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Regional-Scale Groundwater Geoscience in Southern Ontario: The 2021 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House

2022

ONTARIO GEOLOGICAL SURVEY

Open File Report 6378

Regional-Scale Groundwater Geoscience in Southern Ontario: The 2021 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House

Compiled by

E.H. Priebe, D. Ford, S. Holysh, J.E. Nadeau and H.A.J. Russell

2022

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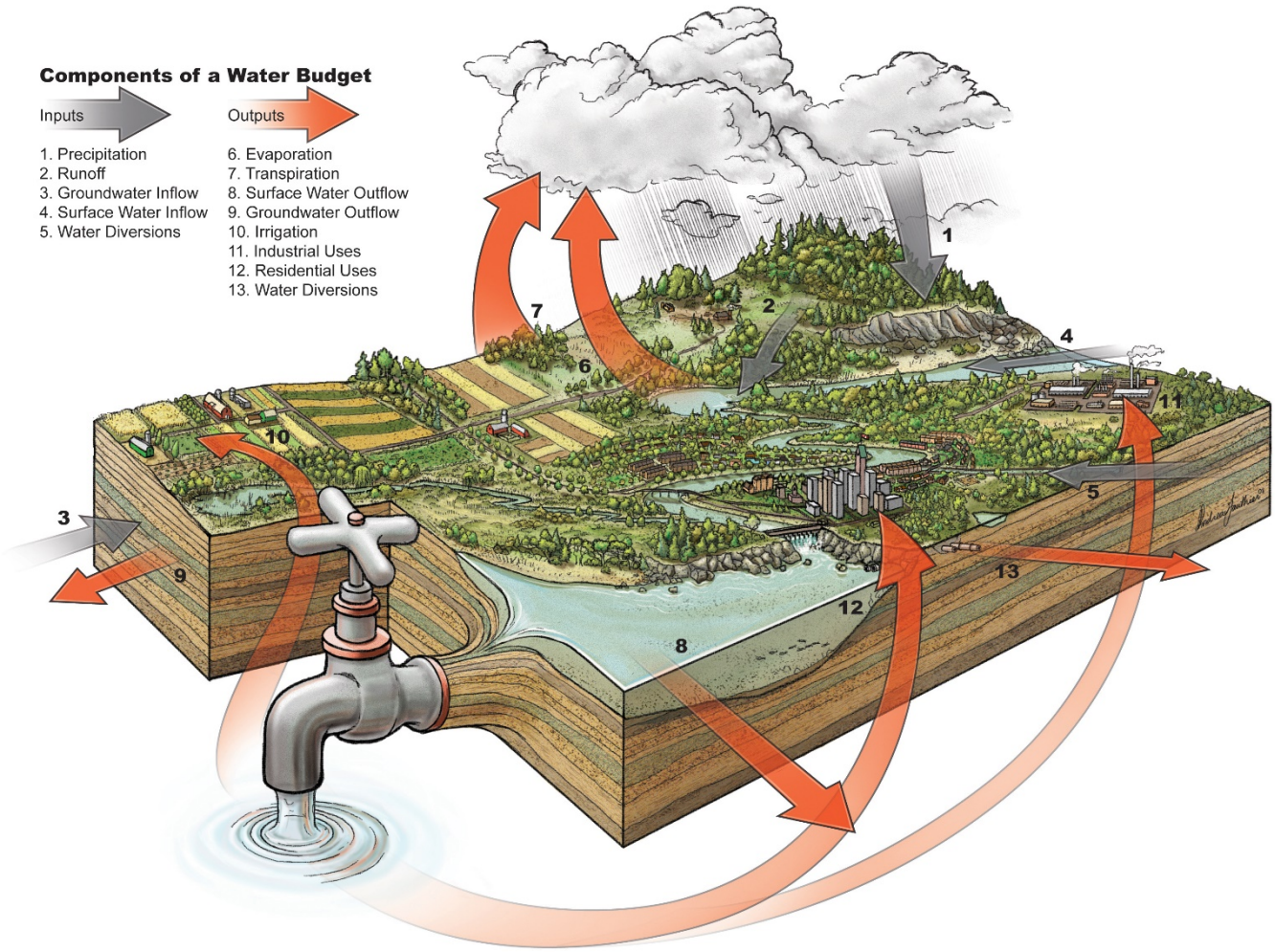
Regional-Scale Groundwater Geoscience in Southern Ontario: The 2021 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House

February 16 and 18, 2021 | Virtual Meeting



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Program

February 16 Presentations

START	END	TITLE	PRESENTER	AFFILIATION	SESSION
1:00	1:10	Opening Remarks	Beneteau / Boisvert	OGS / GSC	**Aqueous Geochemistry, Isotopes and Contaminants**
1:10	1:40	A Publicly Accessible Regional Groundwater Geochemical Data Set for Southern Ontario: Available to Support Public Health, Development and Environmental Research	Hamilton	OGS	
1:40	1:55	Investigating the Effect of Host Rock Lithology on Groundwater Chemistry in Crystalline Silicate Rock Terrain in Northeastern Ontario	Dell	OGS	
1:55	2:10	Tritium: Still a Useful Groundwater Tracer in Southern Ontario	Priebe	OGS	
2:10	2:25	Historic Landfills as a Source of Groundwater Contamination by Per-Fluoroalkylated and Poly-Fluoroalkylated Substances (PFAS: the so-called "forever chemicals")	Roy	Environment Canada	
2:25	2:40	A Machine Learning Approach to Predict Water Quality in the Glacial Aquifer System, USA	Eberts	USGS	
2:40	**3:00**	**Break**			
3:00	3:15	Overview of Current Ontario Geological Survey Groundwater Geoscience Activities	Dyer	OGS	**Groundwater Programs and Policies**
3:15	3:30	Ministry of Environment, Conservation and Parks: Groundwater Activities Update	Brodie-Brown	MECP	
3:30	3:45	Toward a Simplified, Standardized Nomenclature for Geological Materials in Well Records	Burt	OGS	
3:45	4:00	Geological Survey of Canada Groundwater Geoscience Program Activity in Ontario for 2020–2021	Russell	GSC / NRCan	
4:00	4:15	Environmental Change Onehealth Observatory (ECO^2): Ecosystem Services and Role of Hydrogeology	Lapen	Agriculture Canada	
4:15	4:30	Fully Integrated Groundwater–Surface Water Forecasting in Two Contrasting Hydrostratigraphic Settings Within Southern Ontario	Frey	Aquanty	

February 18 Presentations

START	END	TITLE	PRESENTER	AFFILIATION	SESSION
1:00	1:10	Opening Remarks	Ford / Holysh	TRCA	**Paleozoic Bedrock Modelling and Characterization**
1:10	1:25	A Revised 3-D Geologic Model of the Bedrock of Southern Ontario and Progress on Development of a 3-D Hydrostratigraphic Model	Carter	Carter Geologic	
1:25	1:40	Borehole Magnetic Resonance Technology for Hydrogeological Investigations	Crow	GSC / NRCan	
1:40	1:55	Porosity and Permeability Variations in Lower Silurian Stacked Dolostones of Lockport Group, Southwestern Ontario – GIS Analysis	Sun	University of Western Ontario	
1:55	2:10	Recent Advances Toward Borehole Drilling in Southwestern Ontario as Part of Geoscientific Site Characterization for a Deep Geologic Repository (DGR) for Canada's Used Nuclear Fuel	Sterling	Geofirma	
2:10	**2:30**	**Break**			
2:30	2:45	Ontario Geological Survey Borehole Releases: Do More Than Scratch the Surface	Burt	OGS	**Surficial Geology Studies and Applications**
2:45	3:00	What Lies Beneath: Scratching the Surface of Glacial Landforms in Southern Ontario	Mulligan	OGS	
3:00	3:15	Delineation of a Regional Recharge Area: The Waterloo Moraine	Shikaze	Matrix	
3:15	3:30	Multidisciplinary Geoscience Insights on the Western Champlain Sea Regional Aquitard	Hinton	GSC / NRCan	
3:30	3:45	Low-Temperature Geothermal Solution for the New Toronto and Region Conservation Authority Head Office	Ford	TRCA	
3:45	4:00	Aquifer Thermal Energy Storage Study for Ontario's Large Electricity Consumers' District Heating and Cooling Systems – York University Keele Campus Case Study	Djebbar	Canmet	
4:00	4:15	Seismic Data Acquisition Using Multicomponent Vibrating Source and Landstreamer on York University Campus: Preliminary Results	Pugin	GSC / NRCan	
4:15	**4:20**	**Wrap-up and Thank you**			

Context

The 2021 Ontario Geological Survey (OGS), Geological Survey of Canada (GSC) and Conservation Ontario (CO) groundwater open house represents the 6th annual event of its kind and the first time the event was offered virtually. The shift to a virtual open house was the best solution given the risks of meeting in person during the COVID-19 pandemic. Despite the circumstances, the virtual platform offered us the opportunity to keep the southern Ontario groundwater community apprised of new mapping, research and publications while staying safe. The unexpected benefits of the virtual platform were an increase in attendance, which nearly doubled from 2020, and the addition of new attendees from across the globe.

As in previous years, the 2021 open house aimed to share details of OGS, GSC and CO groundwater mapping and collaborations with a wide range of client groups while advancing geoscience knowledge across southern Ontario. Oral presentations were scheduled into themed sessions to facilitate strategic attendance in the virtual setting. The first day comprised talks focussing on groundwater geochemistry, followed by a session on groundwater programs and policy. The first session also featured an invited presentation by the United States Geological Survey, offering the opportunity to hear about how machine learning is helping to predict groundwater chemistry trends in the glacial aquifers of the northern United States. Day two consisted of sessions focussing on Paleozoic bedrock and surficial geology mapping and applications.

We trust that the groundwater open house will remain a valuable forum for sharing information and networking with peers in southern Ontario, whether offered in person or virtually. Contact information for speakers is provided at the end of this compilation to support future connections.

Acknowledgments

The time and effort of the workshop presenters and their respective agencies is much appreciated. Many thanks to OGS geoscientists for their internal abstract review.

Associated publications of previous gap analysis, workshop(s) and open houses between 2015 and 2022.

2015

Russell, H.A.J., Priebe, E.H. and Parker, J.R. 2015. Workshop summary and gap analysis report: Unifying groundwater science in southern Ontario; Ontario Geological Survey, Open File Report 6310, 64p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6310

Russell, H.A.J. compiler. 2015. Workshop on Groundwater Data Framework and Hydrogeology Model, Southern Ontario; Geological Survey of Canada. (no formal publication, *see* **Groundwater Information Network**)

2016

Russell, H.A.J. and Priebe, E.H. compilers. 2016. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey and Geological Survey of Canada Groundwater Geoscience Open House; Geological Survey of Canada, Open File 8022, 34p. doi.org/10.4095/297722

2017

Russell, H.A.J., Ford, D. and Priebe, E.H. compilers. 2017. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Geological Survey of Canada, Open File 8212, 56p. doi.org/10.4095/299750

2018

Russell, H.A.J., Ford, D., Priebe, E.H. and Holysh, S. compilers. 2018. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Geological Survey of Canada, Open File 8363, 62p. doi.org/10.4095/306472

2019

Russell, H.A.J., Ford, D., Holysh, S. and Priebe, E.H. compilers. 2019. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6349 / Geological Survey of Canada, Open File 8528 (doi.org/10.4095/313529), 32p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6349

2020

Priebe, E.H., Ford, D., Holysh, S., Russell, H.A.J. and Nadeau, J.E. compilers. 2020. Regional-scale groundwater geoscience in southern Ontario: An Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6361, 46p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6361

2021

Priebe, E.H., Ford, D., Holysh, S., Nadeau, J.E. and Russell, H.A.J. compilers. 2022. Regional-scale groundwater geoscience in southern Ontario: The 2021 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6378, 24p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6378

2022

Burt, A.K., Ford, D., Holysh, S., Kalmo, K.J.J. and Russell, H.A.J. compilers. 2022. Regional-scale groundwater geoscience in southern Ontario: The 2022 Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists Open House; Ontario Geological Survey, Open File Report 6379, 38p. www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=OFR6379

Presentations from previous years can be found on the Groundwater Information Network (GIN) (http://gin.gw-info.net/service/api_ngwds:gin2/en/gin.html, under "News"). Presentations from 2021 are available on the GSC Groundwater Geoscience Program YouTube channel under Playlists (www.youtube.com/channel/UCHIc7ff3vEdII708VhgsLsg/playlists). Some presentations may be missing and, in those cases, permission was not granted by the respective organization of the author(s).

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Ministry of Environment, Conservation and Parks: Groundwater Activities Update

Brodie-Brown, Heather; and Luciana M. Rodrigues

Ministry of the Environment, Conservation and Parks, North Wing, 2nd Floor, 125 Resources Road, Toronto, ON M9P 3V6

The Ontario government is committed to protecting our lakes, waterways and groundwater supplies, now and for future generations.

Our lakes, waterways and groundwater are a vital resource and the foundation of Ontario's economic prosperity and wellbeing – supplying water to our communities, sustaining traditional activities of Indigenous Peoples, supporting Ontario's economy, and providing healthy ecosystems for recreation and tourism.

Through our Made-in-Ontario Environment Plan, we committed to thoroughly reviewing the province's water taking policies, programs, and science tools to ensure that vital water resources are adequately protected and sustainably used. The ministry has completed this review of its policies, programs and science tools for managing water takings and water resources, assessed water sustainability in selected areas and consulted on proposed amendments to update water taking policies in Ontario.

In addition, the ministry has continued to undertake a number of groundwater-related activities, including updates to the Wells regulation, centralized approvals for permits, and groundwater quality and quantity research funded under the Canada–Ontario Agreement on the Great Lakes.

This talk will focus on providing updates on Ministry groundwater-related activities, such as these.

Ontario Geological Survey Borehole Releases: Do More Than Scratch the Surface

Burt, Abigail K.

Earth Resources and Geoscience Mapping Section, Ontario Geological Survey, Ministry of Energy, Northern Development and Mines, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5

The Ontario Geological Survey (OGS) has been engaged in three-dimensional (3-D) sediment mapping for over two decades, collaborating with the Geological Survey of Canada, Conservation Authorities and municipalities. Each 3-D sediment mapping project culminates in a *Groundwater Resources Study* (GRS) comprising a detailed report, digital isopach and structural contour maps, aquifer vulnerability maps, cross sections, graphic logs, geographic information system (GIS) grids and supporting databases. Prior to the release of the final GRS, annual articles for *Summary of Field Work and Other Activities*, geophysical maps, data sets and reports, continuously cored borehole releases, journal papers, and conference and symposium posters and presentations provide early access to both data and interpretations.

The recent Miscellaneous Release—Data 383 (MRD 383)—*Results of the 2014–2017 Drilling Programs on the Niagara Peninsula: Graphic Logs, Descriptions and Analytical Data*—contains an explanatory report and data organized into 6 folders: analytical data; GIS files; graphic logs; photographs; reference maps and subsurface database. This presentation will explore the contents and answer important questions about each data set. Where do the data come from? Are they qualitative or quantitative? Are there any pitfalls or biases that the user should keep in mind? How is terminology used?

Although MRD 383 is specific to the Niagara Peninsula project, there have been comparable releases for other OGS 3-D sediment mapping projects and monitoring well studies that collectively encompass detailed results from nearly 300 continuously cored boreholes. An in-depth exploration of this release will increase understanding of, and improve efficiency using, other subsurface data releases. The presentation will conclude by highlighting the down-hole geophysical logs, cross sections and interactive maps hyperlinked to graphic borehole logs that feature in some borehole publications.

OGS products are available for free download from Geology Ontario and OGS Earth:
www.mndm.gov.on.ca/en/mines-and-minerals/applications/geologyontario
www.geologyontario.mndm.gov.on.ca/ogsearth.html

Toward a Simplified, Standardized Nomenclature for Geological Materials in Well Records

Burt, Abigail K.[1]; Riley P.M. Mulligan[1], Frank R. Brunton[1], Kei H. Yeung[1], Natalie Spina[2] and Tim Cheng[2]

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[2] *Ministry of Environment, Conservation and Parks, North Wing, 2nd Floor, 125 Resources Road, Toronto, ON M9P 3V6*

The Ministry of Environment, Conservation and Parks (MECP) has publicly available well record data from the Water Well Information System (WWIS). These data include information on geological materials, well construction methods and materials, and water level, quality and quantity for over 835 000 water wells drilled across the province. In recent years, the ministry has addressed some of the problems with location data (i.e., ongoing location verification and assigning and updating reliability codes to reflect the margin of error). Clients who took part in the 2017 MECP WSP stakeholder survey stated that the biggest improvement the ministry could make to its well record data set would be improved quality of the data submitted on the well record form. Approximately one third of respondents, including OGS staff, indicated that the inaccuracy of overburden and bedrock material descriptions is one of their greatest challenges in working with the data set. There are currently 2 771 696 geological records within the database. For each record, up to 3 fields may be populated using 1 of 82 terms for materials, qualifiers and unknowns and 1 field is populated by colour, resulting in 37 836 unique combinations of terms currently in use. Many of the descriptive terms are repetitive or have no geological or hydrogeological meaning, and misidentification of geological materials and regional biases are common.

The Ontario Geological Survey (OGS) and MECP are in discussions regarding a project that will help well technicians to improve the quality of geological data for the approximately 23 000 well records added to the database each year, by developing a simplified, standardized and meaningful geological nomenclature. A stakeholder team of well technicians will be consulted on how current terms are used and on a proposed list of new terms. A guidance document providing simple (plain language) descriptions and tips for identifying and describing geological materials accompanied by representative photographs (section, core and cuttings), short printable field reference sheets and content for a mobile-friendly guide is envisioned. Standardizing nomenclature will increase internal (OGS, MECP) and external client efficiency and improve the quality and reliability of 3-D subsurface geological, hydrogeological and geotechnical projects that incorporate well record data.

An optional phase 2 proposes to consolidate historical terms, which will be retained in a separate field for reference and convert the historical terms into the new nomenclature. This phase would provide clients with a more streamline data set and reduce duplication of efforts. Note that correcting misidentified materials, regional biases or interpreting materials would not be undertaken.

A Revised 3-D Geologic Model of the Bedrock of Southern Ontario and Progress on Development of a 3-D Hydrostratigraphic Model

Carter, Terry R.[1]; Frank R. Brunton[2], Melissa Bunn[3], Jordan Clark[4], Stéphanie Larmagnat[3], Charles Logan[3], Hazen A.J. Russell[3], and Shuo Sun[5]

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A regional three-dimensional (3-D) geologic model of the Paleozoic bedrock of southern Ontario (Carter et al. 2019) has been revised to reflect data corrections and improved model layer rendering. The model encompasses the entire 1500 m of Paleozoic bedrock of southern Ontario over an area of 110,000 km^2. Fifty-three Paleozoic bedrock layers representing 70 formations, as well as the Precambrian basement and overlying unconsolidated sediment, were modelled at a spatial resolution of 400 m.

Revisions to model bedrock layers were largely controlled by corrections to formation top picks in the Ontario petroleum well database completed by QA/QC geologists at the Oil, Gas and Salt Resources Library. Formation top data from a total of 20,836 Ontario petroleum wells, 199 OGS stratigraphic tests, 15 measured sections, 3 Michigan petroleum wells, and 30 control points were utilized, including 7 new control points added to improve layer extrapolation beneath Lake Huron. Resolution of the subcrop surface is improved and there is a more accurate and realistic rendering and correlation of the topography and bedrock geology of the Niagara Escarpment. Many anomalous outliers and structural and thickness anomalies have been removed and gaps in model layers are greatly reduced. There was a focus on improving data quality and quantity for formations of the Lockport Group to improve model layers and support hydrostratigraphic modelling. Features added to the model include: 3-D extent of salt mining leases at Ontario's 2 underground salt mines, 3-D solution-mined caverns in salt units utilized for hydrocarbon and petrochemical storage and for mining of salt, two-dimensional representations of oil and natural gas reservoirs, regional faults, and lithotectonic boundaries in the Precambrian basement. An uncertainty analysis of individual model layers is underway. Public outreach and geological education initiatives include 3-D printed products and virtual reality (VR) realizations. The VR implementation is a fully interactive visualization of the model and also illustrates drill core cuttings and core. Release of the revised model will occur in early 2021.

Conversion of the geologic model to a 3-D hydrostratigraphic model is also underway. Thirteen bedrock hydrostratigraphic units are proposed, and one unit comprising all the surficial sediments. Assignment of lithostratigraphic units as hydrostratigraphic units is based principally on hydrogeologic characteristics in the intermediate to deep groundwater regimes, below the influence of modern meteoric water. Pending review of data support, the depiction of saturated zones of fresh, sulphurous and brine groundwater will be investigated. Related projects include a geospatial analysis of porosity and permeability variations in the Lockport Group, one of the principal bedrock aquifers, using petroleum industry drill core analyses from 11,513 depth intervals in 151 wells. Pore geometry and connectivity are also being investigated in paleokarst intervals from selected drill core from the Lockport and Salina groups using medical-grade computed tomography (CT) scan methodology.

Borehole Magnetic Resonance Technology for Hydrogeological Investigations

Crow, Heather[1]; Peeter Pehme[2], Beth Parker[2], and Hazen A.J. Russell[1]

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[2] G360 Institute for Groundwater Research, School of Environmental Sciences, University of Guelph, 50 Stone Road East, Guelph, ON N1G 2W1

A key aspect of groundwater evaluation and management is the reliable measurement of parameters that predict the quantity and movement of fluids and solutes in the subsurface. Borehole magnetic resonance (BMR) logging is one such technology that provides measurements of volumetric water content and estimates of pore size distributions for hydraulic conductivity (*K*) calculations at sub-metre intervals along the borehole. BMR systems use strong magnetic fields and sequences of radio-frequency pulses to polarize hydrogen in pore fluids surrounding the borehole. Originally developed by the oil sector, BMR tools have recently been adapted into slim-hole instruments, now making them suitable for the smaller diameter boreholes typically used in hydrogeologic investigations.

Early industry adopters have primarily used this slim-hole technology in unconsolidated sediments. In 2018, the Geological Survey of Canada (GSC) began conducting BMR logging in calibration boreholes intersecting deglacial sediments of the Ottawa Valley to investigate the potential for porosity estimations in materials of moderate magnetic susceptibilities. Impartial studies of the tools' reliability in Canadian shallow fractured bedrock and sedimentary settings, however, have not yet been completed.

To address this gap, the GSC and the G360 Institute for Groundwater Research (G360) are collaborating in a multiyear campaign of data collection at their respective bedrock borehole test facilities to assess the performance and limitations of slim-hole BMR technology from a hydrogeologic perspective. The test facilities in Ottawa (the Bells Corners Borehole Calibration Facility) and Guelph (the G360 Fractured Rock Observatory at the University of Guelph Arboretum) are designed to provide ongoing access to multiple well characterized boreholes with geologic variability at a broad range of scales within important water supply aquifers. BMR logging was carried out in fractured Silurian dolomitic and Cambrian sandstone bedrock boreholes where aquifer and aquitard units provide a range of clay contents, as well as primary and secondary porosity types (e.g., reefal structures, vugs, karstic features). Results are being compared to existing core measurements, geophysical logs, and extensive hydrogeophysical testing.

Key indicators of instrument performance were examined, including the vertical response curve, repeatability of porosity measurements, resolution at various fracture apertures, and how motion during logging affects tool response and acquisition time. Early results indicate BMR estimates of total porosity agree with core measurements to within ±4% in both the dolostone and sandstone, but the correlation deteriorates in finely bedded lithologies, and where fracturing is present. Much of the discrepancy is attributed to scaling, as the core samples are much smaller than the entire volume measured beyond the borehole wall with BMR probes. Overall, BMR is found to provide a robust continuous measurement of bulk matrix porosity and variability, which remains an important parameter in understanding contaminant diffusion and assessing remediation technologies in hydrogeologic investigations.

Investigating the Effect of Host Rock Lithology on Groundwater Chemistry in Crystalline Silicate Rock Terrain in Northeastern Ontario

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In 2016, a study was initiated in northeastern Ontario, in part to determine if the methods employed in the Ambient Groundwater Geochemistry Project (AGGP) in southern Ontario could successfully delineate the effect of Precambrian host rock lithology on groundwater chemistry. Field work involved the collection of groundwater in a broad band extending from Blind River in the west to Mattawa in the east, which also included Manitoulin Island. The area encompasses approximately 37 000 km^2 and a total of 437 samples were collected; 112 samples from overburden-completed wells and 325 samples from wells finished in bedrock. Samples were analyzed for metals, anions, bacteria, nitrogen parameters, δ^2H and $\delta^{18}O$, tritium and several other radionuclides.

The AGGP in southern Ontario delineated many natural trends related to geology. Paleozoic sedimentary rocks of southern Ontario are easily weathered and some of the trends and controls on groundwater chemistry identified were a result of minerals dissolving directly into groundwater. In northern Ontario, the crystalline silicate rock is less easily weathered and fractured; therefore, changes in water chemistry are further from equilibrium and thus subtler and not obviously related to geology. Since completion of field work in 2018, efforts have been focussed on characterizing the controls on groundwater geochemistry in the crystalline igneous and metamorphic rock terrain of the study area. Thus far, interpretation suggests that groundwater geochemistry is dominated by factors, including glacial sedimentary drift thickness and composition, deep brine mixing, road salt influence, pH effects and, for some parameters, lithology (on a geologic province scale). For example, groundwater samples collected from Southern Province rocks of the Huronian Supergroup and the Sudbury Basin show relatively high cobalt, arsenic and copper concentrations versus the Grenville Province. This correlation between Co–As–Cu concentrations and Southern Province groundwater samples is likely related to sulphides present in metasedimentary rocks of the Huronian Supergroup and mineralization associated with the Sudbury Igneous Complex and its footwall rocks. Although a host rock lithology signature was observed for some parameters, the trends are subtle and often masked by more dominant factors.

Analyses for $^{87}Sr/^{86}Sr$ were performed on 102 groundwater samples to investigate the utility of strontium isotopes as a tool to distinguish between major bedrock aquifers and to confirm sources of salinity previously identified through Principal Components Analysis. The $^{87}Sr/^{86}Sr$ isotope data present perhaps the strongest spatial correlation between groundwater chemistry and bedrock geology in the study area, showing distinct trends associated with the major geologic provinces and, in some cases, local geologic units. Samples collected from Southern Province and Superior Province aquifers are enriched in radiogenic Sr-87 relative to samples collected from Grenville Province aquifers. In some areas, $^{87}Sr/^{86}Sr$ values in groundwater trend toward known values from subcropping whole rock samples or deep brine samples, thus confirming that groundwater geochemistry is at least partly controlled by either mixing with deep brine or water–rock interactions. Future work will attempt to constrain $^{87}Sr/^{86}Sr$ values of overburden and bedrock strontium sources by analyzing additional groundwater samples collected from wells finished in overburden as well as whole rock samples from anomalous areas.

Aquifer Thermal Energy Storage Study for Ontario's Large Electricity Consumers' District Heating and Cooling Systems – York University Keele Campus Case Study

Djebbar, Reda

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Natural Resources Canada (NRCan) and its six Ontario partners are undertaking a case study aimed at evaluating a multidisciplinary geophysical-borehole approach for identifying suitable aquifers for large-scale seasonal thermal energy storage applications. This work will provide inputs for a feasibility study to assess the techno-economic potential of integrating large-scale underground seasonal storage in an example of an Ontario large electricity consumer, such as at York University Keele campus. Geo-exchange systems in general, and aquifer thermal energy storage (ATES) systems in particular, provide the opportunity to avoid rapid growth in winter heating energy peaks. Perhaps more important for the long term, ATES systems are currently the most efficient cooling system available (using conventional mechanical components), and, thus, can be instrumental in controlling summer energy peaks. This is relevant because, while most of the existing building stock has a higher heating demand than cooling demand, commercial and institutional buildings designed to newer building code requirements are actually cooling dominant. ATES systems are significantly cheaper than traditional borehole-based, closed-loop geo-exchange systems. However, ATES systems are highly dependent on the availability of a suitable aquifer, and the data gathering and analysis of the underground conditions can be costly and time consuming, which is a significant barrier.

In this presentation, the ongoing study aimed at evaluating a seismic survey data acquisition to support characterizing the hydrogeological properties to support a techno-economic analysis that will characterize the potential energy savings and greenhouse gas (GHG) reductions. Integration of state-of-the-art underground seasonal thermal energy storage technology options into the university existing district heating and cooling system will be introduced. Results of the study will inform York University investment decisions and will be shared widely with Ontario's large electricity consumers for potential replication and maximum beneficial impact on the province electrical grid. This project will demonstrate the potential of i) using non-intrusive non-destructive seismic surveys for the cost-effective characterization of large field areas in order to identify suitable aquifers for large-scale thermal storage applications, and ii) integrating large-scale underground seasonal storage for the GHG reductions, annual electricity and electricity peak shaving of large electricity consumers. Additionally, a preliminary map of high-yield suitable ATES sites in relation to medium- and high-density community loads will be published.

Overview of Current Ontario Geological Survey Groundwater Geoscience Activities

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The Ontario Geological Survey Groundwater initiative began in the early 2000s, in the aftermath of the Walkerton tragedy, to address the need for regionally based geoscience information to help inform source water protection plans. The primary objective of this effort is to conduct mapping to characterize the geometry and chemistry of the geology that contains groundwater resources. This objective is achieved by undertaking 3 core mapping activities.

3-D Sediment Mapping and Hydrogeological Characterizations

This activity consists of the development of 3-D geological models of the sediments (clay, sand and gravel) that overlie the bedrock. These models provide information about where groundwater is stored and where precipitation is entering the groundwater system. This activity was initiated in 2003 and has since covered 18,000 km^2. The identification and increased understanding of the "storage" and "recharge" areas for Ontario's groundwater is essential to protect the future of this critical resource. A relatively recent additional activity is the integration of hydrogeological characterization, both physical and chemical, with seamless 3-D Quaternary and bedrock models, to provide value-added support and additional mapping products for clients faced with groundwater-related questions.

Current active projects:
Niagara Peninsula – Abigail Burt, Quaternary Geoscientist
Central Simcoe County – Riley Mulligan, Quaternary Geoscientist
Ottawa and Eastern Ontario – Riley Mulligan, Quaternary Geoscientist
Regional Groundwater Systems Mapping in the County of Simcoe – Elizabeth Priebe, Hydrogeologist

3-D Bedrock Mapping

The 3-D bedrock mapping activity is conducted to characterize large-scale groundwater systems in the bedrock (limestone or carbonate) in southern Ontario. This activity was initiated in 2008 with drilling and bedrock mapping, followed by groundwater-specific investigations to understand groundwater movement and chemistry. The identification of karst features in the bedrock is also part of this mapping, as it can control both the quality and the quantity of the groundwater in southern Ontario. Beginning in 2015, the OGS collaborated with the GSC, Oil, Gas and Salt Resources Library and Ontario Ministry of Natural Resources and Forestry to produce the first 3-D Paleozoic block model for southern Ontario, published in 2019 as OGS Groundwater Resource Study 19.

Current active projects:
Southern Ontario 3-D Paleozoic model – Frank Brunton, Paleozoic Geoscientist; Kei Yeung, Applicationist
Subsurface Karst Mapping and Methodologies – Frank Brunton, Paleozoic Geoscientist

Ambient Groundwater Geochemistry

The goal of this activity is to understand the relationships between geology and groundwater chemistry in Ontario. The project consists of the collection of groundwater samples, primarily from domestic wells, usually at a density of approximately 2 wells per 100 km^2. Since its inception in 2007, this project has collected samples from more than 2500 wells across Ontario. Results from this sampling have identified previously unknown natural chemical trends in Ontario's groundwater that can be related directly to the geology. This program was extended into northern Ontario in 2016, with coverage currently spanning from Manitoulin Island to Mattawa.

Current active projects:
Southern Ontario Ambient Groundwater Project – Stew Hamilton, Senior Science Leader, Geochemistry
Northern Ontario Ambient Groundwater Project – Kayla Dell, Geochemist

A Machine Learning Approach to Predict Water Quality in the Glacial Aquifer System, USA

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The United States Geological Survey (USGS) recently completed a project that sought to observe, understand and predict water quality in the Glacial aquifer system (GLAC) of the northern tier of the contiguous United States. Water-quality data from Federal, State, regional, and local organizations were compiled and compared to health-based and aesthetic benchmarks. Analysis of the data indicates that almost 28% of the aquifer system has high concentrations of a trace element—most notably arsenic and manganese—and that the occurrence of these trace elements is controlled, in part, by pH and redox conditions, as well as position within the flow system. Boosted regression tree (BRT) models were developed to predict the occurrence of arsenic >10 µg/L and manganese >300 µg/L using readily available information on aquifer characteristics (e.g., texture and thickness), precipitation amount and chemistry, and soil texture and chemistry. A novel aspect of these models is the inclusion of estimates of pH and the likelihood of low dissolved oxygen or high iron—indicators of redox conditions—obtained from previously developed three-dimensional (3-D) BRT models, as predictor variables. Similarly, information on groundwater age was obtained by training a BRT model on the output of 115 MODFLOW/MODPATH models developed in select watersheds across the GLAC. Collectively, these 115 models are representative of the various hydrogeologic conditions that occur across the GLAC. Outputs from these previously developed models comprise some of the most important predictor variables in the BRT models of high arsenic and manganese occurrence. The most influential predictor variables for explaining high concentrations of arsenic and manganese were related to anoxic redox conditions, pH, groundwater age and depth in the aquifer, as well as physical characteristics of the aquifer, climatic conditions, and physical and geochemical characteristics of overlying soils. Mapped predictions of high arsenic concentrations at depths used for domestic and public supply show that high concentrations are most likely to occur in the Midwest (from Ohio into Minnesota and the Dakotas) in areas where the glacial sediment is thick. High manganese concentrations are predicted to occur at these depths primarily in the Midwest and Northeast, and over a larger area of the GLAC compared with high arsenic. Model diagnostic tools reveal that predictions of high arsenic and manganese are consistent with the anticipated effect of pH and redox conditions as well as position within the flow system. Information from these models can be used to identify areas where well owners might want to test their water supply for high arsenic or manganese concentrations and take appropriate actions if necessary. The machine learning approach (BRT models) can also be applied to other water-quality constituents. For example, 3-D estimates of nutrients developed using this approach could be coupled with simulations of the groundwater flow system to estimate contributions of nutrients to baseflow in streams that are tributary to the Great Lakes.

Low-Temperature Geothermal Solution for the New Toronto and Region Conservation Authority Head Office

Ford, Don

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The Toronto and Region Conservation Authority is in the process of constructing a new Head Office at 5 Shoreham Drive in Downsview, Ontario. As part of the process to obtain LEED (Leadership in Energy and Environmental Design) Platinum certification of this new structure, an earth energy system is proposed to provide high-efficiency heating and cooling. A preliminary borehole was drilled using the mud-rotary technique in January 2019 by Geosource Energy Inc. This borehole was terminated at a depth of confirmed overburden thickness of 119 m (about 66 m above sea level); much deeper than suggested by the existing mapping of the regional bedrock surface elevations in this area. Because of the deep overburden, Geosource suggested consideration of an aquifer-based system. Three potential aquifers were identified, and a second borehole was drilled with a PQ wireline core system in August 2020 to characterize the aquifers. The data from the two boreholes suggest that a bedrock valley is present in this location, and that a groundwater-based geothermal solution may be optimal in this location. Further work is contemplated in partnership with the Geologic Survey of Canada and York University to confirm the extent of the buried valley in this location.

Fully Integrated Groundwater–Surface Water Forecasting in Two Contrasting Hydrostratigraphic Settings Within Southern Ontario

Frey, Steven K.[1,2]; Omar Khader[1], Helen Zhang[3], Graham Stonebridge[1], D. Steinmoeller[1], Andre R. Erler[1,4], Amanda Taylor[1], Steven J. Berg[1,2], and Edward A. Sudicky[1,2]

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Over the course of the 2014–2019 Southern Ontario Groundwater Project, a fully-integrated groundwater–surface water model was developed and tested. This regional-scale model extends across the Phanerozoic terrain of southern Ontario and localized areas of exposed Precambrian Shield, such that the model boundary is coincident with watershed boundaries. The spatially heterogeneous subsurface component of the regional model includes three soil layers, five Quaternary layers, and either eleven or seven bedrock layers for the respective low (coarsely discretized) and high (finely discretized) resolution model versions. Since 2019, work with the regional model has been ongoing, including the development of a derivative set of watershed-scale models that utilize the same hydrostratigraphy as the regional model, but are constructed with much higher levels of spatial resolution. The watershed-scale models are incorporated into a hydrologic forecasting system that, until recently, had only been evaluated for its ability to predict short-term surface water flows. However, current efforts are focussed on further developing and evaluating the ability of the forecasting system to predict future groundwater conditions, including recharge, discharge, and water table position.

In this presentation, we will discuss the progress that is being made toward the goal of using the platform to provide short term (i.e., 1 to 7 day) and sub-seasonal (i.e., monthly) groundwater forecasts. The watershed regions of particular interest in this work are those that encompass the Quinte and Long Point Region Conservation Authority management areas. While both of these areas are highly susceptible to drought impacts on their groundwater resources, they provide contrasting hydrostratigraphy and hydrologic behavior, which, in turn, makes them ideally suited for forecast model evaluation and comparison.

In addition to the model-focussed discussion, we will also show recent developments with the web portal that is designed to disseminate the groundwater (and surface water) forecast information to a broad base of groundwater and surface water stakeholders.

Environmental Change Onehealth Observatory (ECO^2): Ecosystem Services and Role of Hydrogeology

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The Environmental Change Onehealth Observatory (ECO^2) is a new Government of Canada interdepartmental project founded on how changes in environment and land use impact the services, benefits and trade-offs provided by natural infrastructure and/or features in working agro-ecosystems. Natural infrastructure and/or features in agro-ecosystems in Canada include, but are not limited to, wetlands, riparian buffers, treelines, hedgerows, grasslands, treed blocks, etc. ECO^2 also includes, among this suite of natural elements, subsurface glacial depositional features, such as eskers, that control recharge–discharge functions and surface water temperature and/or quality. The group of natural infrastructure and/or features aforementioned variably regulate surface and subsurface hydrology and water quality, and, as such, the ecological function and biodiversity of many managed and naturalized water courses. Using hydrological modelling tools, ECO^2 has explored the implication of some of these features on flood and drought regulation, nutrient loads and concentrations, and recharge–discharge functions relating to colder and warmer water zones in rivers. The global aim of these assessments is to provide insight into the hydrogeological benefits and/or trade-offs of natural capital in agro-ecosystems, and, thereby, the enhancement of our capacity to quantify the economic, societal, and environmental value of these natural features.

A Publicly Accessible Regional Groundwater Geochemical Data Set for Southern Ontario – Available to Support Public Health, Development and Environmental Research

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Baseline information on groundwater geochemistry is useful in public health studies and to support environmental assessments. But it also has wide utility in groundwater and aquifer research, including studies on the nature and extent of flow systems. The publicly accessible Ambient Groundwater Geochemical (AGG) database covers all of southern Ontario (96,000 km^2) with a standard uniform density of 2 samples per 10 km × 10 km cell, which increases to 4 samples per cell (10,000 km^2) and even 20 samples per cell (2,100 km^2) in specific critical areas. The data all originate from primary sampling and analysis by the Ontario Geological Survey and partners, using a consistent sampling methodology and a geochemical characterization that includes 15 separate analytical datasets. Each of these is subject to its own rigorous quality control program based on 15% blind controls including duplicates, analytical blanks and multiple method-appropriate blind internal standards inserted either once or twice in every block of 20 samples.

Both monitoring wells (7%) and water supply wells (93%) are sampled, that together yield three types of water that we classify as bedrock, overburden, and bored or dug well water. Bored and dug, large-diameter wells (10%) rely on high storage rather than high flow to deliver an adequate domestic water supply. They are problematic for use in research and should be filtered-out of the dataset for most scientific purposes, especially those that require geochemical data representative of *in situ* aquifer conditions. In the AGG database, the remaining 90% of (drilled-well) waters are classified stratigraphically into 1) overburden (regolith), 2) overburden interface, 3) bedrock interface, 4) subcropping bedrock and 5) deeper bedrock. Overburden wells are completed in unconsolidated sediments, which are almost always glacially derived, and necessarily have screens. Interface wells are completed within 3 m above or below the bedrock surface, and even when completed in overburden, their waters usually have the chemical character of bedrock (because locally derived basal tills are similar in composition with an even higher surface area). For geochemical research purposes, they are often grouped together with subcropping bedrock wells, which are completed in the underlying mapped bedrock unit. Deeper wells are interpreted to be completed beneath the mapped surface bedrock layer in a deeper bedrock unit. For purposes such as mapping, or assessing the effect of surface lithology on chemistry, overburden and deeper bedrock wells should be filtered out.

The broad chemical characterization of the AGG data set was specifically intended to facilitate multiple uses and contains components that would not be of use in all studies. With purpose-specific querying and filtering, there is an almost limitless number of potential uses for the data set. It has already been used dozens of times for purposes that could not have been anticipated prior to the start of the study. Outcomes include 15 graduate and undergraduate theses, 9 published peer-reviewed works, with several more pending and dozens of government reports and papers. This is in addition to the projects it has supported by other government agencies, consultants and academia.

Multidisciplinary Geoscience Insights on the Western Champlain Sea Regional Aquitard

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The Rideau Valley Conservation Authority (RVCA) and the City of Ottawa initiated a hazard mapping study to identify flood risk and slope stability hazards along Bilberry Creek in Orleans, a suburb of Ottawa, Ontario. The study provided two cored boreholes for the Geological Survey of Canada (GSC), in collaboration with the University of Ottawa, to investigate pore water, geochemical, and physical influences on the geotechnical properties of Champlain Sea muds and their susceptibility for landslide events. Further research objectives are to characterize the hydrogeology of the regional aquitard and to establish two new reference sites in Champlain Sea sediments. The multidisciplinary geoscience approach will foster improved analysis and interpretation to support regional-scale understanding of the Champlain Sea aquitard in the Ottawa region.

A geophysical survey of ambient seismic noise was used to estimate soft sediment thickness and identify two drilling sites in thick Champlain Sea deposits. The drilling program yielded 147 Shelby tubes of sediment, 2 casings to depths 46 m and 67 m for downhole geophysical logging, 4 vibrating wire piezometers and 2 monitoring wells. Computed tomography (CT) scans provided sub-millimetre–scale imagery of sediment cores. Core extrusions and analyses of pore water and sediment samples are in progress.

Borehole geophysical logs of apparent conductivity and preliminary pore water chemical measurements indicate a substantially lower remnant seawater signature (15%) as compared to previous GSC studies of thick (>40 m) Champlain Sea sequences at Breckenridge, Quebec (63%) and Kinburn, Ontario (88%). The lower relic salinity at Bilberry Creek indicates greater displacement of connate seawater. In borehole geophysical logs, magnetic susceptibility anomalies suggest the possible occurrence of relatively coarser grained horizons. Similarly, CT scans reveal thin layers of higher density sediment, possibly coarser grained (e.g., very fine sand), interbedded with the mud. These observations suggest that higher permeability layers can allow for lateral flow within the Champlain Sea aquitard, providing opportunity for freshwater ingress and enhanced diffusion-driven outflux of solute.

What Lies Beneath: Scratching the Surface of Glacial Landforms in Southern Ontario

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Understanding the sources and flow paths of groundwater systems is an essential part of ensuring the sustainability of the provincial groundwater resource. In southern Ontario, many prolific aquifers are hosted, or originate, within glacial sediments. Determining the characteristics and stratigraphic architecture of these deposits will improve groundwater flow path predictions.

Since production of the southern Ontario seamless surficial geology map in 2003 and its update in 2010 (Ontario Geological Survey Miscellaneous Release—Data 128 – Revised (MRD 128—Revised)), a wealth of new data—particularly high-resolution LiDAR—have become available, permitting better evaluation of the distribution and genesis of surficial sediments. Improved terrain data also allow for the identification of features previously undiscernible through conventional mapping techniques, such as the sub-components of moraine systems, subaquatic fans and deltas, eskers, sinkholes, and tunnel valleys.

The Ontario Geological Survey has been conducting 3-D sediment mapping in southern Ontario since 2002. To date, more than 300 continuously cored boreholes have been drilled through the Quaternary sediment cover and uppermost bedrock, providing critical insights into the architecture and inherent properties of surficial landforms and buried features identified though geophysical techniques. Further integration of improved terrain data with high-quality subsurface geologic information improve predictions of sedimentological variations and modelled stratigraphic relationships between regional sediment units.

Tritium: Still a Useful Groundwater Tracer in Southern Ontario

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The thermonuclear tritium peak of 1963 was a key hydrogeological tracer in the Northern hemisphere for decades, used to estimate groundwater velocity and residence times. Today, the 1963 tritium peak has since been assimilated in most active groundwater systems by decay and dispersion. Long-term monthly tritium data collected in Ottawa show that concentrations in precipitation have been constant, with negligible decline since the early 1990s, with a median value of 15 tritium units (TU). With the assimilation of the 1963 tritium peak and the stability of concentrations in precipitation in eastern Ontario, we endeavour to investigate the future utility of tritium as a groundwater tracer in southern Ontario. Since its inception in 2007, the OGS Ambient Groundwater Geochemistry Project (AGGP) has collected samples from 2,561 wells across southern Ontario. At every sample location, the aquifer type was identified and groundwater samples analyzed for tritium, in addition to a wide range of geochemical and isotopic parameters. The AGGP tritium data set is globally one of the largest of its kind in spatial coverage and sample density.

To investigate the utility of tritium as a present-day groundwater tracer, the AGGP data were used to interpolate a tritium surface that represents the most modern local recharge conditions. The approach was initiated by selecting a subset of AGGP wells that have the greatest probability of representing local recharge conditions based on well depth, aquifer type and tritium content itself. Tritium content from the subset of wells was then interpolated across southern Ontario using the empirical Bayesian kriging method. The quality of the interpolation was assessed and improved upon by reviewing and eliminating wells with large relative differences between predicted and measured tritium. The largest relative differences in measured and predicted tritium content were identified in areas of known brine upwelling on the Niagara Peninsula, in flowing artesian aquifers in the lowland areas of the Laurentian Valley and in upwelling areas near Ottawa where the groundwater chemistry is known to be influenced by Champlain Sea deposits. With anomalous samples removed, the final interpolated tritium surface delineates areas influenced by natural cosmogenic fallout, as well as areas influenced by the anthropogenic effects of nuclear power plants at Pickering, on the north shore of Lake Ontario, and at Kincardine on the eastern shore of Lake Huron.

Although tritium in precipitation is relatively stable in Ottawa, tritium stability has not been assessed near the nuclear power plants. Despite possible inconsistent tritium levels in precipitation near nuclear power plants, long-term monitoring shows that nearby shallow groundwater tritium levels have been stable for more than a decade. Such stability, even where precipitation inputs vary the most, supports the use of our interpolation for estimating recharge end-member tritium concentration for any location in southern Ontario.

Seismic Data Acquisition Using Multicomponent Vibrating Source and Landstreamer on York University Campus: Preliminary Results

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To support a multidisciplinary Aquifer Thermal Energy System (ATES) project on the York University campus, North York, several six component seismic data sets were recorded using an in-house multicomponent vibrator source (Microvibe) and a landstreamer receiver array with 48 3-C 28-Hz geophones at 1.5 m intervals. The receiver spread length was 70.5 m, and the near-offset was 1.50 m. We used two source and three receiver orientations — vertical (V), and transverse-horizontal (H2). The most prominent *P*-wave reflection energy (PP) is recorded by the VV source-receiver orientation, whereas the most prominent *S*-wave reflection (SS) energy is recorded by the H2H2 source-receiver orientation. We computed the semblance spectra of the selected shot records and ascertained the wave modes based on the semblance peaks.

Three seismic lines over 2.5 km have been acquired in November 2020. As a result of poor signal-to-noise ratios created by unusually high wind, and the need to maximize three days of field deployment, available acquisition was limited to acquiring only SS reflection seismic for some of the survey. The results are encouraging as seismic penetration reaches bedrock, which is between 100 and 120 m depth. Two major reflections can be traced through-out the survey coverage, the shallowest reflector may be associated with the top of the Newmarket Till and the lower with the top of bedrock. A potential aquifer has been imaged in the northeastern campus area which is ~500 m wide and ~50 m deep channel structure. This survey demonstrates the capacity of a light and inexpensive seismic system to acquire very useful data for mapping groundwater aquifers in the glacial sediment of the Toronto–Oak Ridges region.

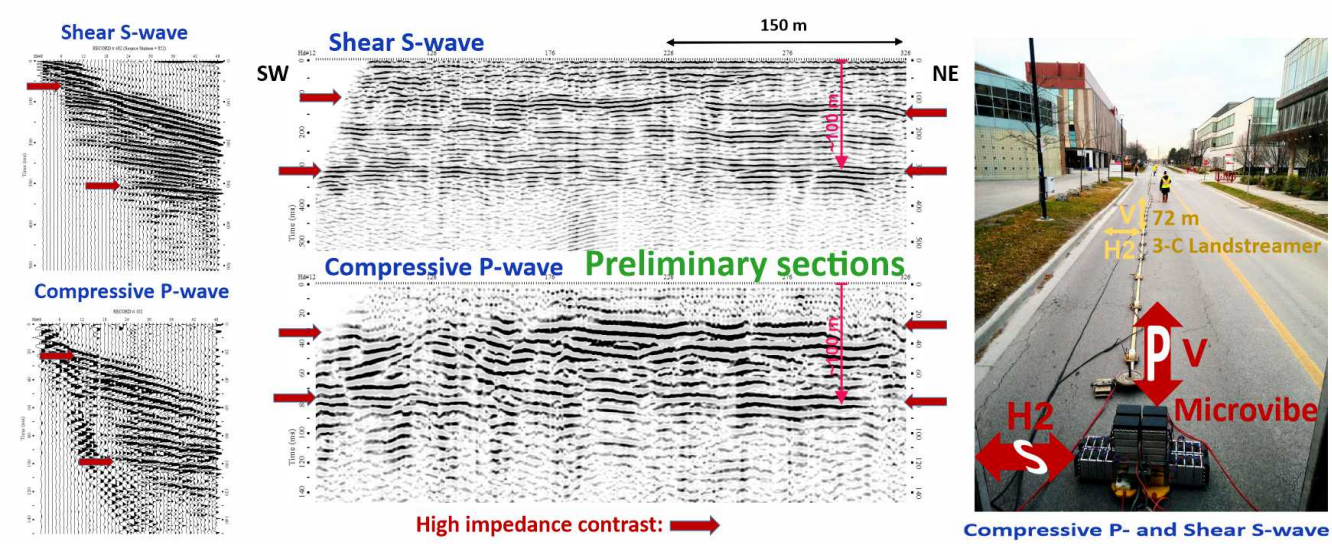

Figure 1. Profile from seismic survey of York University campus; from right to left, raw shot records, preliminary SS and PP seismic section, seismic equipment used for acquisition on a campus road.

Historic Landfills as a Source of Groundwater Contamination by Per-Fluoroalkylated and Poly-Fluoroalkylated Substances (PFAS: the so-called "forever chemicals")

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There is growing concern about the contamination of groundwater from the emerging contaminant group per- and poly-fluoroalkyl substances (PFAS) because of the extreme environmental persistence of many of these compounds and the potential risk they pose to human and ecosystem health. Many PFAS have been measured in the µg/L range in leachate of modern landfills. However, there is little information on PFAS in leachate of historic landfills (≥3 decades since closure), of which there are thousands across Ontario. Such old landfills may pose a greater risk of groundwater contamination and subsequent contaminant transport to nearby surface waters because they typically lack engineered liners and leachate collection systems. The objectives of this study were to investigate PFAS concentrations in historic landfills of Ontario, covering a range of ages and locations, and if possible, demonstrate that these compounds can be transported via groundwater to nearby surface waters.
To address this objective, leachate-impacted groundwater samples were collected from 20 historic landfill sites in Ontario and analyzed for PFAS and other emerging contaminants. At several sites, samples of groundwater discharging to a stream, wetland, or lakeshore were assessed, with surface water impacts measured at two sites.
I wouldn't be giving this talk if we didn't find any high concentrations of PFAS – so come find out how concerning the situation is for PFAS at Ontario historic landfill sites.

Geological Survey of Canada Groundwater Geoscience Program Activity in Ontario for 2020–2021

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Following the end of the 2014–2019 Southern Ontario Groundwater project, the GSC is proceeding with several new and continuing research activities in southern Ontario and the Great Lakes Basin. We have also initiated several new activities in the Ottawa area. This work is being completed within the Archetypal Aquifer Project with a focus on consolidating data and knowledge on Canadian aquifers. The focus of regional work remains on improvements to the regional bedrock model. This research has involved extensive QA and QC of formation identification, particularly in the area of Lake Huron and for the Lockport Group. In response to end user feedback, a number of metrics are being consolidated to support development of confidence measures for each surface. Model visualization and communication work is ongoing with the development of an improved virtual reality (VR) realization of the model supported in part by Oil, Gas and Salt Resources Library data. Detailed work is also being completed on bedrock permeability and porosity in the deeper subsurface and at the University of Guelph borehole facility. Support of regional groundwater studies is ongoing through collaboration on the numeric model and comparative studies involving GRACE (Gravity Recovery and Climate Experiment). This work is being extended into a transboundary Great Lakes Basin activity with the United States Geological Survey (USGS). Surficial geology analysis is ongoing on the geochemical framework and stratigraphic classification of Provincial Groundwater Monitoring Network (PGMN) wells for integration into the regional surficial geology model. Geophysical support for an Aquifer Thermal Energy Storage (ATES) project is being carried out at York University in collaboration with CANMET, and the Toronto and Region Conservation Authority (TRCA). In the Ottawa area, work continues on data collection and analysis at two field laboratories: the bedrock Bells Corners calibration site and the Embrun esker site. In the South Nation River watershed, the GSC is collaborating with Agriculture and Agri-Food Canada (AAFC) on the Environmental Change Onehealth Observatory (ECO^2). The GSC is continuing collaboration with the City of Ottawa and Rideau River Conservation Authority on an investigation of the sedimentology of Champlain Sea muds including pore water chemistry and geotechnical properties. These muds form an important aquitard and are infamous for retrogressive slope failures. In May of 2020, the southern Ontario summary volume was published, and results of that study are available online via GEOSCAN.

Delineation of a Regional Recharge Area: The Waterloo Moraine

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The Region of Waterloo relies on groundwater for approximately 75% of its water supply. With the population projected to increase from 600,000 to 742,000 by 2031, protection of the groundwater resource is critical. In particular, the sand and gravel aquifers in the Waterloo Moraine, which allow water to recharge the groundwater flow system and provide water to over 100 active municipal pumping wells located at over 40 well fields.

The hydrogeologic units that supply the Region include both shallow (unconfined) and deep (confined aquifers) in overburden and bedrock, which are separated by aquitards that are thick in some areas and non-existent in other areas. A detailed understanding of the nature of recharge across the Waterloo Moraine requires an understanding of the complex hydrogeologic units, as well as the nature of groundwater flow from recharge areas to the municipal wells. As part of the continuous improvement approach to maintaining the Regions water supply, a three-dimensional (3-D) groundwater flow model ("Moraine Model") has been continuously updated with results from each new field investigation and applied to inform planning decisions.

One such application is presented here: particle tracking techniques were utilized to delineate contributing recharge areas well fields and surface water features. Through this work, stakeholders and decision makers can benefit from improved understanding of existing and future long-term anthropogenic impacts on the area's local hydrogeology. This includes both municipal supply risk and urban planning perspectives, as well as from an ecological surface water-impact standpoint.

Recent Advances Toward Borehole Drilling in Southwestern Ontario as Part of Geoscientific Site Characterization for a Deep Geologic Repository (DGR) for Canada's Used Nuclear Fuel

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Geofirma Engineering Ltd. has been contracted by the Nuclear Waste Management Organization (NWMO) to implement a Borehole Drilling and Testing Program in South Bruce, Ontario. This work is part of NWMO's Phase 2 Geoscientific Preliminary Field Investigations of the NWMO's Adaptive Phased Management (APM) Site Selection Phase. The purpose of this geoscientific site characterization work is to collect additional information to assess the suitability of the South Bruce area to host a Deep Geologic Repository (DGR) for Canada's used nuclear fuel. This presentation provides an overview of the currently planned borehole drilling and testing program.

This project involves the drilling and testing of two deep boreholes (SB_BH01 and SB_BH02) in the South Bruce area and a similar overall scope of work is planned for each of the two boreholes. Site construction (access roads and drilling pads) started during October 2020 in preparation for drilling and testing activities currently planned to start in the Spring 2021 and completed during 2022. The two boreholes are located in NWMO's potential repository area in South Bruce, approximately northwest of the community of Teeswater, Ontario, and will be drilled vertically to a total target depth of approximately 900 m below ground surface (m BGS) through the entire sedimentary bedrock sequence down to the Cambrian sandstone or Precambrian basement.

Continuous core will be collected during drilling from these deep boreholes and will be digitally photographed (360° image) and geologically logged. Target core specimens will be preserved onsite and distributed to national and international laboratories for a wide range of geoscientific testing including geological, petrophysical, diffusion, porewater chemistry, and geomechanical analyses. During drilling, samples of groundwater will be collected from permeable bedrock formations and submitted for detailed analysis of major and minor ions, gases, and environmental isotopes. Following the completion of drilling, boreholes will be geophysically logged (standard electrical, nuclear and borehole imaging) and profiled for hydraulic conductivity and formation pressure using a custom-fabricated, straddle-packer hydraulic testing tool. At the completion of field hydraulic testing, the two deep vertical boreholes will be completed with multi-port/packer MP55 stainless steel monitoring casings manufactured by Westbay Instruments to allow long-term monitoring of formation pressures using both dedicated MOSDAX transducer strings and conventional pressure profiling.

Geofirma is leveraging their experience collecting similar data as part of previous work at the Bruce Nuclear Site between 2005 through 2011. The results of the two boreholes drilled and tested in the South Bruce area will contribute to NWMO's understanding of the sedimentary bedrock conditions in the South Bruce area.

Porosity and Permeability Variations in Lower Silurian Stacked Dolostones of Lockport Group, Southwestern Ontario – GIS Analysis

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Summary

The Oil, Gas and Salt Resources Library (OGSRL) staff in London, Ontario, have compiled a database of porosity and permeability core test results from 485 oil or gas wells, and 155 tests are from parts of the Early Silurian Lockport Group. The data comprise 11,543 porosity and vertical and horizontal permeability analyses. This data set, in combination with outcrop sections, newly drilled rock cores, and geophysical well logs, has been compiled into a geospatial and temporal analysis of porosity and permeability at the formational rank.

The Lockport Group consists of a cyclic succession of dolostones comprising, in ascending order: Gasport, Goat Island, Eramosa, and Guelph formations. These dolostones, which form the prominent Niagara Escarpment and cuesta, are amongst the most economically significant sedimentary rocks in southern Ontario because, in the outcrop belt, they are arguably the most important aggregate supply for construction industry and possess significant bedrock potable groundwater resources, and, in the deeper subsurface, are among the most significant producing oil or gas plays and natural gas storage reservoirs.

ESRI® ArcGIS® plots of the data provide a spatial distribution of formation isopachs and regional porosity and/or permeability variations in the deeper subsurface, and fills the gap between the shallow potable groundwater zone to the intermediate water zone, improving the representation of bedrock permeability zones, relationships to hydrocarbon traps, and isolation of deeper bedrock formations from interaction with meteoric waters.

Methods and Workflow

To improve the data quality, data validation has been conducted by summarizing laboratory protocols and standards from the 12 different laboratories and reconciling data fields with auxiliary data, including geophysics and duplicate cores. Data have been validated on the parameters of Effective Porosity, Grain/Bulk Density and Valid Permeability. Geology QA/QC of the 155 cored wells have been performed to delineate formational tops using geophysical logs and rock core lithofacies, in order to revise the regional lithostratigraphy. A core analysis database has been created with each porosity and/or permeability parameter plotted and isopach maps of each formation created in ESRI® ArcGIS®.

Results

The core analysis data are derived from the deeper subsurface of southwestern Ontario and represent the intermediate brackish to saline sulphur formational fluid regimes. This newly compiled data reveal that the porosity and/or permeability values are controlled by variations in the dolostone lithofacies, diagenetic destruction and/or enhancement, presence of evaporites, and existence and/or development of paleokarst.
The inter-pinnacle facies of the Guelph Formation have high porosity and permeability values resulting from the paleokarstic nature. The high porosity and permeability of the Guelph Formation within pinnacle structures have enabled entry of oil and natural gas reservoirs and/or saline water–bearing zones and remobilization of salts. From the inferred Algonquin Arch to western Lake Erie, both the karstic top of the Guelph Formation and the overlying A-1 Carbonate have variable and more permeable intervals, and the Gasport Formation also possesses relatively high permeability.

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Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton(short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 9**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy) / ton (short)	1 ounce (troy) / ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights / ton (short)	1 pennyweight / ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors in ***bold*** *type are exact. The conversion factors have been taken from or have been derived from factors given in the* Metric Practice Guide for the Canadian Mining and Metallurgical Industries*, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

Notes

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