



Water Governance from a System of Systems Engineering Perspective

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The global setting in which people live and thrive is composed of complex interwoven systems of systems (SoS) which can be subdivided into societal and natural SoS. Illustrations of societal SoS include urban, industrial, agricultural, infrastructure, financial and political SoS. Examples of large-scale natural SoS are the lithosphere (soil and rocks), hydrosphere (water), atmosphere (air) and biosphere (life). Societal SoS require raw materials from natural systems in order to function but in turn dump waste products into the environment. For instance, most societal SoS, such as energy generation, industrial and transportation systems, rely upon the utilization of fossil fuels from the natural environment resulting in the release of carbon dioxide and other greenhouse gases into the atmospheric SoS, which is a key factor in causing global warming. In reality, many of the current challenging problems facing humankind, such as widespread water pollution, scarcity of drinking water, energy shortages and economic disparities, can best be envisioned

as complex adaptive SoS problems which are interconnected in a myriad of ways and thereby influence one another in synergistic and often surprising ways. Moreover, these SoS are inhabited by decision makers or agents having different value systems who may compete or cooperate with one another to reach resolutions to problems that satisfy their objectives as much as possible. Global warming, for example, causes climate change, which can create extreme droughts and floods which in turn negatively impact the economy and humans' well-being through decreased industrial and agricultural output. Different stakeholders perceive both the problem definition and potential solutions differently according to their value systems, thereby creating conflict among interest groups such as the fossil fuel industry, government and environmentalists. It follows that water governance should be based upon the fundamental paradigm of SoS thinking in order to satisfy important systems principles such as resilience, sustainability and fairness. Within this systems framework, appropriate concepts from economics, sociology, the humanities,

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science, mathematics and engineering can be utilized for jointly modelling the various interconnected societal and physical systems aspects of the problem being addressed.

Formal approaches having a sound mathematical basis for tackling tough large-scale problems were first developed within the field of Operational Research (OR) established by the British military in July 1938. OR mathematicians and scientists, covertly working at Bletchley Park north of London, successfully broke the encryption code for wireless messages sent by the Germans, which helped to shorten the war. Interestingly, one of the famous British mathematicians at Bletchley Park, William Tutte, who joined the Faculty of Mathematics at UWaterloo in 1962, was pivotal in helping to make Waterloo a world-class research institution. Another key field in the development of formal decision technologies is Systems Engineering, which was initiated in the American military during the war and NASA starting in 1958. After WW II, one of the first groups of professionals outside of the military to embrace concepts from OR and Systems Engineering were water resources engineers, who not only had to solve the technical aspects of water problems but also had to satisfy the interests of competing water users from agriculture, industry, service organizations and the general public. As explained in the paper "*Adaptive Systems Thinking in Integrated Water Resources Management with Insights into Conflicts over Water Exports*" that the author wrote with A. Obeidi, L. Fang and D.M. Kilgour (INFOR, 2008, Vol 46, pp 51-69), researchers and practitioners working in the field of water resources are to be congratulated for their many contributions to the development and application of systems thinking methods for addressing complex water problems. Two key interrelated concepts required for achieving effective water governance within a SoS structure are integrative and adaptive management. The Global Water Partnership (GWP) and International Network of

Basin Organizations (INBO) provide an excellent document entitled "*A Handbook for Integrated Water Resources Management [IWRM] in Basins*".

The "implementation gap" for applying IWRM pointed out by Mitchell in his 2012 *Splash Pad* article (Vol2, I3) can be addressed by embedding IWRM within a SoS framework in combination with specific operational systems tools and associated decision support systems. As an example of one of the systems methodologies developed within the UW Conflict Analysis Group, consider the Cooperative Water Allocation Model (CWAM) created by L. Wang, L. Fang and the author, which formally links together under one large optimization model both the societal and physical SoS aspects of water allocation. In particular, the societal component considers the objectives and principles of the multiple stakeholders, while the physical part accounts for relevant hydrological and environmental factors. CWAM connects these societal and physical systems within the framework of a large-scale optimization program which is divided into two main steps. In the first step, water is allocated among users based on existing legal water rights or agreements. Secondly, water and associated benefits are reallocated among stakeholders to maximize basin-wide welfare using concepts from cooperative game theory. To demonstrate how it can be applied to complex water allocation problems, the CWAM methodology was used successfully to study the South Saskatchewan River Basin as well as the Aral Sea basin in middle Asia. In fact, the three developers of CWAM were the recipients of the 2012 Best Publication Award in Environment and Sustainability from the Institute for Operations Research and the Management Sciences (INFORMS) for their paper "*Basin-wide Cooperative Water Resources Allocation*", European Journal of Operational Research, 2008, Vol 190, pp 798-817.

Keith Hipel is a University Professor in the Department of Systems Design Engineering.

<http://www.systems.uwaterloo.ca/Faculty/Hipel/>

Conflict Analysis Group: <https://uwaterloo.ca/conflict-analysis-group/>

Water Researchers in the News

Awards and Honours

Several Water Institute members have recently been recognized by their peers.

Brian Dixon (Biology) was awarded a Partners in Research National Award for his contributions to the Virtual Researchers on Call (VROC) program. Brian and a co-recipient were recognized for contributing the highest number of expert hours to the VROC program. Brian has also contributed to the VROC program with the “*For the Love of Fish*” video in the VROC Science Scoop series.

Josh Neufeld (Biology) was recognized by the Federation of Students for his teaching excellence. The Biology 240 class nominated Josh for the Excellence in Undergraduate Teaching Award. Josh has also been chosen to receive the 2014 Excellence in Science Teaching Award from the Faculty of Science.

Mike Stone (Geography & Environmental Management) and **Monica Emelko** (Civil & Environmental Engineering) are members of the research team that was awarded the Excellence in Water Stewardship Award from The Council of the Federation for their work in the [Southern Rockies Watershed Project](#).

Grand Challenges Canada Project Funded

Sheree Pagsuyoin (Civil & Environmental Engineering), along with co-PIs J.R. Santos (George Washington University) and R.R. Tan (De LaSalle University, Philippines), was awarded \$122,000 in funding from [Grand Challenges Canada](#), Stars in Global Health (round 6). The project proposes to build a low-cost biofiltration system for drinking water treatment in rural areas of the Philippines. The proposed modular design will use indigenous materials and can be adapted for household and communal use.



Many isolated rural communities in the Philippines are without access to a central municipal water supply. Water for household use is often sourced from rivers or unprotected wells, and is often consumed without prior treatment.

Household practices for water storage are also inadequate and can lead to further contamination.

Photos: S. Pagsuyoin

Graduate Student Successes

Peter Thompson (supervised by Bill Annable) received the 2014 CSCE Hydrotechnical Engineering [Award](#) for best masters' thesis related to water resource engineering and water management.

Silvia Vlad (supervised by Peter Huck, Bill Anderson and Sigrid Peldszus) received the Michael R. Provart Environmental [Award](#) for excellence in presentation at OWWA/OMWA annual conference in April.

Mahsa Shayan (supervised by Neil Thomson and Jim Barker) received the Katherine Hadley Memorial [Scholarship](#) awarded by the Real Property Institute of Canada to a graduate student conducting research in environmental issues related to contaminated sites.

Weather Network Interviews

Elizabeth English (Architecture) appeared in two Weather Network segments to discuss her research in [amphibious housing](#), particularly related to [flooding](#) and First Nations communities.

Philippe Van Cappellen (Earth & Environmental Sciences) was featured on the Weather Network to explain the role of ocean currents in the accumulation of [surface debris](#).

Technology and Innovation

Arctic Riverscape: Research On-The-Move

At the dawn of my doctoral studies, I received some seemingly tongue in cheek advice from a fellow canoeist, whose intellect and mindfulness of Arctic realities I admire greatly. “Design your dissertation research so that you have to do a canoe trip”, he said. If memory serves, it was at some point during my comps—a bath in balancing environmental ethics and social theories of nature with community-based research in Nunavut—when the meaning behind my mentor’s counsel hit home. It wasn’t just about doing a canoe trip. It was about using research to participate and live as fully as possible in the ecologies of place; an intention with relevance not just to me as a non-northerner, but also to the Aboriginal communities and participants that I’ve been working with.

Since 2008, my research has centered on a project entitled *Picturing the Thelon River*. This has evolved into a multi-phased, community-based study that engages different knowledges of the Thelon basin (located in central Subarctic Canada) to cultivate an enhanced understanding of, and responsible relationships to, a significant place within contexts of social-ecological change.

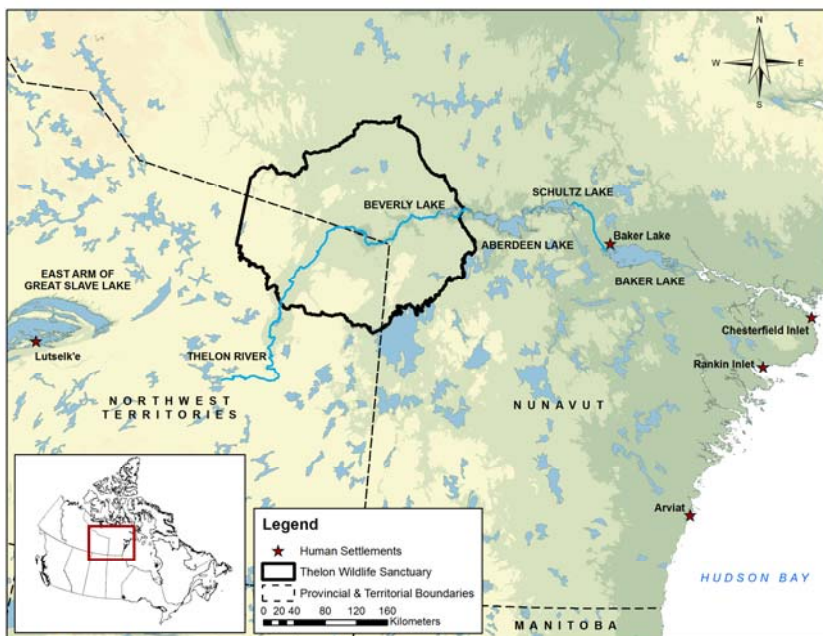
To date, research with Inuit, Dene, and canoe tourists has incorporated a range of participatory methodologies to document the multiple stories, uses, and relationships associated with the Thelon. Heeding my mentor’s advice (or at least my interpretation of it), one approach has been to engage in several experiential riverscape journeys with Aboriginal and tourist representatives. These journeys emphasize knowledge of place as a process of *doing* or *being* – as events that are lived, perceived, felt, and encountered.

So, yes, my research has involved a canoe trip. This was a 10-day, 270 km expedition through the heart of the Thelon Wildlife Sanctuary, taken with an outfitter and eight clients, and documented using ‘mobile ethnography’. Journeys with Inuit hunters from Baker Lake, Nunavut, were recorded similarly but involved various modes of transportation (e.g., snowmobile, motorboat, ATV) and ranged in duration and distances travelled. En route we drank tea, laughed, bumped along tundra, fished, ate caribou, told stories, sat, wandered, and transported supplies to cabins at river’s edge. To be sure, these immersive episodes created windows through which I could better sense Inuit knowledge. But more importantly, they fostered

awareness of the ways that research methodologies and resources can be used to support the expression of Aboriginal identities and cultures. Accordingly, in current work with the Lutsel K’e Dene First Nation, these ideas are being mobilized into plans for a multi-day land camp experience at one of the Thelon’s headwater lakes. Planned for March 2015, the camp will emphasize knowledge exchange among Dene land users, youth, and university researchers, while helping to promote Dene occupancy, traditions, and livelihoods within the Thelon River basin.

Bryan Grimwood is an Assistant Professor in the Department of Recreation and Leisure Studies

<https://uwaterloo.ca/recreation-and-leisure-studies/people-profiles/bryan-grimwood>



Thelon River Watershed. Source: W. Van Hemessen, using shapefiles provided by GeoGratis and DMTI Data Consortium, June 2012.

Water Institute News

Water Institute Renewed for Another Five-Year Term

Following submission of the WI's Five-Year Review Report, at its May 2014 meeting the university's Senate Graduate and Research Council approved the Water Institute for another five years.

Research Symposium 2014

The Water Institute held its second annual Research Symposium on May 1st with over 160 attendees filling the DC lecture rooms. The plenary highlighted the latest trends and emerging challenges in water and included, along with presentations by faculty members, the very popular three-minute thesis talks by graduate students. Breakout sessions heard from researchers, Ph.D. students, government and industry speakers in the areas of Watershed Ecohydrology, Global Change, and Resource Development. A lively roundtable discussion on the Future of the Great Lakes was thought-provoking and rounded out the symposium.

Distinguished Lecture 2014

Peter Gleick, President and Co-founder of the Pacific Institute, delivered an insightful lecture on "*The Past, Present, and Future of the World's Water*", outlining the three 'ages' of water and his vision for addressing our 21st century water problems. Dr. Gleick met with graduate students the following morning to answer questions and for further discussion of water issues. The lecture video is available at: <https://www.youtube.com/playlist?list=PLawkBQ15NDEkajDiQxqbRZlqXCKXbvtJJ>

External Advisory Board Meeting in May

The External Advisory Board met on May 8th to review progress of the Water Institute and provide advice and recommendations. Their report is expected in early summer.



Collaborative Water Program Launched with a Splash!

With generous support from the RBC Foundation, the Collaborative Water Program (CWP) was launched in the winter of 2014, with 25 students from seven different departments participating. The goal of the program is to supplement disciplinary (specialist) training offered in individual departments with perspectives from a variety of water-related disciplines. Students graduating from the collaborative program will be better equipped to work in inter-disciplinary teams to address increasingly complex water issues.

Mark Servos, the CWP Director, points out that “we can’t be experts in every field, but can learn to appreciate what other disciplines have to offer and how it might complement our own skills and knowledge”. Creating opportunities for students to explore and share new ideas is a key objective of the courses being offered as part of the program.

Water 601 was offered for the first time in the winter term with more than 30 water management practitioners and UW faculty participating by giving seminars and engaging in panel discussions.



“It was amazing to hear the diversity of research related to water going on across campus. It highlighted the need for collaboration whilst providing the opportunity to interact with a variety of researchers” said an enthusiastic Ehsan Pasha, MSc student in Earth and Environmental Science. The lecturers/ seminars were supplemented by projects in which inter-

disciplinary teams of students each selected a well-known case study on water management and over the course of the term worked through the complex issues concerning water balance, hydrology, ecology, public health, management and governance. The topics selected by the groups ranged from water management in developing regions such as Lake Titicaca and the La Plata Basin in South America to more developed regions such as the Tiber Basin (Italy), and water issues in Morocco and the Netherlands. “It was a great opportunity to meet people from other faculties that share a passion for water and engage in current and global water issues from a variety of perspectives” said Sonda Eger, MES student in Geography and Environmental Management. “The students met in small groups, made class presentations and submitted a final project report. Victoria Chenette, a MASc student in Civil and Environmental Engineering commented that “the diversity of the group created a unique and rewarding learning environment.”

The Collaborative Water Program (CWP) is open to any student in a participating department whose research is directed at water issues. Students applying for graduate studies can indicate their interests in the CWP when completing their applications. Students that are already enrolled in graduate studies can enter the program by completing a program transfer. Students in the CWP are required to take two core CWP water courses and make a presentation on their research at the Water Institute Annual Symposium in addition to the requirements of their home department. For more information, contact your Graduate Officer or Prof. Mark Servos, CWP Director.



Students of the Water Institute, Graduate Section (SWIGS)

Meet the New Executive Team 2014-2015

Chair:

Sondra Eger (Geography and Environmental Management)

Vice-Chair Academic:

Kristen Leal (Earth and Environmental Sciences)

Vice-Chair Conference:

Maricor Arlos (Biology)

Vice-Chair Operations

Arun Raj (Environment, Enterprise and Development)

Co-Vice-Chairs Outreach:

Victoria Chennette (Civil and Environmental Engineering)

Rahul Mehta (Planning)

Vice-Chair Social:

Ehsan Pasha (Earth and Environmental Sciences)

Recent Events:

World Water Day 2014—
Graduate Research Fair and
Water Celebration

Water Institute Annual Re-
search Symposium

Discussion with Lucilla Spini
from the United Nations

Upcoming Events:

June 5-20: Toronto: 2 SWIGS
members will be attending the
WetSkills Water Challenge

June 19: Seminar by Michael
Azulay, 12-1pm

September: Welcome BBQ for
graduate students studying wa-
ter-related topics

**Stay Tuned for Monthly
Blue Drinks!**



A collage of pictures from World Water Day 2014

NEWS

Over the past year, SWIGS has collaborated with 44 organizations and hosted or been involved with 32 lectures and events!

The NEW Collaborative Water Program was successfully launched this Winter 2014! The first course, WATER 601 - Introduction to Integrated Water Management that promotes multi- and inter-disciplinary perspectives related to water.

Now more than ever, SWIGS continues to reach out to all disciplines for members interested in water research and water-related issues, as well as sharing the values of Teaching, Learning, and Building Relationships centred around water.

Please join our mailing list for event reminders and unique water-related opportunities

www.swigs.uwaterloo.ca

Engage in the conversation on

<https://www.facebook.com/uw.swigs>

Now Recruiting Committee Members, please email us water.grad@uwaterloo.ca if you are interested or for more information!

Follow @UW_SWIGS on twitter



External Partners Program

The External Partners Program continues to grow and we welcome new Silver level external partners, C3 Water Inc. and Peterborough Utilities.



We appreciate the continuing involvement of our Platinum, Gold and Silver external partners. Although the External Partners Program is relatively young, the word is spreading and the program has grown to just over 60 partners. These relationships provide the opportunity to connect business, industry and government with University of Waterloo researchers and students.

The World Water Day Career Fair was a success, providing the opportunity for over 200 students to meet with nine external partners. The Career Fair was successful at providing our External Partners the opportunity to recruit UW water research graduate students into their organizations. New for 2014, an on-line resume database was available for use by both students and employers. This annual event generates a lot of buzz on campus and the Water Institute is pleased to collaborate with Wilfrid Laurier University's Institute for Water Science and their Cold Regions Research Centre in addition to the Water Institute's graduate student chapter, SWIGS, in supporting this event.

Research Symposium 2014 was held on May 1st and once again the event surpassed our expectations, with a 15% increase in attendance from the previous year. Various sessions generated a tremendous amount of discussion around the themes of Watershed Ecohydrology, Global Change and Resource Development. Time was provided for people to network and review posters and throughout the day there was great discussion generated around emerging trends in drinking water treatment, groundwater research and climate change policy. Once again we invited our external partners to act as chairs of the opening plenary session and the breakout sessions.

Through events such as this and other face to face meetings, our External Partners gain access to our broad "water community". If you have any questions about the Water Institute External Partners Program, please do not hesitate to contact Grant Murphy at g3murphy@uwaterloo.ca or at 519 888 4567 ext. 31883.

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