

Beaty Water
Research Centre

ANNUAL REPORT 2019-2020

Queen's University, Kingston, Ontario,
Canada



TABLE OF CONTENTS

1	Director's Message
2	Vision and Mission
3	Overview
4	Outcomes
5	Facilities
6	Year by Numbers
7	Research Highlights
9	COVID-19 Response
11	NSERC Brockhouse Canada Prize Winners
12	Awards
13	LEADERS CREATE
17	Research Highlight – Pascale Champagne
18	Research Highlight – Kevin Mumford
20	Research Highlight – Yves Filion
21	Education
23	Outreach
25	Knowledge Translation
28	Administration
29	Advisory Board
30	Associated Faculty
33	Research Projects
41	Publications
47	Financial Statement

DIRECTOR'S MESSAGE

2019-2020 has been a busy and successful year for the Beaty Water Research Centre (BWRC). In the research pillar, we have submitted a significant number of multi-disciplinary research proposals and we launched the Canadian Algae Research and Technology Network. Our focus has been on building research capacity by fostering national and international interdisciplinary collaborations.

In support of our activities, we have established new industry and community collaborations and through these new partnerships, we launched the BWRC Research Seminar Series. In the education pillar, we are particularly proud of having launched the first of many planned graduate diploma programs – the Water and Human Health Diploma, which was launched in the fall of 2019.

I hope you enjoy learning about some of the highlights of this year's activities through this annual report, we look forward to engaging with you in the year ahead.



Pascale Champagne, Ph.D., P.Eng., D.WRE, F.EWRI, F.ASCE, F.CAE
Director, Beaty Water Research Centre
Queen's University

VISION

The BWRC aims to be a world-class entity for collaborative research and education in the multifaceted realm of water-related issues for the Queen's University and Royal Military College of Canada (RMC) communities.

MISSION

BWRC will develop and support opportunities in research, education, collaborations and international partnerships related to water. We are committed to fostering an environment that encourages collaborative research, excellence in teaching and the development of unique multidisciplinary approaches.

VALUES

Collaboration

Through national and international collaboration with experts and communities, BWRC strives to build partnerships to advance our mandate.

Interdisciplinary

Our membership includes complementary disciplines from engineering, natural, health and social sciences, law and policy studies, to achieve advancements.

Discover

We contribute to debate, development and dissemination of knowledge and innovations in research and education.

Innovation

We develop technology that enhances human and ecosystem health and supports the delivery of education and outreach.

Excellence

We demonstrate excellence through the delivery of programs and contributions to knowledge recognized globally.

Respect (EDI)

We recruit researchers and HQP from equity seeking groups and empower them to participate by offering training and support.

As part of the Centre's Education and Outreach mandate, BWRC develops strong partnerships with academic departments, industry, school boards, public health units and local water conservation authorities. Through these partnerships, we offer educational opportunities and internships across disciplines for students, the public and professionals. In fall 2019, the BWRC launched the first of a number of accredited online diploma programs. Courses offered through the BWRC bridge the gap between disciplines, theory and real-world applications for all students, providing graduates with a competitive edge in their chosen career field.



OUTCOMES

EDUCATION



Interdisciplinary

Graduate Diploma Programs offer courses that span multiple disciplines, providing students an advantage in today's workforce.



Synergy & Collaboration

Cross disciplinary collaborations in the delivery of programs providing learning opportunities that allow application of knowledge broadly.



Networking Opportunities

Our programs allow students to network with a wide variety of stakeholders, providing them with a kick start to their career.



Skill Building & Future Workforce

Our programs help students build practical and professional skills to prepare them to become capable STEM employees.

KNOWLEDGE TRANSLATION

We train our students to effectively translate knowledge from research findings to a broad audience.

RESEARCH



Enhanced Water Quality & Access

Interdisciplinary collaborations leading to the development of methods and innovation to improve water access and quality.



Innovation in Water Treatment Systems

New technologies developed leading to improved water treatment systems and biosustainability.



Sustainable Infrastructure Implemented

Natural and built infrastructure improvements implemented in response to climate change.



Influence Environmental Policy & Law

Policies and innovations developed and implemented to improve water governance, use, resources and quality.



Through interdisciplinary collaborations, research knowledge is easily translated into action through implementation of innovation and policy development.

OUTREACH



Inform & Empower

Informing and empowering the community leading to changing behavior related to water quality and sustainability.



Engagement for Collaborative Change

Informing and educating motivates students and the public to become water stewards in their homes, classrooms and communities.



Align Activities with Knowledge Gaps

Stakeholder consultations leading to alignment of activities with knowledge gaps.



Change Implemented

Implement knowledge and innovation working with conservation authorities, industry, health units and municipal, provincial and federal government.



Our outreach events improve the flow of communication between researches, professionals, policy makers and the public to influence and implement change.

FACILITIES

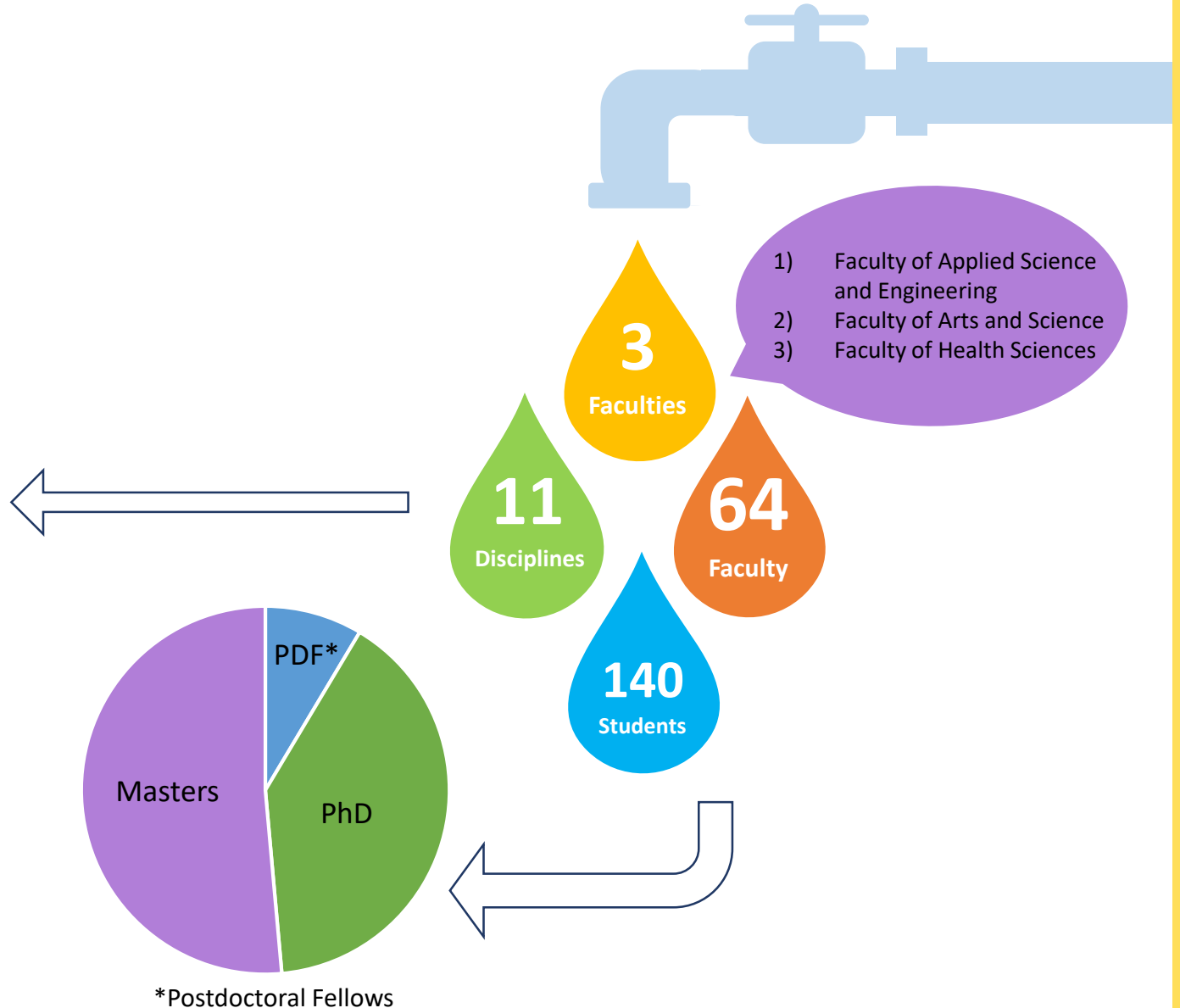
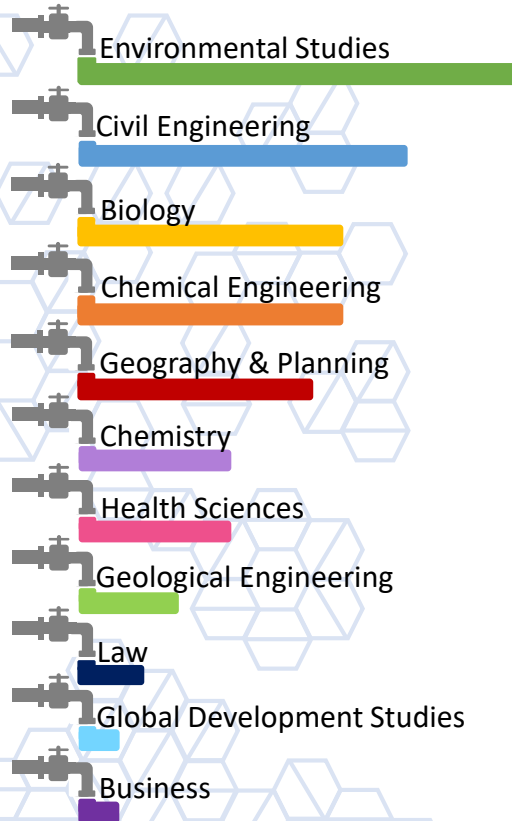
The Centre is located in a new state-of-the-art facility in Mitchell Hall at Queen's University in Kingston, Ontario. The Centre also has a strategic network of affiliated field and large scale facilities which include:

- Queen's Coastal Engineering Lab
- Queen's Biological Station
- Kennedy Field Station
- Tay River Groundwater Network
- Loyalist Township Constructed Wetland
- Cape Bounty Arctic Watershed Observatory (CBAWO)







YEAR BY NUMBERS

100 Publications
65 Research Projects
19 Lectures/Seminars
2 Conferences



RESEARCH HIGHLIGHTS

This year we expanded collaborations with faculty from various disciplines at Queen's, the Royal Military College of Canada and external academic institutions at national and international levels. Our research links to industry and non-profit organizations such as conservation authorities, school boards and public health. This year's highlights include:

	Drs. Champagne, Jessop, Mabee and Cunningham won the NSERC - Canada Brockhouse Prize for interdisciplinary research valued at \$250,000.
	NSERC CREATE Leaders in Water and Watershed Sustainability program (QU - \$1.65 million), has supported 16 new HQP, and hosted its first HQP symposium and training workshop. Co-applicants of the NSERC CREATE training program in Persistent, Emerging, and Oil Pollution in Cold Marine Environments (\$1.65 million - QU \$81,000).
	Initiated internship programs funded through Mitacs Career Connect (\$60,000) - funding partners: Utilities Kingston, Qunite Conservation Authorities and Loyalist Township.
	NSERC Engage grant (\$25,000) and RFP (\$150,000) to assess microbial-induced calcite precipitation to improve the deposit performance of tailings.
	Established new industry and community partnerships to generate \$800,000 for future research including application submissions to NSERC Alliance, Ontario Research Excellence Fund, Mitacs and additional partnerships.
	Launched the Canadian Algae Research Technology Network, which is hosted at Queen's. This network will be leveraged for the submission of a NFRF-Transformation funding application (\$24 million) led by the Centre in 2020.



Hosted two symposiums - NSERC CREATE Leaders in Water and Watershed Sustainability (LEADERS) Symposium and the 2nd BWRC Interdisciplinary Research Symposium.



Projects associated with the Centre generated approximately \$18.7 million in research revenue.



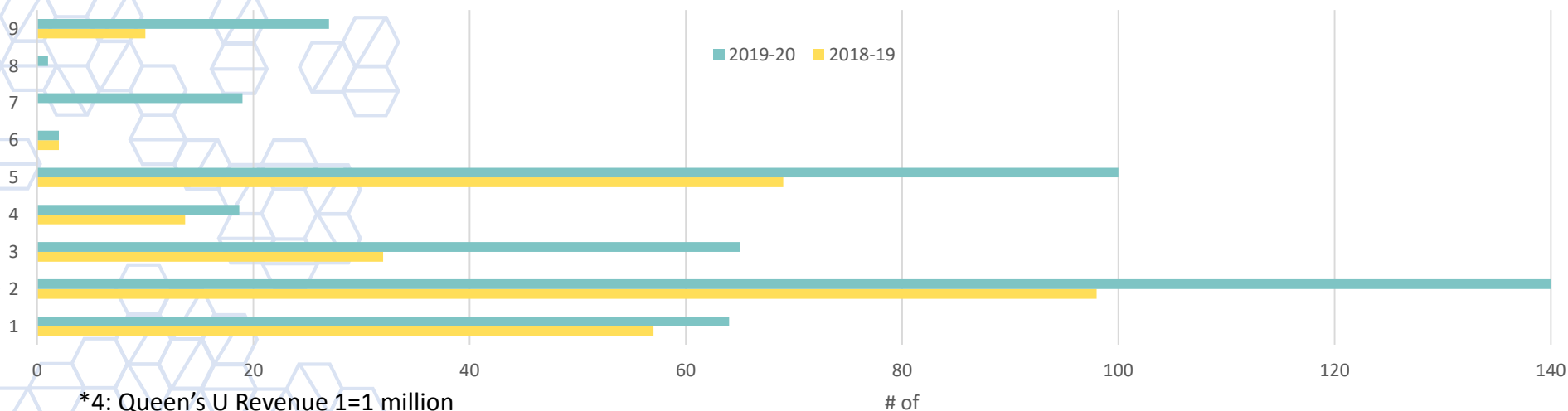
Faculty affiliated with the Centre led 65 research projects that aligned with activities addressing the mandate of the Centre.



Centre affiliated research generated approximately 100-peer review publications.

Annual Research Performance Indicators

- | | | |
|--------------|------------------------|---------------------------|
| 1 – Members | 4 – Queen's U Revenue* | 7 – Seminars |
| 2 – HQP | 5 – Publications | 8 – Awards |
| 3 – Projects | 6 – Symposiums | 9 – Research Applications |

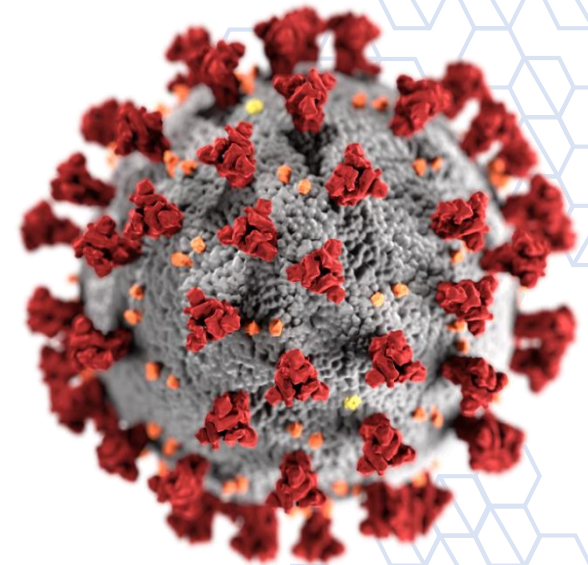


COVID-19 RESPONSE

In response to the COVID-19 pandemic, the Beaty Water Research Centre has made it a priority for staff, faculty and students to follow the advice of the World Health Organization and the Public Health Agency of Canada and continue its research, education and outreach initiatives from home, limiting access to our laboratory and administrative spaces. The BWRC is committed to doing its part in maintaining social and physical distancing and helping to flatten the curve in Canada.

The BWRC is also assisting the local community at Queen's and in Kingston, Ontario. We have lent many pieces of laboratory equipment and donated supplies to our local facilities in order to assist with large volumes of patient testing. In addition to performing extensive testing of masks for our local hospitals, we are also working to develop low cost, easy to implement tests that assess the performance of different grades of surgical masks from different manufacturers. We are looking to test the ability of these masks to withstand sterilization (for re-use) while maintaining protective integrity (i.e. do these masks still resist blood penetration? What about filtration of small particles?). Our focus thus far has been on blood, with broader applications to COVID-19. However, we are providing the hospital with the data and ultimately they will decide where and when to use the masks.

Finally, the BWRC has not strayed from its research mandate. Along with working on our current research projects, we have drawn on the expertise of our existing faculty to assemble an interdisciplinary team to put together a number of proposals for COVID-19 internal and external grant calls. In particular, we have assembled a team of faculty that spans Biomedical and Molecular Sciences, Chemistry, Environmental Studies, Civil, Chemical and Geological Engineering to address using municipal sewage and rural septic systems as a method for the early detection and monitoring of COVID-19 in communities. This is of particular interest given the mounting evidence that demonstrates the virus persists in the feces of a number of patients even after symptoms are resolved and respiratory samples test negative.



COVID-19 RESPONSE

Title	Program	PI(s)	Co-Investigators	Departments	Funding Requested
Sentinel surveillance using sewage as an early detection and monitoring strategy for COVID-19 in communities	Queen’s SARS CoV-2/COVID-19 Research Opportunity	Prameet Sheth	Pascale Champagne, Stephen Brown, Geof Hall, Sarah Jane Payne, Anna Majury	Civil Engineering, Biomedical and Molecular Sciences, Environmental Studies, Chemistry	\$26,591
Sewage-based sentinel surveillance for the early detection and monitoring for SARS-CoV-2	Ministry of College and Universities	Geof Hall	Pascale Champagne, Stephen Brown, Prameet Sheth, Sarah Jane Payne, Anna Majury, Bas Vriens, Yves Filion	Civil Engineering, Geological Engineering, Biomedical and Molecular Sciences, Environmental Studies, Chemistry	\$195,377
Gastrointestinal manifestations of COVID-19: developing a novel early warning system for future outbreaks and examining the risks of fecal-oral transmission	CIHR COVID-19 call	Atanu Sarkar - Memorial University	Prameet Sheth, Geof Hall	Civil Engineering, Biomedical and Molecular Sciences, Environmental Studies	N/A
Canadian sewage sentinel surveillance for the early detection and monitoring of COVID-19 in communities	NSERC Alliance COVID-19 Grants	Pascale Champagne	Geof Hall, Stephen Brown, Prameet Sheth, Sarah Jane Payne, Anna Majury, Bas Vriens, Yves Filion, Kieran Moore, Atanu Sarkar, Laurence Yang	Civil Engineering, Chemical Engineering, Geological Engineering, Biomedical and Molecular Sciences, Environmental Studies, Chemistry, Medicine	\$50,000



NSERC BROCKHOUSE CANADA PRIZE

In May 2019, four leading Canadian researchers from the Beaty Water Research Centre were awarded the **NSERC Brockhouse Canada Prize** for Interdisciplinary Research in Science and Engineering for their collaborative work in enhancing the value and sustainability of our natural renewable resources. The award supports the late Nobel Laureate Bertram N. Brockhouse's vision of interdisciplinary teamwork and collaboration as a way to propel scientific discovery in Canadian research. The Brockhouse Canada Prize for Interdisciplinary Research in Science and Engineering recognizes outstanding Canadian teams of researchers from different disciplines who came together to engage in research drawing on their combined knowledge and skills, and produced a record of excellent achievements in the natural sciences and engineering in the last six years.



The interdisciplinary research team consists of **Pascale Champagne**, Director of the BWRC (Civil Engineering, Chemical Engineering), **Michael Cunningham** (Chemical Engineering, Chemistry), **Philip Jessop** (Chemistry) and **Warren Mabee** (Geography and Planning, School of Policy Studies), each affiliated with the Beaty Water Research Centre and an accomplished scientist in their respective field. With the funding provided by the NSERC Brockhouse (\$250,000), the team will work in unison, bringing their unique but complementary expertise to designing solutions to address a myriad of problems caused by climate change.

AWARDS

NSERC Brockhouse Canada Prize: Wholly Green: Sustainability through a Systems Approach – Pascale Champagne, Michael Cunningham, Philip Jessop, Warren Mabee

Distinguished Professor, Queen's University: John Smol

PEO Engineering Medal in Research and Development: Pascale Champagne

FEAS Excellence in Research Award: Kevin Mumford

Frank H. Rigler Award: Brian Cumming

Diplomate, Water Resources Engineer, American Academy of Water Resources Engineers Board of Trustees: Yves Filion

Mary Rosenthal Award, Algae Foundation: Gisell Pazmino (PhD. Candidate)

125th Anniversary Faculty Award FEAS: Michael Cunningham

The Polar Medal: John Smol

Inducted as Fellow of the Canadian Academy of Engineering: Pascale Champagne

November 2019 BWRC Research Symposium:

Poster Session

1st Alexandria Cushing (PhD Candidate)

2nd Nada Sedeq (MES Candidate)

3rd Katrina Paudyn & Eden Hateley (MES Candidates)

Oral Session Winner - David Patch (PhD Candidate)



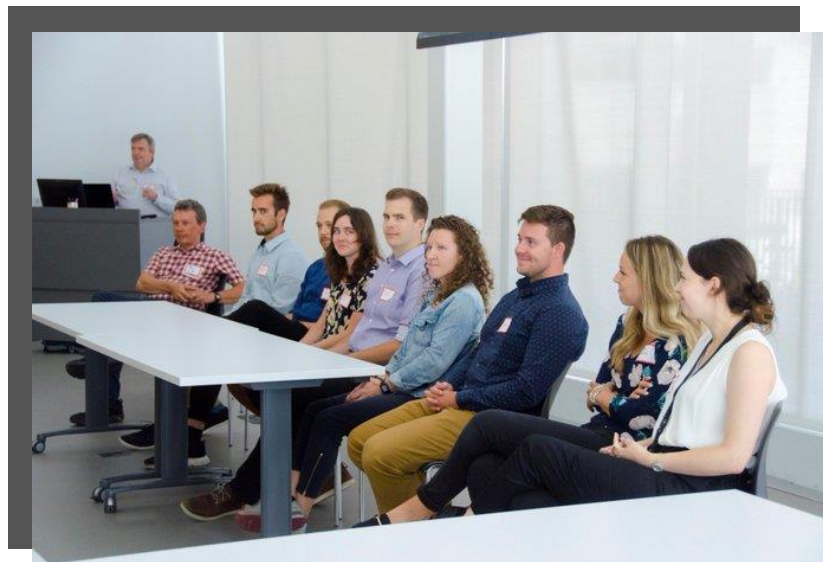
LEADERS CREATE

The LEaders in wAter and wAtERshed Sustainability (the LEADERS) program is lead by Dr. Stephen Brown, Associate Professor in the Department of Chemistry and School of Environmental Studies. The program is funded (\$1.65M over six years) through the NSERC Collaborative Research and Training Experience (CREATE) and was launched in 2018.

The first cohort of Highly Qualified Personnel (HQPs) were recruited to the program earlier this year through a competitive application process and includes 16 graduate students from the Departments of Civil Engineering, Biology, Environmental Studies and Geography and Planning.

Students 2019-2020

Zoe Armstrong, Biology
David Blair, Civil Engineering
Jeffrey Cederwall, Biology
Francois Daudelin, Civil Engineering
Anbareen Farooq, Chemistry RMC
Virgilio Góngora Echeverría, Civil Engineering
Eden Hataley, Environmental Studies
Madeleine Kelly, Environmental Studies
Sarah Lavallee, Environmental Studies
Katherine Moir, Biology
David Patch, Chemistry RMC
Max Robinson, Civil Engineering
Ioan Petculescu, Environmental Studies
Matthew Senyshen, Geography and Planning
Emily Su, Geography and Planning
Paisley Thomson, Water Sciences INRS



Participating Institutions



Institut national
de la recherche
scientifique

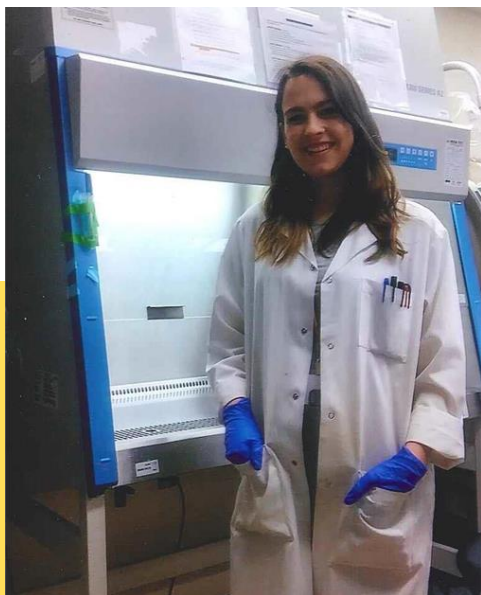


STUDENT PROJECTS

Student	Program	Supervisor(s)	Department	Project
Zoe Armstrong	MSc	Brian Cumming	Biology	Ecological impacts of long-term mercury and heavy metal exposure in the Cornwall waterfront
David Blair	PhD	Pascale Champagne, Stephen Brown	Civil Engineering	"Real time" detection and quantification of indicator organisms for source water protection
Jeffrey Cederwall	PhD	Diane Orihel	Biology	Understanding the ecological impacts of diluted bitumen in freshwater lakes and their watersheds
Francois Daudelin	MASc	Pascale Champagne, Warren Mabee	Civil Engineering	Transient heat flux models for uncertainty based waste stabilization pond design
Anbareen Farooq	PhD	Kela Weber	Chemistry and Chemical Engineering - RMC	The fate and effect of silver nanomaterials on subsurface wetland mesocosms
Virgilio Góngora Echeverría	PDF	Pascale Champagne	Civil Engineering	In situ ammonium and sulfolane bioremediation strategies
Eden Hataley	MES	Diane Orihel, Xavier Ortiz Almirall	Environmental Studies	Can microplastics act as a medium to concentrate waterborne microcystins?
Madeleine Kelly	MES	Anna Majury, Stephen Brown, Paul Hynds	Environmental Studies	Investigation of the levels of antimicrobial resistance in private well water derived <i>E. coli</i> in southeastern Ontario
Sarah Lavallee	PhD	Anna Majury, Stephen Brown, Paul Hynds	Environmental Studies	Exploring the knowledge, attitudes and practices of current well water stewardship in rural Ontario communities: Implications for drinking water vulnerability and public health risks

STUDENT PROJECTS

Student	Program	Supervisor(s)	Department	Project
Katherine Moir	PhD	Brian Cumming	Biology	Cumulative impacts on algal assemblages in Lake St. Francis: The importance of multiple stressors
David Patch	PhD	Kela Weber	Chemistry and Chemical Engineering - RMC	Release of silver nanoparticles from commercial products into the water cycle
Max Robinson	MASc	Ana da Silva, Geof Hall	Civil Engineering	Sediment dynamics and growth/decay of biofilms in a mixed primarily gravel-cobble stream
Ioan Petculescsu	MES	Anna Majury, Stephen Brown, Paul Hynds	Environmental Studies	Assessing the relationship of Total Coliform to <i>E. coli</i> in the context of drivers of microbial contamination of drinking water wells in Ontario
Matthew Senyshen	MSc	Dongmei Chen	Geography and Planning	Land use and climate change impacts on water temperature in the St. Lawrence River Watershed
Emily Su	MSc	Neal Scott	Geography and Planning	Modeling the impacts of headwater stream burial within Kemptville Creek subwatershed
Paisley Thomson	PhD	Valérie Langlois	Water Sciences - INRS	The effects of chronic exposure to agricultural retention pond water in amphibians



Student Project Highlight – Madeleine Kelly

MES Candidate, Environmental Studies

Supervisor(s): Anna Majury, Stephen Brown, Paul Hynds

Research Project: Investigation of the levels of antimicrobial resistance in private well water derived *E. coli* in southeastern Ontario

Groundwater is a vital source of drinking water globally, however most groundwater sources remain largely unregulated by the government, leaving it susceptible to contamination. Bacterial contamination of groundwater may represent a hidden risk of antimicrobial resistance (AMR). AMR is an ever-growing threat and the role of water as a source and dissemination route of antimicrobial resistant organisms and antibiotic resistance genes needs to be investigated. The objective of her research is to elucidate the potential roles of natural and anthropogenic drivers in AMR *E. coli* isolates from private well water sourced from wells in southeastern Ontario.

Recent article: Andrade L, Kelly M, Hynds PD, Weatherill J, Majury A, O'Dwyer J. (2020) Groundwater resources as a global reservoir for antimicrobial-resistant bacteria. *Water Res*, 170: 115360.

Student Project Highlight – Jeffrey Cederwall

PhD Candidate, Biology

Supervisor(s): Diane Orihel

Research Project: Understanding the ecological impacts of diluted bitumen in freshwater lakes and their watersheds

Understanding how lakes respond to human stressors is critical to both fundamental biology and to enable evidence-based environmental policies. Oil spills are one such stressor but we lack a complete understanding of how aquatic food webs will respond following spills. The Boreal lake Oil Release Experiment by Additions to Limnocorrals project is working to give a comprehensive picture of the fate and effects of diluted bitumen (dilbit) on a natural food web in a temperate oligotrophic lake. Within this project, Jeffrey's research is focused on the lower food, assessing diluted bitumen's effects on the structure and function of phytoplankton and microbial communities. He hopes to provide useful algal bioindicators of oil pollution to track ecosystem recovery and determine the extent of microbial biodegradation of dilbit in freshwater environments.

Recent Article: Cederwall J, et al. (2020) Life under an oil slick: Response of a freshwater food web to simulated spills of diluted bitumen in field mesocosms. *Can. J Fish. Aquat. Sci*, 77(5):779-788.

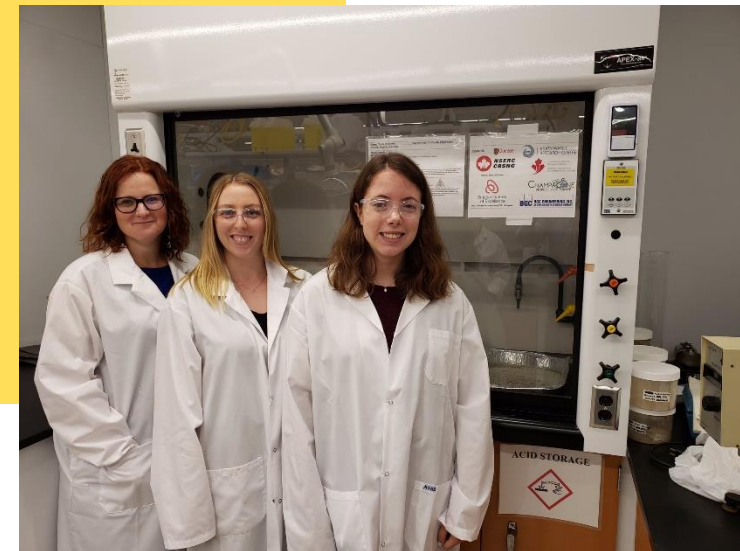


RESEARCH HIGHLIGHT – PASCALE CHAMPAGNE

Dr. Pascale Champagne's research focuses on the development of alternate water and waste management strategies and environmentally sustainable approaches with a focus on integrated bioresource management. Her research activities are interdisciplinary and transdisciplinary and have commonality with the fields of environmental and chemical engineering, biology and green chemistry.

Pascale and one of her Master's Students, Nicole Woodcock, received research funding from the National Science and Engineering Research Council (NSERC) Engage program, the Ontario Centre of Excellence Voucher for Innovation and Productivity I (VIP I) program, and Innovative Solutions Canada Phase I to assess the feasibility of using microbially-induced calcite precipitation (MICP) to improve the deposit performance of tailings. This research is a collaboration with BGC Engineering Inc., a Canadian company with expertise in mine waste engineering and mine closure planning and design.

This is critical research given that tailing dam failures can destroy property and communities and contaminate rivers, fisheries and drinking water. Tailings are by-products from mining operations. Mine tailing particulates easily diffuse into the surrounding environment, leaching acidic drainage and heavy metals to surface and groundwater. Without treatment, these tailings can take several hundred years to consolidate due to their poor water-releasing properties, and, in some cases, failure to consolidate has led to catastrophic disasters. Recent studies suggest biologically-catalyzed reactions can be used to increase the geotechnical strength of soft soils. The application of this process to tailings has the potential to remediate and reduce the risk of tailing dam failures.



Graduate students Nicole Woodcock and Sarah Rodin with industry partner Vanessa Mann from BGC Inc. Vanessa is also an Adjunct Professor with Queen's Civil Engineering.

CHAMPAAGNE
BIORESOURCE GROUP



NSERC
CRSNG

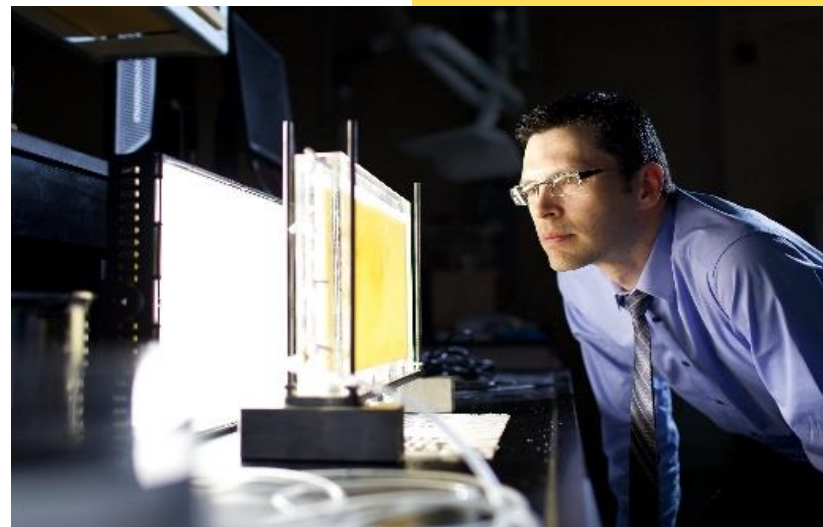


Ontario Centres
of Excellence

RESEARCH HIGHLIGHT – KEVIN MUMFORD

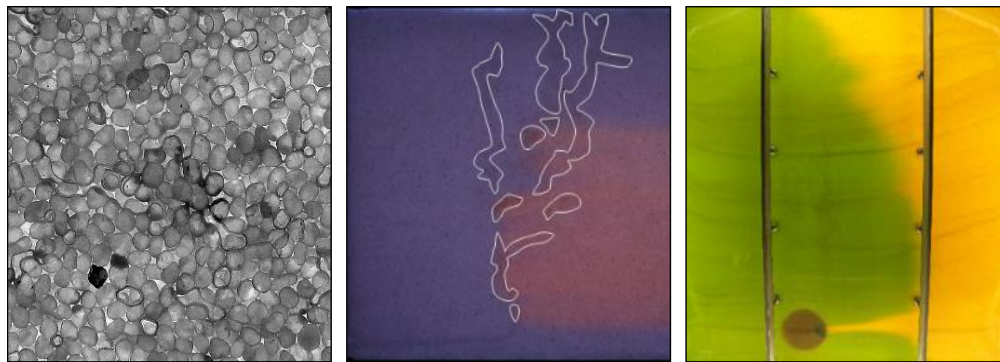
Nearly all of the world's accessible fresh water is groundwater. It's an important source of drinking water and a critical link to other components of the water cycle, including lakes and rivers, but groundwater is threatened by contamination from a variety of different chemicals related to a range of industrial activities. For example, some contaminants enter the subsurface through the accidental release or improper disposal of hazardous industrial liquids, including petroleum fuels (gasoline, diesel fuel), chlorinated solvents (dry cleaning chemicals, degreasers) and coal tar. Others are related to energy resource development, including the migration of methane and other natural gas components outside of well casings.

Dr. Mumford and his research group are working to better understand the movement of contaminants in groundwater systems, and to develop and optimize clean-up technologies. They are particularly interested in the flow of multiple fluid phases (water, oil, gas) in subsurface porous media, and the mass transfer between those phases. Small and intermediate-scale experiments are used to investigate coupled fluid flow and mass transfer, often using two-dimensional flow cells and quantitative visualization techniques designed to collect data at high spatiotemporal resolution. These experiments can be used to measure fluid saturations and dissolved solute concentrations to investigate the coupled reactive transport processes that dictate the fate of contaminants in groundwater.

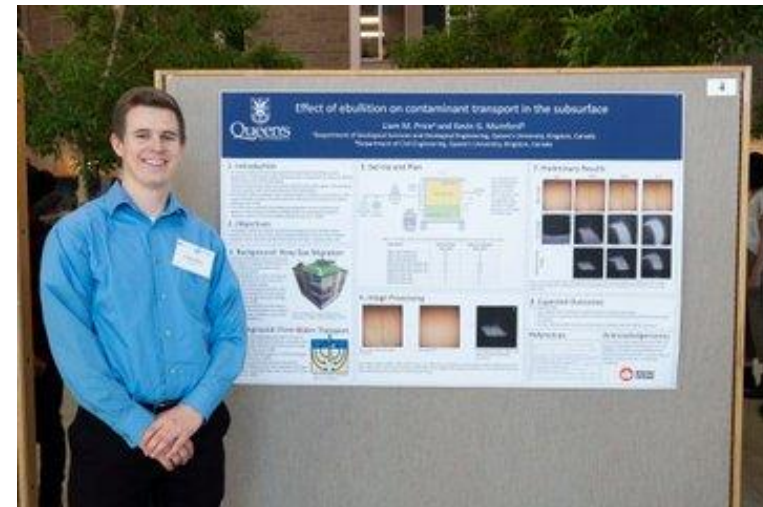


Dr. Mumford and his research group use physical models to investigate coupled flow and transport processes that control contaminant fate in groundwater systems.

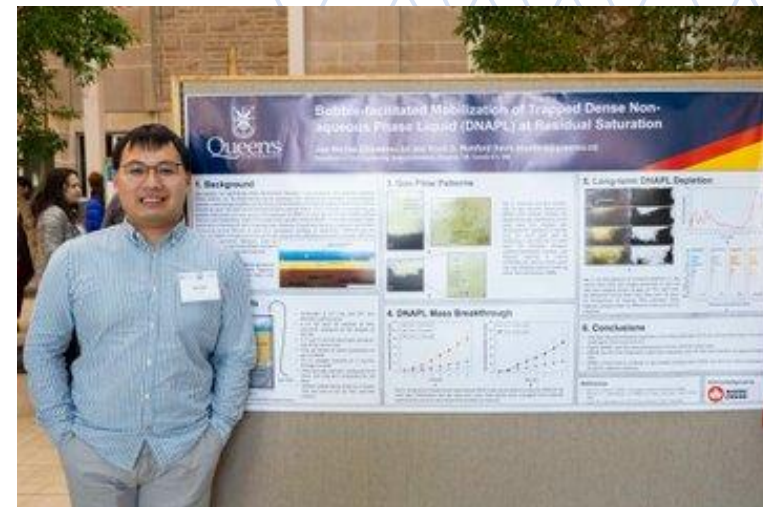
For example, graduate student Zenith Wong is looking for ways to improve in situ thermal treatment technologies used to remove volatile contaminants from groundwater. He hopes to accelerate removal at lower temperatures to save time and energy, resulting in lower costs and a decreased carbon footprint. Graduate students Nicholas Ashmore and Mitchell Davidson are working to develop a better understanding of stray gas migration, which can result in the release of methane to groundwater and the atmosphere in the vicinity of natural gas wells, to improve investigation and monitoring strategies. The goal of these projects, and those like them, are to find better ways to investigate and remediate contaminated groundwater sites to protect both human and ecosystem health.



Examples of data collected at multiple scales: (left) water and trapped gas bubbles in a packing of 0.7 mm sand, (centre) gas injected into a water-saturated 25 cm-high sand pack that dissolves into flowing water, resulting in a colour change from purple to pink, and (right) green dye tracer flowing through a 1.5 m-high sand pack that moves around a black region of injected nano-scale zero valent iron due to hydrogen gas produced by the reaction of iron with water.



Liam Price, one of Dr. Mumford's undergraduate students presenting at this years BWRC research symposium.



Jian Wu, one of Dr. Mumford's Masters students presenting at this years BWRC research symposium.

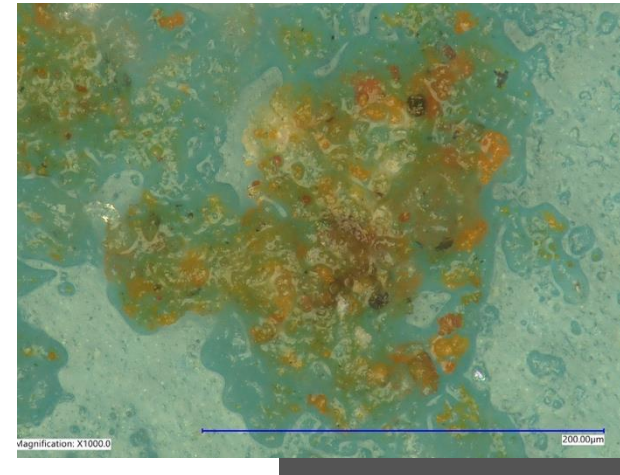
RESEARCH HIGHLIGHT – YVES FILION

Have you ever opened your faucet and seen reddish/brown-coloured water flow out of your tap? Have you ever wondered why the water flowing from your tap is sometimes of such poor quality? Dr. Filion and his research group are examining the physico-chemical and hydrodynamic mechanisms that account for the adhesion and eventual mobilization of inorganics such as iron and manganese on the walls of municipal drinking water pipes that cause water quality problems like “red water” described above. A driving research interest in the group is the question of how microbial communities in drinking water biofilms can mediate the transfer of dissolved and particulate inorganics from the aqueous phase in the bulk water to the pipe wall. To do this, Dr. Filion and his research group are using the full-scale Drinking Water Distribution Lab (DWDL) (featured in photo), which is a unique research facility in North America that can replicate the full hydraulic, physico-chemical, and microbiological conditions of real distribution systems in a fully controlled environment.

Dr. Filion is also collaborating with Dr. Pascale Champagne to examine the role that heavy metals and antibiotic compounds play on the development of bacterial resistance in drinking water biofilms. Molecular methods such as 16s rRNA sequencing are being used to examine how these stressors are causing changes in gene expression in microbial communities and increasing resistance to common-use antibiotics. The new knowledge on the mechanisms of antibiotic resistance will be foundational to setting operational and treatment policies by municipal partner regulators (MOECP, EC) to limit public exposure to resistant bacteria in drinking water systems.



Dr. Filion and Artur Braga (PhD Candidate in Civil Engineering and main researcher) inside the Drinking Water Distribution Laboratory (DWDL) at the Queen’s West Campus.



Iron oxide species embedded in drinking water biofilm on the surface of PVC pipe wall (*Brightfield, reflected light; 1000x objective lens magnification*).

EDUCATION

This year we focused on the creation of our first online graduate diploma program in Water and Human Health, which was launched in the fall of 2019. This diploma program is designed to give recent graduates and professionals an enhanced understanding of the role that water plays in driving health outcomes and ultimately, the sustainability of populations and communities. Additionally, the diploma prepares students for a career in a variety of fields which includes the public health sector, engineering and environmental consulting, conservation authorities, non-profit organizations and government planning and management.

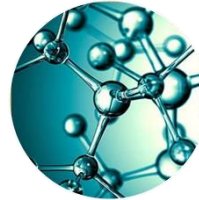
Although the program is a stand alone offering, graduates may ladder the 4 course credits they receive into 2 types of Master's degrees at Queen's; 1) Research Based and 2) Course Based. The laddering pathway of the diploma programs will also support recruitment of highly skilled graduate students to the Faculties of Engineering and Applied Science and Arts and Science.

<https://waterresearchcentre.ca/whh-about/>

COURSES



Watershed
Hydrology



Chemistry &
Biology of Natural
Waters



Water Policy &
Governance



Water &
Human Health

Also, this year we initiated the development of a graduate diploma program (4 courses) and a graduate certificate program (2 courses) in Applied Sustainability, which we hope to launch in fall 2021. These education programs are attracting global interest and the Centre is looking to tailor them for partners in South Africa and Thailand.

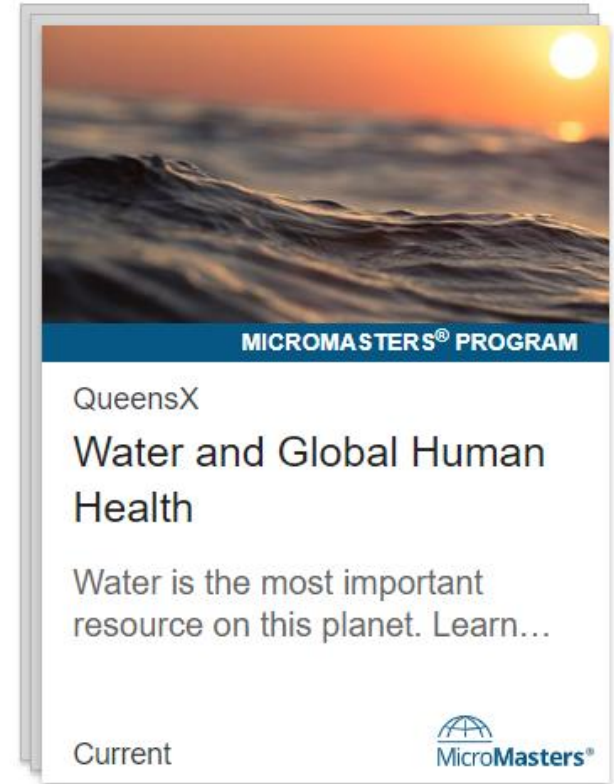
EDUCATION

To support universal access, we have created a subset of our diplomas courses for free participation through the edX platform. edX is an online platform for education and learning founded by Harvard and MIT. It currently hosts over 20 million learners, many top-ranked universities worldwide and various industry-leading companies. edX removes many of the traditional barriers to education including cost, location and access.

The BWRC offers a MicroMasters® program through edX, “Water and Global Human Health,” which consists of 6 graduate level courses taken over approximately 6 months. These courses are also available as stand alone offerings:

1. Water on Earth: An Introduction
2. Opportunities in Water and Health
3. Water Related Health
4. Global Water Use and Climate Change
5. Modelling Watershed Processes for Water Resource Management
6. Watershed Systems and Their Influence on Water Movement and Quality

<https://www.edx.org/school/queensx>



OUTREACH

The BWRC hosted the annual Great Lake Water Festival in collaboration with school boards, the health unit and conservation authorities. This was held at Lake Ontario park in Kingston, Ontario. Supported by Queen's graduate students, over 320 local grade 4 students and their teachers participated in curriculum-based activities designed to instill the values of water and watersheds. The annual impact of this event is to bring a unique cross-section of organizations and volunteers together to bring awareness of the importance of water to hundreds of children. These children are then outlets to a network of many more families to spread the word about water and its importance to daily life.



Community Partners



CATARAQUI REGION
CONSERVATION AUTHORITY



Utilities
Kingston



OUTREACH

The Centre also supported the EngAGE Engineering Summer Academy, which highlights fun and interesting elements of pursuing studies in engineering to high-school students. Students from across Canada and the USA are brought to the Kennedy Field Station to conduct a variety of groundwater studies, including underwater video monitoring of wells, movement of water between wells and groundwater quality sampling and investigate the physical processes that are at play in rivers and streams.



The BWRC has also partnered with regional schools to bring grades 7 and 8 students to Queen's to explore water resources from an energy perspective. This curriculum-linked day allows students to explore flowing water and how the potential energy in this resource may be used in traditional and emerging ways. In the fall of 2018, this program was expanded to include nature-based field training at the Kennedy Field Station and in the Salmon River.

KNOWLEDGE TRANSLATION

The BWRC engages in a number of knowledge translation activities. This year, these activities included the second annual BWRC Research Symposium. This symposium was established to improve the flow of communication and ideas by bringing together researchers from Queen's University and the Royal Military College of Canada, who are often separated by disciplines or institutions.

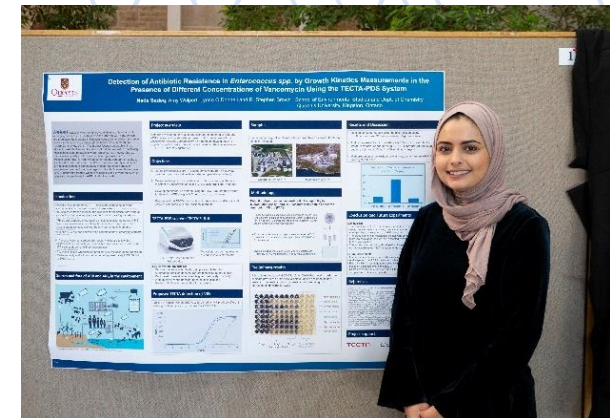


Beaty Water Research Centre Symposium

13 November 2019 9am to 4pm
Mitchell Hall Event Commons (Rm. 103)
+ Biosciences Atrium



For more information contact: BWRC.info@queensu.ca



KNOWLEDGE TRANSLATION

The BWRC and LEADERS program began jointly hosting a Seminar Series in March 2019. Since its inception, the series has brought in a wide range of national and international professionals in academia, government and industry to speak on various water-related topics to our faculty and students. This includes 10 international speakers from the United States, Australia, France, Germany, Italy, the United Kingdom, Ireland and Hong Kong. We also encourage our new and junior affiliated faculty to present in the seminar series as a way of introducing themselves and their research to students and other researchers within the Centre to spark the beginnings of interdisciplinary collaboration.



Fall Series Schedule

September 11th: Dr. Davina Passeri, Research Civil Engineer, U.S. Geological Survey
September 18th: Dr. Saifur Rahaman, Associate Professor, Civil and Environmental Engineering, Concordia University
October 2nd: Dr. Paul Hynds, Principal Investigator, Environmental Sustainability and Health Institute, Technological University Dublin
October 9th: Dr. Ted Mao, VP Research, Trojan Technologies
October 21st: Steve Usher, Senior Hydrogeologist, SLR Consulting
November 13th (BWRC Symposium Keynote): Dr. Matt Hipsey, Associate Professor, Faculty of Science, University of Western Australia



A selection of our Seminar Series speakers from the fall of 2019.



Dr. Bas Vriens, a new faculty member with Queen's Department of Geological Sciences and Geological Engineering. Dr. Vriens also joined the BWRC in fall 2019.

KNOWLEDGE TRANSLATION

In July 2019, the first cohort of students from the LEADERS program participated in the first LEADERS research symposium and training workshop. Students showcased their research and had the opportunity to receive feedback from leading researchers in disciplines such as engineering, chemistry, biology, policy studies, business and public health.

The students also participated in a workshop dedicated to learning field methods in ground water and surface water at the Kennedy Field Station.

This year's symposium attracted over 60 participants and the keynote speaker was Dr. Wenwei Ren, the Water Practice Head of WWF-China and Adjunct Professor at Queen's University and Tongji University in China. He spoke to the audience about WWF-China's water practice strategy and its role in China's Environmental Governance.



ADMINISTRATION



Pascale Champagne, PhD,
PEng, DWRE, FASCE,
FEWRI, F.CAE
Director, BWRC
[pascale.champagne@
queensu.ca](mailto:pascale.champagne@queensu.ca)



Geof Hall, PhD
Associate Director
Education and Outreach,
BWRC
gh26@queensu.ca



Jyoti Kotecha, MPA, MRSC,
CChem
Associate Director Research
and Business Development,
BWRC
kotechaj@queensu.ca



Sophie Felleiter, MSc
Research Coordinator, BWRC
and LEADERS project
sf60@queensu.ca

ADVISORY BOARD

The Centre is governed by an Advisory Board. This board was established in 2019 and its members provide representation from the Queen's Faculty of Engineering and Applied Science, Faculty of Arts and Science, Faculty of Health Sciences, industry and community organization members.



**Pascale
Champagne**
Director BWRC



Holly Evans
Community Partner,
Catarauqui Region
Conservation
Authorities



Amir Fam
Associate Dean
(Research), Faculty
of Engineering and
Applied Science



Geof Hall
Associate Director
BWRC, Education
and Outreach



Jyoti Kotecha
Associate Director
BWRC, Research
and Business
Development



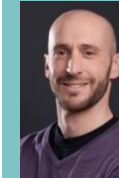
**Anastasia
Lintner**
Community
Partner, Lintner
Law



Nicholas Mosey
Associate Dean
(Research), Faculty
of Arts and Science



Kent Novakowski
Associate Vice
Principal (Research),
Office of Vice-
Principal (Research)



Steven Smith
Director of
Research, Faculty
of Health
Sciences

ASSOCIATED FACULTY



Bruce Anderson
Professor Emeritus,
Civil Engineering



Shelley Arnott
Professor, Biology



Leon Boegman
Associate Professor,
Civil Engineering



Richard Brachman
Professor, Civil
Engineering



Stephen Brown
Associate Professor,
Chemistry



John Casselman
Adjunct Professor,
Biology



Pascale Champagne
Professor, Civil
Engineering



Dongmei Chen
Professor, Geography
& Planning



Brian Cumming
Professor, Biology



Michael Cunningham
Professor, Chemical
Engineering



Ana Maria da Silva
Professor, Civil
Engineering



Ryan Danby
Associate Professor,
Environmental Studies



George diCenzo
Assistant Professor,
Biology



Cao Thang Dinh
Assistant Professor,
Chemical Engineering



Aris Docoslis
Professor, Chemical
Engineering



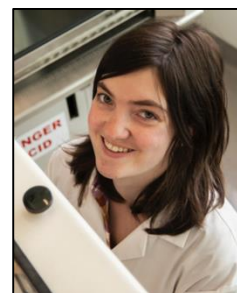
Carlos Escobedo
Associate Professor,
Chemical Engineering



Gerald Evans
Professor, Biomedical
& Molecular Sciences



Yves Filion
Professor, Civil
Engineering



Anna Harrison
Assistant Professor,
Geological Engineering



Peter Hodson
Professor Emeritus,
Environmental Studies



Graeme Howe
Assistant Professor,
Chemistry

ASSOCIATED FACULTY



Michael Hulley
Associate Professor,
Civil Engineering (RMC)



Heather Jamieson
Professor, Geological
Engineering



Philip Jessop
Professor, Chemistry



Bernard Kueper
Professor, Civil
Engineering



Melissa Lafrenière
Associate Professor,
Geography & Planning



Scott Lamoureux
Professor, Geography
& Planning



Dan Lefebvre
Professor, Biology



Anastasia Lintner
Adjunct Professor, Law



Steven Liss
Professor,
Environmental Studies



Steve Lougheed
Professor, Biology



Warren Mabey
Professor, Geography
& Planning



Anna Majury Assistant
Professor, Biomedical &
Molecular Sciences



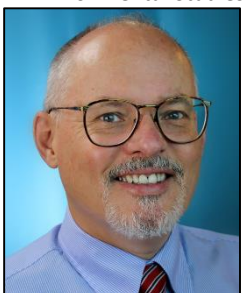
David McDonald
Professor, Global
Development Studies



James McLellan
Professor, Chemical
Engineering



Louise Meunier
Assistant Professor,
Chemical Engineering



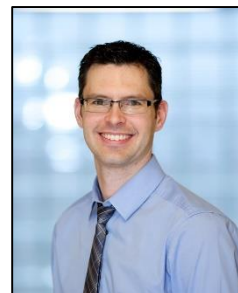
Kieran Moore
Professor, School of
Medicine



Steven Moore
Adjunct Professor,
School of Business



Ryan Mulligan
Associate Professor,
Civil Engineering



Kevin Mumford
Associate Professor,
Civil Engineering



Bill Nelson
Associate Professor,
Biology

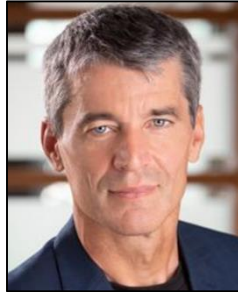


Kent Novakowski
Professor, Civil
Engineering

ASSOCIATED FACULTY



Diane Orihel
Assistant Professor,
Biology



Bruce Pardy
Professor, Law



Sarah Jane Payne
Assistant Professor,
Civil Engineering



Martin Petkovich
Professor, Biomedical
& Molecular Sciences



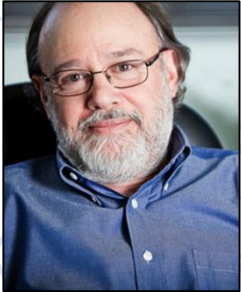
Ugo Piomelli
Professor, Mechanical &
Materials Engineering



Juliana Ramsay
Professor, Chemical
Engineering



Victoria Remenda
Associate Professor,
Geological Engineering



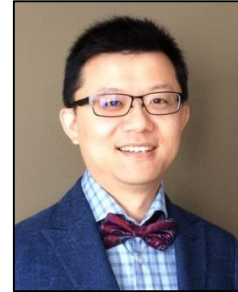
Mark Rosenberg
Professor, Geography &
Planning



Kerry Rowe
Professor, Civil
Engineering



Neal Scott
Associate Professor,
Geography & Planning



Zhe She
Assistant Professor,
Chemistry



Prameet Sheth
Assistant Professor,
Pathology



John Smol
Professor, Biology



Bruce Tufts
Professor, Biology



Bas Vriens
Assistant Professor,
Geological Engineering



Yuxiang Wang
Associate Professor,
Biology



Kela Weber
Associate Professor,
Chemical Engineering (RMC)



Graham Whitelaw
Associate Professor,
Environmental Studies



Louise Winn
Professor, Biomedical
and Molecular Sciences



Laurence Yang
Assistant Professor,
Chemical Engineering



Barb Zeeb
Professor, Chemical
Engineering (RMC)

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Transitioning from Hind-casting to Forecasting: Advancing Computational Models to Enable Predictive Simulations for Public Safety and Resource Management	Leon Boegman Ryan Mulligan	\$82,000	Queen's Dean's Research Fund, FEAS
Discovery Accelerator Supplement	Leon Boegman	\$40,000/yr	NSERC
Internal Solitary Wave-induced Sediment Re-suspension and Offshore Infrastructure Loading	Leon Boegman	\$41,000/yr	NSERC-DG
Leaders in wAtEr anD watershed Sustainability (The LEADERS Project)	Stephen Brown	\$1.65 million over 6 years	NSERC CREATE
Methods for Automated Detection of Bacteria in Drinking Water	Stephen Brown	\$200,000	TECTA-PDS
Methods for Automated Detection of Bacteria in Drinking Water	Stephen Brown	\$194,950	Southern Ontario Water Consortium AWT Program
Persistent, Emerging, and Oil PoLlution in cold marine Environments (PEOPLE CREATE Training Program)	Bing Chen Pascale Champagne - Queen's lead	\$1.65 million over 6 years	NSERC CREATE
Wholly Green: Sustainability Through a Systems Approach	Pascale Champagne Michael Cunningham Philip Jessop Warren Mabee	\$250,000	NSERC Brockhouse Prize

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Analysis and Prediction of Legacy and Emerging Contaminant Discharge and Mixing in the Great Lakes Receiving Environment	Pascale Champagne	\$181,000	Queen’s Dean’s Research Fund, FEAS
Wastewater Treatment Systems Under Changing Climate	Pascale Champagne	\$43,490	National Research Council New Beginnings
Developing Solutions for the Optimization of Ravensview WWTP Anaerobic Digester Biogas Generation	Pascale Champagne	\$35,000	Mitacs Accelerate Utilities Kingston Sentry
Biogeocementation of the Victoria Junction Tailings Basin	Pascale Champagne	\$150,000	Innovative Solutions Canada Phase I, BGC
Biogeocementation-Biologically Catalyzed Reactions to Improve the Geotechnical Properties of Tailings Deposits	Pascale Champagne	\$25,000	NSERC Engage BGC
		\$25,000	OCE VIP I BGC
Advanced Molecular Tools for Characterizing Microbial Structures, Processes and Interfaces in Engineered and Natural Environmental Systems	Pascale Champagne	\$104,008	NSERC RTI
Paleolimnology and Environmental Change	Brian Cumming	\$40,000/yr over 5 years	NSERC Discovery
Role of Climate Change and Fire on the Landscape of Cape Breton Highlands National Park	Brian Cumming	\$112,000	Collaborative Research Agreement

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Babine Lake, British Columbia - Sockeye Salmon nursery ecosystem structure, function and productive capacity: An integrated fisheries, limnological, and paleolimnological assessment	Brian Cumming – Queen’s Lead	\$111,298	Pacific Salmon Commission
Cellulose Nanocrystal Reinforced Polymer Composites	Michael Cunningham	\$25,000	NSERC Engage CelluForce
Dispersion of Cellulose Nanocrystals in Aqueous Media	Michael Cunningham	\$120,000	OCE University of Waterloo
Detection of Intact Pathogenic Bacteria Using Nanoplasmonic Sensors	Carlos Escobedo	\$130,000 over 5 years	NSERC
Examining the Mechanisms for Antibiotic Resistance Development in Drinking Water Systems	Yves Filion	\$30,000	Way Memorial Trust Award, Queen’s University
Examining the Mechanisms for Adherence and Mobilization of Inorganics in Drinking Water Systems	Yves Filion	N/A	NSERC Discovery CFI
Storm Water Quality Field and Modelling Study in the Town of Jasper, AB.	Yves Filion	\$215,000	Parks Canada RMC Canadian Defense Academy Research Program
Dissolution Rates of REE-bearing Fluorocarbonate Minerals and Environmental Impact	Heather Jamieson	N/A	NSERC NT Geological Survey

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Dry Stack Tailings: Influence on Water Quality	Heather Jamieson	N/A	NSERC NT Geological Survey
Multi-element Water Contamination from Silver Mining	Heather Jamieson	N/A	NSERC
The Development of CO2-Switchable Polymers as Draw Solutes for Forward Osmosis	Philip Jessop	\$60,000	Mitacs Accelerate Forward Water Technologies
CO2-Triggered Draw Agents for Forward Osmosis	Philip Jessop	\$552,740	NSERC
PermafrostNet	Scott Lamoureux	\$25,000	NSERC Strategic Partnership
The WELLness Project	Anna Majury	\$25,000	Canadian Foundation of Infectious Diseases
UnWELL: Assessing the Presence of, and Implications for, Antimicrobial Resistant Organisms in Private Drinking Groundwater Wells in Ontario	Anna Majury	\$25,000	N/A
Remunicipalization: The Future of Water Services?	David McDonald	\$181,000	SSHRC
Detection of Hexavalent Chromium in Mine Leachate and Drinking Water	Louise Meunier	\$35,000	NRCan

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Physico-Chemical Characterization of a Biodegradable Flocculant for Oils Sands Tailings Ponds	Louise Meunier	\$42,000	Queen’s SGS Doctoral Award
The Canadian Lyme Disease Research Network	Kieran Moore	\$4 million over 4 years	CIHR
High Resolution Nearshore Wave and Current Modelling to Investigate Nonlinear Wave Effects on Velocity Profiles and Sediment Transport	Ryan Mulligan	\$94,180 USD	US Office of Naval Research (ONR-Global)
Modelling Waves, Storm Surge, and Tides in the Gulf of Maine and Bay of Fundy	Ryan Mulligan	\$36,000	Fisheries and Oceans Canada
Protecting Canada’s Coasts from Extreme Waves and Water Levels	Ryan Mulligan	\$180,000	NSERC
Understanding of Hydrodynamics and Sediment Dynamics Along Coral Reef-Lined Coasts	Ryan Mulligan	\$49,000 USD	US Geological Survey
Remediation Education Network	Brent Sleep – Program Lead Kevin Mumford and Kent Novakowski – Queen’s Leads	\$1.65 million over 6 years	NSERC CREATE
Impacts of Stray Gas Migration on Shallow Groundwater: Insights from Laboratory Experiments and Numerical Modelling	Kevin Mumford	\$537,475	NSERC SPG
Collaborative Research: Towards a Mechanistic Prediction of Methane Ebullition Fluxes from Northern Peat Lands	Kevin Mumford	\$219,640	NSF

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Remediation of Soil and Groundwater Impacted by Per- and Polyfluoroalkyl Substances	Bernard Kueper	\$229,000	NSERC CRD
Soil Remediation Using In-situ Thermal Treatment	Bernard Kueper	\$250,000	MRI OCRIF
The Role of Gases in Groundwater Contamination and Remediation	Kevin Mumford	\$135,000	NSERC DG
A Hybrid Mesocosm-ecosystem Facility for Aquatic Ecotoxicology	Diane Orihel	\$167,602	John R. Evans Leaders Fund, Canadian Foundation for Innovation
A Hybrid Mesocosm-ecosystem Facility for Aquatic Ecotoxicology	Diane Orihel	\$167,602	Ontario Research Fund for Small Infrastructure, Ontario Ministry of Research, Innovation and Science
A Hybrid Mesocosm-ecosystem Facility for Aquatic Ecotoxicology	Diane Orihel	\$163,000	Queen's University
Determining the Effects of a Pipeline Spill in Canadian Boreal lakes: Experimental Additions of Diluted Bitumen (dilbit) to In-situ Enclosures at the IISD-Experimental Lakes Area	Diane Orihel – Queen’s Lead	\$794,290	NSERC - SPG

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Integrated Aquatic Animal Responses to Petroleum Products in the Environment for Freshwater Aquatic Risk Assessment.	Diane Orihel	\$120,000	Environment and Climate Change Canada
Research Initiation Grant	Sarah Jane Payne	\$70,000	Queen's University
Advanced Multiplex Technology for Pathogen Detection and Recognition	Zhe She	\$144,090	National Defense (Canada), (IDEaS)
Environmental Footprints of Human Trace Metal Use: From Sources to Sinks	Bas Vriens	N/A	Queen's University
Mine Waste Rock Management at the Antamina Mine, Peru	Bas Vriens	N/A	UBC, Teck, Antamina
Demonstration of Smoldering Combustion Treatment of PFAS-impacted Investigation-Derived Waste	Kela Weber	\$75,000	SERDP
Development and Validation of Analytical Methods for Comprehensive Profiling of Perfluoroalkyl and Polyfluoroalkyl Substances in Firefighting Foam Impacted Environmental Matrices	Kela Weber	\$65,000	SERDP
Fate and Effects of Metallic Nanoparticles in Wetland Systems	Kela Weber	\$43,000	NSERC

RESEARCH PROJECTS

Project	BWRC Faculty Lead	Funding	Organization
Field Testing of Novel Technologies for Restoring Challenging Contaminated Sites	Kela Weber	\$30,000	NSERC
Remediation of Soil and Groundwater Impacted by Per- and Polyfluoroalkyl Substances	Kela Weber	\$25,000	NSERC
Understanding the Effects of Underwater Munition Disposal	Kela Weber	\$4,750	Canadian Defense Academy
Investigating Mechanisms of Pseudomonas Aeruginosa Pathogenicity by Multi-scale Modeling of Metabolism and Macromolecule Expression	Laurence Yang	\$200,000	Queen’s University, Research Initiation Grant



FACULTY PUBLICATIONS 2019-20

1. Ahmad S, She Z, Kraatz HB. (2019) Electrochemical studies of human nAChR $\alpha 7$ subunit phosphorylation by kinases PKA, PKC and Src. *Anal. Biochem*, 574:46-56.
2. Anand A, Chen K, Catoiu E, Sastry AV, Olson CA, Sandberg TE, Seif Y, Xu S, Szubin R, Yang L, Feist AM, Palsson BO. (2019) OxyR is a convergent target for mutations acquired during adaptation to oxidative stress-prone metabolic states. *Mol. Biol. Evol*, 37(3):660-667.
3. Anand A, Chen K, Yang L, Sastry AV, Olson CA, Poudel S, Seif Y, Hefner Y, Phaneuf PV, Xu S, Szubin R, Feist AM, Palsson BO. (2019) Adaptive evolution reveals a tradeoff between growth rate and oxidative stress during naphthoquinone-based aerobic respiration. *Proc. Natl. Acad. Sci. USA*, 116(50):25287-25292.
4. Anas MUM, Simpson GL, Leavitt PR, Cumming BE, Laird KR, Scott KA, Das B, Wolfe JD, Hesjedal B, Mushet GR, Walker A, Meehahage B, Wissel B. (2019) Taxon-specific variations in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of subfossil invertebrate remains: insights into historical trophodynamics in lake food-webs. *Ecol. Indic*, 102:834-847.
5. Andrade L, Kelly M, Hynds PD, Weatherill J, Majury A, O'Dwyer J. (2019) Groundwater resources as a global reservoir for antimicrobial-resistant bacteria. *Water Res*, 170:115360.
6. Arredondo J, Champagne P, Cunningham M. (2019) RAFT-mediated polymerisation of dialkylaminoethyl methacrylates in tert-butanol. *Polym. Chem*, 10(15):1938-1946.
7. Bdour Y, Escobedo C, Sabat RG. (2019) Wavelength-selective plasmonic sensor based on chirped-pitch crossed surface relief gratings. *Opt. Express*, 27(6):8429-8439.
8. Bdour, Y, Gomez-Cruz J, Escobedo C. (2020) Structural stability of optofluidic nanostructures in flow-through operation. *Micromachines*, 11(4):373.
9. Bellabarba A, Fagorzi C, diCenzo GC, Pini F, Viti C, Checcucci A. (2019) Deciphering the symbiotic plant microbiome: translating the most recent discoveries on rhizobia for the improvement of agricultural practices in metal-contaminated and high saline lands. *Agronomy*, 9(9):529.
10. Belpaire C, Pierro F, Hodson PV, Freese M. (2019) Impact of chemical pollution on Atlantic eels: facts, research needs and implications for management. *Curr. Opin. Environ. Sci. Health*, 11:26-36.
11. Benítez MB, Champagne P, Ramos A, Torres AF, Ochoa-Herrera V. (2019) Wastewater treatment for nutrient removal with Ecuadorian native microalgae. *Environ. Technol*, 40(22):2977-2985.
12. Bielecki M, Howe GW, Kluger R. (2019) Competing Protonation and Halide Elimination as a Probe of the Character of Thiamin-Derived Reactive Intermediates. *Biochemistry*, 58:3566.
13. Boegman L. (2019) Hydrodynamics of lakes (Chapter 104, pp. 1037-1049) in Encyclopedia of Water: Science, Technology, and Society. [Ed. P. Maurice]. Wiley.
14. Bořcinoová Radková A, Jamieson HE, Campbell K. (2020). Antimony mobility during the early stages of stibnite weathering in tailings at the Beaver Brook Sb deposit, Newfoundland. *J Appl. Geochem*, 115: 104528.
15. Bullard GK, Mulligan RP, Carreira A, Take WA. (2019) Experimental analysis of tsunamis generated by the impact of landslides with high mobility. *Coast. Eng*, 152:103538.
16. Cabrerizo A, Muir DCG, Teixeira C, Lamoureux SF, Lafrenière MJ. (2019). Snow deposition and melting as drivers of polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) in Arctic rivers, lakes and ocean. *Environ. Sci. Technol*, 53(24):14377-14386.
17. Cederwall J, Black TA, Orihel DM et al. (2020) Life under an oil slick: Response of a freshwater food web to simulated spills of diluted bitumen in field mesocosms. *Can. J Fish. Aquat. Sci*, 77(5):779-788.

FACULTY PUBLICATIONS 2019-20

- 18.** Chiasson-Poirier G, Franssen J, Lafrenière MJ, Fortier D, Lamoureux SF. (2019). Seasonal evolution of active layer thaw depth and hillslope-stream connectivity in a permafrost watershed. *Water Resour. Res.*, 56(1): e2019WR025828.
- 19.** Coch C, Juhls B, Lamoureux SF, Lafrenière MJ, Fritz M, Heim B, Lantuit H. (2019) Comparisons of dissolved organic matter and its optical characteristics in small low and high Arctic catchments. *Biogeosciences*, 16(23):4535-4553.
- 20.** Collotta M, Champagne P, Tomasoni G, Alberti M, Busi L, Mabee W. (2019) Critical indicators of sustainability for biofuels: An analysis through a life cycle sustainability assessment perspective. *Renew. Sust. Energ. Rev.*, 115:109358.
- 21.** Coristine LE, Colla S, Bennett N, Carlsson AM, Davy C, Davies KTA, Favaro B, Flockhart DTT, Fraser K, Orihel D, Otto SP, Palen W, Polfus JL, Venter O, Ford AT. (2019) National Contributions to Global Ecosystem Values. *Conserv. Biol.*, 33(5):1219–23.
- 22.** Cortes-Esquivel JA, Giacomán-Vallejos G, Méndez-Novelo R, Ponce-Caballero C, Barceló-Quintal ID, Vidal G, Champagne P. (2019) Enhanced Removal of Organic Matter and Nutrients by Sequential Batch Reactors. *Environ. Eng. Manag. J.*, 18(11):2417-2427.
- 23.** Du B, Yang L, Lloyd CJ, Fang X, Palsson BO. (2019) Genome-scale model of metabolism and gene expression provides a multi-scale description of acid stress responses in *Escherichia coli*. *PLoS Comput. Biol.*, 15(12):e1007525.
- 24.** Dzimitrowicz A, diCenzo GC, Swatek P, Cyganowski P, Stencel A, Pogoda D, Jomroz P, Pohl P. (2019) Size-defined synthesis of magnetic nanorods by *Salvia hispanica* essential oil with electromagnetic excitation properties useful in microwave imaging. *J Magn. Magn. Mater.*, 480:87-96.
- 25.** Dzimitrowicz A, Jamróz P, diCenzo GC, Sergiel I, Kozlecki T, Pohl P. (2019) Preparation and characterization of gold nanoparticles using *Melissa officinalis*, *Salvia officinalis*, and *Mentha piperita* aqueous extracts. *Arab. J Chem*, 12(8):4118-4130.
- 26.** Ellis S, Riabtseva A, Dykeman R, Hargreaves S, Tobias R, Champagne P, Cunningham M, Jessop P. (2019) Nitrogen Rich CO2 Responsive Polymers as Forward Osmosis Draw Solutes. *Ind. Eng. Chem. Res.*, 58(50):22579-22586.
- 27.** Elmslie BG, Gushulak CAC, Boreux MP, Lamoureux SF, Leavitt PR, Cumming BF. (2019) Complex Responses of Phototrophic Communities to Climate Warming during the Holocene of Northeastern Ontario, Canada. *The Holocene*, 30(2):095968361988301.
- 28.** Falcone N, She Z, Syed J, Lough AI, Kraatz HB. (2019) Synthesis and Biochemical Evaluation of Nicotinamide Derivatives as NADH analogues in Ene Reductase. *Chembiochem*, 20(6):838-845.
- 29.** Fatehi-Pouladi S, Anderson BC, Wootton B, Wallace SJ, Bissegger S, Rozema L, Weber KP. (2020). Influence of plant species on microbial activity and denitrifier population development in vegetated denitrifying wood-chip bioreactors. *Plants*, 9(3):289.
- 30.** Felleiter S, McDermott K, Hall G, Sheth P, Majury A. (2019) Exploring Private Water Wells for Fecal Sources and Evidence of Pathogen Presence in the Context of Current Testing Practices for Potability in Ontario. *Water Qual. Res. J.*, 55(1):93-105.
- 31.** Feng Y, Chen D, Zhao X. (2019). Impact of aerosols on terrestrial gross primary productivity in North China using an improved boreal ecosystem productivity simulator with satellite-based aerosol optical depth. *GISci. Remote Sens.*, 57(2):258-270.
- 32.** Feng Y, Chen D, Zhao X. (2019) Improved Empirical Models for Estimating Surface Direct and Diffuse Solar Radiation at Monthly and Daily level: A Case Study in North China. *Prog. Phys. Geog.*, 43(1):80-94.

FACULTY PUBLICATIONS 2019-20

- 33.** Geddes BA, Kearsley J, Morton R, diCenzo GC, Finan TM. (2020) The genomes of rhizobia. In *Advances in Botanical Research*. Edited by P. Frendo, F. Frugier, and C. Masson-Boivin. Academic Press – Elsevier, Cambridge, Massachusetts, USA.
- 34.** Glasing J, Jessop P, Champagne P, Hamad WY, Cunningham MF. (2020) Microsuspension Polymerization of Styrene Using Cellulose Nanocrystals as Pickering Emulsifiers: On the Evolution of Latex Particles. *Langmuir*, 36(3):796-809.
- 35.** Hashemi S, Filion Y, Speight V, Long A (2020) The Effects of Pipe Class and Location on Water Main Headloss in Water Distribution Systems. *J Water Res. PI-ASCE*, 146(6).
- 36.** Hodson PV, Adams J, Brown RS. (2019) Oil Toxicity Test Methods Must Be Improved. *Environ. Toxicol. Chem*, 38(2):302–11.
- 37.** Honkanen JO, Rees CB, Kukkonen JVK, Hodson PV. (2020) Temperature determines the rate at which retene affects fish embryos, not the concentration that is toxic. *Aquat. Toxicol*, 22:105471.
- 38.** Howe GW, van der Donk WA. (2019) Temperature-Independent Kinetic Isotope Effects as Evidence for a Marcus-Like Model of Hydride Tunneling in Phosphite Dehydrogenase. *Biochemistry*, 58(41):4260.
- 39.** Hussain MD, Chen D. (2019) Segmentation for Object-based Image Analysis (OBIA): A review of algorithms and challenges from remote sensing Perspective. *ISPRS J Photogramm. Remote Sens*, 150:115-134.
- 40.** Jabbari A, Boegman L, Valipour R, Wain D, Bouffard D. (2020) Dissipation of turbulent kinetic energy in the oscillating bottom boundary layer of a large shallow lake. *J Atmos. Ocean Tech*, 37(3):517-531.
- 41.** Jabbari A, Ackerman JD, Boegman L, Zhao Y. (2019) Episodic hypoxia in the western basin of Lake Erie. *Limnol. Oceanogr*, 64(5):2220-2236.
- 42.** Jozdani SE, Johnson BA, Chen D. (2019) Comparing deep neural networks, ensemble classifiers, and support vector machine for object-based urban land use/cover classification. *Remote Sens*, 11(14):1713.
- 43.** Jozdani S, Chen D. (2020) On the versatility of popular and recently proposed supervised evaluation metrics for segmentation quality of remotely sensed images: An experimental case study of building extraction. *ISPRS J Photogramm Remote Sens*, 160:275-290.
- 44.** Lazar S, Garcia-Valdez O, Kennedy E, Champagne P, Cunningham M, Grunlan J. (2019) Crosslinkable-Chitosan-Enabled Moisture-Resistant Multilayer Gas Barrier Thin Film. *Macromol. Rapid Commun*, 40(6):1800853.
- 45.** Liu X, Wang J, Fu X, Anderson B, et al. (2019) Methane Emissions Driven by Adding a Gradient of Ethanol as Carbon Source in Integrated Vertical-Flow Constructed Wetlands. *Water*, 11(5):1086.
- 46.** Liu B, Mumford KG, Kueper BH, Zhang F. (2020). Low permeability zone remediation of trichloroethene via coupling electrokinetic migration with in situ electrochemical hydrodechlorination. *Chemosphere*, 250:126209
- 47.** Liu Y, Xiang C, Chu H, Qiu S, McLeod J, She Z, Xu F, Sun L, Zou Y. (2020) Binary Co–Ni oxide nanoparticle-loaded hierarchical graphitic porous carbon for high-performance supercapacitors. *J Mater. Sci. Technol*, 37:135-142.
- 48.** Liu L, Hall G, Champagne P. (2020) The Role of Algae in the Removal and Inactivation of Pathogenic Indicator Organisms in Wastewater Stabilization Pond Systems. *Algal Res*, 46:101777.
- 49.** Lloyd CJ, Mih N, Yang L, Palsson BO. (2019) Fundamentals of Metabolic Systems Biology. In: Schmidt, Thomas M. (ed.) *Encyclopedia of Microbiology*, 4th Edition. vol. 2, pp. 315-325. UK: Elsevier.
- 50.** McCune JL, Colla SR, Cristine LE, Davy CM, Flockhart DT, Schuster R, Orihel DM. (2019) Are we accurately estimating the potential role of pollution in the decline of species at risk in Canada? *FACETS* 4: 598–614.
- 51.** McDonald DA, Swyngedouw E. (2019) The New Water Wars: Struggles for Remunicipalization. *Water Altern*, 12(2):322-333.

FACULTY PUBLICATIONS 2019-20

- 52.** McDonald DA. (2019) Will the Empire Strike Back?: Powerbrokers and Remunicipalisation in the Water Sector. *Water Altern*, 12(2):348-359.
- 53.** McDonnell D, Madison BN, Baillon L, Wallace SJ, Brown SR, Hodson PV, Langlois VS. (2019) Comparative Toxicity of Two Diluted Bitumens to Developing Yellow Perch (*Perca Flavescens*). *Sci. Total Environ*, 655:977–85.
- 54.** Medarov G, McDonald DA. (2019) Which Way Will the Winds Blow?: Post-Privatisation Water Struggles in Sofia, Bulgaria. *Water Altern*, 12(2):438-458.
- 55.** Meyer-Jacob C, Michelutti N, Paterson AM, Cumming BF, Keller W, Smol JP. (2019) The Browning and Re-Browning of Lakes: Divergent Lake-Water Organic Carbon Trends Linked to Acid Deposition and Climate Change. *Sci. Rep*, 9(1):16676.
- 56.** Miller CB, Parsons MB, Jamieson HE, Swindles GT, Nasser NA, Galloway JM. (2019) Lake-specific controls on the long-term stability of mining-related, legacy arsenic contamination and geochemical baselines in a changing northern environment, Tundra Mine, Northwest Territories, Canada. *Appl. Geochem*, 109:104403.
- 57.** Miller CB, Parsons MB, Jamieson HE, Arkadani OH, Gregory BRB, Galloway JM. (2020) Influence of late Holocene climate change on the solid-state speciation and long-term stability of arsenic in sub-Arctic lake sediments. *Sci. Total Environ*, 709:136115.
- 58.** Mohammed O, Mumford KG, Sleep BE. (2019) Relative Permeability Measurements during the Exsolution and Dissolution of Hydrogen Gas Produced by the Hydrolysis of Sodium Borohydride. *Vadose Zone J*, 18(1):190043.
- 59.** Molnar IL, Mumford KG, Krol MM. (2019) Electro-Thermal Subsurface Gas Generation and Transport: Model Validation and Implications. *Water Resour. Res*, 55(6):4630-4647.
- 60.** Mulligan RP, Take WA, Bullard GK. (2019) Non-Hydrostatic Modeling of Waves Generated by Landslides with Different Mobility. *J Mar. Sci. Eng*, 7(8):266.
- 61.** Mushet GR, Laird KR, Leavitt PR, Maricle S, Klassen A, Cumming BF. (2019) Bottom-Up Forces Drive Increases in the Abundance of Large Daphnids in Four Small Lakes Stocked with Rainbow Trout (*Oncorhynchus Mykiss*), Interior British Columbia, Canada. *Ecosystems*, 1-18.
- 62.** Nair S, Gomez-Cruz J, Manjarrez-Hernandez A, Ascanio G, Sabat RG, Escobedo C. (2020) Rapid label-free detection of intact pathogenic bacteria in situ via surface plasmon resonance imaging enabled by crossed surface relief gratings. *Analyst*, 145(6):2133-2142.
- 63.** Nakayama K, Sato T, Tani K, Boegman L, Fujita I, Shintani T. (2020) Breaking of internal Kelvin waves shoaling on a slope. *J Geophys. Res.*
- 64.** O'Carroll DM, Jeffries TC, Lee MJ, Le ST, Yeung A, Wallace S, Battye N, Patch DJ, Manefield MJ, Weber KP. (Apr 2020) Developing a roadmap to determine per- and polyfluoroalkyl substances-microbial population interactions. *Sci. Total Environ*, 712:135994.
- 65.** Paez D, Filion Y. (2020) Correlation analysis between reliability surrogate measures and stochastic reliability metrics. *J Water Res. PI-ASCE*.
- 66.** Paez D, Filion Y, Walski T, et al. (2020) Battle of the Post-Disaster Response and Restoration of Water Distribution Systems. *J Water Res. PI-ASCE*.
- 67.** Paez D, Filion Y. (2019) Mechanical and Hydraulic Reliability Estimators for Water Distribution Systems. *J Water Res. PI-ASCE*, 145(11):06019010.
- 68.** Palmer MJ, Chetelat J, Richardson M, Jamieson HE, Galloway JM. (2019) Seasonal Variation of Arsenic and Antimony in Surface Waters of Small Subarctic Lakes Impacted by Legacy Mining Pollution near Yellowknife, NT, Canada. *Sci. Total Environ*, 684:326–39.

FACULTY PUBLICATIONS 2019-20

- 69.** Ramos AC, Regan S, McGinn PJ, Champagne P. (2019) Feasibility of a microalgal wastewater treatment for the removal of nutrients under non-sterile conditions and carbon limitation. *Can. J Chem. Eng.*, 97(S1):1289-1298.
- 70.** Roca MA, Brown RS, Solo-Gabriele HM. (2019) Fecal Indicator Bacteria Levels at Beaches in the Florida Keys after Hurricane Irma. *Mar. Pollut. Bull.*, 138:266–73.
- 71.** Rosenberg D, Filion Y, Teasley R, Sandoval-Solis S. (2020). The Next Frontier: Making Our Research More Reproducible. *J Water Res. PI-ASCE*, 146(6): 01820002.
- 72.** Russell DA, Meunier L, Hutchinson, RA. (2020) Characterization of degradation products from a hydrolytically degradable cationic flocculant. *Polym. Degrad. and Stab*, 174:109097.
- 73.** Sanderson H, Ortega-Polo R, McDermott K, Zaheer R, Brown RS, Majury A, McAllister T, Liss SN. (2019) Comparison of Biochemical and Genotypic Speciation Methods for Vancomycin-Resistant Enterococci Isolated from Urban Wastewater Treatment Plants. *J Microbiol. Methods*, 161:102–10.
- 74.** Sanderson HA, Polo RO, McDermott K, Hall G, Zaheer R, Brown RS, Majury A, Mcallister TA, Liss SN. (2019) Quantification and Multidrug Resistance Profiles of Vancomycin-Resistant Enterococci Isolated from Two Wastewater Treatment Plants in the same Municipality. *Microorganisms*, 7(12):E626.
- 75.** Sarker AK, Brown RS. (2019) Determining Binding of Polycyclic Aromatic Hydrocarbons to CTABr Micelles Using Semi-Equilibrium Dialysis Techniques. *Ecotoxicol. Environ. Saf*, 172:114–19.
- 76.** Sastry AV, Gao Y, Szubin R, Hefner Y, Xu S, Kim D, Choudhary KS, Yang L, King ZA, Palsson BO. (2019). The Escherichia coli transcriptome mostly consists of independently regulated modules. *Nat. Commun*, 10:5536.
- 77.** Seif Y, Choudhary KS, Hefner Y, Anand A, Yang L, Palsson BO. (2020) Metabolic and genetic basis for auxotrophies in Gram-negative species. *Proc Natl. Acad. Sci. USA*, 117(11):6264-6273.
- 78.** She Z, Yao Z, Ménard H, Tobish S, Lahaye D, Champness N, Buck M. (2019) Coordination controlled electrodeposition and patterning of layers of palladium/copper nanoparticles on top of a self-assembled monolayer. *Nanoscale*, 11:13773-13782.
- 79.** She Z, Narouz MR, Smith CA, MacLean A, Loock HP, Kraatz HB, Crudden CM. (2020) N-heterocyclic carbene and thiol micropatterns enable the selective deposition and transfer of copper films. *ChemComm*, 56(8):1275-1278.
- 80.** Song M, Chen D, Woodstock K, Zhang Z, Wu Y. (2019) A RP-MCE-SOP Framework to China's County Level "Three-space" and "Three-line" planning – An integration of rational planning, multi-criterial evaluation, and spatial optimization. *Sustainability*, 11:2997.
- 81.** St-Arnault M, Vriens B, Blaskovich R, Aranda C, Klein B, Mayer KU, Beckie RD. (2020) Geochemical and mineralogical assessment of reactivity in a full-scale heterogeneous waste-rock pile. *Miner. Eng.*, 145:106089.
- 82.** Stager JC, Wiltse B, Cumming BF, Holsen TM, Stetler J, Laxson C, Marcillo CE, Charles DF. (2019) A novel ecological state at Bear Pond (Adirondack Mountains, NY, USA) following acidification and partial recovery. *Lake Reserv. Manag.*, 35(2):208-223.
- 83.** Stoyanovich SS, Yang Z, Hanson M, Hollebone BP, Orihel DM, Palace V, Rodriguex-Gil JL, Faragher R, Mirnaghi FS, Shah K, Balis JM. (2019) Simulating a Spill of Diluted Bitumen: Environmental Weathering and Submergence in a Model Freshwater System. *Environ. Toxicol. Chem*, 38(12):2621–28.
- 84.** Van De Ven CJC, Mumford KG. (2019) Characterization of Gas Injection Flow Patterns Subject to Gravity and Viscous Forces. *Vadose Zone J*, 18(1):1-11.

FACULTY PUBLICATIONS 2019-20

- 85.** Van De Ven CJC, Abraham JEF, Mumford KG. (2020). Laboratory investigation of free-phase stray gas migration in shallow aquifers using modified light transmission. *Adv. Water Resour*, 139:103543.
- 86.** Van De Ven CJC, Mumford KG. (2020). Aqueous and surface expression of subsurface GHGs: mass transfer effects on emissions. *Water Res*, 170(1):115327.
- 87.** Van der Meeren T, Ito E, Laird KR, Cumming BF, Verschuren D. (2019) Ecohydrological Evolution of Lake Naivasha (Central Rift Valley, Kenya) during the Past 1650 Years, as Recorded by Ostracod Assemblages and Stable-Isotope Geochemistry. *Quat. Sci. Rev*, 223:105906.
- 88.** Viner KJ, Roy HM, Lee R, He O, Champagne P, Jessop PG. (2019) Transesterification of Soybean Oil Using a Switchable-Hydrophilicity Solvent, 2-(Dibutylamino)Ethanol. *Green Chem*, 21(17):4786–91.
- 89.** Xiang C, Liu Y, Yin Y, Huang P, Zou Y, Fehse M, She Z, Xu F, Banerjee D, Hermida Merino D, Longo A, Kraatz HB, Brougham DF, Wu B, Sun L. (2019) Facile Green Route to Ni/Co Oxide Nanoparticle Embedded 3D Graphitic Carbon Nanosheets for High Performance Hybrid Supercapacitor Devices. *ACS Appl. Energy Mater*, 2:3389–3399.
- 90.** Xie Q, Mumford K, Kueper B, Zhao C. (2019) A numerical model for estimating the removal of volatile organic compounds in laboratory-scale treatability tests for thermal treatment of NAPL-impacted soils. *J Contam. Hydrol*, 226:103526.
- 91.** Xie E, Wei X, Ding A, Zheng L, Wu X, Anderson BC. (2020) Short-term effects of salt stress on the amino acids of *Phragmites australis* root exudates in constructed wetlands. *Water*, 12(2):569.
- 92.** Yang D, Han Y, Cao L, Anderson BC. (2019) Research of urban community road system layout optimization strategy based on simulation analysis of generation and concentration. *Landsc. Archit*, 26(10):101-106.
- 93.** Yang L, Mih N, Anand A, Park JH, Tan J, Yurkovich JT, Monk JM, Lloyd CJ, Sandberg TE, Seo SW, Kim D, Sastry AV, Phaneuf P, Gao Y, Broddrick JT, Chen K, Heckmann D, Szubin R, Hefner Y, Feist AM, Palsson BO. (2019) Cellular responses to reactive oxygen species are predicted from molecular mechanisms. *Proc. Natl. Acad. Sci. USA*, 116(28):14368-14373.
- 94.** Yazdi SR, Agrawal P, Morales E, Stevens CA, Oropeza L, Davies PL, Escobedo C, Oleschuk RD. (2019) Facile actuation of aqueous droplets on a superhydrophobic surface using magnetotactic bacteria for digital microfluidic applications. *Anal. Chim. Acta*, 1085:107-116.
- 95.** Zeng X, Huang J, Hua B, Champagne P. (2020) Nitrogen Removal Bacterial Strains, MSNA-1 and MSD4, with Wide Ranges of Salinity and pH Resistances. *Bioresour. Technol*, 310:123309.
- 96.** Zhang X, He Y, Wang C, Xu F, Li X, Tan C, Chen D, Wang G and Shi L. (2019) Estimation of Corn Chlorophyll Content Using Derivative Spectra in the O2–A Absorption Band. *Front. Plant Sci*, 10:1047.
- 97.** Zhang X, Zhao L, Cheng M, Wu X, Chen D. (2020) Urban ozone sink inferred from surface measurements in China. *J Clean. Prod*, 253:119881.
- 98.** Zhang X, Zhao L, Cheng M, Chen D. (2020) Estimating Ground-Level Ozone Concentrations in Eastern China Using Satellite-Based Precursors. *IEEE Trans. Geosci. Remote Sens*.
- 99.** Zhang X, Zhao L, Xu J, Chen D, Wu X, Cheng M. (2020) Declining precipitation acidity from H2SO4 and HNO3 across China inferred by OMI products. *Atmospheric Environ*, 224:117359.
- 100.** Zou Y, Liang J, She Z, Kraatz HB. (2019) Gold nanoparticles-based multifunctional nanoconjugates for highly sensitive and enzyme-free detection of *E. coli* K12. *Talanta*, 193:15-22.

FINANCIAL STATEMENT

April 1, 2019 – March 31, 2020

	Item	Actual
Revenue		
	Carry Forward	0
	Research Projects	\$590,572.64
	FEAS Centre Funding	\$40,000
	FEAS Associate Director R&D	\$75,000
	VPR Research (LEADERS Program)	\$40,000
	Mitacs Career Connect	\$20,000
	Total Revenue	\$765,572
Expenses		
	Salaries and Benefits	\$403,386
	Non-salary Expenses (specify)	\$126,999
	Total Expenses	\$530,386
Surplus (deficit)	This value represents committed funds to support completion of research activities that bridge two separate reporting periods.	\$235,187

The Beaty Water Research Centre
351 Mitchell Hall
69 Union Street
Kingston, Ontario
K7L 3N6

🐦 @BeatyCentre

📷 @BeatyWaterResearchCentre

f beatywaterresearchcentre

✉ BWRC.info@queensu.ca

www.waterresearchcenter.ca

