way. Given the open nature of the RTG station designs, this feature has been included in selected above-ground stations but RTG believes it is not applicable to the underground stations.
Systems Design (excluding Vehicles which is in Cutsheet 5.4.1.F 'Vehicle Compliance Matrix'			
11	Schedule 15-2 Part 4 Article 2 Subsection 2.1 (a)	The Traction Power supply system shall consist of a network of TPSS and all Equipment between the interface point with HOL and the interface point with the catenary and the negative return systems. This section provides the performance objectives for the Traction Power system. The Traction Power system shall be designed to be an integrated system for supplying power to the Vehicles, switch heaters, and related equipment in order to meet the OLRT Project Operational Performance Requirements provided in Part 1 Article 2 – Operational Performance Requirements. These criteria govern the Design, performance, and installation requirements of the Traction Power. The system shall provide safe, efficient and continuous operation of the LRT System in all operational and environmental conditions. The Traction Power system and associated components shall perform to the environmental characteristics defined in Schedule 15-2 Part 1 Article 4. In areas where the Traction Power equipment presents high risk of visual intrusion	In order to ensure switch performance in Ottawa's cold winters RTG is providing switch heater/blowers that require AC power which will be provided by a separate panel rather than the DC powered OCS.

Item	PA Schedule 15 Reference Section	Specific Requirement	Assumption/Rationale for Variance
		Project Co shall provide design enhancements to minimise or mitigate visual impact. In all other areas, the equipment shall be of a style and appearance similar to that used by comparable transit systems.	
12	15-2 Part 4 Article 3 Subsection 3.8 (c) (ii)	The maximum allowed weight deviation supported by each truck shall be 910kg.	Compliant with respect to the maximum deviation between a single truck load and the average truck load in normal operating conditions (3.33 pass/m²). But this requirement appears to be in contradiction with requirement 3.8 c (ii) and needs discussion during Preferred Proponent. Any deviation from this requirement would not affect the CITADIS vehicle or system performance, but needs to be confirmed during detailed design.
13	15-2 Part 4 Article 3 Subsection 5.3 (b) (iii)	The ATS workstations at the TSCC shall have display screens that allow TSCC personnel to view the entire line and all the Trains (identified by lead car number), interlockings and switch positions as well as Equipment warnings, alarms, temporary speed restriction zones and work zones. GUI controls shall be provided to allow the TSCC personnel to control interlockings and switches, to clear, cancel and fleet signals, to turn switch point heaters on and off, to stop and release Trains and to transfer interlockings and the entire line between automatic and manual operation.	The RTG design solution has the switch heaters being controlled by the SCADA not the ATS
14	15-2 Part 4, Article 5, Subsection 5.3 (f) (xiii)	Four (4) hour battery backup shall be provided to power all signal and CBTC systems including fixed block detection and switch operation.	2 hours capacity will be provided by UPS. Remaining capacity provided via generator hookup or dual power feed.
15	15-2 Part 4, Article 5, Subsection 5.3 (h) (i)	Wayside signals shall be provided only at MSF and mainline interlockings.	RTG's proposed UTO Yard Is based on the proven Canada Line and Vancouver SkyTrain yards implemented with the Thales CBTC system and therefore does not require track circuits and signals in the portion of the yard where OC Transpo drivers do not operate.