Terra-Dynamics Consulting Inc.
432 Niagara Street, Unit 2 St. Catharines, ON L2M 4W3

March 29, 2023

Craig A. Rohe, Senior Planner
Upper Canada Consultants
3-30 Hannover Drive
St. Catharines, ON L2W 1A3

Re: Irrigation Pond Hydrologic Evaluation, Panoramic Properties Ltd., Former Oaklands Golf Club, Niagara Falls, ON

Dear Mr. Rohe,

1.0 Introduction and Background Information

Terra-Dynamics Consulting Inc. (Terra-Dynamics) respectfully submits this Irrigation Pond Hydrologic Evaluation for the Former Oaklands Golf Club, City of Niagara Falls, Ontario (Site, Figure 1). The 46 hectare Site is associated with 8970 Stanley Avenue, as well as Lots 1 and 2 Broken Front on Chippawa Creek and Part of Lot 20, Concession 3, former Township of Willoughby. Future development of the Site is proposed to be a mixture of single and multi-residential homes (Upper Canada Consultants, 2020). Within this former golf course are a series of 10 ponds which were constructed for irrigation (Figure 2).

The Niagara Peninsula Conservation Authority (NPCA) have requested "*further details as to how the constructed irrigation ponds do not meet the definition of a wetland under the Conservation Authorities Act*" (NPCA, 2023). This hydrologic evaluation was completed to provide those '*further details*' supporting that the constructed irrigation ponds do not represent wetlands regulated by the Niagara Peninsula Conservation Authority (NPCA) pursuant to O. Reg. 155/06.

It is our understanding that the NPCA does not currently have any formal thresholds, or criteria, for determination of a '*groundwater'* hydrologic connection between a '*wetland*' and a watercourse, where no surface water connection is apparent, but leaves this to qualified consultants to demonstrate (NPCA, 2021). A curriculum vitae is attached in Appendix A displaying the author's qualifications to complete this hydrologic evaluation.

This work demonstrates that the irrigation ponds at the former golf course do not constitute '*conservation authority regulated wetland*' under the Conservation Authority Act (Conservation Ontario, Ministry of Natural Resources and Forestry, 2005), specifically with respect to clause "b", see below:

wetland means land that,

a. *is seasonally or permanently covered by shallow water or has a water table close to or at its surface;*
b. *directly contributes to the hydrological function of a watershed through connection with a surface watercourse;*
c. *has hydric soils, the formation of which has been caused by the presence of abundant water; and*

d. has vegetation dominated by hydrophytic plants or water tolerant plants the dominance of which has been favoured by the presence of abundant water, but does not include periodically soaked or wet land that is used for agricultural purposes and no longer exhibits a wetland characteristic referred to in clause (c) or (d).

2.0 Physical Setting

The Site is within the Haldimand Clay Plain, which is the primary physiographic region south of the Niagara Escarpment in the Niagara Peninsula, and is comprised of glaciolacustrine clays and silts (Chapman and Putnam, 1984), a physical feature that "…*prevents significant infiltration to depth*…"(NPCA, 1999).

2.1 Soils

The Site's soils are derived from heavy lacustrine clay classified as Niagara Loamy Phase, having 15-40 cm of loamy textures over the underlying clay (Kingston and Presant, 1989). These Niagara Loamy Phase soils are imperfectly drained, moderately to slowly permeable (Kingston and Presant, 1989). Surface runoff ranges from slow on level topography to rapid on slopes, and surface cracking is common during dry summer periods. No tile-drainage is mapped at the Site (OMAFRA, 2023).

2.2 Overburden

The surficial geology below the irrigation ponds is glaciolacustrine silty clay (Ontario Geological Survey (OGS), 2003). The thickness of the clay and silt underlying the Site is between 22 to 23 m (NPSPA, 2013). Geologic cross-sections drawn through the Site (Figures 4 and 5) visualize the extent of the underlying silty clay as per the regional interpretation by the Ontario Geological Survey (OGS) (Burt, 2020).

2.3 Hydrogeologic Setting - Overburden Aquitard

The Ontario Geological Survey (OGS) have mapped the overburden underlying the irrigation ponds as a series of aquitards (i.e. Upper Whittlesey, Halton, Lower Whittlesey and Wentworth) (Burt, 2020, Figure 1, Appendix B, Section L-L', Borehole logs BH12-NP-2014 and BH26-NP-2014). This is consistent with classification of this unit as an overburden aquitard by the Ministry of the Environment (Conservation and Parks) that "…*transmit very small amounts of groundwater*" (Gartner Lee Limited, 1987). An aquitard is:

> *A geologic formation, group of formations, or part of a formation through which almost no water moves; a low-permeability geologic unit that can store groundwater, but that transmits groundwater slowly* (NPSPA, 2013).

2.4 Irrigation Ponds and Surface Watercourses

The 10 former golf course irrigation ponds (Figure 3) were constructed prior to 2000 based upon aerial photography but after 1965, however: (a) Irrigation Ponds 1 and 2 were enlarged between 2000 and 2006 and, (b) Ponds 3 and 5 were constructed between 2000 and 2006 (Niagara Navigator, 2023).

The Ontario Hydro Network (OHN) has mapped nine of the ten irrigation ponds (Pond 5 was not mapped) as between 0.02 to 0.09 hectares and are on average 0.6 hectares in size (MNRF, 2010a). However, the Ontario Hydro Network has not mapped any watercourses to, or from, these ponds (MNRF, 2010b). NPCA also mapped nine of the ten irrigation ponds (Pond 5 was not mapped), and identified the ponds as constructed, but did not identify any outlets or inlets to the ponds except for an inferred ephemeral swale between Ponds 4 and 6 (NPCA, 2017). It is estimated that the deepest ponds would be between 1.5 and 2 metres deep (Colville Consulting Inc., 2023).

3.0 Discussion

The irrigation ponds do not meet condition (*b*) of the four wetland tests to constitute '*conservation authority regulated wetland*' under the *Conservation Authorities Act*. This conclusion is because the wetlands do not "*directly contribute to the hydrological function of a watershed through connection with a surface watercourse"* (Section 1.0) and "*there is no groundwater connection*" (CO and MNRF, 2005) between the irrigation ponds and nearby watercourses. Reasons for this conclusion include:

1. There are no surface watercourses, swales, or drainage ditches that connect the irrigation ponds to the broader watershed; and

2. A low permeability aquitard is present beneath the Site that does not transmit appreciable quantities of water.

This is "*information to the contrary*" as referenced by Conservation Ontario and MNRF (2005) since no groundwater connection exists between the irrigation ponds and a surface watercourse.

Consequently, the irrigation ponds at the Site are not Conservation Authority regulated wetlands by virtue of no hydrologic connection above, or below, ground.

5.0 Conclusions and Recommendations

The following conclusions are provided:

1. The irrigation ponds are not connected to surface watercourses;

2. The irrigation ponds are underlain by silty clay;

3. The silty clay is an aquitard not transmitting "*appreciable*" quantities of water because of low permeability/hydraulic conductivity;

4. There is no hydrologic connection, above or below ground, between the irrigation ponds and the nearby watercourses; and

5. The irrigation ponds are not regulated by the Niagara Peninsula Conservation Authority.

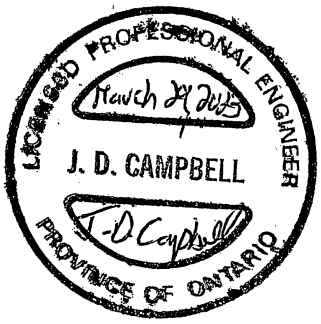
The following recommendation is provided with respect to the Site:

1. The irrigation ponds at the Site should not be regulated by the NPCA.

We trust this information is sufficient for your present needs. Please do not hesitate to contact me if you have any questions.

Yours truly,

TERRA-DYNAMICS CONSULTING INC.



Jayme D. Campbell, P. Eng.
Senior Water Resources Engineer

cc. Ian Barrett, Senior Biologist/Senior Manager, Colville Consulting Inc.

Attachments
Figure 1 – Location of Subject Lands
Figure 2 – Base Map
Figure 3 – Site Details
Figure 4 – Geologic Cross-Section A-A'
Figure 5 – Geologic Cross-Section B-B'
Appendix A – Curriculum Vitae
Appendix B – Supporting Information

6.0 References

Burt, A., 2020. Results of the 2014-2017 drilling programs on the Niagara Peninsula: Graphic logs, descriptions and analytical data; Ontario Geological Survey, Miscellaneous Release – Data 383.

Chapman, L.J., and Putnam, D.F., 1984. The Physiography of Southern Ontario. Ontario Geological Survey, Special Volume 2, 270 p.

Colville Consulting Inc., 2023. Re: Oakland Ponds, Ian Barrett (Senior Biologist/Senior Manager) to Jayme Campbell (Terra-Dynamics Consulting Inc.).

Conservation Ontario and Ministry of Natural Resources (and Forestry), 2005. Guidelines for Developing Schedules of Regulated Areas.

Gartner Lee Limited (GLL), 1987. Water Resources of the Niagara Frontier and the Welland River Drainage Basin. Prepared for the Ontario Ministry of the Environment.

Kingston, M.S. and Presant, E.W., 1989. The Soils of the Regional Municipality of Niagara, Report No.60 of the Ontario Institute of Pedology, Volume 1.

Ministry of Natural Resources and Forestry (MNRF), 2010a. Ontario Hydro Network, Waterbody, Provincial mapping unit.

Ministry of Natural Resources and Forestry (MNRF), 2010b. Ontario Hydro Network, Watercourse, Provincial mapping unit.

Niagara Navigator, 2023. Aerial Photography.

Niagara Peninsula Conservation Authority, 2023. Re: NPCA Review: Am-2021-016 and AM-2022-015 Oaklands-King Waldorf/Lyon's Narrows Second Submission.

Niagara Peninsula Conservation Authority, 2021. Re: 5600 McLeod Road, Niagara Falls – Question. E-mail from Sarah Mastroianni, Manager, Planning and Development, to Jayme Campbell, Senior Water Resource Engineer.

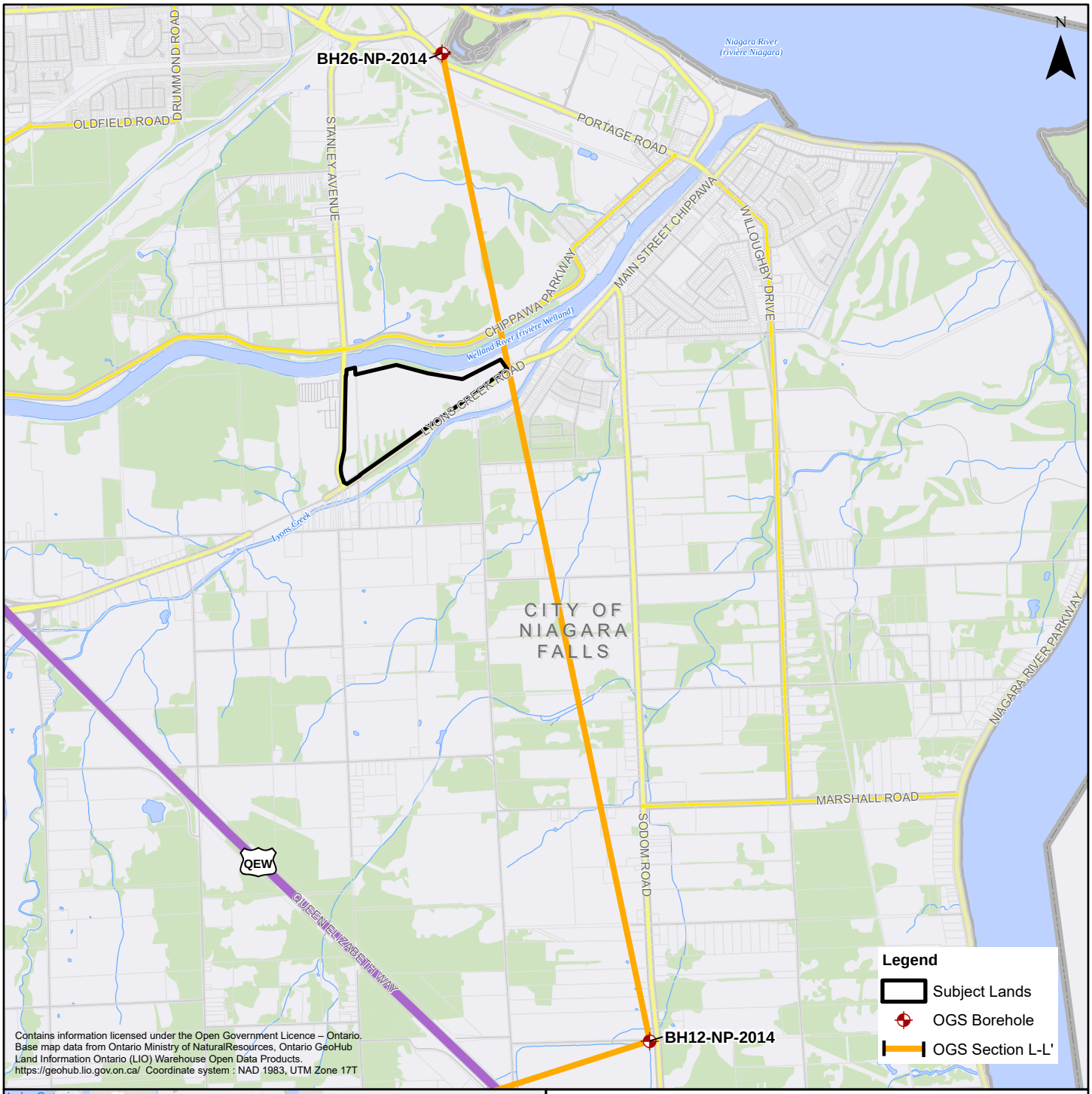
Niagara Peninsula Conservation Authority, 2017. Contemporary Watercourse Mapping.

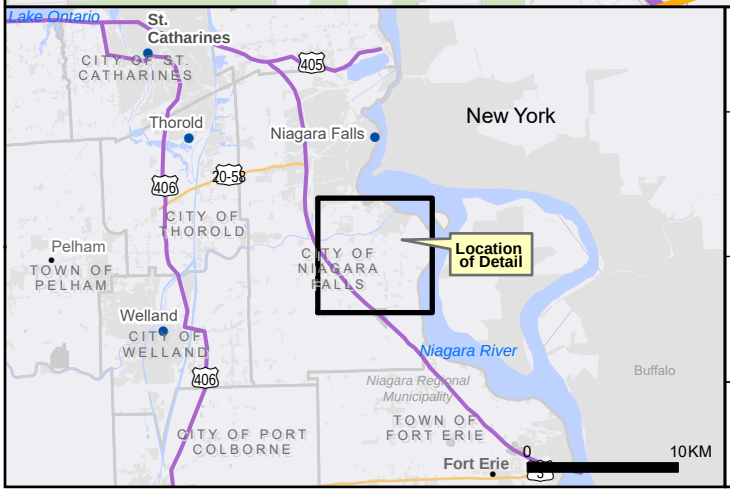
Niagara Peninsula Conservation Authority (NPCA), 1999. Port Robinson West Subwatershed Study.

Niagara Peninsula Source Protection Authority (NPSPA), 2013. Updated Assessment Report, Niagara Peninsula Source Protection Area.

Ontario Geological Survey (OGS), 2003. Surficial geology of southern Ontario. Miscellaneous Release Data – 128. Project Summary and Technical Document, 53 pp.

Upper Canada Consultants, 2020. Concept Plan 5 of Subdivision, Oaklands – Option B.





Location of Subject Lands

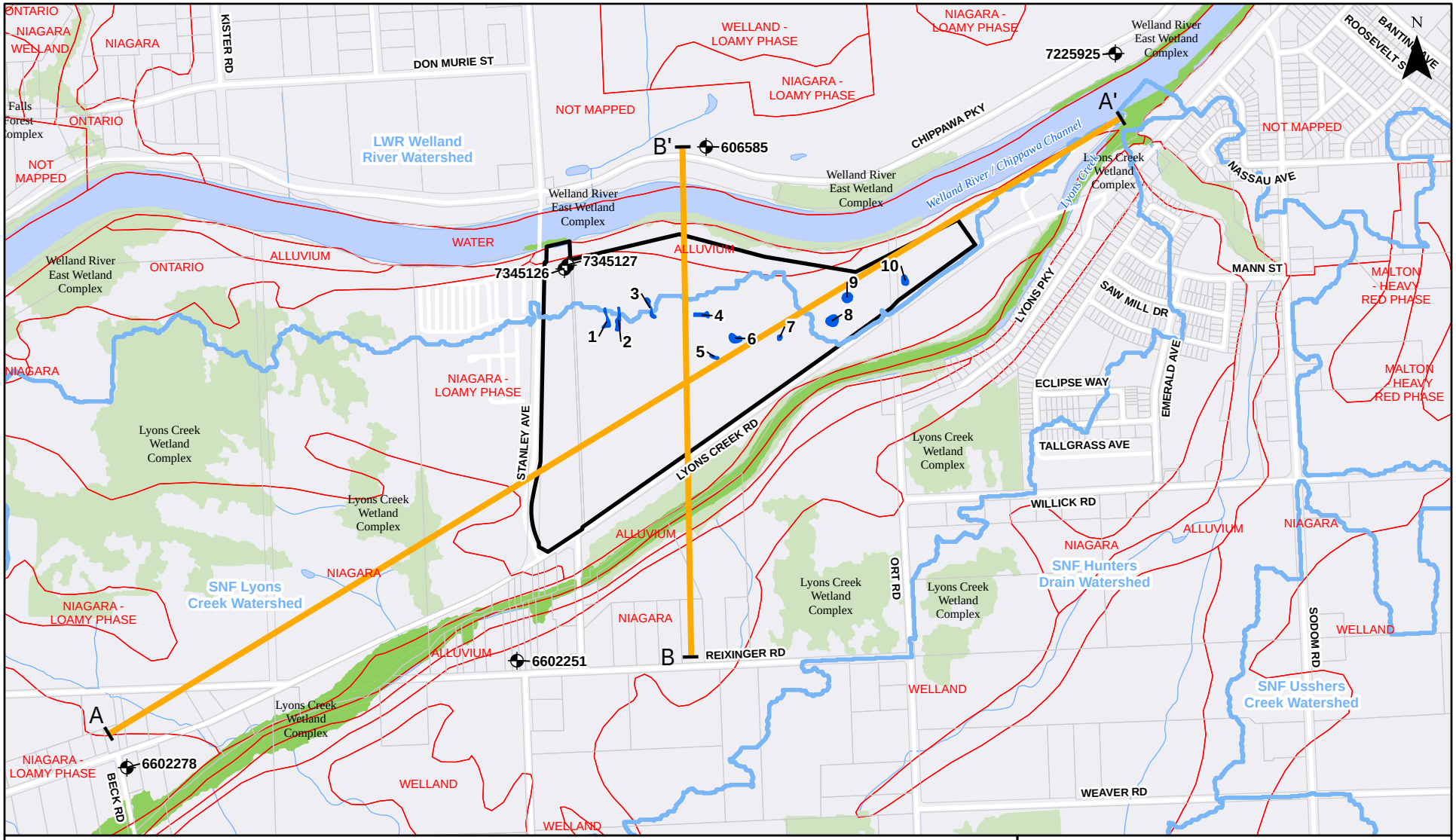
Former Golf Course, Lyons Narrows,
Irrigation Pond Hydrologic Evaluation,
Panoramic Properties Ltd.

TDC Terra-Dynamics Consulting Inc.

0 1 KM

Figure 1

Path: H:\TERRA_DYNAMICS\9441 - TD ___ Lyons Narrows\gis\mxd\2023 03 28 Pond Hydrologic Evaluation\Figure 1 Location of Subject Lands.mxd Revised: March 28, 2023



Subject Lands

Watershed Boundary

Irrigation Pond

Soil Survey Complex

MECP Water Well Records for Geologic Section

Geologic Cross-section

Wetland (Type)

Marsh

Swamp

Base Map

Former Golf Course, Lyons Narrows,
Irrigation Pond Hydrologic Evaluation,
Panoramic Properties Ltd.

TDC Terra-Dynamics Consulting Inc.

0 500 M

1:15,000

Figure 2

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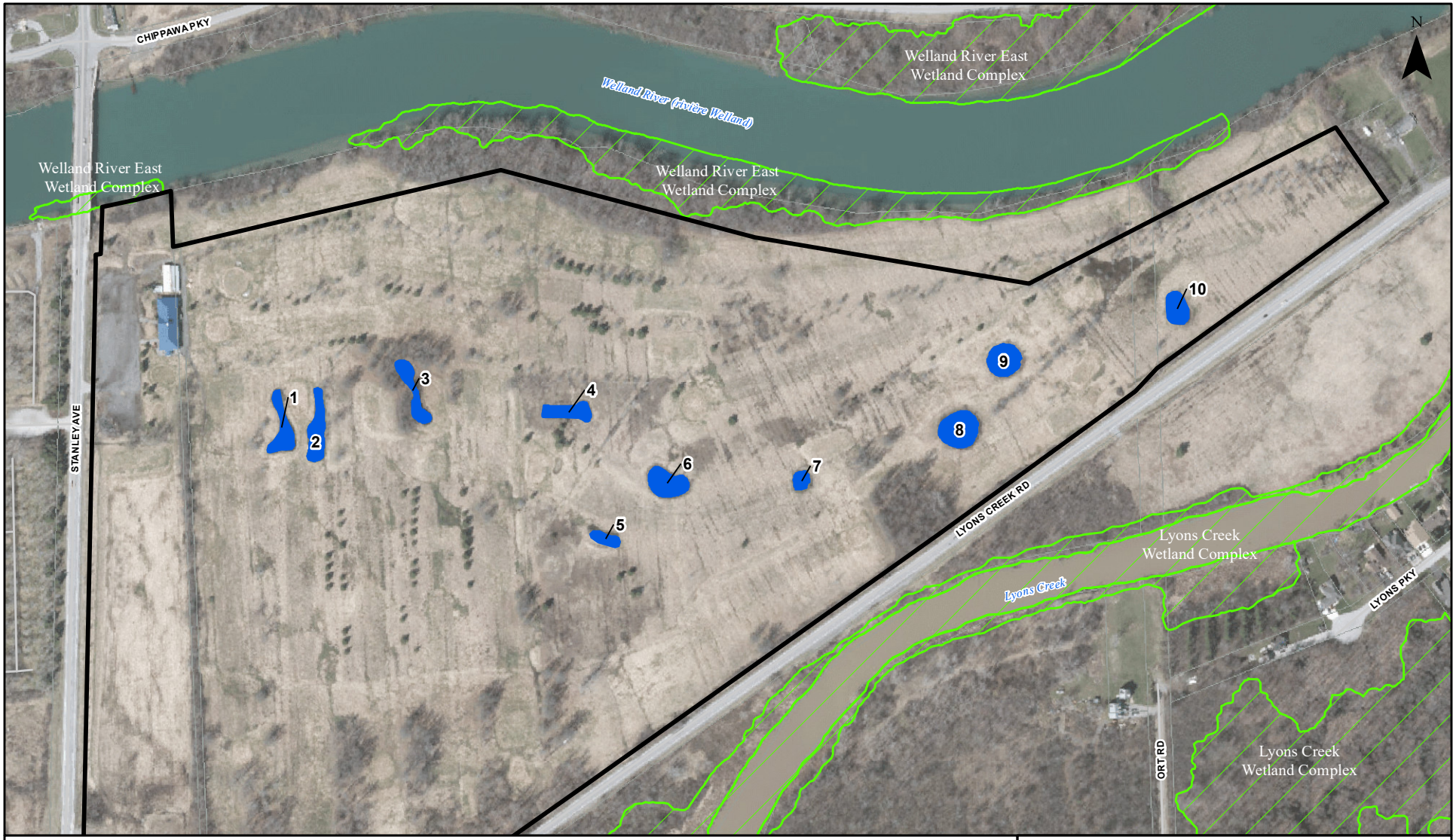


Subject Lands

Irrigation Pond

Provincially Significant Wetlands

Former Irrigation Ponds

Former Golf Course, Lyons Narrows,
Irrigation Pond Hydrologic Evaluation,
Panoramic Properties Ltd.

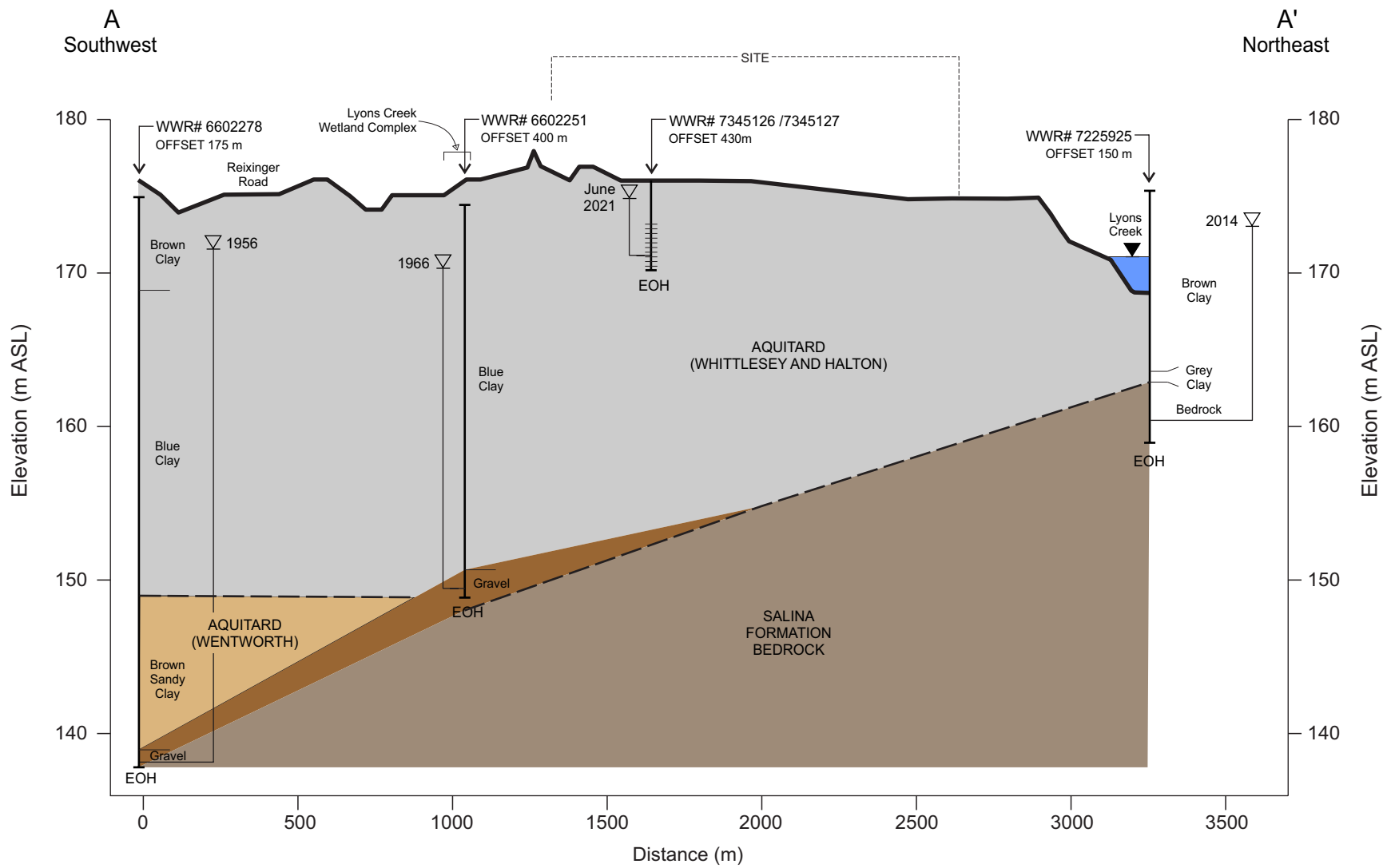
TDC Terra-Dynamics Consulting Inc.

0 150 M

1:5,000

Figure 3

Path: H:\TERRA_DYNAMICS\9441 - TD ___ Lyons Narrows\gis\mxd\2023 03 28 Pond Hydrologic Evaluation\Figure 3 Former Irrigation Ponds.mxd Revised: March 28, 2023



▽ Water Level On Water Well Record and Year

▼ Surface Water Level

EOH End of Hole

Well Screen

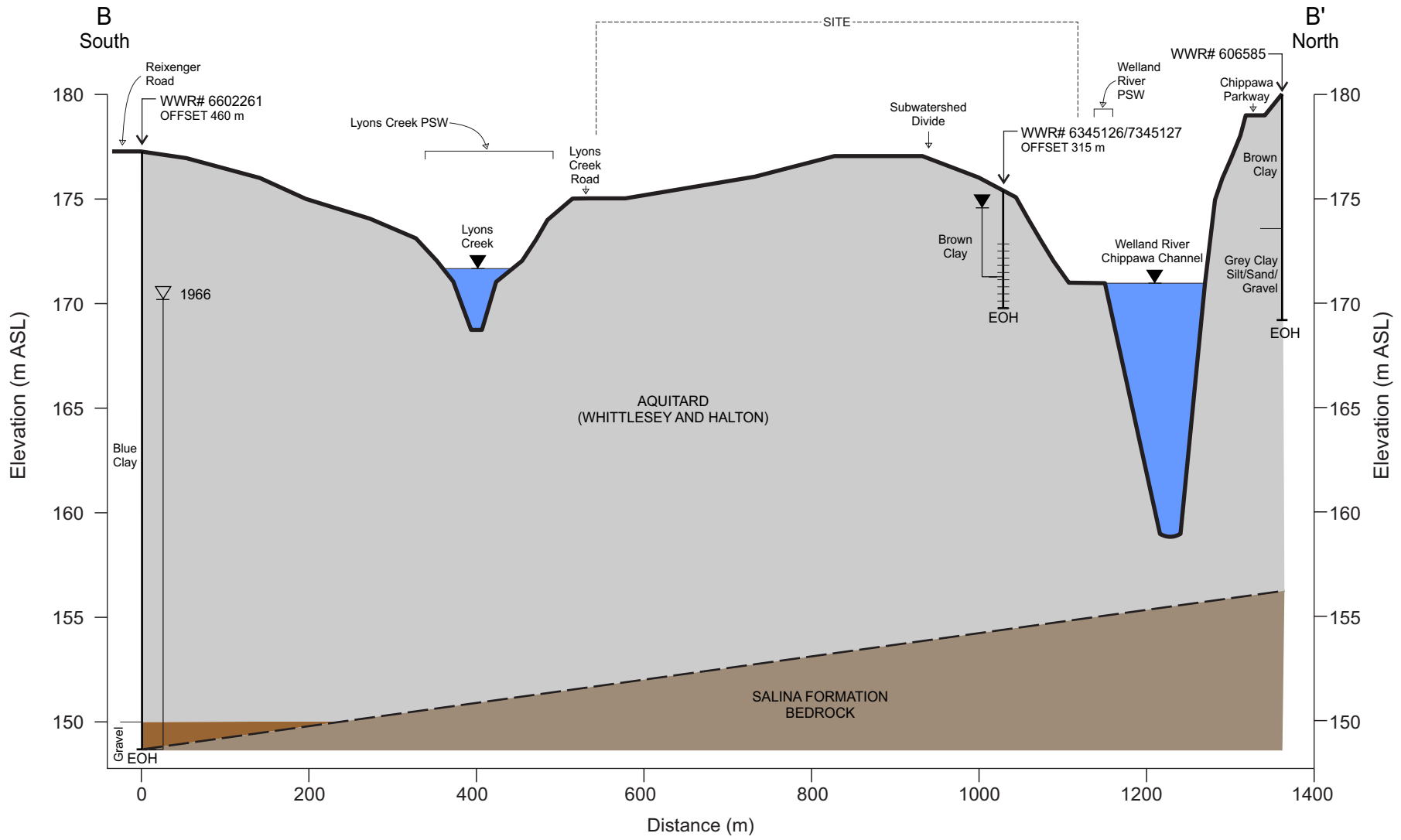
WWR# Water Well Record Number

Geologic Cross-section A-A'

Former Golf Course, Lyons Narrows,
Irrigation Pond Hydrologic Evaluation,
Panoramic Properties Ltd.

TDC Terra-Dynamics Consulting Inc.

Figure 4



▽ Water Level On Water Well Record and Year

▼ Surface Water Level

EOH End of Hole

Well Screen

WWR# Water Well Record Number

Geologic Cross-section B-B'

Former Golf Course, Lyons Narrows,
Irrigation Pond Hydrologic Evaluation,
Panoramic Properties Ltd.

TDC Terra-Dynamics Consulting Inc.

Figure 5

Appendix A

Curriculum Vitae

CURRICULUM VITAE

Jayme D. Campbell, P. Eng.
Senior Water Resources Engineer
Terra-Dynamics Consulting Inc.

432 Niagara Street, Unit 2
St. Catharines, Ontario L2P 2Y2
289-407-0915
jcampbell@terra-dynamics.com
www.terra-dynamics.com

EDUCATION

University of Waterloo, Waterloo, ON. B.A.Sc., Geological Engineering, Water Resources, 1997.
University of Waterloo, Waterloo, ON. Isotope Hydrology & Geochemistry Course, 2001.
Mohawk College, Hamilton, ON. Deterministic Surface Water Modelling Course, 2007-2008.

PROFESSIONAL LICENSE

Professional Engineer, Ontario, License No. 100011845

PROFESSIONAL HISTORY

Terra-Dynamics Consulting Inc., St. Catharines, ON
Senior Water Resources Engineer, 2018 to present

Niagara Peninsula Conservation Authority (NPCA), Welland, ON
Source Water Protection Project Manager, 2016 to 2018
Special Projects Supervisor, 2014 to 2018
Source Protection Engineer / Hydrogeologist, 2006 to 2013

Jagger Hims Limited, St. Catharines, ON – Project Engineer, 2002 to 2006

Stantec Consulting Limited, Kitchener, ON – Project Engineer, 1999 to 2002

Conestoga-Rovers & Associates, Waterloo – Engineer-in-Training, 1997 to 1999

REPRESENTATIVE EXPERIENCE

For over twenty-five years, Mr. Campbell, P. Eng., has been practising water resources management focussing on hydrogeology, with most of that time focussed on the Niagara Peninsula. Mr. Campbell's professional experience has included twelve years as a governmental representative and over thirteen years as an environmental consultant. His projects have included: drinking water protection studies (e.g. intake protection zones, water budgets, source protection planning), rural servicing assessments, policy development and stakeholder consultation, groundwater supply construction, testing, permitting and contract administration, landfill water monitoring compliance, Permit to Take Water reporting, wetland water balances, and contaminant and dewatering assessments.

Other professional experience has included:

- presentations to municipal councils, committees, the public, and technical gatherings;
- project management: request for proposals, proposal submissions, health and safety plans, budgeting, tendering, contract award, and provincial funding negotiations; and
- student training and lecturing (e.g. Niagara College and Brock University) as well as hosting student interns of Niagara College, Brock University and the University of Waterloo.

DETAILED WORK EXPERIENCE

TERRA-DYNAMICS CONSULTING INC.

2018 – PRESENT SENIOR WATER RESOURCES ENGINEER

Project responsibilities have included:

- Consulting Source Water Protection Project Manager services;
- Hydrogeological Assessments, including peer review, of privately serviced rural developments, including on highly vulnerable aquifers and hydrogeologically sensitive areas;
- Permit to Take Water (PTTW) studies for surface and groundwater takings;
- Environmental Compliance Approvals, including (i) sewage system performance reporting and (ii) groundwater impact assessments;
- Water balance assessments of hydrologic impacts to Wetlands;
- Dewatering hydrogeological assessment for new building construction;
- Landfill leachate collection system evaluations, Regional Municipality of Niagara;
- Advising municipalities about rural development on Highly Vulnerable Aquifers;
- Ambient geochemical sampling for the NPCA Niagara Regional Aquifer Study;
- Baseline hydrologic and water quality reporting for Jefferson Salamander protection
- Niagara-on-the-Lake Irrigation System Strategy Consultant Team Member;
- Expert testimony at the Local Planning Appeal Tribunal (LPAT);
- Construction administration; and
- Water well quality baseline and construction monitoring.

NIAGARA PENINSULA CONSERVATION AUTHORITY (NPCA)

2016 – 2018	SOURCE WATER PROTECTION PROJECT MANAGER
2014 – 2018	SPECIAL PROJECTS, SUPERVISOR
2006 – 2013	SOURCE PROTECTION ENGINEER / HYDROGEOLOGIST

Responsibilities included:

- Management of the Source Water Protection program at the NPCA. Duties for the Ministry of the Environment, Climate and Parks (MECP) included annual reporting on source protection plan implementation, workplan and budget submissions, the Source Protection Committee, and assisting plan implementers.
  - In Fall 2017, following stakeholder consultation, under Mr. Campbell's leadership, the first source protection authority workplan to update a Source Protection Plan was submitted to the Province. Implementation of this update involves working with various levels of government (municipal, provincial and federal), agencies (MECP, MNRF, OGS, MMAH, Health Units, Public Health Ontario) and other local stakeholders.
  - Co-authored the Niagara Peninsula Source Protection Plan and Assessment Report.
  - Principal author of the Niagara Peninsula Source Protection Water Budget.
- Highly Vulnerable Aquifer reviews for Niagara municipalities, e.g. ~100 reviews per year were completed in 2016 and 2017. Reviews largely completed during pre-consultation to advise planning and Part 8 Building Code staff if hydrogeological assessment reports were recommended, or to provide development conditions such as increased set-backs on hydrogeologically sensitive areas or nitrogen effluent reduction technology.
- Special Projects to address hydrologic data gaps, including:
  - Ontario Geological Survey Niagara Regional Aquifer Study: co-author of original proposal, procured multi-year grant funding for capital construction of four regional flow system monitoring well networks (28 monitoring wells), procured annual operational and capital budgets for sampling, monitoring and datalogging installations, facilitated annual sampling with the provincial ambient groundwater monitoring program, and partnered in geochemistry research projects with the University of Waterloo, MacMaster University and Environment Canada.
  - Advised municipal planners on: development near Provincially significant wetlands (e.g. near aggregate operations), municipal subwatershed studies, class environmental assessments, PTTWs and Niagara Escarpment Commission permits.
  - Advised NPCA on master planning, e.g. completion of a Water Resource Assessment of the Cave Springs Conservation Area, a karst area along the Niagara Escarpment.

2002-2006	PROJECT ENGINEER, JAGGER HIMS LIMITED

Mr. Campbell was responsible for various tasks including project management, budgeting, reporting and field investigations. He provided a broad range of services including Safe

Drinking Water Act compliance, Permit to Take Water and Waste Management investigations. Projects included:

- Landfill characterization or annual compliance reporting for open, closed and closing landfills (Thorold, Niagara Region, Abitibi-Consolidated Inc.);
- PTTW annual reporting for aggregate operations and municipal takings;
- Class Environmental Assessments: Groundwater Exploration (Whitchurch-Stouffville - York), Water and Wastewater Servicing Plan (Wainfleet – Niagara Region);
- Land development water resource assessment in a significant groundwater recharge area, baseline and construction monitoring (Walker Community Development Corporation);
- Metals-impacted environmentally sensitive area soil remediation and monitoring;
- Microbial Contamination Control Plans (Durham, Halton, Peel, Midland and Tweed);
- Municipal well construction contract administration, aquifer testing and PTTW (Uxbridge, Region of Durham);
- Water works sanitary assessment, industrial waste facility (Clean Harbours);
- Hydrogeological services, Provincial groundwater monitoring network (NPCA);
- Aquifer wellfield testing – Freelton and Carlisle (City of Hamilton).

1999-2002 PROJECT ENGINEER
STANTEC CONSULTING LIMITED (Kitchener)

Mr. Campbell was primarily responsible for field investigations (e.g. monitoring well construction, testing and sampling), data analysis, annual reporting and training of clients. Projects included:

- Well construction, aquifer and well testing, Groundwater Under the Direct Influence of Surface Water (GUDI) assessment, reporting and PTTWs (Thames Centre);
- Hydrogeologic assessments for subsurface sewage disposal facilities, PTTW and water quality (various Provincial Parks, Conservation Authorities);
- Safe Drinking Water Act Compliance assessments, including water quality monitoring training, inspections, and reporting (municipalities, corporations & conservation authorities);
- Phase I and II Environmental Site Assessments, and monitoring of remediation programs for gasoline, diesel and metals impacted sites.

1997-1999 ENGINEER-IN-TRAINING
CONESTOGA-ROVERS & ASSOCIATES (now GHD, Waterloo)

Mr.Campbell provided hydrogeologic communications services for understanding of complex physical settings by non-hydrogeologists. Computer models were created using EVS™ /MVS™ of topography, buildings, geology, groundwater flow, and soil/water chemistry for the public, regulatory authorities and clients. For example, an Ohio buried-valley aquifer system was visualized to evaluate contaminant risk to municipal wells. Indicator krigging was used to determine till aquitard distribution protecting the drinking water aquifer from contamination.

AUTHORED PUBLICATIONS or CONFERENCE/WORKSHOP PROCEEDINGS

Fitzpatrick, K. and Campbell, J.D. (2021)
Hydrogeological Tour of the Niagara Escarpment. Technical Tour for the 74th Canadian Geotechnical Conference (Joint CGS-IAH) 2021 Conference, Niagara Falls, Ontario.

Burt, A.K., and Campbell, J.D. (2021)
The Niagara Peninsula goes 3D. Proceedings, 74th Canadian Geotechnical Conference (Joint CGS-IAH).

Post, R. and Campbell, J.D. (2018)
Use of Provincial Data by Conservation Authorities. Regional-scale Groundwater Geoscience in Southern Ontario: an Ontario Geological Survey (OGS), Geological Survey of Canada, and Conservation Ontario Geoscientists Open House.

Campbell, J.D. (2018)
Rural development review from a conservation authority perspective. Ontario Onsite Wastewater Association Annual Convention.

Campbell, J.D. and Burt, A.K. (2015)
Addressing Niagara Decision Making Groundwater Gaps. OGS Open File Report 13-108.

Radman, M., M^{c}Innes, S. and Campbell, J.D. (2013)
Understanding and Protecting Groundwater. Workshop for Niagara Region area planners, Centre for Conservation, Balls Falls, Vineland, ON.

Fitzpatrick, K. and Campbell, J.D. (2012)
Technical Tour Book for: (i) Lake Erie to Lake Ontario, (ii) Spills, Mills and Landfills and, (iii) GW-SW Glacial Geology. Prepared for the International Association of Hydrogeologists 2012 Congress, Niagara Falls, Ontario.

Campbell, J.D. and Lee, J. (2012)
Source Water Sewage System Analysis. Proceedings, ESRI Canada Conference, Toronto.

Campbell, J.D., Golas, B., and Hendy, G. (2006)
Region of Durham Microbial Contaminant Control Plans. Proceedings, Joint Annual Conference (OWWA – OMWA).

Sarwar, G., Rudolph, D.L., Campbell, J.D. and Johnston, C.T. (2002)
Field Characterization of Road Salt Impacts on Groundwater Resources in an Urban Setting: Kitchener, Ontario. Proceedings, 55th Canadian Geotechnical Conference (Joint CGS-IAH).

PROFESSIONAL AFFILIATIONS

Professional Engineers Ontario (2000)
National Ground Water Association (2002)

Appendix B

Supporting Information

Borehole: BH12-NP-2014

Northing: 4763144
Easting: 658276
Elevation: 175.5 m asl

Conservation Authority: Niagara Peninsula Conservation Authority
Watershed / basin: South Niagara Falls
Subwatershed / subbasin: Usshers Creek

Depth (m)	Hydrostratigraphy* Unit Name	Description and Interpretation
0	Upper Whittlesey Aquitard	Fill
		Rhythmically bedded, clayey, deep water glaciolacustrine deposits with ice-rafted debris concentrated in the lower part of the unit. Ice retreat.
	Halton Aquitard	Stone-poor silty clay diamicton with some thin beds of silt. Halton deposits.
10	Lower Whittlesey Aquitard	Amorphous clay with rare ice-rafted debris. Deep water glaciolacustrine deposits with rainout diamicton (Halton deposits).
		Rhythmically bedded, clayey, deep water glaciolacustrine deposits. Rare beds of diamicton, clay with sporadic ice-rafted debris and laminations with gritty debris concentrated in the lower part of the unit.
	Wentworth Aquitard	Slightly stony, sandy silt diamicton with clayey beds in the upper part of the unit. Wentworth Till.
		Locally derived, stony, sandy silty diamicton with some deformed inclusions of clay. Wentworth deposits.
20	Bedrock	Rubble and highly fractured shale, dolostone and gypsum becoming more competent below 17.2 m bgs. Salina Group. Drilling mud losses in highly fractured interval.

Depth (ft): 0, 10, 20, 30, 40, 50, 60

Detailed Lithology: fine – coarse

Unconfined Compressive Strength (kg/cm²): 0 – 5

Grain Size: 0 % 100

Total Carb %: 10, 20, 30, 40, 50

Calcite Dolomite Ratio: 0, 2.5, 5, 7.5, 10

Pebble Lithology: 0 % 100

Core Recovery %: 0, 25, 50, 75, 100

Oxidation
- Fill
- Oxidized
- Reduced
- Coarse layers oxidized
- Fracture planes oxidized
- Bedrock

Evaporite Crystals
- Macroscopic crystals in sediment
- Macroscopic crystals in bedrock
- Not observed

Fractures
- Fractures/desiccation cracks in sediment
- Fractures in bedrock
- Not observed

Well Construction
- Riser
- Screen
- Benseal - bentonite
- Concrete
- Quickgrout - bentonite grout
- Holeplug - bentonite chips
- Sand pack

Class
- Aquifer / potential Aquifer
- Aquitard
- Bedrock

Lithology
- No recovery
- Clay
- Clayey silt, silty clay
- Silt
- Fine sand to silt
- Fine to medium sand
- Medium to coarse sand
- Sand and gravel
- Gravel
- Sand and gravel with some silt/clay in matrix
- Clayey silt to clayey diamicton
- Sandy to silty diamicton
- Fill

- Fill
- Rhythmically bedded
- Interbedded
- Fragmented beds, intraclasts
- Ripples
- Cross-beds
- Grit
- Slightly to somewhat stony
- Stony to very stony
- Diamicton and other debris

- Rubble, fractured rock
- Ordovician bedrock
- Silurian bedrock
- Devonian bedrock

Symbols
- Rare ice-rafted debris
- Striated bedrock
- Polished bedrock
- Organic material
- Cold core
- Trace fossils
- Radiocarbon (C^{14}) date

Deformation
- Disturbed or low recovery intervals
- Not observed
- Slight
- Moderate
- High

Grain Size
- Coarse to medium sand
- Fine to very fine sand
- Silt
- Clay

Pebble Lithology
- Limestone
- Dolostone
- Sandstone
- Shale
- Chert, evaporite
- Precambrian

Drilling Method
- Hollow-stem auger
- PQ coring
- Split spoon
- Tricone
- Hydrovac

*Hydrostratigraphic units are intended to reflect regional-scale sediment packages that will be modeled in three dimensions. The units are time-transgressive and may group lithologic packages.

Borehole: BH26-NP-2014

Northing: 4770080.1
Easting: 656818.27
Elevation: 185.35 m asl

Conservation Authority: Niagara Peninsula Conservation Authority
Watershed / basin: Lower Welland River
Subwatershed / subbasin: Welland River

Depth (m)	Hydrostratigraphy* Unit Name	Description and Interpretation
0	Upper Whittlesey Aquitard	Fill
		Rhythmically bedded, clayey, deep water glaciolacustrine deposits with some thin beds of diamicton and other ice-rafted debris concentrated in the lower part of the unit. Ice retreat.
	Halton Aquitard	Variably stony, sandy silt diamicton with thin diffuse to well defined beds, inclusions or lenses of sand, silt and clay. Bed of glaciolacustrine silt and clay with somewhat stony, silty diamicton. Halton Till, Niagara Falls Moraine.
10		Stone-poor clayey silt diamicton. Rainout diamicton, Halton ice advance.
	Lower Whittlesey Aquitard	Generally fining upwards silty to clayey deep water glaciolacustrine deposits reflecting decreasing sediment loads. Sporadic ice-rafted debris concentrated in upper part of unit. Rare gritty laminations.
		Beds of laminated and fining upwards glaciolacustrine sand and silt.
20	Whittlesey Aquifer	Generally fining upwards rippled and laminated sand to silty sand. Subaqueous current deposits, possibly confined to bedrock channel.
	Wentworth Aquitard	Firm to hard, variably stone-poor to stony, silty sand diamicton with locally concentrated beds, inclusions or lenses of sand, silt and clay. Wentworth Till and stratified deposits.
30	Bedrock	Fractured, vuggy dolostone with fossiliferous beds. Eramosa Formation. Some fractures widened. Lost return circulation in fractures. Bedrock surface glacially polished and striated.

Depth (ft): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110

Unconfined Compressive Strength (kg/cm²): 0 – 5
Grain Size: 0 % 100
Total Carb %: 10, 20, 30, 40, 50
Calcite Dolomite Ratio: 0, 2.5, 5, 7.5, 10
Pebble Lithology: 0 % 100
Core Recovery %: 0, 25, 50, 75, 100

Oxidation
- Fill
- Oxidized
- Reduced
- Coarse layers oxidized
- Fracture planes oxidized
- Bedrock

Evaporite Crystals
- Macroscopic crystals in sediment
- Macroscopic crystals in bedrock
- Not observed

Fractures
- Fractures/desiccation cracks in sediment
- Fractures in bedrock
- Not observed

Well Construction
- Riser
- Screen
- Benseal - bentonite
- Concrete
- Quickgrout - bentonite grout
- Holeplug - bentonite chips
- Sand pack

Class
- Aquifer / potential Aquifer
- Aquitard
- Bedrock

Lithology
- No recovery
- Clay
- Clayey silt, silty clay
- Silt
- Fine sand to silt
- Fine to medium sand
- Medium to coarse sand
- Sand and gravel
- Gravel
- Sand and gravel with some silt/clay in matrix
- Clayey silt to clayey diamicton
- Sandy to silty diamicton
- Fill

- Fill
- Rhythmically bedded
- Interbedded
- Fragmented beds, intraclasts
- Ripples
- Cross-beds
- Grit
- Slightly to somewhat stony
- Stony to very stony
- Diamicton and other debris

- Rubble, fractured rock
- Ordovician bedrock
- Silurian bedrock
- Devonian bedrock

Symbols
- Rare ice-rafted debris
- Striated bedrock
- Polished bedrock
- Organic material
- Cold core
- Trace fossils
- Radiocarbon (C^{14}) date

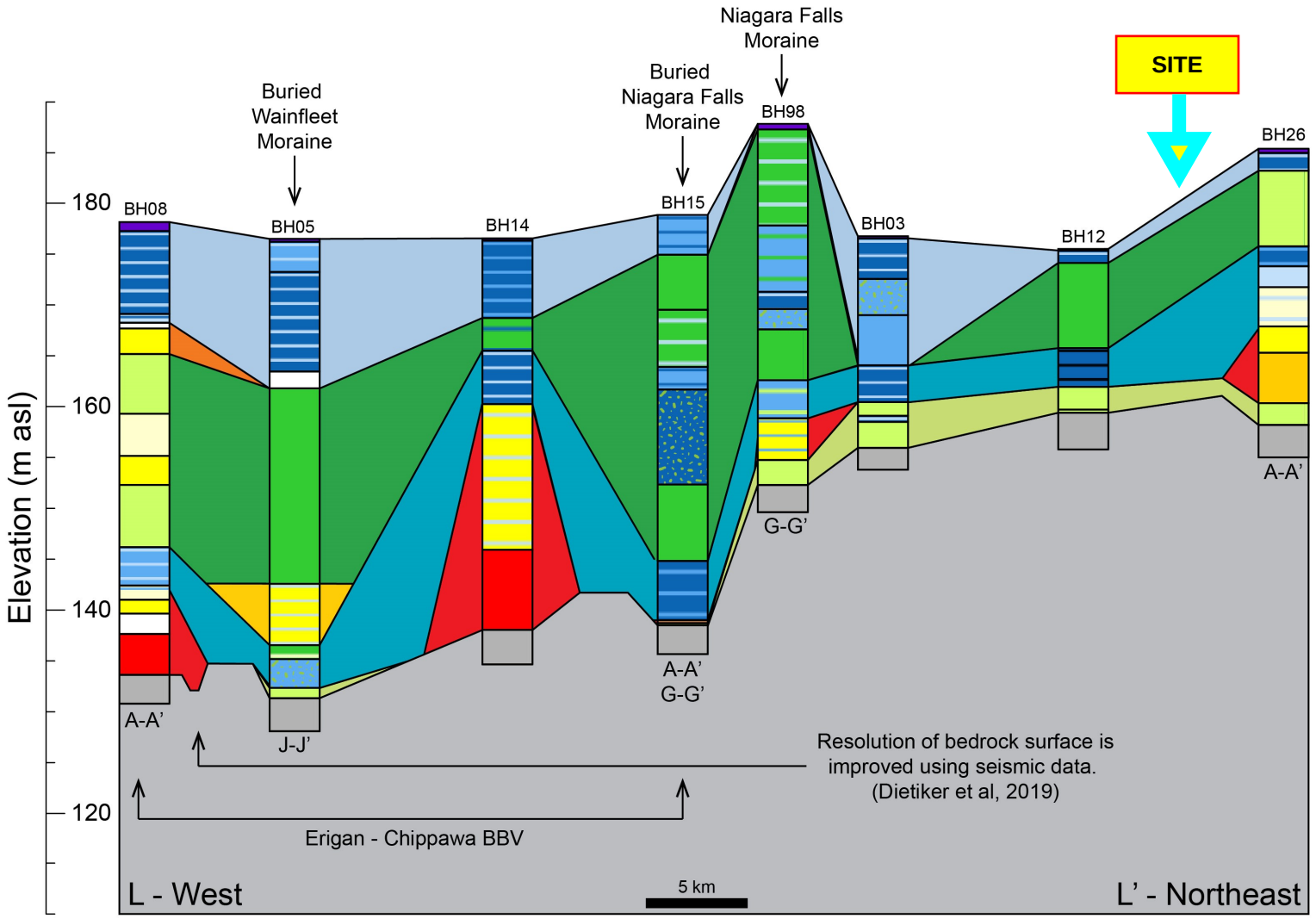
Deformation
- Disturbed or low recovery intervals
- Not observed
- Slight
- Moderate
- High

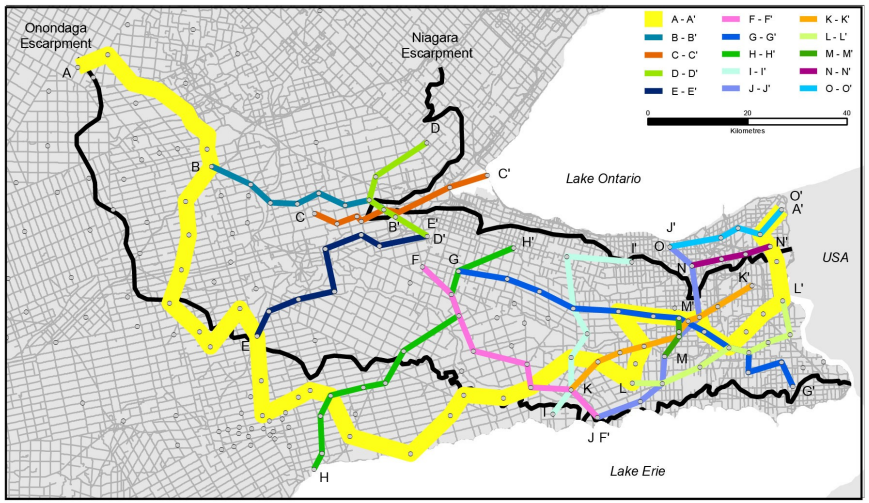
Grain Size
- Coarse to medium sand
- Fine to very fine sand
- Silt
- Clay

Pebble Lithology
- Limestone
- Dolostone
- Sandstone
- Shale
- Chert, evaporite
- Precambrian

Drilling Method
- Hollow-stem auger
- PQ coring
- Split spoon
- Tricone
- Hydrovac

*Hydrostratigraphic units are intended to reflect regional-scale sediment packages that will be modeled in three dimensions. The units are time-transgressive and may group lithologic packages.





Hydrostratigraphic Units

- Regressive aquifer
- Upper Whittlesey aquitard
- Upper Halton aquitard
- Halton aquifer
- Lower Halton aquitard
- Pre-Halton aquifer
- Lower Whittlesey aquitard
- Whittlesey / Ypsilanti Low aquifer
- Wentworth Till aquitard
- Maumee-Arkona aquitard
- Caledon - Grand River Outwash aquifer
- Upper Till / Port Bruce Phase aquitard
- Waterloo / Orangeville moraines aquifer
- Maryhill Diamicton / Erie Phase aquitard
- Lower Erie Phase aquifer
- Catfish Creek aquitard
- Pre-Catfish aquifer
- Pre-Catfish aquitard
- Lower Pre-Catfish aquifer
- Canning / Older Drift aquitard
- Pre-Canning / Older Drift aquifer
- Pre-Canning aquitard
- Paleozoic Bedrock

Lithology

- Silt / clay diamicton
- Sand / silt diamicton
- Dirty gravel
- Gravel
- Coarse sand
- Fine sand
- Sandy silt
- Silt
- Silty clay
- Clay
- Ice-rafted debris
- Rhythmic bedding
- Bedrock
- Fill
- No recovery