Dear G360 Collaborating Colleagues & Friends,

In association with UN World Water Day on March 22, we bring you positive news on our G360 Institute 2019 projects, involving local and international activities focused on groundwater resource protection and remediation. Our multi-disciplinary field-focused efforts in collaboration with site owners, groundwater technology, service companies, and government sponsors truly set us apart. We appreciate everyone’s contributions, from funding to on-the-ground efforts using expert knowledge to collect novel datasets and their interpretations. The current situation with COVID-19 and social distancing is redirecting our early spring field plans toward data analysis and writing theses and papers, however we remain productive with our 2020 research activities. Two news stories are worth highlighting:

Announced March 23, Dr. John Cherry received the prestigious **Stockholm Water Prize** for his lifelong contributions to groundwater science, education, practice and for translating his well-earned stature into a passionate and highly effective advocacy for groundwater science (see page 24). As a University of Guelph adjunct professor and G360 Principal Investigator, John continues to inspire hydrogeologists young and old around the globe with his participation in G360 projects and work with our industry sponsors through The University Consortium (founded in 1987). His current focus is developing a modern groundwater “textbook”, an eBook referred to as **The Groundwater Project (GWP)** to serve as a compilation of the current state of science, highlighting the essential and increasingly important role groundwater plays in nearly all facets of society as we recognize climate change and anthropogenic activities create increased vulnerability for freshwater resources. The **GWP website** is open to the public as of March 23, with the first round of publications available August 2020.

Second, we are proud to announce the University of Guelph Board of Governor’s approval for our on campus G360 field research facility to support our novel field-based research program and collaborations. The facility design supports technology development, knowledge transfer, and public outreach. We have already reached **50% of our fundraising goal** and we seek remaining funds from alumni, friends and partners via personal contributions on our **donation page**. Please see page 4 for further details and inspiration for advancing our goals. With your support, we aim to open this facility by UN World Day in March 2022, with the theme ‘Groundwater: Making the Invisible Visible.’ Please consider participating with us in realizing this vision.

Again, we thank you for the opportunities to work together and look forward to continual dialog.

Please stay healthy and hydrated in 2020.

Sincerely,
Beth Parker
New Team Members

**Students**

Michelle Leahey has joined our team as an MASc student and recently completed a Bachelor of Science in Earth and Environmental Sciences from McMaster University. Michelle is looking forward to expanding her knowledge of contaminant hydrogeology and wishes to contribute meaningful advances to the field.

Faran Vahedian completed her MASc degree in Water and Environmental Engineering from Shahid Beheshti University in 2017. She has since joined the G³60 group as an MASc student. Faran’s research interests include groundwater dynamics and contaminant transport and fate, groundwater remediation, source water protection, risk assessment of groundwater vulnerability to contamination, and numerical modeling.

Mónica Resto-Fernandez recently completed a MSc in Environmental Engineering from Mercer University with a graduate focus in Engineering for Development. She completed a BSc in Civil Engineering from the University of South Florida (Tampa, Florida, USA). Monica is looking forward to her time at the University of Guelph as a PhD student.

**Staff**

Chrystyn Skinner completed her BSc in Environmental Earth Sciences at the University of Alberta and recently her MSc in Environmental Sciences (Hydrogeology) at the University of Guelph as part of the G³60 team. She has since transitioned to Staff Researcher, with a focus on high-resolution methods to characterize groundwater flow systems, particularly in municipal supply aquifers for designing monitoring networks and evaluating potential impacts to drinking water resources.

Tarju Dweh-Chenneh has joined the group as Manager of Finance, Grants & Contracts. Tarju is a financial professional with over 10 years of experience in financial reporting and evaluation, project management and auditing within government and non-profit sectors. She has specific expertise in budget forecasting for grants proposals, and monitoring and tracking grants and contracts.

Saeid Shafieiyoun completed his PhD in Civil and Environmental Engineering at University of Waterloo. His research is focused on the enhancement of chemical and biological remediation practices in the petroleum-contaminated subsurface systems. He has employed computational fluid dynamic (CFD) methods as well as experimental and field approaches to explore mass transfer and hydrogeochemical characteristics of the aquifer system.

**Interns**

Carole Ruppli completed her Bachelor of Environmental Engineering at Ecole Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. Before starting her Master’s program in the Fall, Carole joined the G³60 team through the International Association for the Exchange of Students for Technical Experience (IAESTE) as an Intern to experience working as an environmental engineer.
**College Royal (University of Guelph)**
In 2019 we marked the 95th Annual College Royal Open House weekend at the University of Guelph, drawing thousands of visitors each year. Our team enjoyed connecting with the public where families and students alike engaged with us viewing and talking about local Guelph aquifer and aquitard rock core, our bedrock groundwater flow tank model and project posters.

**H₂O Go Festival (City of Guelph)**
Once again the G³⁶⁰ Institute exhibited at the H₂O Go Festival, coupled for the first time with the eMERGE EcoMarket – a sustainability expo where attendees learned about developments in local water and energy conservation.

**Grade 12 Headwaters Student Workshop (Upper Grand River School Board)**
Graduate students from our Institute were invited to give a workshop to grade 12 Headwaters students in April 2019 to promote groundwater research in Guelph. The workshop included a basic introduction to the aquifer water cycle, demonstrations with rock core and discussion of careers in hydrogeology.

**University of Guelph Interaction Conference**
Geared towards senior high-school students, the Interaction Conference held each April allows the G³⁶⁰ Institute to bring a sense of mystery and adventure through hands-on detective work involving groundwater science and engineering.

**Waterloo-Wellington Children’s Groundwater Festival**
The Waterloo-Wellington Children’s Groundwater Festival is a week-long event that allows children to get involved in a variety of activities related to groundwater and their environment, incorporating fun and excitement to foster remembrance. MSc student, James Hommersen volunteered his time to help with demonstrations.

**GCVI & CCVI Workshops (Upper Grand River School Board)**
The G³⁶⁰ Institute visited two local high schools to talk with grade 11 and 12 students about groundwater, covering the fundamentals of hydrogeology with a Guelph area twist. Students had an opportunity to learn about our field-focused research and potential career opportunities related to water. Students especially enjoyed learning with hands on demonstrations of aquifer flow tanks and exploring over 20ft of bedrock core from a borehole drilled at the University of Guelph’s Arboretum.
Groundwater represents 99% of all available liquid fresh water on the planet and more than 50% of the world’s population depends on groundwater as their primary source of drinking water. Not only does groundwater provide storage throughout the terrestrial landscape to sustain nearly half of all surface water flows annually, but the aquifers and aquitards through which this groundwater flows help to purify the water through various physical, chemical, and microbial mediated processes to replenish the freshwater quality that sustains ecosystem and community health. Improved knowledge of our groundwater resources is an essential component of the resilience and sustainability of our planet. Creating solutions for long-term sustainability is dependent on new characterization and monitoring technologies and advancing our understanding of groundwater and its interactions with both the community and natural systems.

The University of Guelph is proud of its commitment to research along with knowledge and technology transfer as a means to develop future leaders who will “Improve Life” by protecting one of our world’s most essential resources: water. We are fundraising for the structural completion of the BAFF to support hands-on training and novel technology development and demonstrations for students, professionals, and community outreach.

Facility sponsorship and naming features include:
- Classroom(s) – 1x120 or 2x60 person capacity
- Transparent 20-ft above-ground demonstration well
- In-classroom access to a borehole cluster
- “Outcrop style” Guelph aquifer rock wall
- Rock core library for COREDFN & DataDFN methods
- Mobile borehole technology facilities
- Arboretum groundwater monitoring network wells
- Borehole clusters supporting the Fractured Rock Observatory across campus, the city, and regionally

Technology sponsorships include:
- Telemetry systems
- Groundwater-based geothermal heating & cooling
- Alternative solar and wind energy sources
- Grey water and stormwater management
- Green roofing
- Real-time data display systems and remote sensing with dashboards for fibre-optics, fluid pressure, and chemical and temperature sensors

This facility will strengthen our ability to serve as a state-of-the-art research and learning centre, and an ongoing critical component of G³60’s field site network.

Figure 1: Rendering of the Field Facility that will serve as an international hub dedicated to protecting groundwater.

Figure 2 (left): Rock core library and mobile technology trailers for novel G³60 and partner technologies.

Figure 3 (right): Classroom rendering for community engagement and training of students and professionals.

Our Vision:
How G³60 is Improving Groundwater Awareness and Knowledge & Its Role in Freshwater Sustainability

Donate Here

Help us meet our goal of $10M to build the G³60 Bedrock Aquifer Field Facility to solve global water-related issues, which directly impact local, regional, and international communities.

To Learn More, Contact:
Dan Penfold, Alumni Affairs, dpenfold@uoguelph.ca
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Sometimes studying fundamental processes at contaminated sites can lead to interesting paleoclimatic findings. This is the case at the Santa Susana Field Laboratory, in southern California, where analyzing the chloride (Cl) distribution in the subsurface, we reconstructed the amount of recharge that occurred in the last five centuries (Manna et al., 2019b). At this site, the analysis and assessment of groundwater recharge is fundamental because it determines the amount of flow through the system and governs the flux of groundwater available to transport contaminants in plumes. Among the different techniques used (Manna et al., 2016; 2017; 2019a), the analysis of porewater Cl concentration profiles obtained from depth-discrete rock core samples from both the vadose and groundwater zones proved to be effective to quantify local recharge rates and to distinguish mechanisms of flow in the unsaturated zone (Manna et al., 2017). In particular, the team found that the vertical variability of porewater Cl concentration in the vadose zone is correlated to the climate and, thus, the recharge history of the site. This is because the concentrating effect of evapotranspiration causes the Cl in the water that infiltrated below the root zone to be much greater than the atmospheric input. Based on the premise that rain percolates vertically downward through the vadose zone, each year’s recharging water displaces downward the previous year’s water. Given the recharge rate, the portion of recharge occurring as matrix flow, the thickness of the vadose zone (81m), and the physical properties of the fractured porous rock, we were able to reconstruct a 468-year history of groundwater recharge. The local recharge shows a decadal cyclical oscillation with variable periodicity around a decreasing linear trend. This periodicity and trend match well with those identified by the analysis of on-site precipitation and observations reported by others in precipitation data, lake sediments, and groundwater levels and appear to be consistent with the pattern of the Pacific Decadal Oscillation (PDO), as reconstructed for the last millennium by examination of tree-rings (Figure 1). The consistency between different observations supports our recharge reconstruction approach and confirms the legitimacy of the use of Cl profiles as an archive of past climate conditions in fractured porous aquifers. The detection of a multidecadal trend of variation of recharge is fundamental to forecast long-term recharge conditions in southern California, where major droughts and water scarcity are so important to both local and global populations and to identify possible diverging trends caused by human-induced climate change.

Figure 1: Comparison of recharge reconstructions with the PDO Index and their respective long-term trends. (a) Time series of Recharge Index calculated at RD-103 and RD-106 and linear trend for RD-103 only (longest time series); (b) 7-year moving average PDO Index time series and linear trend. Yellow and blue background colors represent drier and wetter than normal recharge or precipitation conditions respectively; dotted lines represent linear trends.

Sponsors, Partners & Collaborators:
An integrated monitoring and modelling investigation of the Upper Parkhill watershed in southwestern Ontario is underway, led by PhD student Elisha Persaud, principal investigator Dr. Jana Levison, and committee members Dr. Beth Parker and Dr. Genevieve Ali. This project, which began as a collaboration with the Ontario Ministry of the Environment, Conservation and Parks in 2017, aims to assess the potential influence of climate change on watershed hydrologic processes in an agricultural setting. Recent project milestones include the creation of a 3-D integrated HydroGeoSphere model for the Upper Parkhill watershed (Figure 1) which was used to simulate mid-century climate scenarios (Persaud et al., 2020). These simulations provide valuable insight regarding the temporal resolution of meteorological forcing, the importance of Great Lakes consideration, as well as anticipated groundwater and surface water response to changing climate conditions. This research was disseminated at both the Annual IAH Canadian National Chapter meeting in Quebec City (May 2019) and the Geological Society of America Annual meeting in Phoenix, Arizona (September 2019).

New directions for this project include an assessment of groundwater contamination risk in the Upper Parkhill watershed using the DRASTIC-LU methodology. This evaluation will be expanded to determine potential changes in contamination risk as a function of changing climate conditions and land use (Figure 2). Variable crop rotations and developed land coverage, water table depth, and recharge scenarios will be explored. It is anticipated that results from this study will be used to inform groundwater and land management strategies in the Upper Parkhill watershed in light of changing future conditions. A preliminary assessment of study methodology was presented at the Latornell Conservation Symposium in November 2019 with a planned opportunity for further discussion at the GeoConvention2020 meeting in Calgary.

**Figure 1:** HGS domain illustrating variations in the overburden hydrostratigraphy.

**New Insights:**

**G^360 PROJECT TEAM**

Elisha Persaud (PhD Student), Dr. Genevieve Ali, Dr. Jana Levison & Dr. Beth Parker


**Sponsors, Partners & Collaborators:**
The Land Conversion Impacts project, funded by the Ontario Ministry of Food, Agriculture, and Rural Affairs (OMAFRA), aims to gain valuable baseline information on the existing soil and water conditions along the Highway 11 Corridor. As part of the Northern Livestock Action Plan, the project is intended to gain insight into how land use conversion, from forest uses to livestock farming, will impact conditions and dynamics within the area. Objectives of the project include the characterization and assessment of soil, shallow groundwater, and water quality conditions and basic modelling of groundwater resources using these collected data sets and future land use scenarios.

The area of study includes a farm in Kapuskasing, Ontario, and another in Val Rita, Ontario. The chosen sites are within the Highway 11 Corridor and are underlain by clay-rich soil. Both farms also have a range of land uses: forested, cropped, and pasture lands; each farm has distinct soils, geology and topography that are typical of the landscape in the Highway 11 Corridor. The site selection was done by overlying open-source map data in ArcMap. The soil characteristics and water conditions under the three different land uses at each farm will be studied to establish the changes at those sites from clearing forests and establishing crops and pasture. To collect the required data, 14 piezometers, 18 lysimeters, and a tipping bucket rain gauge were installed at the selected sites during Summer 2019 and Fall 2019.

Piezometers were installed 2-3 meters below ground surface. Pressure transducers were installed in the piezometers to collect time-series water level data. The lysimeters provide insight into water content in the vadose zone. Additionally, near-surface in-situ hydraulic conductivity at each site was measured using the Guelph Permeameter. Water samples were collected from both lysimeters and piezometers for water quality analysis. A total station was used to determine elevation and consequently groundwater flow direction more accurately. 48 soil cores were extracted and preserved for analyzing the physical characteristics of the vadose zone. An additional 160 subsamples of soil were collected to analyze ammonium and nitrate levels in the porous media. More details on soil characteristics, water quality, shallow groundwater characteristics and site-specific conceptual models of the study sites will be available in 2020. With these data, the Ministry aims to make informed decisions on livestock expansion into Northern Ontario and to create a region-specific set of best management practices.
The G³60 Institute for Groundwater Research at the University of Guelph is collaborating with the Government of the Northwest Territories and the University of Calgary to conduct a baseline groundwater quality investigation in the portion of the Liard Basin located within the boundaries of the Northwest Territories. The Liard Basin is the second largest natural gas reservoir in Canada. In the past, oil and gas has been extracted using conventional methods and more recently using unconventional development methods (i.e. hydraulic fracturing) in British Columbia. The main goal of the study is to install a groundwater monitoring network near to the **Hamlet of Fort Liard** with the following objectives: 1) characterize the fresh groundwater zone, 2) establish baseline groundwater quality and flow rates, and 3) monitor potential impacts from current and future oil and gas development. In August 2019, the G³60 team completed an exploratory drilling campaign at the Municipal Waste Facility Site located outside of Fort Liard, with the support of **Beaver Enterprises LP** and the **Acho Dene Koe First Nation**. The goal of this work was to gain an initial understanding of the geology in the Fort Liard region and install a string of transducers behind a **FLUTE** liner along with a **Westbay Multi-Level System (MLS)** in two boreholes. Unstable rock was found, which resulted in the premature abandonment of these holes. Despite this, 22 rock core samples were collected for further study and analysis. A permanent fibre optic cable used to collect temperature data was installed.

**Figure 1:** Dr. Jonathan Munn, Dr. Beth Parker, Amanda Pierce, Nathan Glas and Marina Nunes (left to right) of G³60 on-site at the Municipal Waste Facility outside of Fort Liard in August 2019.

These 22 samples will be analyzed for porewater ion chemistry, gas composition and isotopes, and water isotopes. Further, physical property samples will be analyzed for porosity, permeability, magnetic susceptibility and thermal conductivity. Additionally, collected core will be logged in detail to better understand the deltaic depositional environment that existed at the time and how this could impact groundwater and contaminant flow, before thin sections are created and described. The G³60 team plans to complete a second drilling campaign where paired boreholes will be drilled at three separate sites. One borehole at each site will have a string of vibrating wire transducers with a fibre optic cable installed to collect hydraulic data with time, while the second hole at each site will have a Westbay MLS installed to provide the possibility for high-resolution groundwater sampling (Figure 2).

**Figure 2:** Block model showing the geology of the region and the two fault systems, the Liard Thrust and Bovie Fault Zone, that bound the study area, which is the Petitot Syncline. A conceptualization of the paired boreholes at one site is shown.

**Sponsors, Partners & Collaborators:**
G360 PROJECT TEAM
Andrew Stockford (MASc Student), Chrystyn Skinner, Jackie Harman, Dr. Emmanuelle Arnaud & Dr. Beth Parker

The G360 Institute is collaborating with the City of Guelph and Golder Associates to implement high-resolution depth-discrete groundwater characterization and monitoring technologies in the vicinity of a newly proposed municipal supply well in the south end of Guelph at the Hanlon Creek Business Park development. The project involves construction of a large diameter test well as a potential future water supply well. The sustainable pumping rate will be tested with a 30-day pumping test in the summer of 2020 with a network of multilevel monitoring systems (MLS’s) using novel G360 methods and G360 MLS designs to complement an existing network of bedrock and overburden monitoring wells in the area. This study, using multiple high-resolution methods will examine the effect of groundwater pumping rates on surface water (i.e. wetlands and streams) and nearby wells with a focus on vertical hydraulics. Overburden drilling commenced in the fall of 2019. Three G360 MLS’s were installed using rotosonic drilling with continuous coring to maximize core recovery. High-resolution natural gamma and core logs were used in combination to characterize the Quaternary sediments and top of rock interface and determine port positions for each MLS. The G360 MLS design for this study consists of a backfilled 3” ID system with 6 ports with tubing diameters of 7/8” and 1/2”. The depth discrete vertical head profiles for each MLS will be used to identify distinct hydrogeological units (HGUs) and assess vertical hydraulic connection and conductivity across HGUs during supply well pumping.

New Project:
Overburden Drilling Completed for City of Guelph Groundwater Impact Assessment at Hanlon Creek Business Park

Five bedrock boreholes will accompany the overburden monitoring network with multilevel monitors, either as commercially available MLS systems (Westbay) or a temporary deployment of sensors behind removable fabric liners (i.e. FLUTE). One new bedrock borehole was continuously cored in Fall 2019. A DFN-M framework consisting of high-resolution geophysical, core and porosity logs will be used to characterize the bedrock stratigraphy. The overburden MLS network is aligned orthogonal to the orientation of the front slope of the Paris Moraine, and shows overburden thickness thinning to the north from 33 m to 17.5 m. Flowing artesian conditions were observed in 2 locations, 1 overburden MLS central to the wetland, and 1 bedrock borehole north of the wetland, creating a need to design packers for small diameter tubes to shut in the flowing artesian ports. In 2020 the 3-D monitoring network will be instrumented with transducers to monitor transient changes in hydraulic conditions before, during and after pumping.

Figure 1: Dr. Emmanuelle Arnaud (left) and Andrew Stockford (right), MASc Candidate, logging and sampling a rotosonic Quaternary sediment core.

Figure 2: From left to right, G360 Institute members Carlos Pena, Philip Taylor, Brandyn Leitert and Underground Sonic drillers Scott and Tim helping install a G360 MLS in overburden at Hanlon Creek Business Park, Guelph, Ontario.

Sponsors, Partners & Collaborators:
The most amazing fresh pristine groundwater exists naturally from many flowing artesian wells located on the flat agricultural plain near the town of Elmvale ON, an hours drive northwest from Toronto. The artesian groundwater originates from two or three sand aquifers at depths between 15 and 70 meters. This groundwater is pristine in that it shows no trace of chemical constituents derived from human activities (no anthropogenic chemicals) such as chemical agriculture and the water shows exceptionally low concentrations of natural constituents such as chloride, organic carbon and trace elements. Fresh pristine groundwater with no anthropogenic constituents at the very lowest levels of detection is extremely rare in Canada and elsewhere. This study in collaboration with Professor William Shotyk, University of Alberta; Professor Ian Clark, University of Ottawa; Elizabeth Priebe, Ontario Geological Survey; and Canadian Soil Drilling / Canadian Well Drilling, is aimed at determining origins of the groundwater in the aquifers and aquitards and of the dissolved chemical characteristics. One hypothesis is that the pristine water is in part remnant glacial-age water many thousands of years old and hence is disappearing as the flowing wells discharge their water to the surface. Another hypothesis is that the pristine groundwater is not glacial age but is modern water that acquires its pristine characteristics by purification processes in the subsurface in which case the pristine water is replenished. The aquifers receive their recharge within a few kilometers of the artesian area by infiltration from rainfall and snowmelt in an upland forested area formed of sand and gravel deposits. This project, which aims to determine which of the two hypotheses is most plausible, will apply many investigation methods including new types of groundwater monitoring devices expected to provide at relatively low cost more information than conventional approaches. In addition to answering questions about the origin of this rare type of groundwater, this study will provide an assessment of the value of a new approach to assessing and monitoring groundwater conditions. This is important because groundwater in Canada and the world at large is poorly monitored in general, which limits prospects for science-based groundwater management. The Elmvale area is well suited for this collaborative study because of the excellent background information from previous groundwater research in the area conducted by William Shotyk, Ian Clark and the Ontario Geological Survey. NSERC has granted the funds to initiate this project and more funds are being applied for in a large collaborative project led by William Shotyk.
Naturally occurring radium in groundwater has become a growing concern for some communities dependent on their groundwater supply for drinking water. For example, the city of Waukesha, Wisconsin discovered concerning levels of radium in the water supplied by their wells drawing from the Cambrian-Ordovician aquifer system (COAS), an important water supply unit throughout the midwest US. The city of Waukesha is in the process of switching from groundwater to Lake Michigan water due to this contamination issue. Radium in groundwater has also become a concern in nearby Dane County.

Madeleine Mathews, under the supervision of Matthew Ginder-Vogel (University of Wisconsin) and in collaboration with the USGS and the Wisconsin Geological and Natural History Survey (WGNHS) is investigating the occurrence of radium in the COAS in Dane County. Madeline’s research aims to understand the source of the radium and how geochemical conditions influence radium transport through the sedimentary bedrock aquifers. Improving the understanding of the source and transport characteristics of radium through these units is an important step toward informed management of these critical water supplies.

A new collaboration with G360 provides a unique opportunity for Madeline and colleagues to study radium occurrence both in rock core and groundwater collected from high-resolution multilevel systems. The cores where collected and multilevel systems (MLS’s) were installed over the past 15 years as part of ongoing G360 research at a contaminated site in east central Dane County. The cores were logged in detail in the field and then preserved at the WGNHS core repository to support future studies such as these. The MLSs were designed to minimize blending and provided detailed vertical profiles of groundwater chemistry. Dr. Jessica Meyer (University of Iowa) provides site specific technical expertise on the design of the multilevel sampling intervals within the context of the hydrostratigraphy and on the historical data sets being used to select the intervals for sampling and interpretation of the subsequent data. Madeline is currently using a core/MLSs pair to evaluate the specific source of radium in the rock units and its mobility through these aquifer units. She is also using G360 supplementary data including spectral gamma geophysical logs, core lithology logs and major ion sampling to design the study. This collaboration will not only lead to a better understanding of the relationship between geochemical conditions and radium transport but will also add insight to G360’s ongoing flow system characterization for the Hydrite site.

**Sponsors, Partners & Collaborators:**

**Figure 1:** (Left) Madeleine Mathews (UWM) operating the Westbay Sampling System at Hydrite well MP-16. (Right) Madeleine Mathews filling sampling containers.
A new collaboration with the Engineering for Development program (E4D.mercer.edu) at Mercer University will serve to prepare graduate students, both at the University of Guelph and Mercer, to become leaders in implementing sustainable groundwater solutions for people and the environment. This collaboration stems from shared interests in cost-effective solutions to improve access to safe drinking water in developing communities and will enhance student capacities to conduct innovative applied groundwater-related research and service work in national and international developing communities. The inaugural Spring Wells Project, pairs G360’s hydrogeology expertise with Mercer’s specialty in water, sanitation and hygiene (WASH) for international community development, led by Dr. Michael MacCarthy, director of the E4D program. This first project is part of a larger research initiative. The Portable Drills for Water Wells Project is motivated by the need to develop solutions to characterize hydrogeology in areas that are hard-to-access because of challenging site characteristics such as overgrowth, steep terrain, ecological sensitivity, and hard rock subsurface geology. The assessment of groundwater quality, contamination, and geological site characteristics will be achieved by installing monitoring wells, multilevel systems, and water wells utilizing the Shaw Tool Company Generation 3 Drill that will soon be ready for field trials. The implementation of multilevel monitoring devices, as described by Pierce et al., 2018 will support study of water quality and contamination at different depths below ground surface. These methods will be piloted on-campus at the University of Guelph before being implemented at a field research site in southwest Dominican Republic. Subsequently, the research methods developed in conjunction with the use of the Shaw Drill will be used to study groundwater at other G360 field sites worldwide. Research initiatives have already begun for The Spring Wells Project at the Dominican Republic field site, which encompasses the town of El Cercado (San Juan province), to characterize the entire study area and assess mountain spring water quality and contamination levels. Future work includes pilot testing of the Shaw Drill and establishment of well drilling, installation, development, and monitoring techniques for making water wells at mountain springs. This project is motivated by the many millions of people worldwide living in rural mountainous communities who currently rely on contaminated mountain spring drinking water sources. The broader implications of this project relate to both humanitarian work and the geosciences. It is hypothesized that, through the use of the Shaw Drill to make water wells at mountain springs, a contaminant-free water source below ground surface will be accessed that can provide safer drinking water to rural dwellers. The methods developed through this project will improve our understanding of groundwater flow to mountain springs which will guide future mountain spring development initiatives in similar settings worldwide.
The development of 3-D site conceptual models used for groundwater flow modelling requires detailed knowledge of an area’s hydrostratigraphy. The non-invasive nature of airborne geophysical surveys offers a method to rapidly characterize the subsurface. However, the usefulness of such surveys for resolving complex hydrostratigraphy such as a buried bedrock valley remains to be assessed. With the goal of investigating how remote-based technologies can help advance source water management, G360 partnered with CGG Canada through an Ontario Water Consortium Advanced Water Technologies grant to complete a 50 km² helicopter-borne survey using a frequency-domain electromagnetic sensor (Resolve system) over an area south of Elora/Fergus. This sensor provides information on the electrical properties of the soil and rock within the upper 150 m of the ground with an approximate vertical resolution of 1 m to 10 m, decreasing with depth. In addition to the airborne survey, G360 collected co-located high-resolution surface geophysical surveys using electrical resistivity tomography, gravity, and seismic refraction along two transects overlying the valley. Using these surface geophysical results, along with historical surface geophysical measurements and cores, the airborne survey was interpreted to characterize the bedrock morphology and hydrostratigraphy of the valley. The airborne survey was able to reveal the complex architecture of the buried bedrock valley and variable Quaternary-bedrock conditions associated with major hydrostratigraphic facies. The results of the airborne survey were also compared to an existing regional-scale Quaternary model constructed by the Ontario Geological Survey (OGS). Preliminary results indicate that the airborne and surface geophysical methods can significantly improve the conceptualization of small yet complex features such as buried bedrock valleys within a regional-scale context. Using the surface geophysics, together with the OGS Quaternary model, G360 will continue to evaluate the capacity of an airborne geophysical survey to characterize hydrogeologic systems, with an emphasis on the relationship between buried bedrock valley development and the formation of dissolution enhanced features. G360 believes these results will be of interest to regional groundwater resource managers in Southern Ontario requiring detailed subsurface characterizations but recommends validation of these findings with continuous core and borehole geophysics to design groundwater monitoring to construct a robust hydrogeological model.
1,4-dioxane, a highly mobile, semi-volatile cyclic ether typically used as a chlorinated solvent stabilizer, has been detected at a municipal supply wellfield pumping water from the karstic Upper Floridan Aquifer (UFA). In partnership with a site owner and their environmental consultants, University of Florida and HSW Engineering, Inc., efforts are underway to assess potential 1,4-dioxane contributions from a nearby industrial site to the wellfield. Not only are the horizontal gradients in the UFA hard to determine due to the high transmissivity in the bedrock, but also the karstic nature of the limestone suggests preferential flowpaths dominate 1,4-dioxane transport. To avoid multiple measurement uncertainties, we advanced direct mass flux measurement techniques in two cored holes. Direct mass flux measurements complement the suite of tools deployed as part of the Discrete Fracture Network – Matrix method (DFN-M). Depth-discrete, high-resolution rock core 1,4-dioxane profiles, borehole geophysical and hydrophysical logs were collected and analyzed. Physical caliper profiles captured the significant variability in borehole diameter, locating zones that could be sealed using oversized FLUTE borehole liners. Variability in the borehole wall required the adaptation of several DFN-M techniques.

Hydraulically active features under natural hydraulic conditions were qualitatively identified using active line heating deployed with fiber optic cables for distributed temperature sensing (A-DTS; Maldaner et al., 2019). These datasets informed placement of modified passive flux meters (PFM) in multiple, depth-discrete zones (1-2 meters long), external to the FLUTE liners, to quantify water and contaminant fluxes. Vertical arrays of pressure and temperature sensors were co-deployed with the PFMs to capture transient hydraulic conditions. These datasets combine to inform a conceptual site model showing systemic variation to seasonal forcing and short-term transience at the site paired with a heterogenous 1,4-dioxane flux distribution. The high-resolution methods deployed at this site demonstrate the detail needed to characterize complex sites.
The objective of this research was to conduct a high-resolution study to characterize the baseline aqueous geochemistry and isotopic compositions within a hydrostratigraphic framework of the shallow freshwater zone informed by high-resolution characterization data sets at a gas injection field research site called the CMC field research site (FRS). To achieve this, multiple lines of evidence using complementary borehole data sets (hydrogeologic, geochemical, isotopic and geophysical) were collected following the DFN-M (discrete fracture network-matrix) Approach (Parker et al., 2012).

Data were collected from a continuously cored 106.3 m deep borehole, to inform the design of a 26 port Westbay multi-port system (MPS) to a 100.0 m depth. Nearby, a 67.1 m deep domestic well and a G360 MPS with 13-ports over 85.3 m bgs were installed, along with three conventional wells with screened intervals at 27 to 28.5 m bgs, 63.5 to 65.0 m bgs and 99.5 to 101.0 m bgs. This groundwater monitoring infrastructure is in addition to the 350 m deep geochemical and geophysical monitoring boreholes located adjacent to a 550 m deep CO2 injection well. Pilot CO2 injections occurred at 300 m bgs in 2017.

Results from the Westbay well and the rock core revealed variability and stratification in hydrophysical and hydrochemical parameters. Ports completed in coal seams from 26.9 to 34.9 m bgs had high flow rates and yielded sodium bicarbonate water type, water isotope compositions resembling local meteoric water, with elevated methane and ethane concentrations, and biogenic $\delta^{13}C$-CH$_4$ values of $<-82\%o$. Below the coals (34.9 – 105.7 m bgs), ports were characterized by lower flow rates, higher $\delta^{18}O$ and $\delta^2H$ values of water and variable water types. Methane and ethane concentrations were also lower compared to samples obtained from coals and $\delta^{13}C$-CH$_4$ values ranged between -75‰ and -60‰. A comparison of the geochemical results of the domestic water well to the Westbay results revealed that the domestic water well yielded groundwater with chemical and isotopic compositions resembling groundwater from only the high-flowing coal-containing aquifer.

Figure 1: Terri Cheung collecting samples from the Westbay multi-level system (left), CO2 injection well (right).

Sponsors, Partners & Collaborators:
G³60 PROJECT TEAM
Jessica Bulova, Steven Chapman, Ryan Kroeker, Marina Nunes, Philip Taylor, Dr. Carlos Maldaner, Dr. Peeter Pehme & Dr. Beth Parker

The Räven site is a former dry cleaner in Helsingborg, Sweden which operated between the 1930s to the 1970s. The overburden and bedrock underlying the facility is contaminated with perchloroethylene and degradation products from historical releases at the facility. In a new collaborative research program, G³60 is working with the Swedish Geological Survey (SGU) and its consultant Sweco on applying the Discrete Fracture Network – Matrix (DFN-M) field approach at the site for characterizing contamination in the fractured sedimentary bedrock underlying the site. In 2018, an initial phase of investigation was conducted involving a single borehole in an area outside of the area of contamination to test drilling methods and field techniques. Then, in Spring 2019 additional investigations were conducted with drilling of new boreholes including one borehole in the source area on-site and three boreholes along a transect down gradient of the site. Cores were logged in detail and subsampled in high-resolution for volatile organic compounds, followed by application of several borehole geophysical and hydrophysical logging techniques. FLUTE liners were used to seal boreholes as well as for the hydrophysical logging techniques (ALS and A-DTS) and for temporary transducer deployments including cross-hole hydraulic tests. Lund University researchers are also collaborating at the site testing new geophysical methods (ERT / DCIP) in the boreholes. The various high-resolution datasets were then used to design multilevel systems (MLS) for the boreholes, which were installed in Fall 2019 including two backfilled G³60 MLS and two hybrid CMT MLS (Chapman et al., 2014). Monitoring and sampling of the MLS are ongoing to assess temporal changes and dissipation of cross-connection effects. Additional DFN-M investigations are planned in 2020 to refine understanding of down gradient plume and source area conditions. Ultimately the goal of the collaboration is to improve the Site Conceptual Model (SCM) and for remedial decision making, including assessment of Soil Vapor Extraction (SVE) in the source area. As part of the technology transfer efforts, G³60, SGU and Sweco presented project results and provided site tours for a Swedish national trade organization Nätverket Renare Mark.

Figure 1: Aerial view of site during source area drilling.

Figure 2: Drilling along the down gradient Transect.
The Malmen site is a former metals fabrication facility in Hovmantorp, Sweden. The overburden and bedrock underlying the site is contaminated with trichloroethylene and degradation products from historical releases. G360 is collaborating with the Swedish Geological Survey (SGU) and its consultant WSP on applying the Discrete Fracture Network – Matrix (DFN-M) field approach for characterizing contamination in the fractured igneous bedrock. In Spring 2017, coring was conducted at three “Golden Spike” boreholes: one on-site in the suspected source area, one cross-gradient and one a short distance down gradient from the site.

Several complementary DFN-M techniques were applied shortly after drilling including FLUTE FACT for contaminant mass flux assessment and various borehole geophysical / hydrophysical logging techniques such as ALS and temporary transducer deployments. In Fall 2019 follow-up investigations were conducted including re-deployment of FLUTE FACT to assess contaminant flux far removed from drilling, where large quantities of water were used which may have impacted the early FACT results, and A-DTS to assess groundwater flux to contribute to the FACT assessment. Blank FLUTE liners were used to seal the boreholes between these periods. Then, a new lower cost type of multilevel system (MLS) from FLUTE, referred to as the FLUTE CHS (cased hole sampler), was installed in two of the boreholes designed based on the high-resolution datasets. Monitoring and sampling of the MLS are ongoing to assess temporal changes. Ultimately the goal of the collaboration is to improve the Site Conceptual Model (SCM) and for remedial decision making.

Advanced Project:
Collaborative DFN-M Investigations at a Former Metals Fabrication Facility in Hovmantorp, Sweden
The objective of the 2019 field work at the Hydrite site, as part of the Industrial Chair Program, was to investigate an aged Dense, Non-Aqueous Phase Liquid (DNAPL) source zone that has undergone groundwater flushing over several decades. The source zone was originally investigated from 1999-2002. Since then, very little work has been done due to concerns about mobilizing DNAPL or creating higher dissolved phase concentrations in the downgradient plume. Hence, downgradient monitoring (along multi-level system (MLS) transects) and operation of a hydraulic barrier system was emphasized from 2003-2018. There is an expectation that variable groundwater flow rates and variable DNAPL composition and saturation will cause differential rates for DNAPL dissolution. To constrain the source zone size and internal variability, four continuously cored holes were drilled. Three are across the width of the DNAPL zone as observed in the upper Tunnel City Group sandstones, perpendicular to the direction of groundwater flow (i.e., transect) and one is up gradient. This drilling occurred in July of 2019 with a five-person team: Jessica Bulova, Chris Morgan, and Glen Hook representing G360, UoGuelph and Riley Kniptash (University of Iowa), and Liz Occhi (University of Iowa). During core sampling, Red Oil O was used to identify where the non-water phase DNAPL was present with depth in each borehole. There was only one positive hit for the presence of DNAPL out of 405 samples, with an average spacing of ~1.5 feet, from all four cored holes. This sample came from a hydrogeological unit (HGU) above the Tunnel City Group, where DNAPL was previously found. Rock core samples are needed to further inform contamination levels, but it is suspected that Red Oil O may not be the best method for DNAPL observation in incompetent sandstone rock. Another finding was that the upgradient core location showed higher levels of contamination compared to the other three source zone boreholes. This speaks to the highly variable DNAPL distribution. DNAPL distribution on site needs further understanding to characterize the nature of mass discharge and the applicability of enhanced mass removal in the future.

The observed DNAPL source zone already has 17 wells open to the upper 20-40 feet of the Tunnel City Group. These wells were drilled and pumped intermittently during initial remediation efforts, between 1999 and 2002, to remove free-product DNAPL. These holes provide an opportunity to collect quantitative information about the fracture network providing DNAPL storage and contributing contaminant flux to the groundwater plume, by providing samples that inform the composition of pure-phase DNAPL. Information from reconnaissance studies (Peeter Pehme, Ryan Kroecker, Marina Nunes, Jessica Meyer) was used to design a prototype removable depth-discrete temporary G360 MLS to target specific bedding plane fractures shown to be significant in terms of hydraulic conductivity and DNAPL retention. A G360 MLS, designed for DNAPL collection at four targeted depths was installed (Philip Taylor, Brandyn Lietert, Chris Morgan) in an existing borehole in June. The temporary deployment relies on water inflated rubber packers that isolated 4 ports for water level and sampling, with two ports yielding DNAPL. DNAPL was sampled 2 times, yielding 6x16 mL VOA samples that were analyzed with Nuclear Magnetic Resonance (NMR) by Dr. James Longstaffe at the University of Guelph. Monitoring data and inspection of the MLS upon removal in December showed there was a good seal through September 2019. Thereafter the bottom packer burst, likely due to chemical degradation of the packers.

Figure 1: Brandyn Lietert and Philip Taylor installing a prototype G360 system into a previously abandoned DNAPL pumping well.
A new patented multilevel system, referred to as the G\textsuperscript{360} MLS, has been under development by the G\textsuperscript{360} Institute during the past six years for research projects. The system is modular, similar to the Solinst-Waterloo System, but with increased versatility through use of different external casing diameters (e.g. 2.0, 2.5, 3.0, 4.0-in ID Sch. 80 PVC) which allows flexibility in the numbers and/or diameters of internal tubes that connect to each port that run inside the PVC casing to surface. This provides more options for monitoring (e.g. allowing use of self-contained transducers) and groundwater sampling (e.g. allowing use of bladder pumps or double valve pumps for deeper water tables beyond peristaltic pumping limits). The system is versatile and can be installed in different configurations in both overburden and fractured bedrock boreholes. Backfilled type installations are used in overburden holes where the casing stays in the ground to facilitate the G\textsuperscript{360} MLS insertion into the borehole and is then incrementally removed as the annular space is backfilled using bentonite for seals and inert sand or gravel for ports. In stable bedrock holes, backfilled installations can also be used or systems with custom packers which create the seals between the monitoring ports, where different packer versions are available including water filled packers allowing system removal.

The system components are comprised of lengths of Sch. 80 PVC casing (e.g. 2, 3, 5, 10 ft), couplings that connect the casings and ports, screened ports with a hole connecting to a brass “L” fitting that attaches to the internal tubing running from each port to surface (different tubing materials possible for compatibility / performance), and lightweight rubber packers attached to casing sections.

Recent G\textsuperscript{360} MLS installations in 2019 include backfilled systems in boreholes drilled with dual rotary Clarington and sonic (Guelph) methods in overburden holes (6-8 ports), a removable packer system in bedrock (4 port) with specially configured ports to capture DNAPL (Hydrite) and backfilled systems (5-6 ports) in fractured bedrock boreholes with deep water table (Sweden).

The system has been sufficiently used at a variety of field sites to now be ready for commercialization, which Solinst will be undertaking with G\textsuperscript{360} in 2020.
Surfactant flushing involves the injection of surfactants to promote hydrocarbon removal from the subsurface. A risk associated with surfactant flushing is the uncontrolled migration of hydrocarbons in the aquifer. Reversible double water in oil in water emulsions were developed to contain subsurface hydrocarbon spills during surfactant flushing (Figures 1-3). Double emulsions were prepared by emulsifying CaCl₂ solutions in canola oil, and subsequently by emulsifying the water in oil emulsions in aqueous sodium alginate solutions. The double emulsions reversed and gelled when mixed with selected surfactants, acting as ‘emulsion locks’ to prevent spreading of the hydrocarbon plume from the areas treated with surfactant flushing.

Figure 1: Schematics of pumpable barriers (‘emulsion locks’) placed around a polluted area where contaminants (depicted as black circles) are emulsified by injecting surfactants (Surfactant IN) and extracted through pumping wells (OUT).

Figure 2: Optical microscopy image of the double water in oil in water emulsions, prior to mixing with surfactants (a) and confocal microscopy images (b, c). In image (b) the oil phase is bright because of Nile Red dye, and the water phase is black. The scale bar is 100 mm.

Figure 3 Gel obtained by mixing double emulsions with surfactants.

Injectable oil-water separation filters were produced by injecting aqueous solutions of natural polymers on sand, followed by rinsing with deionized water. These filters could retain non-polar solvents while allowing water flow through sandy media (Figure 4). These filters can serve as semi-permeable barriers for the remediation of hydrocarbon spills in the subsurface.

Figure 4: Injectable filters exclude apolar solvents, while allowing water flow.

Sponsors, Partners & Collaborators:
Per- and poly fluorinated alkyl substances (PFAS) are a class of partially or fully fluorinated organic compounds widely used in the manufacturing of consumer products, including textiles, food packaging and aqueous film forming foams (AFFF). Due to the strength of the carbon-fluorine bonds that comprise the backbone of these compounds, PFAS exhibit unprecedented persistence in the environment. This class of compounds is particularly present in agricultural soils due to the application of PFAS contaminated organic amendments derived from municipal digestates and numerous studies have reported the uptake of PFAS from soils into crops.

The goal of this ongoing study is to explore the relationships between soil chemistry, and the uptake of PFAS into plants. In general, studies of PFAS uptake focus on conventional measures of either accumulation in plant tissues or the impacts on plant growth. Nevertheless, the concentrations of PFAS necessary to induce these observations are typically much higher than those observed in typical agroecosystems. As a result, PFAS do not normally exhibit noticeable effects on crops, even when uptake and accumulation is active at low-levels, therein potentially impacting the food chain.

To overcome the limitation of measuring the impact of PFAS on crops at lower levels, Dr. James Longstaffe’s group has been developing protocols for measuring PFAS exposure based on metabolomics.

Metabolomics is the study of the metabolic profile of an organism in response to an outside stressor, such as contaminants present at levels at which physiological effects may not be readily observed. We are developing metabolomics as a research-tool to both identify the responses of plants grown in PFAS impacted soils and to help further elucidate the mechanisms through which PFAS interact with the plant, including mechanisms of uptake and transport. Figure 1 shows the $^1$H Nuclear Magnetic Resonance (NMR) spectrum of the metabolites extracted from *Arabidopsis thaliana*, a model plant. A principal component analysis (PCA) of plants exposed to perfluorooctanesulfonate (PFOS) can be used to identify how PFAS is interacting with the plant at the molecular-level. This initial study has shown that metabolomics is able to elucidate the effects of PFAS at concentrations for which physiological effects are not evident. Further steps in this project are ongoing and involve using this approach to explore the role of soil organic matter composition on the retention and availability of PFAS in agricultural soils.

Figure 1: $^1$H NMR spectrum of plant metabolites and Principle component analysis of spectra of plants exposed to PFOS.
G\textsuperscript{360} prides itself on the multi-disciplinary methodology we employ. Dr. Kari Dunfield is a professor in the School of Environmental Science at the University of Guelph and holds a Canada Research Chair in Environmental Microbiology of Agro-ecosystems. Dr. Dunfield’s Soil Microbial Ecology Lab studies microbial diversity under contrasting land uses and agricultural practices. Soil microbes can affect land use change and restoration, inform crop rotation and cover crop selection, and tillage and fertilization practices. Microbial functions are also associated with ecosystem services such as phosphorus cycling, nitrogen cycling and greenhouse gas emissions. But how does the Soil Microbial Ecology Lab fit with G\textsuperscript{360}? The Lab is an integral part of multiple projects, including a remediation study on how hybrid poplars and their associated microbes can degrade toluene in a fractured bedrock aquifer. The team studies microbial populations in the soil near the tree root zone (rhizosphere) and in plant tissues (endosphere), measuring contamination levels in the plant and roots to confirm the presence of toluene and where the degradation reactions occur. The lab uses quantitative polymerase chain reaction (qPCR) to detect the presence, abundance and activity of toluene degraders on site (i.e. TOD, RMO, PHE and \textit{bssA} genes). High-throughput DNA sequencing is used to assess the impacts of toluene on fungal and bacterial communities. Here, metagenomic analysis are used not only to detect shifts in microbial community structure, but also to predict the biodegradation capacity of the microbiome. A paper (Ben-Israel et al., 2020) on this multi-disciplinary research was recently published, sharing the findings that groundwater conditions can change rapidly from oxic to anoxic within just a few months, and that toluene biodegradation and natural attenuation can vary depending on the seasons. A notable enrichment of toluene degrading bacterial taxa was also observed in roots collected under high toluene conditions. This important knowledge can change our understanding of the effectiveness of monitored natural attenuation.

**Figure 1:** Plants growing in contaminated soils selected for microorganisms able to degrade toluene.

**Figure 2:** Eduardo Mitter and Michael Ben-Israel sampling soil for BTEX-F1 analysis.
This **Ontario Ministry of Transportation** (MTO), **City of Guelph**, and **NSERC** funded project provides research and analysis services to assist the Ministry in identifying the viability of new technologies for use in the next generation of highway roadside ditches in salt vulnerable areas and/or discharging into thermally sensitive receiving streams. We are conducting field monitoring and analyzing a large number of historic storm events and road salt application data for the City of Guelph and for our Provincial Highway research sites. Our advanced highway runoff and water quality models use Road Weather Information Systems (RWIS) and climate data as well as road salt application data as input for simulation of roadside ditch runoff rates and water quality. This will allow us to assess the long-term performance of enhanced roadside ditch drainage systems in attenuating the peak chloride concentrations in winter months and to assess the thermal effects of typically shallow stormwater management wet ponds discharging in summer months. Improving the habitat suitability index for aquatic life in the receiving watercourses and in protecting groundwater quality in the salt vulnerable areas is key.

**PROJECT TEAM**

Sepideh Emami Tabrizi (PhD Student), Arman Amouzadeh (MEng Student) & Dr. Bahram Gharabaghi

**Featured External New Insights:**

**Identification and Protection of Salt Vulnerable Areas**

**Sponsors, Partners & Collaborators:**

- **Ontario Ministry of Transportation**
- **City of Guelph**
- **NSERC**

**Figure 1:** Highway 401 and Highway 6 Research Site.

**Figure 2:** Highway 8 Research Site.
Dr. Beth Parker Honoured as 2019 AGU Fellow

Dr. Beth Parker has been recognized as a 2019 AGU Fellow for her ground-breaking work that has markedly advanced conceptual models and methods to understand contaminants in fractured porous geologic media. AGU Fellows are recognized for their “scientific eminence in the Earth and space sciences”. Their breadth of interests and the scope of their contributions are remarkable and often groundbreaking. Only 0.1% of AGU membership receives this recognition in any given year.

Dr. John Cherry Awarded the 2020 Stockholm Water Prize

Dr John Cherry receives the Stockholm Water Prize 2020 for discoveries that have revolutionized our understanding of groundwater vulnerability. His research has raised awareness of how groundwater contamination is growing across the world and has led to new, more efficient methods to tackle the problem. The prize is awarded by SIWI in cooperation with the Royal Swedish Academy of Sciences and will be presented by H.R.H Crown Princess Victoria of Sweden, at a Royal Award Ceremony on August 26th, during World Water Week in Stockholm. The Stockholm Water Prize Nominating Committee said: “With the Stockholm Water Prize, John Cherry is recognized for his contributions to science, education, practice and for translating his well-earned stature into a passionate and highly effective advocacy for groundwater science to inform current and future policies, laws and collective deliberations that governments must establish to protect water, our most essential and yet most imperiled resource.”

Arthur D. Latornell Travel Scholarship

The Arthur D. Latornell Travel Scholarship awarded to MASc student, Nathan Glas, for the Winter 2019 semester, provided Nathan an opportunity to attend a three day workshop hosted by the Canadian Young Hydrologic Society, focusing on the perspectives and insights of early career researchers across the field of hydrology, to foster open science and collaboration across disciplines.

Queen Elizabeth II Graduate Scholarship in Science & Technology

MASc student Oliver Conway-White is using his Queen Elizabeth II Graduate Scholarship in Science & Technology, awarded until April 2020, to apply geophysical methods to the delineation of subsurface features such as bedrock buried valleys. The results of this research will lead to better groundwater flow models and ultimately more sustainable water resource decision making.

Ontario Graduate Scholarship

The Ontario Graduate Scholarship (OGS) program recognizes academic excellence in graduate studies at the master’s and doctoral levels in all disciplines of academic study. An Ontario Graduate Scholarship awarded to Nathan Glas for September 2019 –August 2020 will allow Nathan to focus on his research more thoroughly through additional financial support.

Arrell Food Institute Graduate Scholarship

As part of the Arrell Food Institute Graduate Scholarship, Kathleen Johnson worked in a transdisciplinary team of four graduate students for 8 months on a project with a community partner, the Ecological Farmers Association of Ontario. Their reflective journal article about the experience was published in Action Research Journal in November 2019. Kathleen also attended the 2019 University of Guelph Agri-Food Excellence Symposium and 2019 Arrell Food Summit.
Masters Graduates

Chris Morgan, MA Sc (August 2019)
Primary Supervisor: Dr. Beth Parker
Thesis: Fracture Network Characterization of an Aquitard Surface within the Wonewoc Sandstone using Digital Outcrop Photogrammetry and Discrete Fracture Network (DFN) Modelling
Current Position: Geoscientist (G.I.T) at Geofirma Engineering Ltd

Chrystyn Skinner, MSc (September 2019)
Primary Supervisor: Dr. Beth Parker
Thesis: High-Resolution Hydrogeological Characterization of a Fractured Dolostone Municipal Supply Aquifer to Create a Refined 3-D Conceptual Site Model with Hydrogeologic Units
Current Position: Staff Researcher at G360 Institute for Groundwater Research

Terri Cheung, MSc (December 2019)
Primary Co-supervisors: Dr. Bernhard Mayer (UCalgary) & Beth Parker
Thesis: Establishing High-Resolution Hydrogeological, Geochemical and Isotopic Baseline Conditions of the Fresh Water Zone at a Field Research Site near Brooks, Alberta, Canada
Current Position: Junior Hydrogeologist at Dillon Consulting

In 2019, the G360 group celebrated 5 graduations, two of which were featured in our 2019 Newsletter; Tim Spiers, MA Sc and Greg Martin, PhD.

Conferences Presented at in 2019 to March 2020

PFAS EXPERTS SYMPOSIUM
May 20-21, 2019 | Arlington, Virginia
May 28-31, 2019 | Waterloo, Canada

10th International Groundwater Quality Conference
September 9-12, 2019 | Liège, Belgium

NGWA Conference on Fractured Rock and Groundwater
September 23-24, 2019 | Burlington, Vermont

ALGA High Resolution Site Characterisation Seminar
March 2, 2020 | Sydney, Australia
Parker Published Papers Jan 2019 – March 2020


Saleem, S., Levison, J., Parker, B.L., Martin, R., Persaud, E. 2020. Impacts of Climate Change and Different Crop Rotation Scenarios on Groundwater Nitrate Concentrations in a Sandy Aquifer. Sustainability, 12(3), 1153. https://doi.org/10.3390/su12031153


Selected G360 PI Published Papers Jan 2019 – March 2020


Selected G360 PI Published Papers Jan 2019 – March 2020 (Continued)


**G360 Project Sites:**
Informing Our Global Datasets

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Thanks and Acknowledgements

The G$^3$60 Institute would like to sincerely thank all who supported us in 2019, presently, and in our long standing relationships.

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If you would like more information on any of the material presented in this newsletter, please contact us.
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