Appendix 'H' – Hydrogeological Technical Memo

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Date:	4/26/2021	File:	119104
To:	Gagan Batra, City of Brantford		
From:	Joanna Olesiuk, M. A. Sc., Matthew Long, M. Eng., P. Eng., GM BluePlan Engineering Ltd.		
Project:	Three Grand River Crossings, City of Brantford		
Subject:	Desktop Hydrogeological Review		

TECHNICAL MEMO

INTRODUCTION

The City of Brantford retained GM BluePlan Engineering Limited (GM BluePlan) to provide consulting services related to a Schedule 'B' Municipal Class Environmental Assessment (MCEA) to review alternatives for three bridges over the Grand River. These are collectively referred to as the Three Grand River Crossings and include the Lorne Bridge, the Brant's Crossing Bridge and the TH&B Crossing Bridge, as well as lands in the vicinity of the bridges, hereafter referred to as the Study Area for the purpose of this Desktop Hydrogeological Review.

The Study Area is located in the City of Brantford, in a residential, commercial and open space land use setting and is currently the subject of a MCEA to review alternatives for the three river crossings. For the purposes of the MCEA process, the three bridges are encompassed within a Study Area (approximate outline of which is shown on **Figure 1**), which comprises an area of approximately 13.56 ha and includes the Grand River, the three bridges as well as lands in the vicinity of the three bridge structures.

OBJECTIVES

The main objective of this desktop hydrogeological review is to provide a high-level overview of the hydrogeology of the Study Area, as shown on **Figure 2.** Particular tasks include:

- Description of the geological setting (i.e. physiography and surficial geology).
- Identification of Source Water Protection (SWP) policy areas and the potential for special mitigative measures.
- Identify regulatory requirements associated with the construction dewatering should excavation and dewatering be required as part of the preferred alternatives for either of the three structures.
- Identification of water wells in the area and preliminary assessment of potential impacts to shallow groundwater supply related to construction site dewatering should it be required as part of the preferred alternatives for the three structures.

BACKGROUND

The Study Area is located west of the central district of the City of Brantford. The Study Area consists of the river crossing infrastructure associated with the portion of the Grand River where the three bridges are located. The Study Area consists of lands in the immediate vicinity of the bridges including the Grand River, open space, forested lands, trails and parkland. There are no buildings in the Study Area. **Figure 1** shows the location of the Study Area and the three bridges on a regional scale and **Figure 2** shows an aerial view of the Study Area.

Lorne Bridge carries five lanes of traffic on Colborne Street West across the Grand River. The roadway accommodates three lanes of traffic in the eastbound direction and two lanes in the westbound direction. There is a sidewalk on the north and south sides of the bridge. The Lorne Bridge consists of Lorne Arch Bridge, Lorne Girder Bridge and the Lorne Bridge Pedestrian Underpass.

Brant's Crossing Bridge is a four span bridge that was originally designed to convey railway traffic but has since been converted to carry pedestrian and cyclist traffic across the Grand River. The bridge was closed in February 2018 following flooding and an ice jam event.

The TH&B Crossing Bridge is a four span bridge that was also originally designed for railway traffic and now currently carries pedestrian and cyclist traffic over the Grand River.

PHYSIOGRAPHIC, GEOLOGICAL AND HYDROGEOLOGICAL SETTING

Geologically, the Study Area is located within a physiographic region known as the Norfolk Sand Plain, near the Haldimand Clay Plain region, and lies within a sand plains physiographic landform (Figures 3 and 3b) (Chapman and Putnam, 1984; Ontario Geological Survey 2000 and 2007). This plain is mainly gently-sloping and consists of alluvial sands and silts deposited as a delta in glacial Lake Whittlesey and Lake Warren underlain in some regions by silt or clay strata with boulders in other areas. Drainage in this region is through a network of rivers and streams flowing to Lake Erie, some of which have cut deep valleys across the sand plain with valleys in some areas up to 30 m deep (Chapman and Putnam, 1984). The overburden soils in the Study Area and vicinity are reported as modern alluvium deposits, consisting of a mixture of clay, silt, sand and gravel deposits (**Figure 4**).

The bedrock underlying the overburden deposits in this region is reported as the Silurian age Salina Formation dolostone which is described as thin bedded, grey brown, argillaceous dolostone interbedded with shale and gypsum, with occurrence of salt beds at depth (Southern Ontario Quaternary Geology, Map 2326; GRCA GIS, 2020).

The topography across the Study Area is relatively flat along the open space surrounding and within the Grand River with an elevation of approximately 196 metres above sea level (masl) with a steep slope leading to the surrounding lands, at an elevation of approximately 200 to 204 masl.

From the review of the Ministry of the Environment, Conservation, and Parks (MECP) water well records (**Table 1, Figure 5**, MECP, 2020) overburden is reported to consist of variable soils, including deposits of sand; sand and gravel; clay; silt with sand and gravel underlain by clayey silt; silty sand; clay; clay with sand and gravel; clay with silt; clay with gravel; sand and gravel and silt deposits. Bedrock was reported at a depth of 12 metres below ground surface (mbgs) at a location of a well record east of the Study Area (MECP, 2020).

Shallow groundwater flow often correlates to topographical features and groundwater typically flows towards nearby lakes, streams and wetland areas, except where modified by service trenches. Based on review of local topography and drainage features in the Study Area and vicinity (GRCA, 2020), the inferred groundwater flow direction is towards the Grand River.

Geotechnical Assessment (Golder Associates Ltd., 2020)

A geotechnical assessment was completed by Golder Associates Ltd. (Golder) as documented in May 2020 Draft report titled *"Geotechnical Assessment Three Grand River Crossings (Lorne Bridge, Brant's Crossing Bridge and TH&B Crossing Bridge Bridge), City of Brantford, Ontario"*. The geotechnical assessment consisted of review of existing geotechnical data and reports for the project area at the three bridge locations.

In the Study Area, groundwater levels are reported to correspond to river water levels and are expected to fluctuate seasonally (Golder, 2020). More specific geological information is reported by Golder (2020) based on boreholes drilled as part of previous geotechnical investigations, as summarized below. For additional details regarding the geotechnical findings in the Study Area, including the locations of the boreholes and encountered stratigraphy as summarized below, refer to the geotechnical report (Golder, 2020).

Lorne Bridge

- Boreholes BH19/BH20 – adjacent to the east abutment of Lorne Bridge – sand and gravel fill up to 5 m in thickness overlying clayey silt, silty clay and silt. Bedrock encountered about 7.5 mbgs (elevation approximately 194.56 elevation).
    - In these boreholes, the groundwater level was inferred during drilling to be at elevations of about 198.2 to 199.6 masl in interlayered silty clay and silt and in sand and gravel fill, respectively.
- Boreholes BH7 and BH8 under Lorne Bridge – subsurface soils reported as firm to very stiff clayey silt overlying very stiff hard silt till layers to a depth of 7.6 to 9 mbgs overlying inferred bedrock (194.5 - 193.5 m elevation).
    - In these boreholes the groundwater level was noted to be at elevations of about 198.4 to 199.6 masl within silty till.
- Borehole BH11 – near east abutment – sand and gravel fill to a depth of 4.3 mbgs, underlain by stiff grey silt with clay seams.

- Borehole BH9 – near west abutment – fill to a depth of 4.5 mbgs, underlain by fine sand and silty sand, overlying compact fine sand with gravel.

Brant's Crossing Bridge

- Borehole BH18 – located near east abutment – 5 m of inferred very loose sand fill overlying approximately 1.5 m of sand and gravel, and sand strata of silt, clayey silt and silty clay.
  - Fill material described as brown sand and gravel fill, overlying very loose to loose brown sand, trace to some silt, occasional gravel, wood, sawdust, cinders (fill).
  - Groundwater level was inferred during drilling to be at an elevation of 196.9 masl, lying within a layer of (apparently) native sand and gravel below the fill.
- Boreholes 15, 16 and 17 – drilled through west, centre and east piers encountered concrete overlying limestone block masonry (inferred former abutment structure). A 0.4 m thick hard silty clay layer encountered beneath masonry. Bedrock encountered between elevation of about 194.3 and 195.6 m. Bedrock reported as fresh, massive grey to light grey, fine grained limestone.

TH&B Railway Bridge

- Boreholes BH 5 and BH 6 – located on north and south side of the west abutment - fill and topsoil overlying strata of sand, sand and gravel, silt, silty clay and clayey silt till, to depths of 8.1 and 8.2 mbgs, or elevations of about 194.1 m and 194.2 m, respectively.
  - Groundwater levels were reported to be at elevations of 196.5 to 196.8 masl, corresponding to sand or sand and gravel layers.
- Fill material further described in Golder 1989 report No. 881-3443 and 1989 Golder report No. 881-3443-1) as:
  - BH5 – fill material approximately 4.85 m thick described as black sand and gravel, loose black foundry sand, occasional gravel, overlying loose silty topsoil (fill), loose brown sandy silt occasional gravel (fill), loose to very dense black and brown cinders and ash, metal, roofing shingles, tar and coal (fill).
  - BH6 – sandy silt, some gravel, occasional metal and glass, occasional cloth. Loose to compact black and brown cinders and ash, with sandy silt layers, glass and shingles.

Review of River Level Data

A set of river level data (dating back to 2002) and a set of river flow data (dating back to 1913) were provided by consultant Ecosystem Recovery. The data were obtained from the Water Survey of Canada gauge 02GB001, located between the TH&B Railway Bridge and the Veteran's Memorial Bridge. GMBP correlated a set of flow readings to a set of level readings taken on the corresponding dates and developed a rating curve for the Grand River (Chart 1). Based on data provided by Ecosystem Recovery, corresponding flow and water level readings were available for select years between 2004 and 2019. Shown on Chart 1 are also the lowest elevations of the top of the bridge deck for each of the three bridges (based on existing topographic information provided by 3DS Technologies Inc. based on survey completed March 5, 2020).

Based on this rating curve and the dates of the historical geotechnical groundwater level readings, the following trends were identified, relating groundwater levels and river water levels:

- Where fine-textured soils prevail (such as at BH19 and BH20 near the east abutment of Lorne Bridge), groundwater levels may be as high as 3.6 m higher than river levels.
- Where coarse-textured soils prevail (such as at BH5 and BH6 near the west abutment of TH&B Railway Bridge and BH18 near the east abutment of Brant's Crossing bridge), groundwater level may be about 0.5 to 1 m higher than river levels.

The typical annual average river level at gauge 02GB001 is 196.3 masl, and so it is interpreted that typical annual groundwater levels are in the range of about 197.3 m (e.g. at TH&B west abutment and Brant's Crossing east abutment) to potentially as high as 199.9 masl (e.g. east abutment of Lorne Bridge).

SOURCE WATER PROTECTION

The *Clean Water Act* (2006) and the Source Protection Plans that follow under it provide guidance and requirements in land use planning for the protection of Ontario's water resources. Construction activities including potential dewatering that may be required may have an impact on quantity or quality of water in an aquifer, therefore it is relevant to this study to complete a review of the Source Protection framework for the Study Area. The Study Area is located within the Grand River Source Protection Area (GRSPA), downstream of the City of Brantford water supply intake on Grand River.

The Approved Drinking Water Source Protection Plan for the above Source Protection Area contains unique policies that apply to certain designated zones/areas and certain activities.

The lands within the Study Area boundaries, do not overlap any identified Wellhead Protection Areas (WHPA). However, the Study Area resides entirely within surface water Intake Protection Zones: IPZ-3 of vulnerability 6 overlaps most of the Study Area and areas near the River and IPZ-3 of vulnerability 8 overlaps areas further upland away from the River.

Reviewing the Tables of Drinking Water Threats, it does not appear that the project will result in or require the undertaking of activities that would trigger a "Significant" drinking water threat condition for the applicable IPZ-3 (6,8) zones. Therefore, it is not expected that a Risk Management Plan would be required by the municipal Risk Management Office.

CONSTRUCTION SITE DEWATERING

The requirement for construction site dewatering has the potential to increase construction costs where intensive dewatering is required or where contaminated groundwater is encountered. Dewatering may also affect nearby groundwater users, ecological features, or the systems that receive the dewatering discharge. Water taking for construction dewatering may also require an approval from the Ministry of the Environment, Conservation and Parks (MECP). As such, it is important to identify potential requirements for construction site dewatering.

Based on the concurrent Phase One Environmental Site Assessment (GM BluePlan, 2020), several potential contaminating activities (PCAs) have been identified upgradient of the Study Area resulting in several areas of potential environmental concern (APECs) related to soil and groundwater quality within the Study Area. This indicates that there is the potential risk of encountering contaminated soil and/or groundwater should excavation and construction dewatering be required, particularly if the excavations extend to below groundwater table.

Generally speaking, projects that involve deeper excavations have a greater chance of intersecting the groundwater table and so incur greater risk of requiring dewatering. Furthermore, the deeper that excavations are advanced below the groundwater table, the greater the expected flow rates for dewatering.

With respect to the existing geological system reported for the Study Area, several factors that may contribute to higher discharge quantities for construction dewatering are as follows:

- Shallow groundwater table.
- Increased permeability or hydraulic conductivity of geological materials (e.g. coarse deposits with high proportions of sand and gravel or conductive bedrock layers).

Data available from the historical geotechnical investigations (Golder, 2020) indicates sand or sand and gravel materials in native deposits on both sides of the River and groundwater levels approaching as high as 199.6 masl at the Lorne Bridge, and about 196.9 masl at the other two bridges. The discrepancy between the water level at Lorne Bridge and at the other two bridges appears to be due to the fact that the groundwater levels at Lorne Bridge (east abutment) were measured within a less-conductive till layer which would thus maintain a higher water level than the more well-drained sand and sand and gravel materials encountered at the other two bridges. It is noted that groundwater levels would also be expected to fluctuate in a similar fashion to river level fluctuations.

Though it is noted that groundwater levels may fluctuate seasonally and with changing levels in the river, as a starting point it is expected that if excavations proceed to depths below 199.9 masl, minor dewatering is likely to be necessary to maintain a dry working area at the excavation floor. If these higher groundwater levels are indeed associated with fine-grained materials (which would retain higher water levels than coarser materials), the lower hydraulic conductivity would result in a lesser dewatering requirement. This minor dewatering would likely be managed under an approval in the form of registration to the Environmental Activity and Sector Registry (EASR).

Deeper excavations, especially those extending below about 197.3 masl and more likely into the saturated sand or sand and gravel materials at depth, would likely require significant dewatering: these would likely require approval in the form of a Permit to Take Water (PTTW).

In either case, should excavation be required for the final recommendation, it is recommended that additional investigation be undertaken to characterize the groundwater and soil conditions in the context of the proposed excavation works so that a detailed construction dewatering assessment may be prepared.

REGULATORY/APPROVALS REQUIREMENTS

Should the preferred alternative require excavations at either of the three bridge locations, particularly for pier foundations, there is potential that the excavations will extend to below the river and groundwater level, and excavations will be subject to groundwater flow from the native granular soils (Golder, 2020) or the underlying bedrock unit.

As noted in the previous section (Construction Site Dewatering), it is expected that excavations extending to elevations below 199.9 masl are likely to require some amount of dewatering. Excavations extending below elevations of 197.3 masl are likely to require significant dewatering due to the presence of coarse soils and the proximity to the typical average River level (which is 196.3 masl).

As the preferred alternatives for each of the structures are finalized, and excavation requirements are confirmed, where excavations are proposed, a detailed construction dewatering assessment is recommended to be completed. This assessment would likely require additional hydrogeological field investigation to characterize the soil and groundwater conditions, provide dewatering estimates, and determine approval requirements. This additional assessment should be completed in close consultation with the structural and/or geotechnical engineering consultants to ensure that the assumptions used in determining the dewatering estimates are reasonable and fitting to the proposed construction works and methodology (e.g. deployment of impermeable shoring or cut-offs, depths of excavations, and other considerations).

This additional investigation is recommended to include the installation of monitoring wells, confirmation of groundwater levels and groundwater quality (i.e. sampling and analyses), and characterization of the hydraulic properties of the geological materials (e.g. grain-size distribution tests, slug tests). Nested wells may also be helpful to establish vertical gradients and determine whether there is potential for base-heave, internal erosion, or other seepage-related causes of excavation instability: these would be especially useful in situations where excavations extend below 197.3 masl or below the water level of the river. These investigation activities could be conducted in conjunction with the project geotechnical investigation or Phase Two Environmental Site Assessment (if completed).

Should the assessment indicate that the required construction dewatering flow rate will exceed 50,000 L/day, water taking approval from the MECP via the Environmental Activity and Sector Registry (EASR) will be required. The requirements for an EASR approval are provided in Ontario Regulation 63/16 and typically involve the input of a Qualified Person to provide water-taking and discharge plans to govern the dewatering activities and minimize impacts. The registration of the EASR itself does not require review from the MECP: approval is granted once the application is submitted online.

Should the water taking be anticipated to be greater than 400,000 L/d, such water taking will require a Permit to Take Water (PTTW) from the MECP. If dewatering is expected to last less than 7 days, then this project may be eligible for a Category 2 PTTW. If the dewatering is expected to last more than 7 days, a Category 3 PTTW will be required. Further supporting assessments, and/or additional studies will be required to obtain the necessary water taking approvals. Typically, the level of effort associated with completing supporting studies and developing monitoring and mitigation plans is greater for a PTTW application/approval compared to an EASR water taking approval. There is also additional timing required for the MECP to review PTTW studies/applications (i.e. 90 day review period, not including “pause” time associated with MECP requests for clarification or amendments to the application package).

Where high rates of construction dewatering are expected (e.g. greater than about 1,000,000 L/d) or where dewatering is proposed to be completed using deep wells, the MECP is likely to request a pumping test to be completed at the Study Area of the proposed dewatering. The pumping test and subsequent analyses would provide additional hydrogeological characterization and would also provide proof-of-concept to the Ministry regarding the dewatering design, as well as greater confidence in the accuracy of the water-taking estimates. Such a pumping test would likely need to be run for at least 24 hours and would require a Category 2 PTTW itself. Obtaining the PTTW for the pumping test could take one to four months, from the start of preparation of the application to receipt of approval from the Ministry, and would likely require the well IDs or tag numbers of the test wells (i.e. the well(s) would need to be installed prior to submission of the application). For construction dewatering projects in which multiple deep wells are proposed to be installed, the MECP may require the testing of more than one, potentially all of the wells.

SUMMARY AND CONCLUSIONS

A planning-level hydrogeological review has been conducted to support a Class EA to review alternatives for three bridges over the Grand River, collectively referred to as the Three Grand River Crossings, including the Lorne Bridge, Brant's Crossing Bridge and the TH&B Crossing Bridge in the City of Brantford.

The main findings of the hydrogeological review are as follows:

- The Study Area is located in the physiographic region known as the Norfolk Sand Plain.
- Native soils in the Study Area are reported to consist of modern alluvium deposits, consisting of a mixture of clay, silt, sand and gravel deposits.
- MECP water well records and previous geotechnical investigations within the Study Area and vicinity indicate that the overburden in the Study Area is typically less than approximately 10 to 12 m thick, and is of variable texture, ranging from clay to sand and gravel. At the location of the bridge infrastructure within the river channel, overburden deposits are expected to be significantly thinner.
- Bedrock in this region is reported as the Silurian age Salina Formation dolostone which is described as thin bedded, grey brown, argillaceous dolostone interbedded with shale and gypsum, with occurrence of salt beds at depth.
- Fill materials up to 5 m in thickness were reported at select boreholes completed as part of previous geotechnical investigations in the Study Area and vicinity (Golder, 2020). The fill was reported to contain foundry sand, cinders and ash, metal, roofing shingles, tar and coal, glass, cloth and wood.
- In terms of Source Protection, the lands within the Study Area are within an Intake Protection Zone IPZ-3. The preferred solution is not likely to trigger a "Significant" drinking water threat in these IPZ-3 areas.
- Should the preferred solution require excavations, especially where excavation depths extend below the groundwater table (inferred to be in the range of 197.3 to 199.9 masl), the project would benefit from additional investigation to confirm dewatering requirements as well as to support the obtainment of necessary approvals and the development of dewatering plans, including monitoring and mitigation activities.
- Due to the historical activities in the Site area, there is potential for impacted groundwater to be encountered during excavation and/or dewatering activities conducted on-Site.
- Where dewatering must occur in the vicinity of impacted groundwater (if any), significant costs may be incurred due to either treating the dewatering discharge or in providing cut-offs or seepage barriers to minimize handling of impacted groundwater.
- Where dewatering in excess of 50,000 L/day be required, an EASR approval is required to ensure regulatory compliance for construction dewatering. However, should dewatering in excess of 400,000 L/day be required, a PTTW will need to be obtained.

Regarding the hydrogeological conditions and potential regulatory requirements of the project, we therefore make the following recommendations:

- That a door-to-door water well survey be completed for all properties in the Study Area vicinity, to confirm the nature of water supply, determine baseline usage conditions, and identify existing private shallow overburden wells which may have greater potential to be impacted should extensive dewatering at those locations be required. Alternatively, should the Municipality confirm that all the properties in the Study Area are supplied with municipal water, and no private wells are in use currently, a door-to-door water well survey will not be required. Further, should the selected alternative not require excavation and therefore no dewatering, a door-to-door water well survey will not be required.

- That the preferred solution minimizes the amount of excavation required to minimize potential costs of groundwater control, which may include handling, treating or excluding (i.e. by cut-off walls or impermeable shoring) impacted groundwater taken up by a construction dewatering system.
- That, where excavation below elevations of 199.9 masl is necessary, additional hydrogeological investigation be carried out to assist in deciding on the construction and dewatering (or seepage cut-off) approach, identify potential water treatment requirements, and support the obtainment of approvals, as necessary.
  - these future hydrogeological/ geotechnical investigations are recommended to include, at minimum, the installation of monitoring wells, a combination of single-well response tests and grain size distribution tests to characterize the hydraulic conductivity of subsurface materials below the groundwater table, and collection and analyses of groundwater samples to confirm groundwater quality to determine treatment or isolation/cutoff requirements. Additional study (e.g. pumping tests) may be required depending on excavation depths and approval application requirements.
- That it be recognized that excavation (without an effective cut-off or seepage barrier) below an elevation of 197.3 masl is more likely to result in significant dewatering efforts with very large daily discharge volumes, especially where sand and gravel or other coarse-textured, highly-conductive geological materials exist.
- That construction dewatering assessments and water-taking estimates be prepared in close consultation with the structural and/or geotechnical consultants to ensure that the seepage calculations are completed using reasonable assumptions fitting the proposed works and construction methodologies (e.g. respecting shoring, cut-offs, excavation depths and other considerations).

All of which is respectfully submitted.

GM BLUEPLAN ENGINEERING LIMITED

Per:

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Enclosures:
Table 1: Water Well Inventory
Figures 1 to 5
Chart 1: Rating Chart – Grand River at WSC Gauge 02GB001

REFERENCES

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ENCLOSURES:
Table 1: Summary of Water Well Records
Figures 1 to 5
Chart 1: Rating Chart - Grand River at WSC Gauge 02GB001

Table 1: Summary of Water Well Records

MOECC Well ID	Easting	Northing	Township	County/ Municipality	Well Use	Bedrock/ Overburden	Depth to Bedrock (m)	Total Depth of Well (m)	Static Water Level (m)	Year Drilled
Wells on Neighbouring Properties										
1305813	559649	4776494	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	3.05	~	2001-12-17
1306139	559617	4776447	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	5.00	~	2004-05-19
1306340	559661	4776207	BRANT	BRANTFORD CITY	Test Hole	Bedrock	12	12.00	7.00	2005-02-28
1306481	559920	4775800	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	4.50	~	2005-04-15
1306571	559601	4776037	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	7.80	~	2006-03-03
7113425	559717	4776206	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	9.14	~	2008-10-03
7116470	558955	4776675	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	7.60	5.50	2008-07-09
7128793	559972	4775881	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	7.60	~	2009-05-15
7129841	559049	4776011	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	6.00	~	2009-09-09
7129841	559064	4776021	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	6.00	~	2009-09-08
7129841	559033	4776013	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	6.00	~	2009-09-09
7129841	559033	4776013	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	6.00	~	2009-09-09
7129841	559033	4776013	BRANT	BRANTFORD CITY	Test Hole	Overburden	~	6.00	~	2009-09-09
7135146	559590	4776402	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	21.95	~	2009-10-01
7210581	559626	4776427	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	7.00	~	2013-09-17
7210582	559642	4776428	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	7.60	~	2013-09-17
7210583	559631	4776376	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	4.60	~	2013-09-17
7210584	559648	4776376	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	6.10	~	2013-09-17
7226195	559547	4776502	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2014-06-11
7226196	559557	4776514	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2014-06-11

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Table 1: Summary of Water Well Records

MOECC Well ID	Easting	Northing	Township	County/ Municipality	Well Use	Bedrock/ Overburden	Depth to Bedrock (m)	Total Depth of Well (m)	Static Water Level (m)	Year Drilled
Wells on Neighbouring Properties										
7226197	559580	4776509	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2014-06-19
7229271	559076	4776650	BRANT	BRANTFORD CITY	Unknown	Unknown	~		~	2014-03-11
7230654	559707	4776432	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	7.20	~	2014-10-02
7230655	559675	4776428	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	7.50	~	2014-10-02
7230656	559660	4776426	BRANT	BRANTFORD CITY	Monitoring	Unknown	~		~	2014-10-02
7230657	559575	4776375	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	3.90	~	2014-10-02
7230658	559578	4776372	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	10.50	~	2014-10-02
7230687	559649	4776385	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	5.90	~	2014-10-03
7230688	559726	4776386	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	5.20	~	2014-10-03
7230693	559640	4776423	BRANT	BRANTFORD CITY	Monitoring	Overburden	~	7.50	~	2014-10-02
7240552	559709	4776400	BRANT	BRANTFORD CITY	Unknown	Unknown	~		~	2015-04-15
7240575	559679	4776390	BRANT	BRANTFORD CITY	Unknown	Unknown	~		~	2015-04-15
7242521	559698	4776297	BRANT	BRANTFORD CITY	Unknown	Unknown	~		~	2014-12-18
7244821	559657	4776220	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.62	~	2015-06-25
7244822	559714	4776184	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2015-06-25
7245938	559729	4776270	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2015-06-25
7245939	559687	4776176	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2015-06-25
7245940	559761	4776290	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2015-06-26
7245941	559698	4776261	BRANT	BRANTFORD CITY	Monitoring and Test Hole	Overburden	~	7.01	~	2015-06-26
7259431	559606	4776318	BRANT	BRANTFORD CITY	Unknown	Unknown	~		~	2015-02-04

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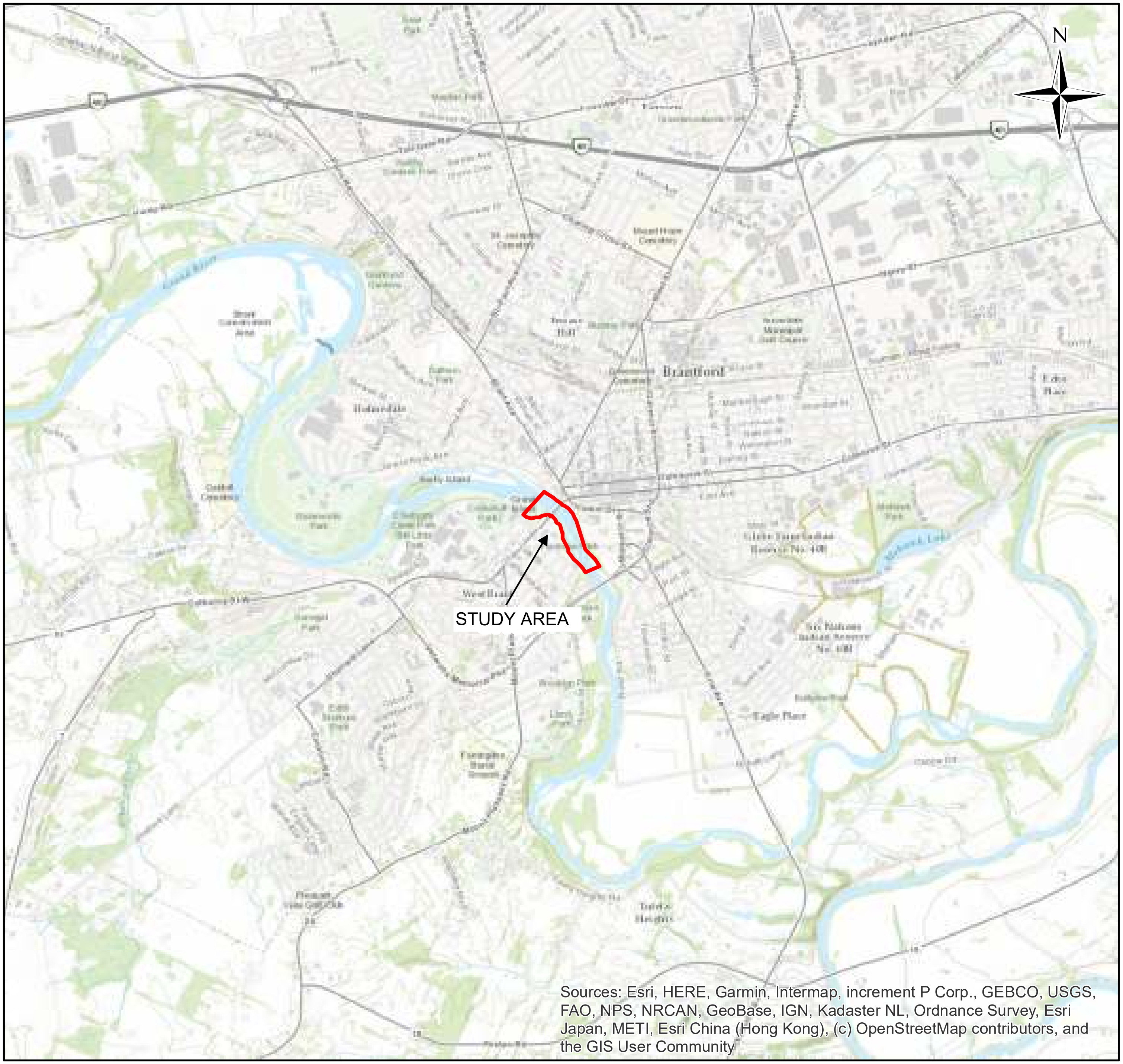

Project: 119104
Hydrogeological Review
Three Grand
River Crossings
City of Brantford, ON

Study Area

Scale: 1: 50,000
July 2020

Figure 1:
Site Location

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Hydrogeological Review
Three Grand
River Crossings
City of Brantford, ON

Bridges
Roads
Study Area (250m)
Site

Scale: 1: 8,000
February 2021

Figure 2:
Study Area Layout

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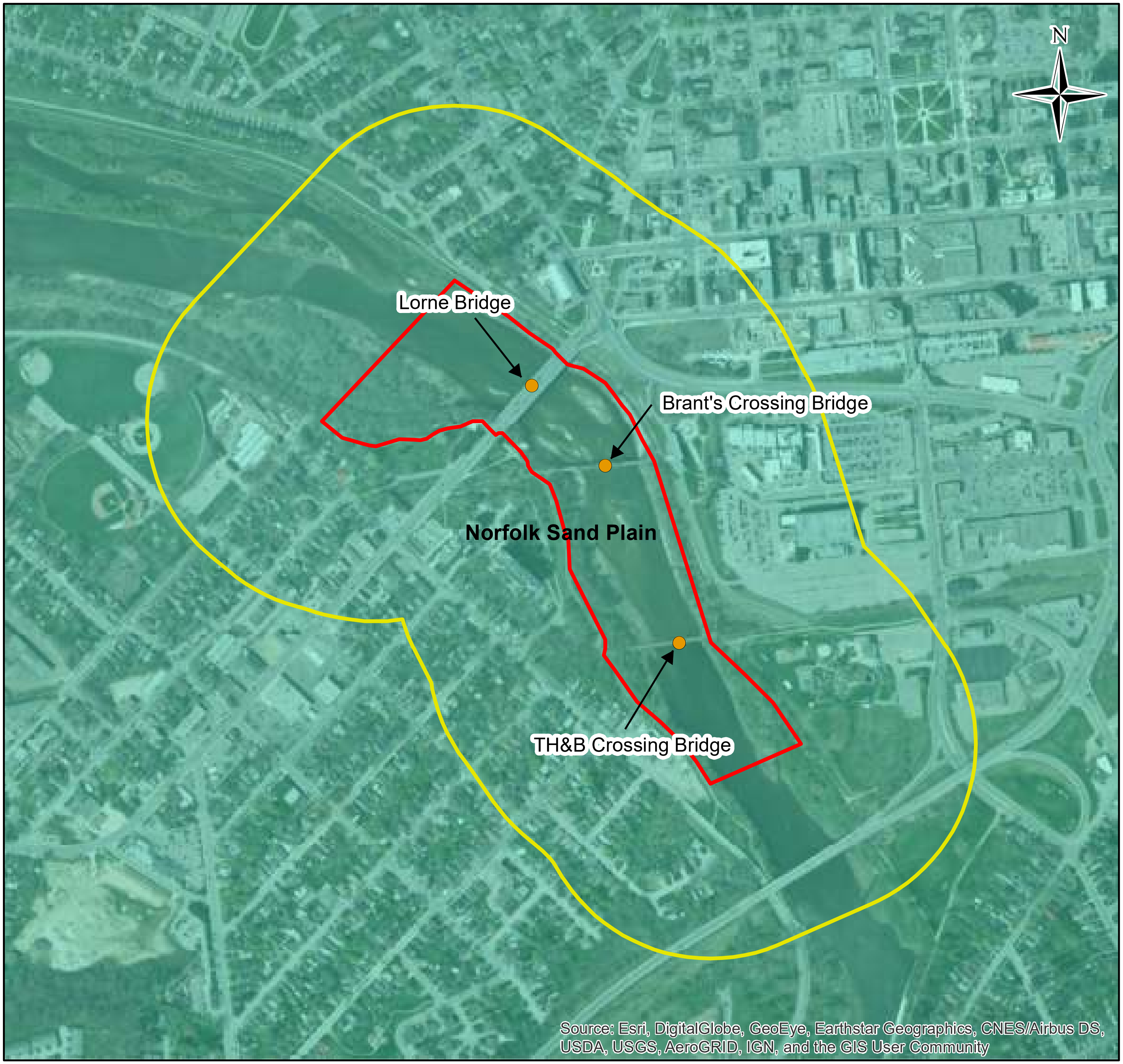

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Hydrogeological Review
Three Grand
River Crossings
City of Brantford, ON

Bridges
Study Area (250m)
Site

Physiographic Regions

UNIT, REGION

22, Norfolk Sand Plain

Scale: 1: 8,000
February 2021

Figure 3a:
Physiographic Regions

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Three Grand
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City of Brantford, ON

Bridges
Study Area (250m)
Site
Physiography of Southern Ontario
Sand Plains

Scale: 1: 8,000
February 2021

Figure 3b:
Physiographic Landforms

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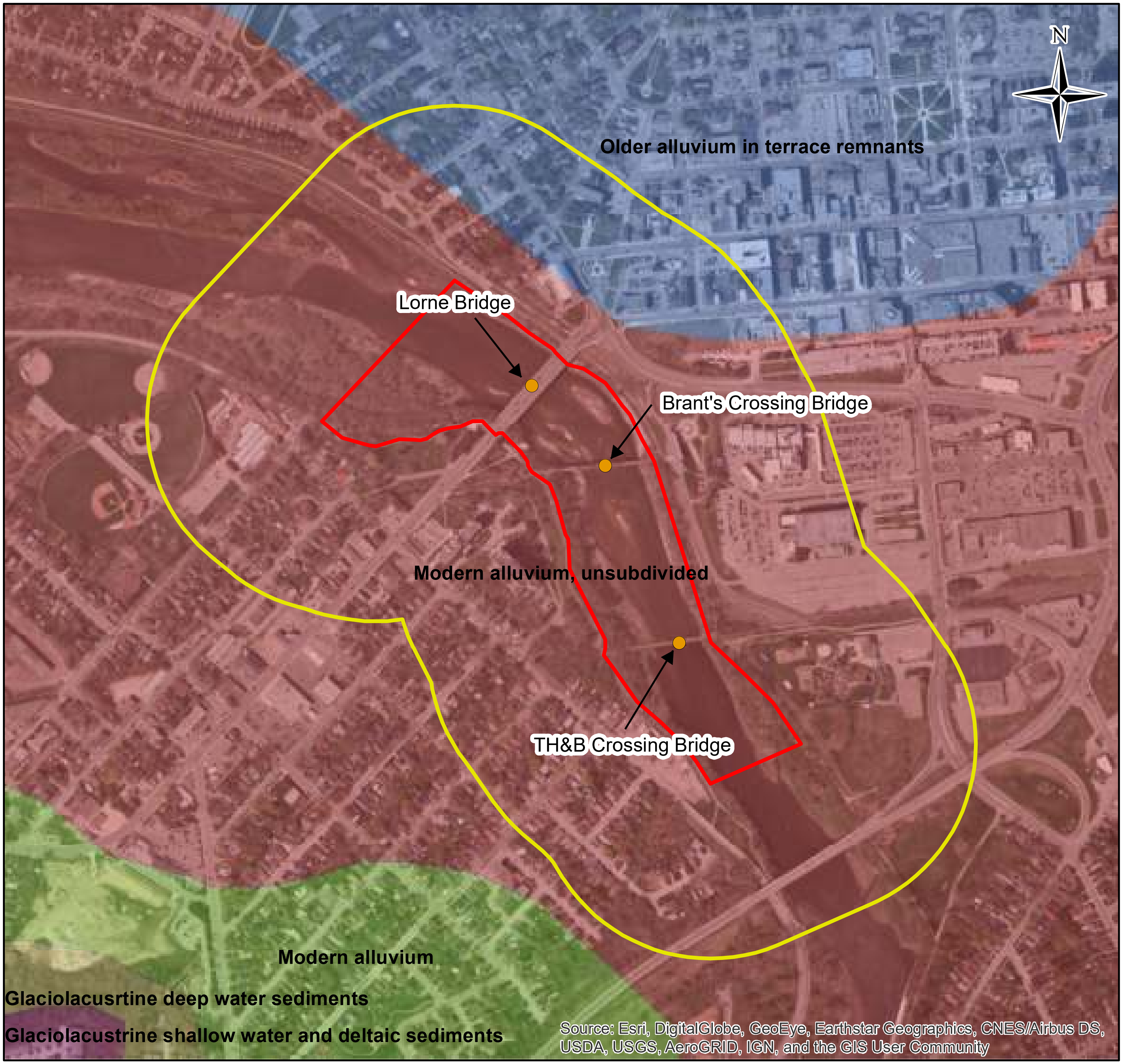

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Three Grand
River Crossings
City of Brantford, ON

Bridges
Study Area (250m)
Site

Surficial Geology of Ontario

Glaciolacusrtine deep water sediments
Glaciolacustrine shallow water and deltaic sediments
Modern alluvium
Modern alluvium, unsubdivided
Older alluvium in terrace remnants

Scale: 1: 8,000
February 2021

Figure 4:
Surficial Geology

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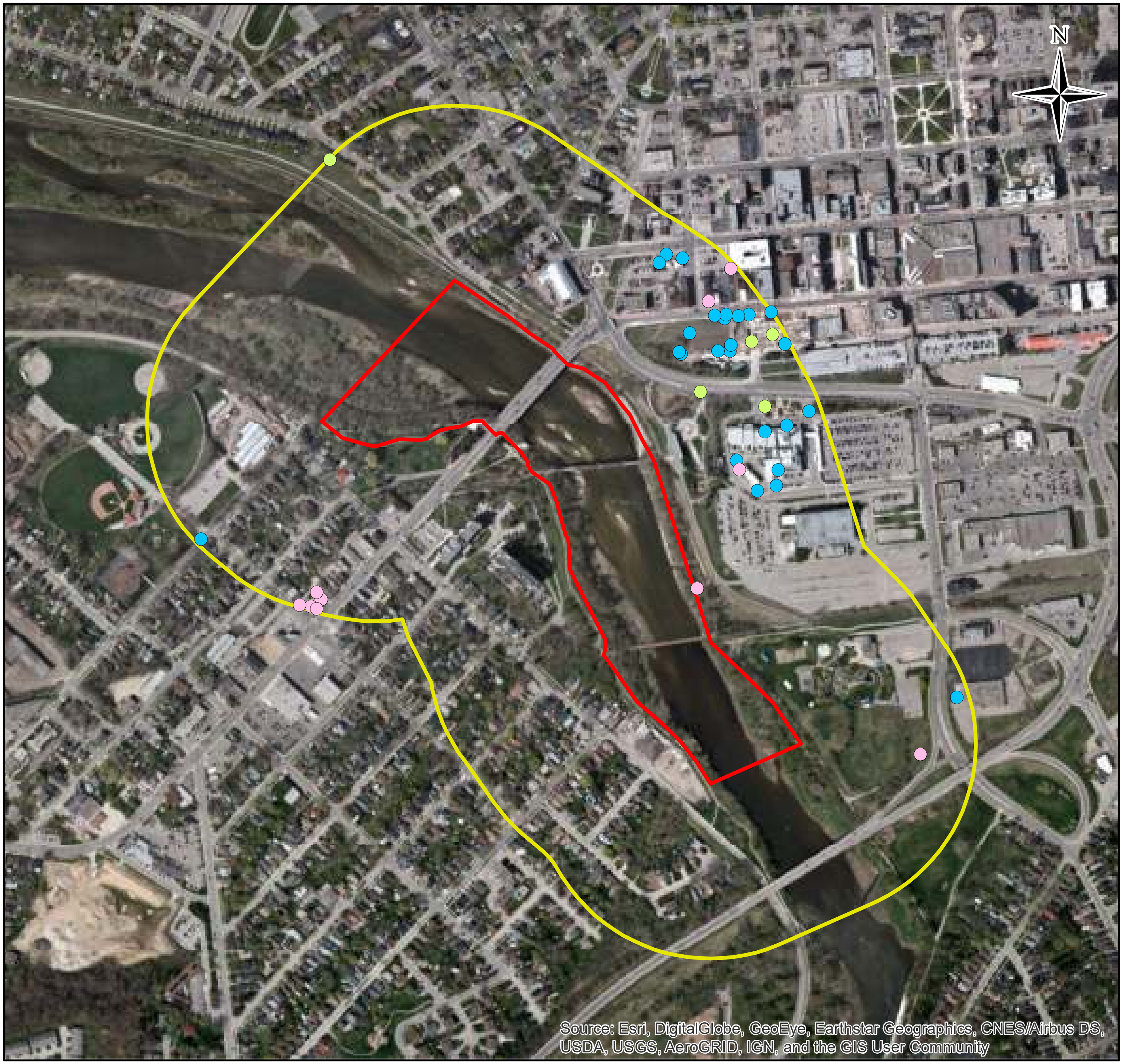

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Three Grand
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City of Brantford, ON

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Usage

- Monitoring
- Test Hole
- Unknown
- Greater Study Area (250m)
- Study Area

Scale: 1: 8,000
July 2020

Figure 5:
MECP Water Well Records

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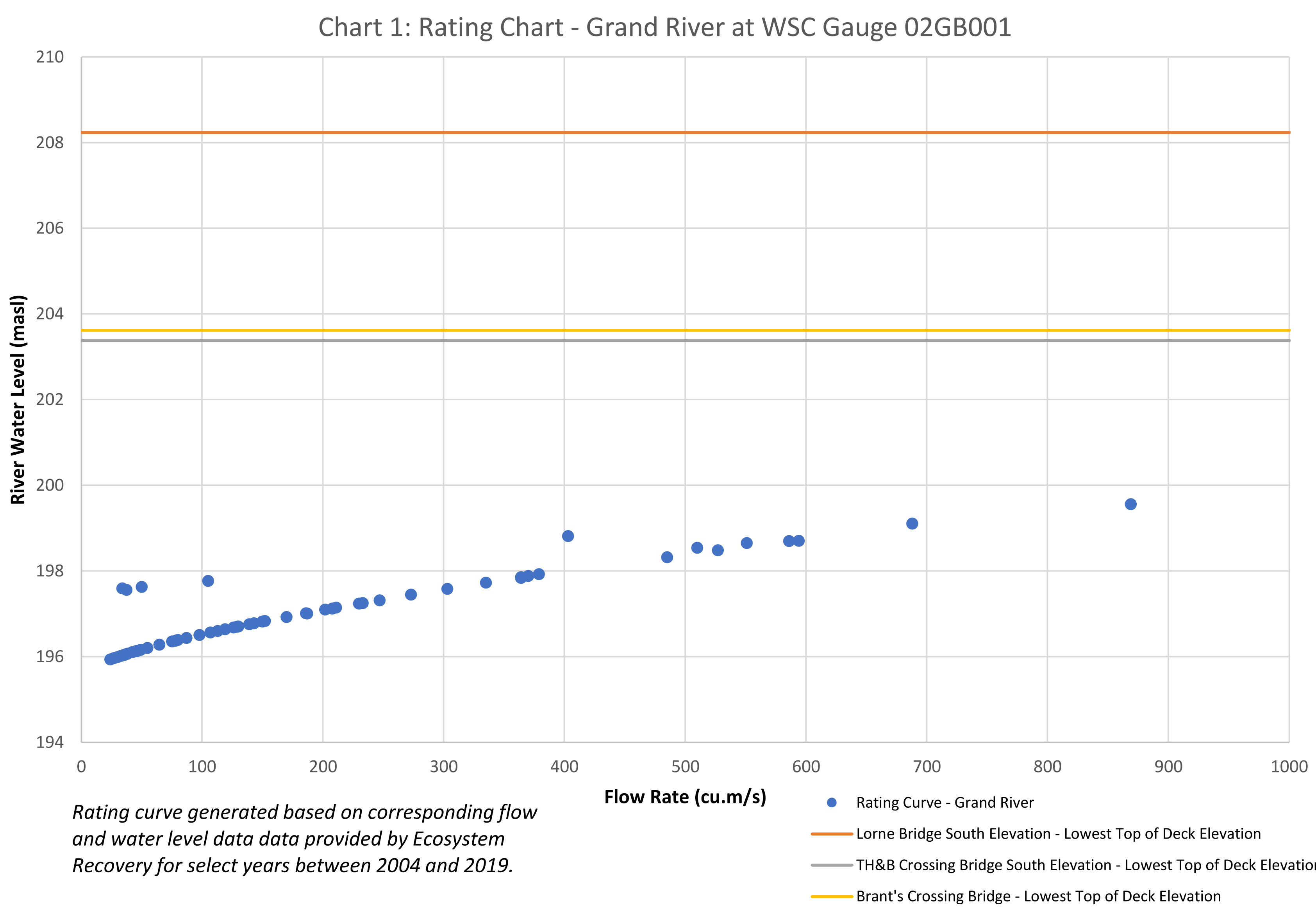

Rating curve generated based on corresponding flow and water level data data provided by Ecosystem Recovery for select years between 2004 and 2019.

Top of deck elevations (masl) based on existing topographic information provided by 3DS Technologies Inc. based on survey completed March 5, 2020