Before we launch into 2015 field work, I would like to take a moment to summarize some key accomplishments and activities undertaken through G360 this past year (2014). I invite you to read on to see specific examples of our collaborative work at a variety of field sites, with various technologies and themes.

A key focus has been the development of improved field methods for characterizing and monitoring heterogeneous environments along three major themes: 1) chlorinated solvent source zone and plume behaviour in heterogeneous sedimentary deposits, including bedrock; 2) groundwater flow system and aquitard characterization, including aquifer vulnerability for community and private water supplies; and 3) migration pathway identification and monitoring for potential impacts to groundwater from unconventional oil and gas exploration and extraction.

We have expanded our application of the DFN Approach for sedimentary rocks to complex industrial properties through a collaboration with Dow Chemical Company on a site in Schkopau, Germany, with an MSc thesis completed by Robert Stuetsle. We are also extending this work to chlorinated solvent contamination in a weathered igneous rock environment through the initiation of a project in collaboration with the University of Sao Paulo, Brazil. The various high resolution techniques for cores and borehole methods are variants of methods developed and honed for unlithified sediments. They allow for improved site conceptual models where variably thick zones of lower permeability can store substantial contaminant mass and control plume concentration variability and attenuation—a major theme within The University Consortium for Field-Based Contamination Research. Back diffusion concepts controlling chlorinated solvent plume behaviour and remediation time-scales demonstrating this important effect have been employed at real sites since the mid-1990s. This work has advanced through a multi-year collaboration with Dr. Tom Sale from Colorado State University, with detailed laboratory studies providing strong visual and quantitative lab-scale models of these effects (supported by SERDP funding from the US DOD). A Best Project of the Year Award was received from SERDP, Fall 2014.

We are also completing a multi-disciplinary, 5-year project with 14 Principal Investigators and dozens of graduate students at three southern Ontario universities (University of Waterloo, McMaster University, and the University of Guelph) on the sustainability of bedrock groundwater for community source water using the City of Guelph as the model community. In 2014, major advances were made in creating a network of experimental boreholes in the Guelph dolostone aquifer at the BAFF (Bedrock Aquifer Field Facility) on the University of Guelph campus, with support from the Southern Ontario Water Consortium. New technologies and intense data collection continue to evolve with fibre optic cable sensing; this is another new method in our DFN “tool kit”, advancing through collaborations with G360 alumnus Thomas Coleman (Silixa Ltd.) and graduate students. Our profession faces major challenges with respect to how to effectively capture and manage the high resolution data sets stemming from technological advances, and this too has become a major thrust in our field-based program. It is vital to build a data system structure that can facilitate both quantitative and descriptive data capture and transferability and thus enhance the value and utility of the data for building robust conceptual site models. These challenges and opportunities are being advanced in parallel with many of our professional colleagues, and we enjoy working collaboratively whenever and wherever challenges present themselves.

Please enjoy reading the details highlighted in this G360 newsletter and contact us for access to further information. We are very excited about our new technologies and field research facilities and furthering our collaborations as we see signs of spring and a new field season ahead. Thank you for your involvement and support.
**Expertise — Hydrogeophysics**

Borehole Geophysics/Hydrophysics, *by Dr. Peeter Pehme*

Hydrophysical research refers to the application of physics (often geophysics) for hydrogeologic purposes. G360 began its work in hydrophysics with the revitalization of temperature logging to identify flow in fractured rock, using high sensitivity (0.001 C) sensors as a compliment to a suite of rock core chemistry techniques within the overall approach to site characterization we now refer to as the DFN methodology. The applicability of the thermal technologies were broadened first with the employment of temporary borehole liners to eliminate cross connected flow and then with the introduction of the active line source technique which eliminates the inherent depth limitations created by relying on natural thermal disequilibrium. G360 further advanced the science with the development of the thermal vector probe which holds great promise in being able to quantify both flow and direction. These developments in thermal technologies evolved alongside a series of steady refinements to conventional borehole characterization and imaging methods (core logging, rock chemistry, acoustic & optical televiewers, gamma, conductivity, full wave form sonic and video) as well as advancements of techniques that estimate rock and fracture transmissivity (e.g. packer testing and FLUTe profiling).

Within a borehole such as temporary sensor deployments (TSDs) which can be used to optimize sophisticated multi-level monitoring systems, conduct cross-hole analysis, and facilitate a broad range of dynamic hydraulic testing at the new BAFF (Bedrock Aquifer Field Facility) field laboratory on the University of Guelph campus. The BAFF field laboratory is a unique, world class facility consisting of a central cluster of five vertical boreholes surrounded by three angled holes and background monitoring installations, all drilled to a depth of 75m through the regional aquifer and into the shale below. The spacing and orientation of the boreholes is optimized to the local fracture orientations to facilitate three dimensional characterization of the rock mass, there setting the framework to conduct a broad range of cross-hole geophysical and hydro-physical testing. The boreholes are lined to provide ongoing, flexible access and facilitate hydraulic monitoring (with TSDs for pressure and/or high sensitivity temperature) which can be customized for specific experiments and technology development. The BAFF field laboratory provides the foundation for expansion of G360’s collaborations with both domestic as well as international researchers and industry partners (e.g. Silixa, UK and ALT, Lux.). Together we are developing new, exciting tools and techniques to improve characterization of hydraulic and chemical conditions at contaminated sites; ultimately to inform numerical models, improve understanding and strategic planning to solve real world groundwater challenges.
Near-surface geophysics has proven to be an effective and valuable tool in the advancement of complex environmental and hydrogeological problems over the past 30 years. Recent advancements in the field hydrogeophysics—a relatively new and rapidly evolving discipline which applies geophysical concepts to better manage, monitor and understand hydrologic processes—demonstrate the value surface geophysics brings to understanding complex hydrogeological problems. An excellent assessment of the state of hydrogeophysical research can be found in a recent article by Knight et al. (2013) (The Leading Edge, Vol. 32) entitled “The State of the Science and Vision of the Future: Report from the Hydrogeophysics Workshop”:

“A number of exciting topics on the cutting edge of basic hydrology research are likely to become the focus of hydrogeophysical research and applications in the near future. There is a demand for watershed-scale science and hydrogeophysical observations are a clear avenue to obtain data at increasingly larger spatial scales and over increasingly finer time scales. We see hydrogeophysics as providing a valuable link between microscale and macroscale processes across a range of hydrogeologic disciplines including biology and chemistry. New methods for managing water resources such as water injection/extraction and aquifer storage and recovery may be supplemented by hydrogeophysical monitoring. We see key opportunities for geophysical observations to integrate hydrologic and ecosystem studies, as well as related plant biology investigations. There are opportunities to develop strong, interdisciplinary links between the geosphere, hydrosphere, biosphere and atmosphere with geophysical support.”

Over the past few years, G360 has integrated novel and innovative geophysical methodologies to advance our conceptual understanding of fractured rock hydrogeology. Substantial surface geophysical investigations have been conducted at our Hydrite and Eramosa River research sites to investigate the function of complex geological formations to groundwater flow and contaminant transport, and the nature of groundwater-surface water interaction along a fractured bedrock river, respectively. Surface geophysics will continue to become an integral component of G360’s fractured rock research program.

Focus on Research - Source Water Protection
Collaborations with Municipalities

City of Guelph Tier 3 Well Study

The regional geochemical study in progress at the Tier 3 wells and ten locations with nested type piezometers, part of the City of Guelph groundwater monitoring network focus on the evaluation of groundwater geochemistry aiming to understand the natural attenuation capacity of the aquifer for contaminants such as nitrate and for a better understanding of the groundwater flow system. This last objective is supported by the use of environmental isotopes. A key outcome of this research are estimates of groundwater residence time in various parts of the Guelph dolostone aquifer. The geochemical and isotopic characterization included measurement of redox conditions and analysis of major chemical constituents (e.g.: nitrate, chloride, iron, manganese), O, H and H in water, S and O in sulfate, C in dissolved inorganic carbon (DIC). This study also includes data of Helium-Tritium, a powerful environmental groundwater dating tool, collected through the deployment of diffusion samplers in selected multi-level piezometers for noble gas analysis, which has been done in collaboration with Dr. Ian Clark from the University of Ottawa. Ultimately, this regional data will be essential to inform boundary conditions in future numerical groundwater flow modeling simulations to address potential contaminant behavior in fractured dolostone aquifer in the Guelph area. Two UW MSc students Nickie Unonius and Marina Nunes supervised by Dr. Ramon Aravena and Dr. Beth Parker have been involved in this research.
We are currently involved at the site of the future Clarington Transformer Station on the Oak Ridges Moraine, north of Oshawa, to characterize the nature of the Quaternary glacial sediments and to gain a better understanding of the groundwater flow system on site in order to inform decisions related to construction of the Station and groundwater quality risk assessments as well as provide infrastructure that will allow us to monitor conditions both before and after construction. Several conventional wells have been installed on site with five feet screened intervals installed in shallow, intermediate and deep sediments overlying bedrock in collaboration with Stantec and Hydro One. In this past winter, a continuously cored hole through the glacial deposits into the bedrock shale was drilled to a total depth of one hundred and fifty metres. This hole has provided detailed information about the geology, which comprises various aquifers and aquitards. The plan is to use rotosonic drilling to recover additional core and install a multilevel system that will enable us to collect hydrogeological and geochemical data and to better characterize the upper groundwater flow system. We also hope to compare the preservation of sedimentary records using different drilling techniques since the first few holes were carried out using a mud rotary drilling method obtaining continuous, undisturbed core. This geological work is being led by Dr. Emmanuelle Arnaud. This project is being carried out in collaboration with Jim Smith (McMaster University), Rick Gerber (Oak Ridges Moraine Hydrogeology Program) and with the help of several graduate students including Lori Labelle (PhD, Waterloo), Sydney Duggan and Kelly Whelan (MSc, McMaster University).

**Municipality of Clarington**

**Advances in Groundwater-Surface Water Interaction**

*New Methods being Developed at the Barber Scout Camp in Guelph, ON*

The lack of understanding of groundwater – surface water (GW-SW) interaction in bedrock rivers was brought to the research table by Dr. Beth Parker in 2010. The topic had both global and local relevance given that the Eramosa River, abutting the University of Guelph campus, is a bedrock river flowing over the groundwater supply aquifer for the City of Guelph. Advancing GW-SW science, combined with interest from groups like the Ministry of Natural Resources, Grand River Conservation Authority, Scouts Canada and the City of Guelph prompted a strong effort from our research team. The problem being addressed by Celia Kennedy (PhD student) is the need for a predictive conceptual model based on the discrete fracture network (DFN) approach. Conceptual models currently used in water management decision-making are based on flow fundamentals governed by the size, shape and orientation of the sandy sediments that we commonly see in alluvial streambeds. A DFN model, based on fracture geometry and connectivity, will provide more realistic insights to potential flow velocity, volume and distribution of groundwater at and below the streambed interface of these bedrock-governed environments. Following completion of a 12-km stream survey to categorize the Eramosa streambed as exhibiting exposed bedrock, sediment cover and/or thermal indicators of possible groundwater discharge, the Barber Scout Camp was selected as the pilot study site, where fractured dolostone is exposed on both the streambed and floodplain. One of the reasons bedrock rivers are seldom explored is their vulnerability to ecological disturbances. This challenge presented the opportunity for Dan Elliot and Bob Ingleton (Technicians) to explore the use of small-diameter portable drills to achieve data collection results of the same quality, quantity and scale currently obtained from more invasive, truck-mounted methods. In addition to eco-sensitivity, advances in GW-SW research in bedrock rivers is also challenged by the nature of the environment itself. Our group took this as an invitation to think outside the box and to develop and field-test new research tools, while extending field training to undergraduate co-op students (Donovan Capes, Keelin Scully, Tammy Zidar and Racheal Harman-Denhoed). Dr. Colby Steelman has been developing non-invasive geophysical methods under his post-doctoral Banting Fellowship grant, while Dr. Pete Pehme has helped guide our temperature (as a GW tracer) methods development. G360 is looking forward to the publication of several papers from this project in 2015 and continued research by new MSc students (Donovan Capes and Hari Bhatti).
Non-Point Source Contamination in Ontario—Nitrate
Changing Agricultural Landscapes and Ground Sensitive Aquifers (Ontario Ministry of Food)

The research objective of this initiative led by Dr. Jana Levison, is to define and quantify the transport of excess nutrients (specifically nitrogen from commercial and animal sources) related to cash crop modifications and variable weather, into groundwater to anticipate and mitigate potential water quality impacts.

**Approach:** State-of-the-art groundwater modeling coupled with agricultural nutrient management expertise and supported by a specialized hydrogeological field data network will be used to find critical cases for sensitivity to contamination. This in turn can be applied to on-farm nutrient management policies. Several geological conditions encountered across Ontario will be studied. New methodologies to investigate how agricultural and climate evolutions may affect groundwater quality will be developed. The project will use a multidisciplinary research team approach.

**Expected Benefits:** This research will yield an improved understanding of the fate of nitrate in groundwater related to crop and weather changes, in order to determine how agricultural practices may be adjusted to mitigate rural water quality impacts in Ontario. This topic is of extreme importance since groundwater is the main water source for farms and for rural residents. Gleaned principles can be applied to on-farm nutrient management and wellhead protection initiatives across the province. Rural and urban well users will benefit from resulting improved groundwater protection. First Nations' Source Water Protection: Current federal guidelines in Canada for First Nations’ on-reserve source water protection planning discard hydrogeological studies as too expensive to carry out, and recommend using ‘rules of thumb’ to determine wellhead protection zones. However, this lack of hydrogeological data leaves communities unprepared and vulnerable to a host of potential drinking water threats. The University of Guelph has partnered with a First Nations community in Ontario to develop an effective SWP process.

Graeme MacDonald, developing unique groundwater quality monitoring stations (nitrate and other parameters) in SW Ontario

Rachael MacDonald, working with a First Nations community in Ontario to protect the drinking water supply
Carter Well Nitrate Project (Arkell Research Station and Victoria East Golf Course)

The main objective of this study was to identify possible nitrate sources affecting the water chemistry of the City of Guelph Carter municipal supply wells through application of the discrete fracture network (DFN) approach to investigate fractured rock sites impacted by contaminants. This research is a continuation of regional nitrate study that was done previously in the area by a UW MSc student, Tomas Opazo. Two bedrock boreholes at these sites were instrumented with Westbay multilevel groundwater monitoring systems from Schlumberger early in 2014. Groundwater samples for hydrogeochemistry and isotopic characterization were collected from CMT MLS in the overburden and Westbay MLS in the bedrock at these two locations, including isotope analysis of $^{18}O$, $^2H$ and $^3H$ in water, $^{34}S$ and $^{18}O$ in sulfate, $^{15}N$ and $^{18}O$ in nitrate and $^{13}C$ in dissolved inorganic carbon (DIC). The high resolution data obtained from the instrumentation installed in the bedrock boreholes will provide additional information to evaluate the fate of nitrate in the Guelph formation and the sources of nitrate for the Carter wells. A UW MSc student, Kamilo Campos, supervised by Dr. Ramon Aravena and Dr. Beth Parker is carrying out this research.

Origin, Occurrence and Fate of Nitrate in Sedimentary Bedrock Groundwater in the Maritimes

This Canadian Water Network (CWN) project (http://www.cwn-rce.ca/project-library/project/origin-occurrence-and-fate-of-nitrate-in-sedimentary-bedrock-groundwater-in-the-maritimes) continued in 2014 with collaborations with Dr. Cathy Ryan, University of Calgary and Agriculture Canada. Field work at PEI research sites including additional drilling and installation of Hybrid CMT Multilevel Systems (MLS) at the Harrington site. Amanda Malenica defended her M.Sc. thesis in March 2015 focusing on these datasets. Field trials of portable drills involving the Shaw Backpack drill (http://www.backpackdrill.com/index.html) and the Mobile Minuteman drill (http://www.mobiledrill.net/new-drill-rigs/Minuteman) were also conducted. The combination of auguring capability of the Minuteman to set casings through overburden and then rock drilling with the Backpack drill proved successful in collecting core and installing instrumentation in sensitive areas along streams and the estuary in Mill River. The project was also extended into Nova Scotia with drilling at the Bio-Environmental Engineering Centre (BEEC) on the Dalhousie Agricultural Campus in Truro as part of this and another CWN project that Jana Levison of G360 and her student Carolina Klabunde are involved with “Impacts of Alkaline Stabilized Biosolids Application on Fate and Transport of Emerging Substances of Concern in Agricultural Soils, Plant Biomass and Drainage Water” (http://www.cwn-rce.ca/project-library/project/impacts-of-alkaline-stabilized-biosolids-application-on-fate-and-transport-of-emerging-substances-of-concern-in-agricultural-soils-plant-biomass-and-drainage-water). The annual CWN project meeting was held in Charlottetown in June, which included presentations by G360 members (Parker, Malenica, Chapman) and site tours of Harrington and the City of Charlottetown’s Coles Creek wellfield. The project will be completed in late 2015.

Shallow drilling in Mill River Basin PEI by Cathy Ryan and Steve Chapman using Minuteman drill to auger through overburden and set a casing and the Backpack drill to core bedrock, followed by installation of piezometers.
Hydrite—Cottage Grove, Wisconsin USA

2014 was a busy year at the Hydrite field research site. Three new MSc students (Andrew Buckley, Lucas Ribeiro, and Tara Harvey) joined the Hydrite research crew to apply the DFN approach to 5 new coreholes arranged in a transect just downgradient of the DNAPL source zone. In addition to application of the fundamental DFN approach tools, a novel technique developed by Pete Pehme and Ryan Kroeker of deploying pressure and temperature transducers behind FLUTE liners to collect transient data prior to multilevel installation was tested in the source zone transect coreholes. Carole Johnson and Krystal Kiel of the USGS also made the trek to the Hydrite site from Connecticut to test new geophysical techniques as part of a collaborative SERDP project being led by Lee Slater and Kristina Keeting (Rutgers), Beth Parker, and Fred-Day Lewis (USGS). The characterization activities were not limited to the boreholes. Postdoctoral fellow, Colby Steelman, collected surface resistivity and seismic surveys along 7 additional lines both outside the plume and near the new source zone transect to better constrain the role of heterogeneity in the overburden deposits and overlapping unconformities in the shallow rock on flow and contaminant distribution. The data collected during 2014 will be used to better understand the spatial distribution of DNAPL, calculate a snap shot of the contaminant flux from the DNAPL source zone, characterize the hydraulic characteristics of the fracture networks in key bedrock units, and direct future phases of source zone characterization. Pat Quinn was hustling late fall to finish up the high resolution packer testing in these holes and through wind, rain sleet and snow, the multilevel systems were installed. We have already collected 3 rounds of head profiles from them, too!
Guelph Tool—Guelph, Ontario, Canada

The main objective of this study was to provide a comprehensive understanding of TCE distribution and hydraulic properties of the site and obtain additional information of potential sources related to the TCE-impacted inactive nearby municipal wells. Groundwater sampling rounds and hydraulic monitoring events were conducted at this site to provide information related to spatial and temporal changes in chlorinated solvents distribution and evaluate potential attenuation processes occurring in the dolostone bedrock aquifer. Part of these depth-discrete monitoring results was obtained through temporary deployments of pressure transducers and sampling tubes behind blank FLUte liners. This study included groundwater analysis for isotopes 13C and 37Cl in TCE and its degradation products, 13C in dissolved inorganic carbon (DIC) and 34S in sulfate. Part of this research site instrumentation (five multilevel systems - MLS with pressure transducers in 51 locations) provided time series datasets to determine depth profiles to assess the degree of confinement and estimate uniaxial specific storage incorporating the heterogeneity of this fractured dolostone aquifer. Two UoG MASc students Joanna Olesiuk and Paul Trudell supervised by Dr. Beth Parker have been involved in the abovementioned studies.

Clayey Aquitards
Former DuPont Florence Site—South Carolina, USA

In 2007 a small mixed DNAPL source at this DuPont site was treated via soil mixing with ZVI-Bentonite. G360 began a study led by Dr. Beth Parker, of response of the down-gradient plume to this source treatment in 2008 using high resolution methods, which formed the basis of Adam Gilmore’s M.Sc. Thesis (completed 2010). The ongoing monitoring continues to show some improvement in plume water quality but also persistence owing both to mass released from low permeability zones as well as small areas of residual DNAPL outside the treated zone, driving home the importance of high resolution characterization. Steve Chapman gave an update on investigation of aquitard integrity at this site at the DuPont Site Characterization Network Meeting in November 2014.

DuPont Chambers Works—New Jersey, USA

Dr. John Cherry is involved on the Scientific Advisory Board (SAB) for the DuPont Chambers Works Site in New Jersey. In November 2014, Steve Chapman representing G360 visited the site to work with URS to oversee drilling and installation of a 15-port Waterloo MLS, recommended by the SAB as part of a detailed study of contamination in the aquifer. The MLS was based on previous G360 work outlined in the paper “A Multilevel System for High-Resolution Monitoring in Rotasonic Boreholes” by Beth Parker, John Cherry & Ben Swanson in Groundwater Monitoring & Remediation in 2006. As a collaborative project involving DuPont, Geosyntec (Dr. Gary Wealthal), and AECOM, the MLS was successfully installed in the rotasonic-cored hole under challenging conditions and groundwater sampling was recently conducted. The data from this MLS is providing exceptional insight into the vertical hydraulic head and contaminant distribution and hydrochemistry leading to additional installations at the site for improvement of the site conceptual model (SCM).

SERDP 2014 Project-of-the-Year Award:

Environmental Restoration, Basic Research Addressing Contaminants in Low Permeability Zones

We’re delighted to announce that “Environmental Restoration, Basic Research Addressing Contaminants in Low Permeability (SERDP)” was awarded the SERDP 2014 Project of the Year (https://www.serdp-estcp.org/News-and-Events/Blog/Contaminant-Storage-and-Release-in-Low-Permeability-Zones) for this closing project on contaminant storage and release in low permeability zones. The project team included Dr. Tom Sale, Colorado State University; Dr. Charles Newell, GSI Environmental Inc.; Dr. Beth Parker, UoG; Dr. J.F. Devlin, KU; Steven Chapman, UoG; Dr. Kevin Saller, TSU-CDM Smith; Dr. David Adamson, GSI Environmental Inc.
US EPA Region 2 – Garfield, New Jersey, USA

Research on behavior of chromium in fractured sedimentary rock is continuing through collaboration between G360 and Dr. Tom Al and his PDF Jiujiang Zhao at the University of Ottawa, with funds and technical support from US EPA Region 2. Coring and rock core subsampling was performed at the Garfield Chromium Contamination Superfund Site in New Jersey in 2012 and for detailed assessment of Cr(VI) distribution in the plume. The initial project included development of new analytical techniques for processing rock core samples for Cr(VI) with a manuscript in submission. The current follow-on stage involves detailed assessment of Cr(VI) diffusion and reaction processes in the rock matrix with lab studies ongoing at University of Ottawa. This collaborative research is expected to provide much more insight on processes controlling Cr(VI) transport and fate in fractured sedimentary rock resulting in better assessment of risks and remedial options.

Tank which released chromium at Garfield Superfund site, core collection and rock core subsampling.

Contaminant Behavior in Aquitards and Back Diffusion – CFB Borden & Clean Harbours, Ontario

Research on long-term contaminant behavior in clayey aquitards is ongoing including collaborations with Dr. Ramon Aravena (University of Waterloo), Dr. Daniel Hunkeler and his PhD Student Philipp Wanner (Centre for Hydrogeology & Geothermics at the University of Neuchâtel). Recently this work has included coring into the aquitard below the plume at the BDI (Borden DNAPL Infiltration) research site at CFB Borden and below long-term DNAPL sources emplaced in the aquitard at the Clean Harbors Hazardous Waste Facility near Sarnia, Ontario. Research includes application of Compound Specific Isotope Analyses (CSIA) for improved understanding of diffusion and reaction processes.

Collecting cores below the emplaced DNAPL sources and detailed field subsampling of cores.

Precision Fabricating & Cleaning – Cocoa, Florida, USA

G360 has been conducting research at the PFC site, where since 1996, and continued groundwater sampling there in 2014. The facility has been operating an innovative hydraulic capture system since 2002, designed with G360 input, to cut off mass discharge from the source zone at the property boundary and enhance rates of down-gradient plume cleanup via reinjection of treated water to avoid stagnation zones and enhance plume flushing. The down-gradient plume has been routinely monitored since the system was initiated using transects of multilevel wells. The recent sampling shows continual improvement of down-gradient water quality with TCE concentrations now below MCLs along transects, and continued declines in degradation products with the tailing attributed to back diffusion from thin clayey layers.
Extraction of natural gas from shale formations by hydraulic fracturing has fundamentally shifted the world’s energy landscape. Due to the abundance of this resource in North America, shale gas development has the potential to transform the Canadian economy creating jobs, significant wealth and energy security over the coming decades. However, the necessary extraction technique, i.e. hydraulic fracturing, could potentially give rise to significant environmental impacts. Contamination of shallow groundwater by leakage of natural gas originating from shale gas development is one aspect of significant concern about which little is known. In particular, knowledge on the most effective monitoring and detection methodologies regarding natural gas contamination in groundwater and the potential impacts on groundwater quality over appropriate temporal and spatial scales is lacking. Thus prior to widespread shale gas development within Canada it is essential that the implications of groundwater contamination by natural gas and the most effective monitoring and detection strategies are investigated, proven and employed.

G360 has initiated a strategic thrust into this field of research due to its synergy with group expertise. This thrust has over the last 18 months formed the beginning of a significant and exciting research program. The strategic thrust began with group directors Dr. Parker and Dr. Cherry becoming involved in a Canadian Council of Academies report on shale gas development in Canada. This subsequently led to hiring of Postdoctoral Fellow Dr. Aaron Cahill to spearhead initiation of a new research theme using the groups expertise to answer questions surrounding environmental impacts of shale gas development. Since inception the group has been successful winning (either leading or as a collaborator) 3 projects including; a University of Guelph led NSERC strategic Project Grant ($600k over 3 years) entitled ‘Environmental Impacts of Shale Gas Development: A Shallow Aquifer Controlled Methane Release Experiment’, a University of Calgary led NSERC strategic project ($500k over 3 years) in collaboration with the French Geological survey entitled ‘Environmental baseline conditions for impact assessment of unconventional gas exploitation: advancing geochemical tracer and monitoring techniques’, and a Canadian Water Network Project ($120k over 1 year) entitled ‘Hydraulic Fracturing Knowledge Integration’ also led by the University of Calgary. In addition to these successful and ongoing projects an additional project is about to commence in collaboration with Carbon Management Canada at the University of Calgary and various private sector organizations. This project will concern gas migration in the subsurface and will lend G360’s groundwater expertise to geophysically focused $9 million deep gas injection project. The core team working on this new research thrust has recently expanded with the hiring of an M.Sc. Student and two interns.

Dr. Aaron Cahill
We live in the Age of Information. With the rise of digital technology our desire and ability to gather information has ushered in a new era of informed decision making. This trend towards solving problems based on having the right information at our fingertips is transforming business, education, health and safety, and our personal lives. At the G360, we are leveraging leading information technologies in conjunction with our specialized toolsets of scientific instruments and methods to analyze and transfer data faster and more efficiently than ever before.

The use of custom apps on mobile devices in the field ensures data is collected consistently, is error checked on the spot, and can be transmitted in real time to a central online database ready for analysis. Our central database is equipped with custom application logic to digest raw environmental data and return it in formats compatible with a host of sophisticated visualization and processing software packages. Furthermore, our central database is hosted online in a multi user collaborative environment, meaning all of our research collaborators have access to a single unified data resource.

In addition to collection of raw data in the field, we are leveraging the power of Google for all of our core communications, coordination, and document management. Much like our central database, Google’s cloud based platform allows our whole team to work with a unified set of information that is always available, and far more feasible to manage and organize than traditional client-side technologies where information is tied to physical devices. Overall, these technologies greatly facilitate the complex pathway that starts with raw data from the real physical processes happening in the environment, becomes usable information on our computer screens, and ends with knowledge transfer in peer reviewed publications.
Congratulations Students!

**Robert Stuetzle**
Primary Supervisor: Dr. Beth Parker
MASc., Water Resources Engineering, May 2014
*Vertical Profiling Data Sets for Improved Characterization of Hydrologic Units Influencing Contaminant Migration in Strongly Heterogeneous Triassic Sediments*

**Paul Trudell**
Primary Supervisor: Dr. Beth Parker
MASc, Water Resources Engineering, May 2014
*Hydraulic Head Hydrographs From Depth-Discrete High Resolution Multilevel Systems For Estimating Loading Efficiency and Specific Storage in the Silurian Dolostone in Guelph, ON*

**Kaifying Qui**
Primary Supervisor: Dr. Andre Unger
Co-Supervisor: Beth Parker
MSc., Earth Sciences, University of Waterloo, December 2014
*Simulating the TCE DNAPL Source Zone Below the Water Table at the Santa Susanna Field Laboratory*

**Amanda Malenica**
Primary Supervisor: Dr. Beth Parker
Defended her MSc. Thesis project on March 30th, 2015!
*Evaluation of nitrate distribution and matrix storage effects in a dual permeability fractured bedrock aquifer with heterogeneous hydrochemistry*

---

**2014/2015 Arrivals**

**Academic Visitors:**
- Marcos Barbosa, University of Sao Paulo, Brazil, Jan 2014-Dec 2014
- Eleonora Frollini M.Sc. Visiting Scholar, University of Roma La Sapienza, March 2015
- Prof. Reginaldo Bertolo, University of Sao Paulo, Brazil, January 2014
- Nino Cilona, PDF, Stanford University, February 2015

**New Staff:**
- Amanda Buttenham (Scientific Communications Coordinator)
- Kelly Moore (Executive Assistant)
- Cinthuja Leon (Procurement Officer)
- Kenley Bairos (Research Associate)
- Terri Cheung (B.Sc. Research Assistant)

---

**Paul Trudell**
Primary Supervisor: Dr. Beth Parker
MASc, Water Resources Engineering, May 2014
*Hydraulic Head Hydrographs From Depth-Discrete High Resolution Multilevel Systems For Estimating Loading Efficiency and Specific Storage in the Silurian Dolostone in Guelph, ON*


Dr. Beth Parker has been featured in two media publications in the year 2014. Dr. Parker has a feature in International Innovation, a communication publication for the scientific community that features interviews and independent content from varying scientific disciplines. The article featured in International Innovation titled, “Clear as Water” (International Innovation: Clear as Water) includes an interview with Dr. Parker characterizing her research in groundwater contaminants in fractured rock and the progress of groundwater research within G360 Centre for Applied Groundwater Research. In 2014, Dr. Parker was also featured in Co.lab.o.rate, a local media outlet in Guelph, ON produced by Guelph Sustainable Solutions Group. On page 20, this feature, The G360 Centre for Applied Groundwater Research: Looking Out for What’s Most Important, describes the global issue of groundwater contamination and how Dr. Parker and her team of researchers are playing a vital role in safeguarding groundwater supplies worldwide through conducting groundwater contamination research in fractured rock locally.

G360 in the Media

Dr. Beth Parker has been featured in two media publications in the year 2014. Dr. Parker has a feature in International Innovation, a communication publication for the scientific community that features interviews and independent content from varying scientific disciplines. The article featured in International Innovation titled, "Clear as Water" (International Innovation: Clear as Water) includes an interview with Dr. Parker characterizing her research in groundwater contaminants in fractured rock and the progress of groundwater research within G360 Centre for Applied Groundwater Research. In 2014, Dr. Parker was also featured in Co.lab.o.rate, a local media outlet in Guelph, ON produced by Guelph Sustainable Solutions Group. On page 20, this feature, The G360 Centre for Applied Groundwater Research: Looking Out for What’s Most Important, describes the global issue of groundwater contamination and how Dr. Parker and her team of researchers are playing a vital role in safeguarding groundwater supplies worldwide through conducting groundwater contamination research in fractured rock locally.
G360 Principal Investigators

From left to right: Dr. Emmanuelle Arnaud * Dr. Jana Levison * Dr. Ramon Aravena * Dr. Kari Dunfield * Dr. Orfan Shouaker-Stash* Dr. Peeter Pehme * Dr. John Cherry

Our 2014-2015 Industry Sponsors/Collaborators
2015 Conference Attendance

ORF Annual Meeting, Sustainable Bedrock Water Supplies for Ontario Communities, Guelph, ON, March 4-5, 2015

Unified Approach to Sustainable Groundwater Use in Southern Ontario Workshop, Guelph, ON, March 6, 2015

NGWA Summit, San Antonio, Texas, March 16-18th, 2015

SAGEEP, Austin, Texas, March 22–26, 2015

AGU Joint Assembly, Montreal, QC, May 3-7, 2015

GSA North Central Meeting, Madison, WI, May 19—20, 2015

The University Consortium Annual Meeting, Guelph, ON, June 2-4, 2015. (by invitation only)

42nd IAH International Congress, AQUA2015, Rome, Italy, September 13-18, 2015


IAH-CNC Waterloo, Waterloo, ON, October 27-30, 2015

The University Consortium Fall Focus Meeting, Denver, Colorado, TBA Fall 2015

GSA Annual Meeting, Baltimore, Maryland, Nov. 1-4, 2015

The G360 Team

Learn more about:

**G360 The Centre for Applied Groundwater Research**

by visiting our website,

[G360.uoguelph.ca](http://www.g360.uoguelph.ca)

50 Stone Road East
Guelph, Ontario
N1G 2W1

admin@g360group.org
communications@g360group.org
G360.uoguelph.ca