MORRISON HERSHFIELD

REPORT

Ottawa Public Library – Library Archives Canada Joint Facility LRT Proximity Study

Ottawa, Ontario

Presented to:

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1. Introduction

A Proximity Study of the new Ottawa Public Library – Library Archives Canada Joint Facility (OPL-LAC) to the LRT is required to examine and assess the following:

- The manner in which development has been designed to support the transit infrastructure and support the realization of transit focused development
- The risk of structural settlement and/or damage to Confederation Line facilities;
- The risk of liability/litigation from damage to Confederation Line facilities;
- The potential impact on access to Confederation Line facilities for future maintenance of Confederation Line assets;
- The risk of operational impacts resulting from construction;
- Protection of current and future Confederation Line infrastructure needs, including: fire ventilation, station ventilation, additional exits, accessibility for persons with disabilities, and other operational requirements; and
- The risk of encroaching on a location required for future Confederation Line works or operational requirements.

The LRT Impact Study is important to ensuring that the impacts from the tunnel are mitigated and included in the site and building design for the new Central Ottawa Public Library. According to the guidelines, the scope of the Proximity Study varies depending on the nature of the project, and the vertical and horizontal spatial proximity to the Confederation Line's alignment. Some requirements of the Proximity Study may overlap with the requirements of other studies for a development application. Where this is the case, the applicant is to ensure that all studies are coordinated and that the relevant study conclusions are properly articulated, and cited, in the Proximity Study.

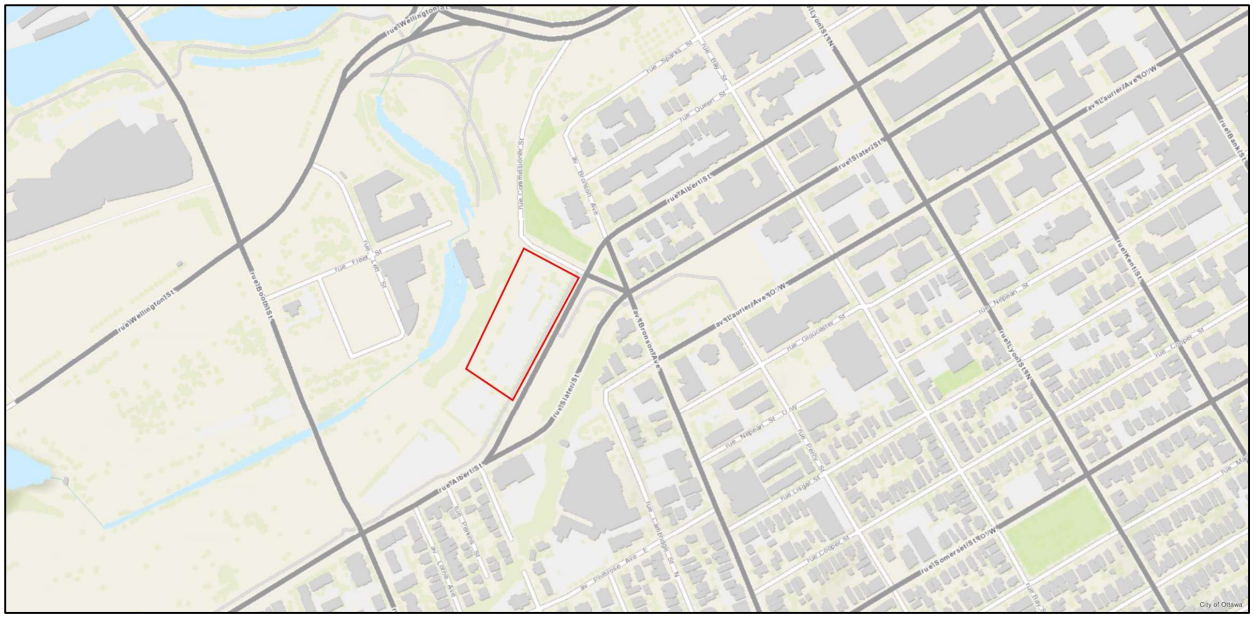
2. OPL-LAC Site Development

The proposed OPL-LAC Joint Facility is a 5-storey mixed-use commercial building located at 555 Albert Street. Refer to Location plan **Figure 1**. The OPL-LAC will house in a shared facility, the new central Ottawa Public Library and the Library and Archives Canada's public services. The building will include two underground parking levels with access lanes and a loading dock area. The top of slab the slab of the lowest parking level (P2) is at an elevation of 58.5m above datum. The development will also include a mixed use landscaped area to the south of the proposed building and a landscaped berm on the west side of the building which will connect the proposed facility to future multi-use pathways running parallel to the Fleet Street Aqueduct.

The existing Confederation Line LRT tunnel runs parallel to the proposed building on the west extents of the site. The tunnel was constructed by a cut and cover method with a shored approach from Commissioner Street to the west portal, located just southwest of Brickhill Street. The bottom of the existing tunnel ranges from approximately 8m to 12m

below ground level, or 54.0m to 48.0m above datum. The tiebacks from the tunnel shoring pass through bedrock under the proposed library building.

Figure 1 - Key Plan



3. Construction Methodology and Impact Review

The following is a list of issues and requirements addressed in the proximity study for the Public Library development:

- A site plan of the development with the centerline or reference line of the Confederation Line structure and/or right-of-way located and the relevant distances between the Confederation Line and developer's structure shown clearly;
- Plan and cross-sections of the development locating the Confederation Line structure/right-of-way and founding elevations relative to the development, including any underground storage tanks and associated piping;
- A geotechnical investigation report showing up-to-date geotechnical conditions at the site of the development. The geotechnical investigation shall be prepared in accordance with the Geotechnical Investigation and Reporting Guidelines for Development Applications in the City;
- Structural, foundation, excavation, and shoring drawings; and
- Acknowledgement that the potential for noise, vibration, electro-magnetic interference and stray current from Confederation Line operations have been considered in the design of the project, and appropriate mitigation measures applied.

The Public Library development is to be constructed within the Confederation Line Development Zone of Influence (as defined in Annex X of the Official Plan). Substantial integration and impact on Confederation Line structures and facilities is anticipated, therefore, the following items are required:

- A structural analysis or calculations of the effects of loadings, including construction loading, on the Confederation Line structure, and demonstrating that the Confederation Line structure will not be adversely affected by the development, including solutions to mitigate any impact on the Confederation Line structure. The documentation must include identification of the “affected” Confederation Line structural units;

- Documentation showing that the excavation support system and permanent structure adjacent to the Confederation Line property are designated for at-rest earth pressures. Unless otherwise proven through mutually accepted geotechnical analysis, At-rest pressures shall be determined using a pressure coefficient of 0.5 (K0 = 0.5);

- Structural drawings, including caisson/foundation plans, sections and details, floor plans, column and wall schedules and loads on foundation for the development. The relationship of the development to the Confederation Line structure should be depicted in both plan and section;

- Shoring design criteria and description of excavation and shoring method;

- Ground water control plan, including the determination of the short-term (during construction) and long-term effects of dewatering on the Confederation Line structure, and provision of assurances that the influences of dewatering will have no impact on the Confederation Line structure;

- Identification of utility installations proposed through or adjacent to Confederation Line property. Where known, show Confederation Line utility connections where associated municipal connections are to be modified;

- Identification of the exhaust air quality and relationship of air in-take/discharge to the Confederation Line at-grade vent shaft openings and station entrance openings. Confederation Line shaft openings would typically be located a minimum of 12 meters from entrances or exits because vent shaft openings are used as emergency ventilation in-take or exhaust vents for high temperature smoke in the event of a fire. The project must ensure that air intakes, exhausts, entrances or other similar features within the development are not located within 12 meters of the Confederation Line’s ventilation structures.

- Proposal for a pre-construction condition survey of the Confederation Line structure, including a survey to confirm locations of existing walls and foundations; and

- Monitoring Plan for movement of the shoring and Confederation Line structure prior to and during construction of the development, including an Action Protocol.

The above items have been addressed by a multi-disciplinary team through the design process of the Public Library, and are summarized in **Section 4**.

3.1 Vibration and Settlement Monitoring Plan

One of the main items of concern is the vibration and movement of the LRT Tunnel during construction. A complete vibration and settlement monitoring plan is to be developed prior to any construction activity.

Golder Associates has developed Settlement and Vibration Monitoring Specifications for the proposed OPL-LAC Joint Facility dated July 2020. The specifications lay out the requirements for the settlement and vibration monitoring of the LRT tunnel to minimize the impact on the structure throughout construction. A summary of the specifications in regards to the LRT tunnel are in the following sections. The complete report is provided in **Appendix A.**

Monitoring of LRT Tunnel Movements

The intent of the monitoring plan is to monitor any movements of the LRT tunnel during mass excavation and the other stages of construction of the central library building. Monitoring movements will be established by three sets of monitors on the LRT tunnel wall in two locations. Baseline conditions will be defined prior to construction and readings will continue to be taken on a daily basis during any shoring and excavation work and twice per week for all other phases of construction until mass excavation is complete.

Monitoring shall be performed to an accuracy within 1mm and will be reported to the Contract Administrator daily. The maximum allowable movement of the LRT tunnel is 5mm. If, at any time, movement of the OLRT tunnel is recorded, the Contractor is to inform the Contract Administrator immediately. If movement of the tunnel exceeds the allowable tolerance, the Contractor is required to stop all work immediately, and inform the Contract Administrator.

Vibration Monitoring of LRT Tunnel

Vibration monitoring of the tunnel is recommended to take place until the mass excavation, foundation, and foundation wall construction and backfill is complete. Prior to the commencement of construction work, vibration monitoring equipment will be installed at the closest accessible point in the LRT tunnel to the proposed library structure. The vibration monitoring equipment shall remain in place for 48 hours to establish baseline readings and continue to remain in place during mass excavation, foundation construction, foundation wall construction, and backfill.

Vibration monitoring shall be carried out with a seismograph capable of monitoring on a continuous basis and providing peak levels at regular intervals (no greater than 5 minutes) as well as full waveform data. The equipment shall be capable of measuring vibration intensities up to 254 mm/s at a frequency response of 2 to 250 Hz. The Contractor shall retain a professional engineer licensed to practice engineering in the Province of Ontario to undertake the vibration monitoring. **Table 1** below outlines the vibration limits on the LRT tunnel.

Table 1 - Maximum Allowable Peak Particle Velocity (PPV) on the LRT Tunnel (Golder, 2020)

Frequency Range	Peak Particle Velocity (PPV) Vibration Limits (millimeters/second)
< 40	20 (sliding scale)
> 40	50

Vibration Monitoring Plan

Golder has outlined the requirements for the vibration monitoring plan. The contractor is responsible for submitting a complete monitoring plan for review and approval prior to start of construction. This plan will be required to include the following:

- Proposed excavation methodology and equipment
- Proposed vibration monitoring equipment and instrumentation
- Proposed locations for vibration monitoring equipment/instrumentation
- Proposed vibration monitoring recording and warning systems.
- Proposed monitoring triggers, precautionary actions and measures required to adjust construction methods if readings show vibrations approaching the maximum allowable levels.
- Proposed adjustments to construction methods if readings show vibrations exceed maximum levels.

In addition, weekly vibration monitoring summary reports will be submitted and will contain the following:

- A written description of the construction and monitoring activities completed that week and a summary of the measured vibrations.
- The date(s) and time(s) of all construction and monitoring activities carried out.
- Changes to vibration monitoring locations to reflect construction progress.
- A statement by the Vibration Monitoring Specialist Engineer that the results of the monitoring show that measured vibrations are below the specified vibration limits and construction practices as established on site can continue.

4. Proximity Requirement Responses

This section provides a summary of the responses to the required items covered by the Confederation Line Proximity Study - Level 2 study. **Table 1** provides the applicable requirements for the Level 2 study and the response location for each item.

Table 1 – List of Confederation Line Proximity Study Requirements and Responses

Level 2 Project Issue	Response
A site plan of the development with the centerline or reference line of the Confederation Line structure and/or right-of-way located and the relevant	Presented in **Appendix B**

distances between the Confederation Line and developer's structure shown clearly	
Plan and cross-sections of the development locating the Confederation Line structure/right-of-way and founding elevations relative to the development, including any underground storage tanks and associated piping	Presented in **Appendix B**
Structural, foundation, excavation, and shoring drawings	Based on the structural report on foundation interaction with existing tunnels prepared by Fast + Epp, dated July 2020, the design will be a piled foundation with the exception of the north side of the site where the footings will be founded directly on the limestone bedrock. The structural report outlines that being sufficiently distant from the LRT tunnel and being supported on piles, the proposed building will not impart any load on the LRT tunnel The complete structural and foundation design drawings are not available at the time of the preparation of this study. Excavation and shoring drawings are the responsibility of the contractor and will be presented once available. The complete report and a draft foundation plan can be found in **Appendix C**
Acknowledgement that the potential for noise, vibration, electro-magnetic interference and stray current from Confederation Line operations have been considered in the design of the project, and appropriate mitigation measures applied	Detailed Vibration and Settlement Monitoring Specifications have been developed by Golder Associates, date July 2020. Refer to **Appendix A.**
A structural analysis or calculations of the effects of loadings, including construction loading, on the Confederation Line structure, and demonstrating that the Confederation Line structure will not be adversely affected by the development, including solutions to mitigate any impact on the Confederation Line structure. The documentation must include identification of the "affected" Confederation Line structural units	The proposed building will not impose any loads on the LRT tunnel as a result of being sufficiently distant from the LRT tunnel and being supported on piles. Reference can be made to the structural report prepared on June 4, 2020 by Fast + Epp titled Foundation Interaction with Existing Tunnels presented in **Appendix C** The complete structural analysis and drawings will be submitted once they are finalized.
Documentation showing that the excavation support system and permanent structure adjacent to the Confederation Line property are designated for at-rest earth pressures. Unless otherwise proven through mutually accepted geotechnical analysis, At-	Temporary shoring system will be designed to at-rest earth pressures as required by the Geotechnical Report. The contactor is fully responsible for the design and performance of the temporary shoring system. Temporary shoring system design

rest pressures shall be determined using a pressure coefficient of 0.5 (K0 = 0.5)	recommendations will be provided by the Geotechnical Engineer and presented once available. Temporary excavation support system drawings will be submitted once they have been finalized by the Contractor.
Structural drawings, including caisson/foundation plans, sections and details, floor plans, column and wall schedules and loads on foundation for the development. The relationship of the development to the Confederation Line structure should be depicted in both plan and section	Not available at time of submission of the Impact Study. The proposed building will not impose any loads on the LRT tunnel as a result of being sufficiently distant from the LRT tunnel and being supported on piles. Refer to the structural report prepared on June 4, 2020 by Fast + Epp titled Foundation Interaction with Existing Tunnels presented in **Appendix C**. **Note: Complete structural design drawings will be available and referred to once they are finalized.**
Shoring design criteria and description of excavation and shoring method	Shoring is planned to be along Albert Street, along the proposed hydro vault adjacent to Commissioner Street, and along the Bell /Telus/ Rogers compound. The temporary shoring design criteria are provided in the Geotechnical Report prepared by Golder Associates. A pre-drilled soldier pile and timber lagging system has been proposed by the contractor in order to eliminate the vibrations associated with pile driving. The Contractor will drill a liner, set a pile inside the liner, pour the toe of the pile and utilize a lean concrete pour to the top. Lean concrete (low MPa) will be poured to ensure no degradation or settlement occurs around the soils. Wood lagging will be placed with a horizontal 'dam' section of lagging to prevent soil settlement along the shoring as excavation proceeds. Two to three layers of whalers will be installed, allowing the subsequent contractor to destress the system. Tiebacks will be required below Albert Street. The Contractor is confident this system will fit within the dimensional constraints of the adjacent utilities and that tiebacks will not interfere with the utilities. Little to no vibration is expected with this type of shoring system. Refer to the Geotechnical Investigation report no. 19131600, Prepared by Golder Associates dated June 2020 for the complete shoring design criteria. Temporary excavation support system drawings will

	be submitted once they have been finalized by the Contractor.
Ground water control plan, including the determination of the short-term (during construction) and long-term effects of dewatering on the Confederation Line structure, and provision of assurances that the influences of dewatering will have no impact on the Confederation Line structure	**Note: Groundwater control plan for the construction will be referenced once completed** Geotechnical Investigation report no. 19131600, Prepared by Golder Associates dated June 2020.
Identification of utility installations proposed through or adjacent to Confederation Line property. Where known, show Confederation Line utility connections where associated municipal connections are to be modified	No utility installations are expected within the Confederation Line property as a result of the development. New utilities are required to be installed to service the proposed building. All new service connections for domestic water, sanitary, and storm service utilities will be located on the south-east side of the building and connect to existing utilities on Albert St. An existing 35mm gas main located along the west property line will be relocated by others to facilitate the construction of the proposed building.
Identification of the exhaust air quality and relationship of air in-take/discharge to the Confederation Line at-grade vent shaft openings and station entrance openings. (Confederation Line shaft openings would typically be located a minimum of 12 meters from entrances or exits because vent shaft openings are used as emergency ventilation in-take or exhaust vents for high temperature smoke in the event of a fire.)	The exhaust air quality and air in-take/discharge was identified and considered in the mechanical and code consultants design. It was confirmed that simultaneous fire events in the OPL-LAC Facility and the LRT Tunnel do not need to be considered. If the LRT tunnel smoke ventilation system is operating, and smoke is entrained into the Ottawa Public Library HVAC systems, those systems will automatically shut down based on feedback from in-duct sensors until the smoke is cleared. **Note: A letter from Arup will provided confirming this requirement is met.**
Proposal for a pre-construction condition survey of the Confederation Line structure, including a survey to confirm locations of existing walls and foundations	A thorough pre-construction survey of the LRT tunnel will be completed by the contractor. Details of the proposal are currently unknown and will be submitted once finalized by the contractor.
Monitoring Plan for movement of the shoring and Confederation Line structure prior to and during construction of the development, including an Action Protocol	Detailed Vibration and Settlement Monitoring Specifications have been developed by Golder Associates, date July 2020. Details of the monitoring plan will be developed by the contractor to meet the specifications. See **Appendix A**.
Impact of landscaping berm encroachment over the Confederation Line Tunnel	The Engineer on Record (EOR) for the cut-and-cover section of the tunnel at the west portal has advised

	that the tunnel is designed for 16.8 kPa unfactored service load (equivalent to 800mm of 21kN/m3 fill). **Note: A letter from DSA will be provided confirming this requirement is met.**

5. Closure

We trust that this report is sufficient for your current requirements. Please contact the undersigned with any questions or clarifications.

Sincerely,

Morrison Hershfield Limited

James Fookes, P.Eng.

Senior Municipal Engineer

Noah Chauvin, BASc

Municipal Designer

APPENDIX A: Settlement and Vibration Monitoring Specifications, Golder Associates

Part 1 GENERAL

In general, the Contractor shall be responsible for the protection and monitoring of all existing services and utilities across and adjacent to the proposed construction works.

However, the Contractor shall pay particular attention to protecting the existing high pressure watermain (HPWM), the existing hydro duct, the Combined Sewage Storage Tunnel (CSST), the interceptor outfall sewer (IOS) tunnel, and the Ottawa Light Rail Transit (OLRT) tunnel which will remain in service at all times during the work.

Part 2 SCOPE OF WORK

2.1 Monitoring of Watermain Movements

The Contractor must take all precautions necessary to minimize settlement or movement of the high pressure watermain during both working and non-working periods.

The top center of the watermain will be hydro-vacced at four locations; at the center of the alignment parallel to the proposed excavation on Albert Street, and 10m on either side of this central location on Albert Street, and at the closest location on Commissioner Street or as directed by the Consultant. The location of the monitoring locations may be moved prior to installation as directed by the Consultant based on ground conditions encountered. These daylight holes (monitoring locations) will be used to measure pipe elevations continuously throughout the construction work as described below. The hydro-vac holes will need to be cased (prepared and maintained) to prevent collapse of the hole and an insulated temporary cap shall be fitted on the top of the holes for safety and to prevent water and / or debris falling into the hole.

Baseline elevations of the HPWM survey monuments shall be established by taking three complete sets of readings, on three separate days, prior to construction. The average of the three readings will be used as the baseline measurement all for subsequent readings.

Throughout the duration of shoring, excavation, and foundation and basement wall (to finished grade) construction work within 20 m of the watermain, movement readings are to be taken twice per shift. Movement readings should be taken once per shift at all other times during construction work until completion of the mass excavation, shoring, foundation construction, and backfill of perimeter foundations. Measurement of movement readings shall be performed to an accuracy of 1 mm. Movement readings are to be reported to the Consultant daily. If, at any time, movement of the watermain is recorded, the Contractor is to inform the Consultant immediately.

The maximum allowable settlement/heave of the watermain is 5 mm. If settlement/heave of the watermain exceeds this allowable tolerance, the Contractor is required to stop all work immediately and inform the Consultant. The Contractor shall then be required to prepare a new work plan detailing how the revised work will prevent further any movement of the watermain.

If, in the opinion of the Consultant, the degree of movement presents a concern to the integrity of the watermain, the Consultant reserves the right to stop the progress of the work and request additional information from the Contractor in terms of how the site work will be changed to stop the unacceptable excessive movement.

The monitoring shall continue until the mass excavation, shoring, foundation construction, basement wall construction (to finished grade) and backfill (including compaction) is completed, and shall then also be carried out monthly for 2 months following the completion of the work above.

After that time, provided there is no on-going movement (in which case the monitoring could need to be extended), the holes/casings are to be filled/decommissioned and the pavement surface reinstated.

2.2 Vibration Monitoring of Watermains

Vibration monitoring shall be carried out with an approved seismograph capable of monitoring on a continuous basis and providing peak levels at regular intervals (no greater than 5 minutes) as well as full waveform data. The proposed equipment must meet the requirements outlined in Section 2.8.

Prior to the commencement of construction work within 20 metres of the watermain, the HPWM pipes are to be exposed with the use of hydro-vac equipment. Once the HPWM pipe is exposed, vibration monitoring equipment shall be installed immediately and remain in place for 48 hours to establish baseline readings.

The seismic equipment is to be encased to prevent collapse of the hole with an insulated cap fitted on top to prevent water or debris from falling into the casing.

The seismic equipment is to remain in place until the mass excavation, foundation, and perimeter basement wall (to finished grade) construction and backfill and compaction is completed.

The maximum allowable Peak Particle Velocity (PPV) on the HPWM is as follows:

Frequency Range	**Peak Particle Velocity (PPV) Vibration Limits (millimetres/second)**
< 10	5
10 to 40	5 to 50 (sliding scale)
> 40	50

The Contractor shall retain a licensed and experienced professional engineer licensed to practice engineering in the Province of Ontario to undertake the vibration monitoring of ground (pipe) vibrations during mass excavation, shoring, foundation and foundation wall construction, and backfilling.

Vibration Monitoring Reports shall be prepared on a daily basis during mass excavation, shoring, foundation and basement wall (to finished grade) construction, and backfilling (including compaction) construction activities and must be submitted to the Consultant. Vibration Monitoring Reports shall be prepared twice weekly during other construction activities until the basement wall (to finished grade) construction and backfill is completed.

Upon construction completion, a Final Vibrations Report must be submitted to the Consultant. The final monitoring report shall be signed and sealed by a qualified Professional Engineer licensed to practice in the Province of Ontario. The report shall clearly summarize the monitoring method implemented, the duration and vibration results, with a recommendation as to the meaning of these results in relation to the monitored infrastructure.

2.3 Monitoring of Hydro Duct Movements

The Contractor must take all precautions necessary to minimize settlement of the hydro duct during both working and non-working periods.

The hydro duct along the length of the Albert Street site will be exposed as part of the proposed shoring works along the exposed section or as directed by the Consultant. . Survey monitors should be affixed to the length of the hydro duct at 10 metre intervals.

Baseline elevations of the survey monuments shall be established by taking three complete sets of readings in advance of any construction, completed on three separate days. The average of the three readings will be used as the baseline for subsequent readings.

Throughout the duration of shoring, excavation, and foundation and basement wall (to finished grade) construction work within 20 m of the hydro duct, movement readings are to be taken twice per shift. Movement readings should be taken once per shift at all other times during construction work until completion of the basement wall (to finished grade) and backfill (including compaction). Monitoring shall be performed to an accuracy of 1 mm. Movement readings are to be reported to the Consultant daily. If, at any time, any movement of the hydro duct is recorded, the Contractor is to inform the Consultant immediately.

The maximum allowable settlement/heave of the hydro duct is 15 mm. If settlement/heave of the hydro duct exceeds this allowable tolerance, the Contractor is required to stop all work immediately and inform the Consultant. The Contractor shall then prepare a new work plan detailing how the revised work will prevent any further movement of the hydro duct.

If, in the opinion of the Consultant or the utility owner, the degree of movement presents a concern to the integrity of the hydro duct, the Consultant reserves the right to stop the progress of the work and request additional information from the Contractor in terms of how the operation will be changed to reduce the unacceptable movements.

The monitoring shall continue until the mass excavation, foundation, and basement wall (to finished grade) construction and backfill is completed, and shall then also be carried out 1 and 2 months later to document any subsequent movement.

After that time, provided there is no on-going movement (in which case the monitoring could need to be extended), the exposed hydro duct is to be reinstated.

2.4 Vibration Monitoring of Hydro Duct

Vibration monitoring shall be carried out with an approved seismograph capable of monitoring on a continuous basis and providing peak levels at regular intervals (no greater than 5 minutes) as well as full waveform data. The proposed equipment must meet the requirements outlined in Section 2.8.

The hydro duct along the length of the Albert Street site will be exposed as part of the proposed shoring works. Once the hydro duct is exposed, vibration monitoring equipment shall be installed immediately at two locations spaced 40 m apart and remain in place for 48 hours to establish baseline readings.

The seismic equipment is to be encased to prevent water or debris from falling into the casing.

The seismic equipment is to remain in place until the mass excavation, foundation, and basement wall (to finished grade) construction and backfill is completed.

The maximum allowable Peak Particle Velocity (PPV) on the hydro duct is as follows:

Frequency Range	Peak Particle Velocity (PPV) Vibration Limits (millimetres/second)
< 10	5
10 to 40	5 to 50 (sliding scale)
> 40	50

The Contractor shall retain a licensed and experienced professional engineer licensed to practice engineering in the Province of Ontario to undertake the vibration monitoring of ground (pipe) vibrations during mass excavation and construction of the foundations and basement walls (to finished grade).

Vibration Monitoring Reports shall be prepared on a daily basis during mass excavation and foundation construction activities and must be submitted to the Contract Administrator. Vibration Monitoring Reports shall be prepared twice weekly during other construction activities until the basement wall (to finished grade) construction and backfill is completed.

Upon construction completion, a Final Vibrations Report must be submitted to the Contract Administrator. The final monitoring report shall be signed and sealed by a qualified Professional Engineer licensed to practice in the Province of Ontario. The report shall clearly summarize the monitoring method implemented, the duration and vibration results, with a recommendation as to the meaning of these results in relation to the monitored infrastructure.

2.5 Monitoring of OLRT Tunnel Movements

The Contractor must take all precautions necessary to minimize settlement or movement of the OLRT tunnel walls and this will include both working and non-working periods.

Within the OLRT tunnel, one set of three monitors should be installed at the closest point to the proposed works, and two sets of three monitors should be installed at 10 metres offset from this location. The monitors should be placed at the top, center, and base of the tunnel wall on the side closest to the proposed excavation to monitor for potential differential movement. All elevations shall be monitored relative to a non-settling benchmark within the tunnel (e.g., a station located outside the influence of the project built on piles or bedrock, or an existing maintenance structure not impacted by construction). These benchmark monument(s) shall clearly be identified in the Contractor's Settlement Monitoring Plan, which shall also reference which buildings are monitored relative to which benchmark. Alternatively, a tunnel profile monitoring system may be considered and installed at the closest point to the excavation. The proposed tunnel monitoring system must be reviewed and approved by the Consultant prior to implementation.

The tunnel wall shall also be monitored for total, lateral or shear movements of existing cracks, features, etc. that are identified during the pre construction survey using pins, glass plate telltales, and/or movement telltales (to be identified in the Settlement Monitoring Plan). Access must be confirmed and coordinated with the OLRT access management team for the OLRT tunnel. It is anticipated that access will be restricted to overnight during periods where trains are not running, however access should be confirmed with the OLRT access management team prior to installation of the movement monitoring system.

Baseline elevations of the survey monuments shall be established by taking three complete sets of readings in advance of any construction, completed on three separate days. The average of the three readings will be used as the baseline for subsequent readings.

Throughout the duration of shoring, excavation, and foundation and basement wall (to finished grade) construction work within 30 metres of the OLRT tunnel, movement readings are to be taken once per shift. Movement readings shall be taken twice weekly at all other times during construction work until completion of the mass excavation, shoring, foundation and basement wall (to finished grade) construction, and backfill (including compaction). Monitoring shall be performed to an accuracy of 1 mm. Movement readings are to be reported to the Consultant daily. If, at any time, movement of the OLRT tunnel is recorded, the Contractor is to inform the Consultant immediately.

The maximum allowable movement of the OLRT tunnel wall is 5 mm. If movement of the tunnel wall exceeds this allowable tolerance, the Contractor is required to stop all work immediately and inform the Consultant. The Contractor shall then prepare a new work plan detailing how the revised work will prevent further movement of the tunnel wall.

If, in the opinion of the Consultant or the OLRT project team, the degree of movement presents a concern to the integrity of the OLRT tunnel, the Consultant reserves the right to stop the progress of the work and request additional information from the Contractor in terms of how the operation will be changed to reduce the unacceptable movements.

The monitoring shall continue until the mass excavation, shoring, foundation and basement wall (to finished grade) construction and backfill (including compaction) is completed, and shall then also be carried out 1 and 2 months later to document any subsequent movement.

2.6 Vibration Monitoring of OLRT, CSST and IOS

Vibration monitoring shall be carried out with an approved seismograph capable of monitoring on a continuous basis and providing peak levels at regular intervals (no greater than 5 minutes) as well as full waveform data. The proposed equipment must meet the requirements outlined in Section 2.8.

Prior to the commencement of construction work, vibration monitoring equipment shall be installed at the closest accessible points to the OLRT, and IOS tunnels. Access points must be confirmed and coordinated with the OLRT access management team for the OLRT tunnel, and City AMB for the IOS tunnel. It is understood that access to theseinfrastructure may be limited and access coordination with the above noted teams should be anticipated.

For vibration monitoring of the CSST, vibration monitors will be installed in boreholes adjacent to the CSST tunnel. The boreholes should be advanced into the bedrock to the depth of the CSST at 4 locations along the length of the CSST. The locations are to be reviewed and accepted by the CSST project team prior to installation of the instrumentation. The vibration monitors should be secured in the base of the borehole and the borehole should be cased to prevent surface water or debris from entering the hole.

The vibration monitoring equipment shall remain in place for 48 hours to establish baseline readings.

The seismic equipment is to be encased to prevent water or debris from falling into the casing.

The seismic equipment is to remain in place until the mass excavation, foundation, and basement wall (to finished grade) construction and backfill is completed.

The maximum allowable Peak Particle Velocity (PPV) on the OLRT, CSST and IOS is as follows:

Frequency Range	Peak Particle Velocity (PPV) Vibration Limits (millimetres/second)
< 40	20 (sliding scale)
> 40	50

The Contractor shall retain a licensed and experienced professional engineer licensed to practice engineering in the Province of Ontario to undertake the vibration monitoring of ground (pipe) vibrations during mass excavation and construction of the foundations and basement walls (to finished grade).

Vibration Monitoring Reports shall be prepared on a daily basis during mass excavation,shoring and foundation construction activities and must be submitted to the Consultant. Vibration Monitoring Reports shall be prepared twice weekly during other construction activities until the basement wall (to finished grade) construction and backfill is completed.

Upon construction completion, a Final Vibrations Report must be submitted to the Consultant. The final monitoring report shall be signed and sealed by a qualified Professional Engineer licensed to practice in the Province of Ontario. The report shall clearly summarize the monitoring method implemented, the duration and vibration results, with a recommendation as to the meaning of these results in relation to the monitored infrastructure.

2.7 Settlement Monitoring Plan

In advance of construction, the Contractor shall submit to the Consultant a detailed Settlement Monitoring Plan. This Plan shall include:

- A detailed pre-construction survey of structures and utilities in areas where settlement monitoring is required. Any existing interior/exterior structural deficiencies (such as cracks) in the structures shall be identified during this pre-construction survey as well as the methodology for how these will be monitored during construction.
- A description of the scope of the monitoring program and the methodology required to meet the plans objectives.
- Locations of settlement monitoring (with the types of survey monuments used for the settlement monitoring specified).
- Settlement monitoring benchmarks.
- Survey staff and equipment for settlement monitoring (with achievable tolerances).

Included in the Settlement Monitoring Plan shall be the Contractor's Contingency Plan which provides the mitigation and response plan for potential exceedances of the Review Limits assigned for total and differential settlement. The Contingency plan shall include how the Contractor will first address the exceedance (such as immediately stopping all settlement inductive work and increasing monitoring intervals) and then how they will alter their construction methodology to ensure that no further settlement beyond the limit occurs.

Once the plan has been implemented, the Contractor shall provide weekly monitoring Reports to the Consultant detailing settlement readings. The Consultant and Owner shall be notified immediately if limits are exceeded, and a report shall be provided immediately if limits are exceeded. Information required to be required in the Monitoring Reports shall include:

- A written description of the monitoring activities completed that week.
- The date(s) and time(s) of all monitoring activities carried out.
- Survey grade control elevations taken that week on the settlement monitoring points including an historical tabulation of all shots taken since the establishment of the points.

A statement indicating that the results of the monitoring show that the risks of settlement of adjacent structures are within acceptable tolerances and construction practices as established on site can continue.

2.8 Vibration Monitoring Plan

In advance of construction, the Contractor shall submit to the Contract Administrator a detailed Vibration Monitoring Plan. This shall include:

The vibration monitoring plan shall, at a minimum, include the following information:

- Proposed excavation methodology and equipment
- Proposed vibration monitoring equipment/instrumentation
- Proposed locations for vibration monitoring equipment/instrumentation
- Proposed vibration monitoring recording, reporting and warning systems.
- Proposed monitoring triggers, precautionary actions and measures required to adjust construction methods if readings show vibrations approaching the maximum allowable levels.
- Proposed adjustments to construction methods if readings show vibrations exceeding maximum levels.

Vibration equipment/instrumentation:

- Vibration monitoring shall be carried out with an Instantel Minimate Plus seismograph or an approved equivalent capable of monitoring on a continuous basis and providing peak levels at regular intervals (no greater than 5 minutes), as well as, full waveform data.
- The vibration monitoring equipment shall be capable of measuring vibration intensities up to 254 mm/s at a frequency response of 2 to 250 Hz.
- The vibration monitor shall be equipped with a real time warning system consisting of either a red flashing light and an air horn alert, with a remote warning also sent to the Owner, Consultant and Contractor by text message or e-mail when the threshold value is reached.

Weekly vibration monitoring summary reports:

- A written description of the monitoring activities completed that week and a summary of the measured vibrations.
- The date(s) and time(s) of all monitoring activities carried out.
- Changes to vibration monitoring locations to reflect construction progress.
- A statement by the Vibration Monitoring Specialist Engineer that the results of the monitoring show that measured vibrations are below the specified vibration limits and construction practices as established on site can continue.

As construction progresses and a suitable quantity of vibration monitoring data has been measured and analyzed, the Vibration Monitoring Specialist Engineer may formally recommend increasing the spacing between vibration monitoring points provided that the data shows measured vibrations to be well below the vibration limits specified and that ongoing construction activities will use the same equipment and methodology, will be further away from the existing infrastructure, and will be within similar subsurface material to that under which previous vibrations were measured.

Approval to increase the spacing between monitoring points will be at the sole discretion of the City and the Consultant.

PART 3 PENALTY FOR DAMAGE TO INFRASTRUCTURE

It is agreed by the parties to the Contract that in the event of infrastructure damage (i.e. leak and/or break) occurring during the duration of the Contract, damage and/or loss will be sustained by the Owner. The Consultant shall assess the Contractor a penalty of $50,000.00 for the first day or part thereof that the damage occurs, and a further penalty of $50,000.00 per day for each subsequent day or part thereof that any infrastructure is not operational and City of Ottawa or other utility owner crews are required onsite to carry out repairs. The Contractor will be responsible for the cost of the repairs to be completed by the City or utility owner, the cost of all traffic control operations performed by the Contractor and the City or utility owner, and the cost of the reinstatement of the damaged areas. The Consultant shall deduct penalty amounts from monies owing to the Contractor.

PART 4 MEASUREMENT FOR PAYMENT

Payment shall be as a lump sum, all inclusive, in accordance with the following payment schedule:

- 20% upon submission and acceptance of all specified pre-construction submissions and system installation testing and verification
- 70% pro-rated over the duration of the approved construction schedule
- 10% upon completion of the settlement and vibration monitoring programs, final reporting, and reinstatement at the settlement and vibration monitoring points to the satisfaction of the Contract Administrator.

Note that the monthly pro-rated payments will be withheld until such time as all weekly Summary Reports have been provided up to the cut-off date for the progress payment.

APPENDIX B: Impact Review Site Plan and Sections

OPL - LAC JOINT FACILITY
LRT IMPACT STUDY

SITE PLAN - PLAN VIEW

Alain C. Gonthier, P. Eng.	Paul Hussar
Director, Infrastructure Services	*Project Manager*

Ottawa

Contract No.	Drawing No.
202093300	

Sheet No. 1 of 2

Asset No.

Asset Group: ISD

Des: NC	Chk'd: EE
Dwn: NC	Chk'd: JF

Utility Circulation No.:

Construction Inspector:

Scale: 1:300

0m 5 10

NOTE:
The location of utilities is approximate only, the exact location should be determined by consulting the municipal authorities and utility companies concerned. The contractor shall prove the location of utilities and shall be responsible for adequate protection from damage.

MORRISON HERSHFIELD

REVISIONS	No.	Description	By	Date (dd/mm/yy)

D E F G H I J K L M

FUTURE MULTI USE PATHWAYS

LANDSCAPED BERM

LRT TUNNEL

LRT SHORING

PROPERTY LINE

ROOF OVERHANG

BUILDING FOUNDATION

BUILDING OUTLINE

OPL-LAC JOINT FACILITY
5 STORIES
FFE=66.50 m
USF=58.50 m

BUILDING FOUNDATION, TOP OF P1 ROOF SLAB=61.50

COMISSIONER STREET

HYDRO VAULT FOUNDATION OUTLINE

AT GRADE RETAINING WALL (REFER TO ARCHITECTURAL)

EXTENT OF BUILDING FOUNDATION, TOP OF P1 ROOF SLAB=64.50

ALBERT STREET

1050MM SANITARY SEWER

1800MM SANITARY SEWER

1350MM SANITARY SEWER

1200MM SANITARY SEWER

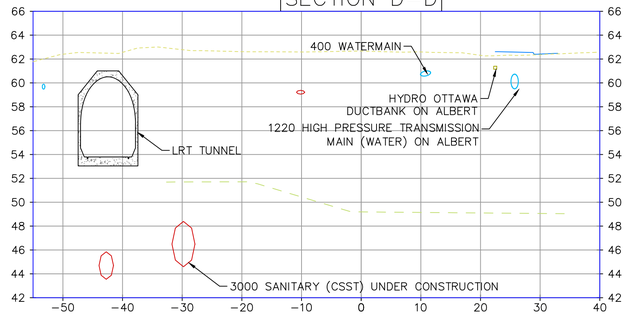
600MM HYDRO

400MM WATER

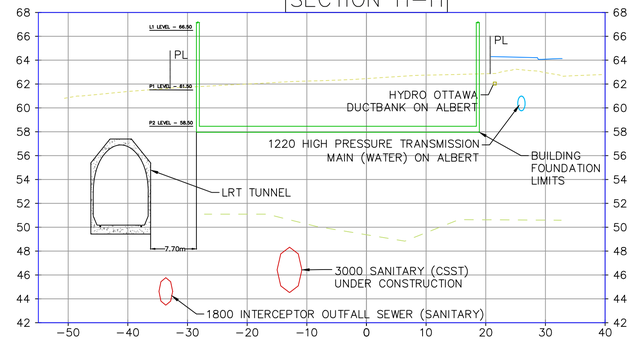
300MM WATER

PRELIMINARY ONLY
MORRISON HERSHFIELD LIMITED
NOT TO BE USED FOR CONSTRUCTION PURPOSES

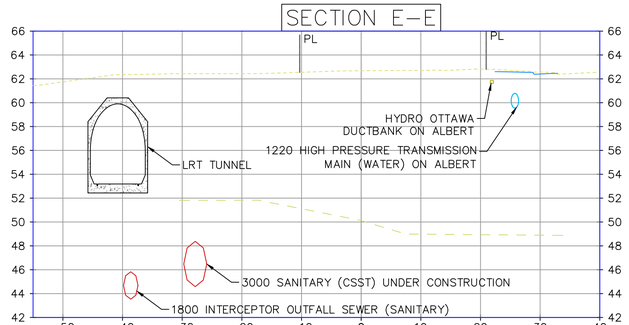
SECTION D–D



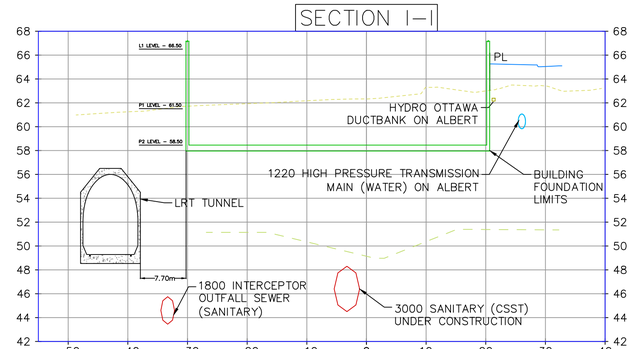
SECTION H–H



SECTION E–E



SECTION I–I



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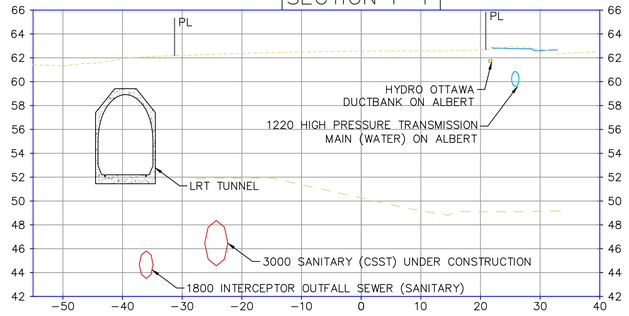

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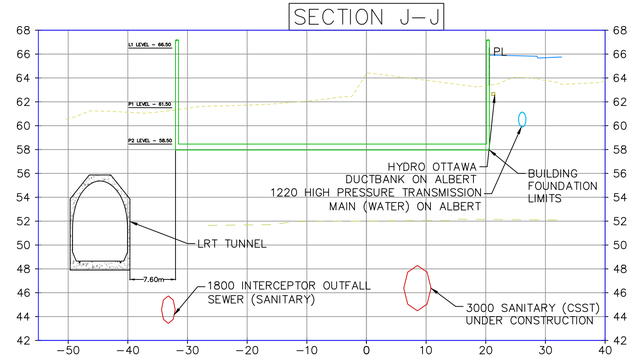
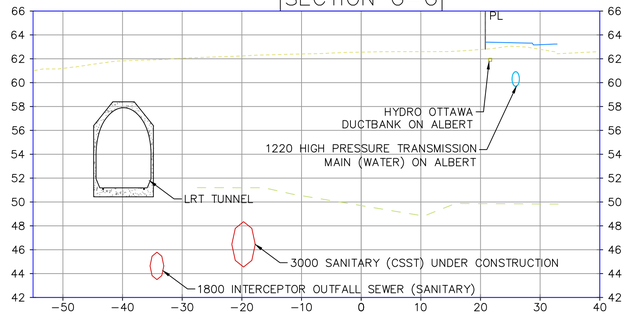
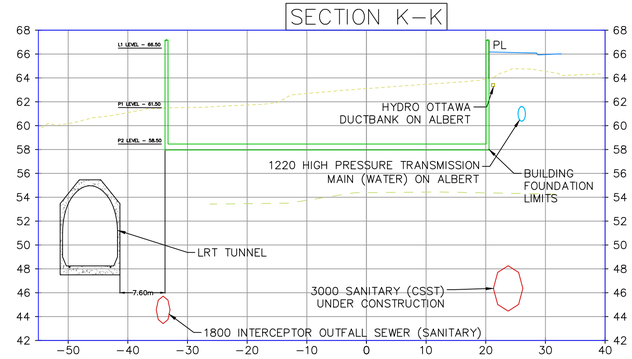


SECTION G–G



SECTION K–K



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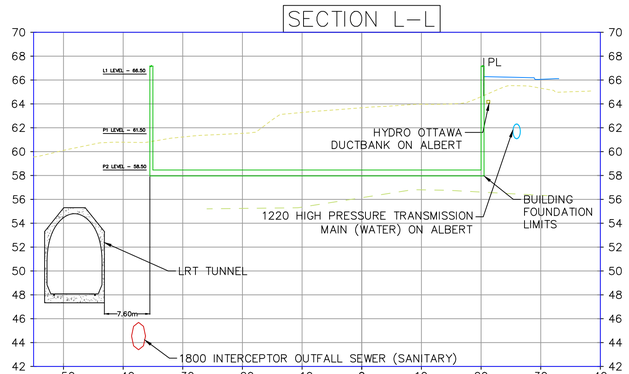
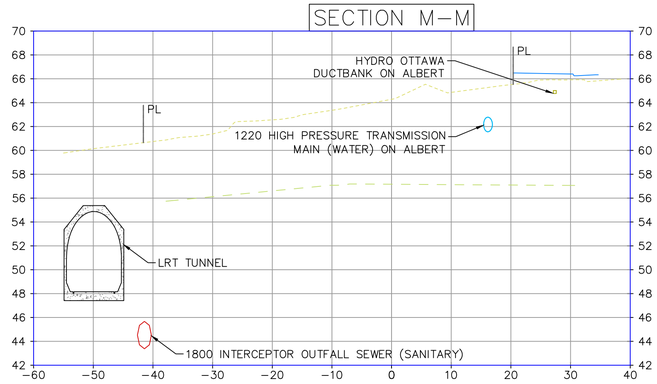


SECTION M–M



OPL - LAC JOINT FACILITY
LRT IMPACT STUDY

SITE PLAN - CROSS SECTIONS

Alain C. Gonthier, P. Eng. *Director, Infrastructure Services*	Paul Hussar *Project Manager*

Contract No. 202093300 | Drawing No.
Sheet No. 2 of 2
Asset No.
Asset Group ISD
Des: NC | Chk'd: EE
Dwn: NC | Chk'd: JF
Utility Circulation No.:
Construction Inspector:
Scale: 1:300
0m 5 10

NOTE:
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MORRISON HERSHFIELD

REVISIONS	No.	Description	By	Date (dd/mm/yy)

ALBERT ST. DESIGN GRADE
TOPO SURFACE
BEDROCK SURFACE
BUILDING FOUNDATION

PRELIMINARY ONLY
MORRISON HERSHFIELD LIMITED
NOT TO BE USED FOR CONSTRUCTION PURPOSES

APPENDIX C: Structural Report, Fast + Epp dated June 4, 2020

City of Ottawa

Ottawa Public Library – Library and Archives Canada Joint Facility

Foundation interaction with existing tunnels

Structural report

Fast + Epp
201 - 1672 West 1st Avenue
Vancouver BC V6J 1G1

First issue
4 June 2020

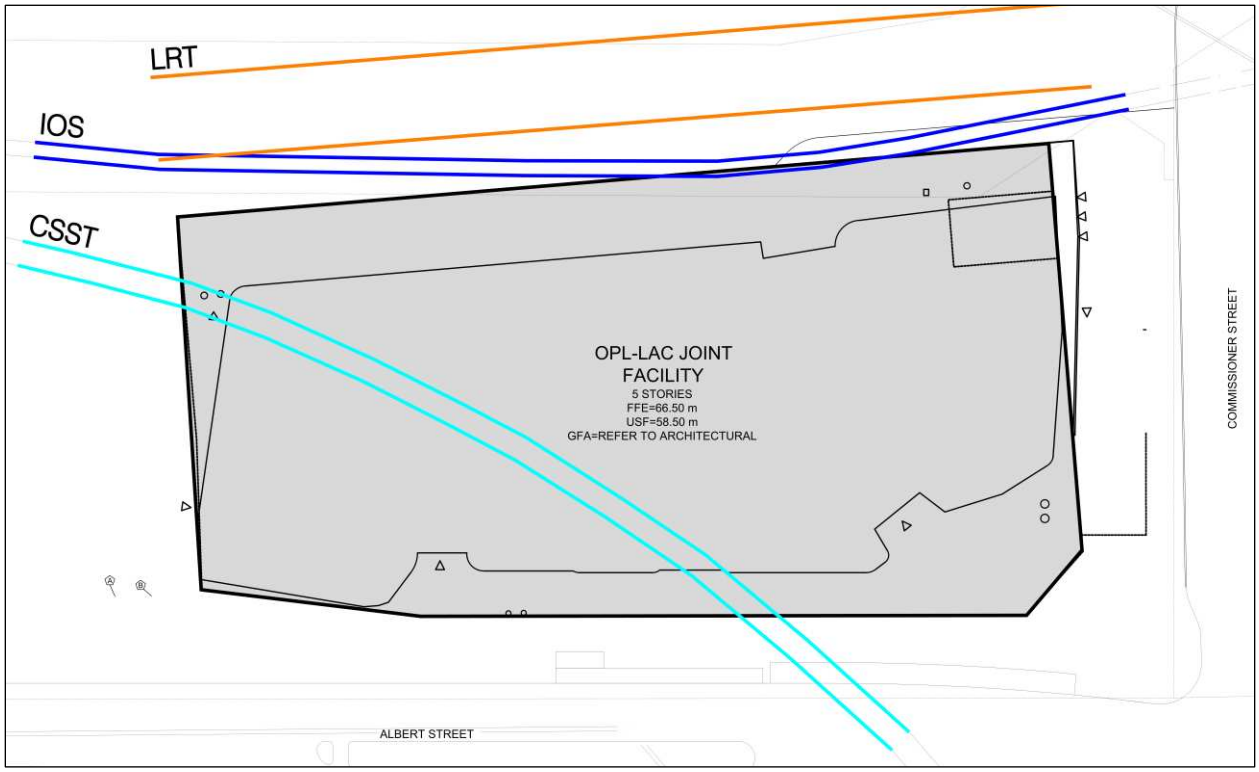
Table of contents

1 Introduction

The proposed Ottawa Public Library – Library and Archives Canada Joint Facility passes over or near to three tunnels:

- the combined sewer storage tunnel (CSST), recently constructed (in cyan below)
- the interceptor outfall sewer (IOS) tunnel, constructed in the 1960s (in dark blue below)
- a light rail transit (LRT) tunnel, recently constructed (in orange below)

This report describes the interaction of the foundations of the proposed building with these existing tunnels.



Plan showing building basement (grey) and tunnels (colour) [Background: Morrison Hershfield; Mark-up: Fast + Epp]

2 Site conditions

Reference should be made to the draft geotechnical report by Golder Associates Ltd. (report number 19131600, dated February 2020) and clarifications in subsequent email correspondence. A final geotechnical report will be required in due course.

The slab level for the lowest parking level (P2) is at +58.5m above datum.

2.1 Soil and rock profile

The existing ground level falls from the north-east corner (at around +64m) of the proposed building to the south (at around +62.5m).

The ground is understood to be made up of a fill stratum between 1.4m and 3.7m thick, overlying a glacial till stratum between 2m and 8.2m thick. The glacial till stratum lies on limestone bedrock with shale interbeds.

The limestone bedrock is closest to the ground at the north of the building, where its surface is expected to be close to the lowest parking slab level (P2 at +58.5m). Away from the north end of the building, the surface of the limestone bedrock falls away to between approximately +49m and +53m.

2.2 Ground water

Ground water levels have been recorded between 2m and 6m below ground and between +56m and +62m above datum. The ground water level is expected to be above the lowest basement level across parts of the east side of the building.

3 Foundation system

The building foundation is a piled foundation, except at the north of the site, where the limestone bedrock is near to the basement and footings may be founded directly on the bedrock. A draft foundation plan is included in Appendix A.

The following construction sequence is anticipated:

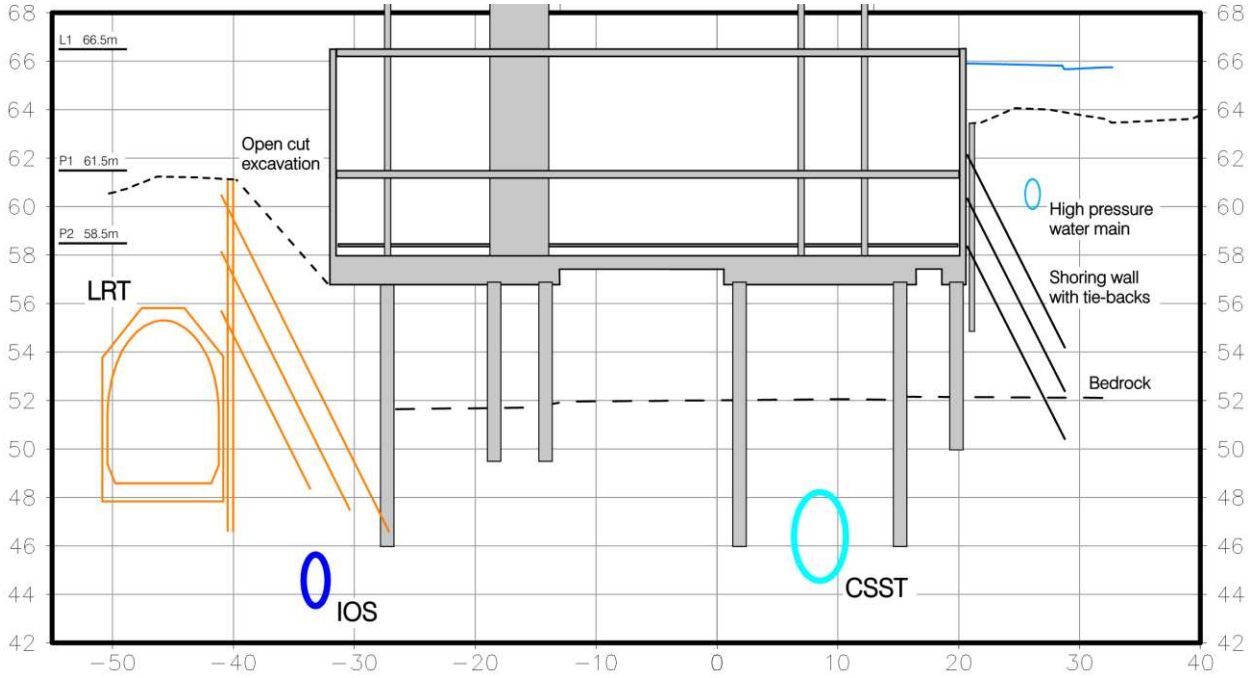
- Secant pile shoring wall installed.
- Basement excavated using the shoring wall, with tie-backs installed as excavation progresses, or as an open cut excavation, where possible.
- Caissons installed.
- Pile caps and tie beams installed.
- Basement constructed.
- Open cut back-filled.

The piles are 1200mm concrete caissons passing through the soil and socketed into the bedrock. Temporary steel casings are expected to be used within the soil during construction of the caissons. A drill head will be used to advance the drilling to the required depth within the bedrock. The caissons will be socketed approximately 2.4m into the bedrock, except where the interaction with the existing tunnels requires deeper sockets, as described in the following sections.

The geotechnical capacity of the caissons will be derived from the skin friction between the concrete caisson and the rock. The end of the caissons will also bear directly on the base of the rock sockets, but this component of the resistance will not be relied on in calculating the geotechnical capacity of the caissons.

4 Foundation interaction with existing tunnels

The typical section below shows the relationship between the building foundation and the three tunnels passing under or near to the site. Note that the vertical and horizontal scales are different.



Typical transverse section across site [Background: Morrison Hershfield; Mark-up: Fast + Epp]

4.1 Combined sewer storage tunnel (CSST)

The CSST runs across the site from the south-west to the east. The tunnel, including its lining, is understood to be 3.71m in diameter.

Columns located above the CSST are supported on a transfer slab which is founded on lines of caissons which are set back a clear distance of 4.35m from the outside of the CSST. This clear distance includes:

- 4m design clearance
- 0.15m tolerance in as-built location of CSST
- 0.2m tolerance in location of caisson base

The caissons are founded at or below the centreline of the CSST.

This foundation layout follows guidelines received from Jacobs and Stantec in June 2019 and is therefore expected to be acceptable to the CSST design team. However, the CSST design team should review the design drawing and confirm that the layout is acceptable.

4.2 Interceptor outfall sewer (IOS) tunnel

The IOS tunnel runs approximately parallel to the west property line and outside of it, except at the north end of the building where it passes inside the property line.

The west side of the building basement is supported on ground beams which cantilever from the first interior line of caissons. This ensures that no foundation load is applied directly over the IOS tunnel. The caissons will be constructed to the depth required to ensure that there is an acceptably small impact on the IOS tunnel. This depth will be analyzed and confirmed by Golder prior to construction. It is possible that the caissons will need to be constructed to the depth of the centreline of the IOS tunnel, matching the design approach used for the foundations around the CSST.

4.3 Light rail transit (LRT) tunnel

The light rail transit (LRT) tunnel runs by the west side of the site, outside the property line. It gets deeper as it proceeds north, away from Pimisi station, and near the north end of the site it begins to turn further west, away from the site.

The tunnel was built using a cut-and-cover approach, with a shored excavation. The tie-backs from the shoring pass under the proposed building within the bedrock. It is possible that one or more of these tie-backs are cut during the piling operation for the proposed building. It is understood that these tie-backs are not required for the stability of the LRT tunnel and that there is no impact on the LRT tunnel of cutting them.

Being sufficiently distant from the LRT tunnel and being supported on piles, the proposed building will not impart any load on the LRT tunnel.

5 Conclusion

The foundation design approach for the proposed building has been developed to ensure that the existing tunnels below and around the site are not adversely affected by the construction of the building. The construction details of the foundation are currently being developed based on this approach and the specific interactions described in this report.

Please contact us if you have any questions about the contents of this report.

William Loasby
P.Eng. Struct.Eng. CEng MIStructE MICE MHKIE MIEAust
ASSOCIATE

Appendix A – Draft foundation plan