
IMPC
Integrated Modelling
Program for Canada
Global Water Futures
GWF
Second Annual
General Meeting
Report
June 12-13, 2019
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Introduction

The Integrated Modelling Program for Canada (IMPC) held its second annual general meeting on June 12-13, 2019 at Louis' Loft, Saskatoon. The meeting allowed IMPC researchers, the Global Water Futures (GWF) Core Modelling team, and partner organizations to discuss research progress and knowledge mobilization successes in the second year of the program.

More than 92 people from academic, regulatory, and industrial sectors attended the meeting in-person, including representatives from the University of Saskatchewan; University of Manitoba; University of New Brunswick; University of Waterloo; Environment and Climate Change Canada; Agriculture & Agri-Food Canada; the Prairie Provinces Water Board; Saskatchewan Water Security Agency; SaskPower; Partners for the Saskatchewan River Basin; Saskatchewan Chamber of Commerce; City of Saskatoon; and individuals from Alberta and Northern Village of Cumberland House.

In addition to presentations by lead researchers, the meeting provided additional opportunities to engage in discussions via café discussion tables, a user panel, lightning talks and poster presentations. Overall, the meeting highlighted:

- the importance of developing a coherent vision for the research, with adequate project management support;
- the need to find strategies to integrate the various work across the project, possibly through a task force or panel;
- the importance of strategies to benchmark modelling progress and systematically apply outputs across the research program; and
- the continued need to strengthen ties with user communities, enhancing communication by being clear about millstones and deliverables.

An Agriculture-Water Expo co-organized by IMPC and two other GWF projects (Agricultural Water Futures and Prairie Water) directly followed the IMPC Annual Meeting. The Research Expo was a two-way engagement opportunity to ensure that research knowledge actively informs decision-making and practice. 106 individuals participated in the Expo, including 57 GWF researchers and 49 representatives from partner organizations. In a follow-up survey, 90% of attendees rated the event 4 or 5 (out of 5), and 100% said they would attend a similar event.

This report provides a list of participants, followed by a synthesis of discussions under each section. A copy of the final report, all presentations, and posters are found on the IMPC webpage. Thank you to all who participated and contributed to making this meeting a big success!

Hayley Carlson
IMPC Program Manager

Laila Balkhi
IMPC User Engagement Specialist

Saman Razavi
IMPC Principal Investigator

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List of Participants

Name	Organization	Name	Organization
Laurie Tollefson	Agriculture & Agri-Food Canada	Lintao Li	University of Saskatchewan
Tom Tang	Alberta Environment & Parks	John Pomeroy	University of Saskatchewan
Jeniffer Lento	University of New Brunswick	Kevin Shook	University of Saskatchewan
Kristin Bruce	City of Saskatoon	Chris Marsh	University of Saskatchewan
Darrin Qualman	City of Saskatoon	Diogo Costa	University of Saskatchewan
Bruce Davison	Environment & Climate Change Canada	Youssef Loukili	University of Saskatchewan
Frank Seglenieks	Environment & Climate Change Canada	André Bertoncini	University of Saskatchewan
Daniel Princz	Environment & Climate Change Canada	Peter Lawford	University of Saskatchewan
Emily Anderson	Environment & Climate Change Canada	Dominique Richard	University of Saskatchewan
Charmaine Hrynkiw	Environment & Climate Change Canada	Zhibang Lv	University of Saskatchewan
Al Pietroniro	Environment & Climate Change Canada	Chandra Rajulapati	University of Saskatchewan
Fisaha Unduche	Manitoba Infrastructure and Transportation	Abbas Fayad	University of Saskatchewan
Alain Bishoff	Northern Village of Cumberland House	Zhihua He	University of Saskatchewan
Kelvin MacKay	Northern Village of Cumberland House	Mohamed Elshamy	University of Saskatchewan
Bob Halliday	Partners for the Saskatchewan River Basin	Fuad Yassin	University of Saskatchewan
Mike Renouf	Prairie Provinces Water Board	Shervan Gharari	University of Saskatchewan
Bob Schutzman	Saskatchewan Chamber of Commerce	Elvis Asong	University of Saskatchewan
Jaret McDonald	SaskPower	Amin Haghnegahdar	University of Saskatchewan
Helen Wong	SaskPower	Saman Razavi	University of Saskatchewan
Sajad Khoshnod	University of Gorgan, Iran	Leila Eamen	University of Saskatchewan
Tricia Stadnyk	University of Manitoba	Mohammad Ghoreishi	University of Saskatchewan
Masoud Asadzadeh	University of Manitoba	Kasra Keshavarz	University of Saskatchewan
Hervé Awoye	University of Manitoba	Razi Sheikholeslami	University of Saskatchewan
SuJin Kim	University of Manitoba	Mustakim Ali Shah	University of Saskatchewan
Ajay Bajracharya	University of Manitoba	Hayley Carlson	University of Saskatchewan
Jay Famiglietti	University of Saskatchewan	Nhu Do	University of Saskatchewan
Vincent Vionnet	University of Saskatchewan	Jared Wolfe	University of Saskatchewan
Karl-Erich Lindenschmidt	University of Saskatchewan	Andrew Ireson	University of Saskatchewan
Prabin Rokaya	University of Saskatchewan	Ines Sanchez	University of Saskatchewan
Sujata Budhathoki	University of Saskatchewan	Seth Kwaku Amankwah	University of Saskatchewan
Luis Morales Marin	University of Saskatchewan	Menna Elrashidy	University of Saskatchewan
Brandon Williams	University of Saskatchewan	Helen Baulch	University of Saskatchewan
Graham Strickert	University of Saskatchewan	Chris DeBeer	University of Saskatchewan
Azza Mohammadiazar	University of Saskatchewan	Amber Peterson	University of Saskatchewan
Amin Elshorbagy	University of Saskatchewan	Nasim Hosseini	University of Saskatchewan
Mohanad Zaghloul	University of Saskatchewan	Colin Whitfield	University of Saskatchewan
Mohamed Ahmed	University of Saskatchewan	Patrick Lloyd-Smith	University of Saskatchewan
Simon Papalexiou	University of Saskatchewan	Mohamed Abdelhamed	University of Saskatchewan
Salma Hobbi	University of Saskatchewan	Corinne Schuster-Wallace	University of Saskatchewan
Carl Gutwin	University of Saskatchewan	Roy Brouwer	University of Waterloo
Ishan Saxena	University of Saskatchewan	Jorge Hernandez	University of Waterloo
Ricardo Rheeder	University of Saskatchewan	Rute Pinto	University of Waterloo
Venkat Bandi	University of Saskatchewan	Juli Mai	University of Waterloo
Yanping Li	University of Saskatchewan	John-Mark Davies	Water Security Agency
Xiao Ma	University of Saskatchewan	Curtis Hallborg	Water Security Agency
Mostofa Kamal	University of Saskatchewan	John Fahlman	Water Security Agency

Principal IMPC Investigator Saman Razavi

Presentations on Day One

The first day of the annual meeting featured researchers for Theme A – Integrated Earth Systems Modelling – and Core Modelling representatives, providing an overview of progress during year two of the IMPC and GWF research programs. The morning focused on presentations from Work Package Leads, while the afternoon featured Lightning Talks, a poster session and break-out café discussion tables.

Discussions for Theme A

Visioning for IMPC

During his presentation, Dr. Famiglietti engaged the room in a discussion of the long-term vision for, and legacy of the IMPC research program. Discussion focused on the intention behind the term 'integrated model.' Attendees agreed the IMPC research program refers to integrated modeling in terms of bringing natural and human systems together in a modelling framework, as opposed to the coupled systems of differential equations (multi-physics models). The vision is for a set of models, perhaps represented in a platform, and to comment on how we operationally account for or incorporate uncertainty in water systems. IMPC and GWF also have to contend with how they are going to move what is learned into answering user questions and informing decision processes beyond the lifetime of the project.

Presentations

- **Welcome and IMPC Overview** (*Saman Razavi*)
- **GIWS vision for Integrated Large scale Modelling** (*Jay Famiglietti*)
- **Global Water Futures: modeling progress, and new opportunities for international modelling and predictions** (*John Pomeroy*)
- **GWF Core Modelling Team: Progress, Challenges and Opportunities** (*Al Pietroniro*)
- **High-Resolution Atmospheric Modelling** (*Yanping Li)*
- **Progress in model couplings for water quality and river ice modelling** (*Karl Lindenschmidt)*

Dr. Famiglietti suggested an important legacy for the research program may be contributing to the modeling capacity in our partnering institutions and/or building a model or set of models that can be used by Canadian institutions.

Dr. Famiglietti also commented on the importance of the project management role in documenting objectives and progress, and keeping the project on track. This management role helps the research program deliver 'big' things. The program may have to do some consideration about what they are doing and not doing, and how they connect to the GWF Core Teams, particularly Core Modelling.

The status of testing atmospheric model results for application to water resources modelling

In terms of Dr. Li's work on WRF (the Weather Research and Forecasting Model – a weather prediction system), Dr. Razavi asked if the new products had been tested in terms of hydrologic consistency as his water resources engineering work requires climate change projections from the physical hydrological models. Dr. Li noted that they are tested in some cases; her team has been providing data to many groups, such as Dr. Pomeroy's team in Canmore to do small river basin simulations. In follow-up, Dr. Pomeroy noted that using Noah-MP (land surface model) - used by Dr. Li's team in connection with WRF - is not part of the Core Modelling Strategy and doesn't include important cold region/prairie pothole processes such as blowing snow, frozen soils, ponds or slews. Dr. Pomeroy encouraged Dr. Li's team to look at WRF runs with MESH (A Hydrology-Land Surface Model) and others where there exist verifications in the larger domains. WRF has been used with the CRHM (Cold Regions Hydrological Model) in small regions and very little bias correction was needed, but substantial bias correction is needed in the mountainous regions. It is much more challenging to do bias correction in certain basins, such as the Bow River Basin. In the Bow River Basin, Dr. Pomeroy's team has used WRF to drive MESH, which almost worked better without bias correction, and obtained some very credible simulations of future runs. The convection permitting resolution of WRF suggests it is a good model to be used in the mountains. Similarly, when paired with GEM-CaPA (a dataset that combines hourly forecasts from the Global Environmental Multiscale (GEM) atmospheric model at 40 m with 6 hourly Canadian Precipitation Analysis (CaP)), Dr. Pomeroy noted MESH performs better further away from the mountains, but not well in the high mountains where resolution is lost. Dr. Elshamy

concurred with Dr. Pomeroy, and noted that his work with WRF on the Athabasca and Peace River required significant bias correction due to the inherent cold bias. He attempted to bias correct with GEM-CaPa and lost resolution, but obtained a better hydrological performance. He hopes new WRF simulations address some of these biases.

In conclusion, Dr. Pomeroy noted that there are some serious issues to address before modellers can advance confidently to large-scale applications. Dr. Pietroniro also noted that it is important that the modellers using different models and couplings gather and discuss benchmarking to understand more about how these models compare and why they are different. For example, is Fuad's domain going to be the benchmark domain for everyone working on the Saskatchewan River Basin?

Background on GWF Modelling and Future Directions

After the second set of presentations on Day 1, including overviews of progress on key GWF models such as HYPE (Hydrological Prediction for the Environment model), MESH and VIC (Variable Infiltration Capacity hydrologic model), Dr. Pomeroy provided a background perspective on the overall modeling strategy for GWF. Models such as MESH are long-standing in Canada, have a strong physical basis, include cold region processes and are familiar to partner organizations. At the same time, in the future, GWF hopes to move towards a new modelling strategy that increases functionality. For example, in the USA, Dr. Clark has built a flexible multi-scale system called SUMMA (Structure for Unifying Multiple Modeling Alternative) that can be a model for our work.

- **Improving large scale models through representation of cold region processes: advances and next steps** (*John Pomeroy*)
- **Canadian Hydrological Model: Status and prospects** (*Chris Marsh*)
- **Progress with HYPE hydrological modelling** (*Tricia Stadnyk and Hervé Awoye*)
- **Progress with MESH and GEM-Hydro** (*Dan Princz*)
- **Model inter-comparison and multi-model analysis** (*Julie Mai*)
- **Data Management in GWF: Information for modellers** (*Amber Peterson*)
- **Does one distribution fit all? Proof of concept on streamflow across Canada** (*Amin Elshorbagy)*
- **Overview of VARS-TOOL for sensitivity and uncertainty analysis** (*Saman Razavi*)

Data Sharing

An attendee remarked that it would be a significant achievement if IMPC and GWF at large could contribute to Canadian water-related data that is publically available. Dr. Pomeroy replied that this a key requirement of the GWF program already, and that the GWF Data Management team

is currently developing a variety of tools, such as Radium, that will support Investigators to manage and share metadata.

Integrating Water Management and Hydrology

Dr. Razavi asked if there were plans to set the hydrology models up using a vector based system, so that they can be easily coupled with water management systems representing reservoirs, diversions and withdrawals. Dan Princz responded with regard to MESH. One of the misconceptions about the MESH modelling system is that it has to be set up using a square grid, but there is nothing stopping users from applying the physics to use a vector-based system. The decision around how to do this will depend on if the project is using one model or a set of models – in the first case the physics can be set up manually; in the latter case, a script can be used to interpolate between the models. This is done with RAVEN (hydrological modelling framework) where several models are coupled together. Dr. Stadnyk noted that similarly, for HYPE, runoff can be fed into any kind of routing scheme at any resolution. Users can obtain different dispertization of the sub-basins and create different input files at the sub basin scale.

Café Discussion Table Reports

In the afternoon of the first day, attendees had a half hour to break into café discussion tables to discuss questions led by a facilitator. Questions included:

- How has your experience with knowledge mobilization been so far with the project? What have been your major challenges, and how can we improve user engagement moving forward?
- What are of the key challenges we have experienced with research so far and how can these challenges be overcome?
- Given our progress so far with the project, what are the remaining research areas and questions we have yet to address? What new research areas should IMPC and GWF consider in the future?

Various participants presented a summary of discussions held at each of the seven tables. Key points of their summaries is outlined below:

Table 1

- More frequent meetings with users to present modelling progress is required to garner more interest from new users.
- Collecting historical water demand data has been the biggest challenge – water licenses that represent maximum historical demand can be a good starting point.
- Bringing traditional knowledge, getting feedback from Indigenous communities and visualizing results that is of interest to Indigenous communities will be very beneficial to the project. But this process will likely extend beyond the lifetime of the project.

Table 2

- Communicating research outcomes to the broader community is a challenge, but the annual IMPC and GWF science meetings can facilitate the process. Another challenge open communication can address is making sure research products are directly useful to users. Researchers should have a good understanding of users' needs from the very beginning.
- IMPC can help address other issues such as data fragmentation by setting up an integrated database for aggregate environmental data such as precipitation (etc.).
- Specifically in the context of Saskatchewan, IMPC projects could define metrics for approving and assessing drainage projects.
- Developing a national forecasting system and floodplain maps could be a potential IMPC or GWF legacy that both federal and provincial governments can use.

Table 3

- Knowledge mobilization and outreach take a long time, and students who are working on small pieces of larger projects feel unsure about how to effectively include their research pieces into broader knowledge mobilization activities.
- Documentation of successes, challenges and especially failures, was suggested as a way of tackling steep learning curves associated with using new tools and addressing problems

that may have already been solved by others. Another way of achieving the same goals is organizing training workshops on building tools to cut down learning time.

- Some considered integration of present research as a bigger priority than exploring new research ideas.

Table 4

Participants of table 4 presented with "headlines" for their discussion points for each of the questions:

- "Take a policy person to lunch". Participants form this table also made additional recommendations from a knowledge mobilization perspective including, fitting IMPC products with clients' needs; ensuring consistency in scale or scope of research; and potentially branding research products to make them more appealing to specific users.
- Investigators could present their "lightning bios" i.e. a quick introduction and a one sentence description of what they are looking for to create more opportunities for people with similar interests to connect.
- Referring to the third question, the headline was stated as "a death to empiricism" indicating that empirical science used to be the domain of hydrology, but we are and we should be moving away from that mode of thinking towards more transdisciplinary research, so we can understand the nature of uncertainties better. An additional domain of future possible research could be Artificial Intelligence applications of hydrological sciences.

Table 5

- Some participants felt that some knowledge mobilization elements such as co-supervision of HQPs or co-authoring were present within GIWS but were somewhat lacking at a cross-institutional scale. These participants suggested organizing more informal meetings that focused on data integration and statistical modelling more frequently.
- An integrated platform could possibly be a solution to bring all different modelling components together, both for consistency in use of research tools and integration of results to better develop an understanding of our ecosystems. This can further help us better adapt to climate change.

Table 6

- Ensuring that research done in IMPC can be implemented to address real-world challenges should be a key goal of IMPC knowledge mobilization.
- Participants highlighted gaps in our understanding of ecological aspects and environmental flows.
- They also suggested use of online newspapers that communicate science in plain language.

Table 7

- Issues regarding data access were brought up, along with an emphasis on the need for stakeholders or organizations to recognize the importance of the work being done to

consider sharing their data in the first place. Formalized student internship programs could be a way for HQPs to immerse in partner organization culture and maximize engagement.

- Table 7 participants recognized the complexities of interdisciplinary work and cross-disciplinary communication. They suggested having more frequent meetings that can utilize collaborative approaches such as the 'agile approach' that facilitates discussions on feedbacks, future roadmap, and sets concrete deliverables to increase efficiency.

Presentations on Day Two

The second day of the IMPC annual meeting was allocated to the latter research themes of the project, Themes B, C and D. The morning provided time for lead researchers and highly qualified personnel to introduce the project and provide an overview of progress during year two of the IMPC program. The morning also featured a special session featuring hydro-economics work by Dr. Brouwer and his students. The afternoon featured a user panel, brief reporting on project management and user engagement activities, and an open poster session.

- **Overview of Water resources Modelling and Challenges** (*Saman Razavi*)
- **Future demand scenario from policy discourse** (*Hayley Carlson*)
- **Web-based Decision Support System** (*Carl Gutwin*)
- **Water Resources Modelling –Manitoba** (*Masoud Asadzadeh*)

Discussions for Themes B, C & D

Coupling Atmospheric Models, Hydrologic Models and Water Resources Models for Future Climates

Dr. Stadnyk noted, based on her experience working with Manitoba Hydro, that they are focused on coupling atmospheric, hydrological and water resources model to simulate from the

atmosphere down, realistic hydrologic scenarios in response to climate change. She asked if this was the long-term plan for the rest of the Nelson-Churchill basin as well. Dr. Razavi replied that it is the long-term goal, notwithstanding certain challenges such as delays in products (such as testing of WRF-MESH simulations for large domain modelling). In the meantime, the Plan B is to use stochastic weather generation and bottom-up approaches to scenario discovery. The water resources team is ready to move when we have realistic hydrologic flows. Dr. Stadnyk mentioned that future climate change flows from HYPE are ready and Dr. Razavi acknowledged that this might be a good way forward for coupling.

GWF Traveling Roadshow

An attendee (Mike Renouf from the Prairie Provinces Water Board) asked about the timing of a workshop focused on policy and model application. He noted that travel can be an impediment for people in other provinces, and a virtual workshop may have to be an option. Hayley Carlson (User Engagement Specialist) mentioned that Dr. Gober has discussed February 2020, but there has also been discussion of a GWF traveling roadshow. Dr. Pomeroy followed up, noting that some discussion has taken place in terms of visiting provincial and territorial cities and Indigenous communities. While this is a lot of work, it is a GWF priority.

Representations in Water Management Model MODSIM

An attendee (Bob Halliday from Partners for the Saskatchewan River Basin) asked two questions related to the water management model MODSIM. The first pertained to how the model addresses evaporation, because the evaporative loss in Lake Diefenbaker is substantial. The second question related to the assertion that environmental uses were non-consumptive, when in fact, water is diverted and lost through evaporation in projects such as wetlands constructed or maintained by Ducks Unlimited. Mustakim Ali Shah replied that MODSIM has the capability to incorporate the recorded precipitation as well as the estimated evaporation using an input series. The team can use climate models to provide an evaporation range for the future, because evaporation is very important, especially in large reservoirs like Lake Diefenbaker.

Dr. Asadzadeh noted that in Manitoba, his team is coupling hydrologic models with MODSIM and they are expecting the hydrological model to do a better job in terms of estimated evaporation and other losses from the system over the whole basin.

Regarding environmental flows and environmental uses that are consumptive, Mustakim Ali Shah explained some of these works have licences to divert certain amounts for environmental purposes. In that case, they are considered in the model as a demand node based on max license allocation capacity.

Another attendee asked a question about how MODSIM handles return flows, and Mustakim Ali Shah replied that return flows are incorporated based on the literature and existing models such as WRMM. Some Irrigation Districts, for example, have estimated return flows of 10% and others of 20%. Dr. Razavi remarked that is it often hard to get actual data on return flows, so modellers have to use estimates. Tom Tang, with long time work experience at Alberta Environment and Parks, explained that Alberta uses an Irrigation Demand Model to simulate crop demand and return flow based on a number of variables such as crop type and farm management efficiency. From his perspective, there is still a lot of work to do in terms of issues such as the fail criteria for irrigation and the real environmental flows (as opposed to minimum flow). Another issue to be considered is current operations versus how operations may change in response to climate change or other pressures.

- **Challenges of Model Integration and Overview of the IMPC Hydro-Economics Approach** (*Roy Brouwer*)
- **Environmental flow and hydro-ecologic metrics** (*Jen Lento*)
- **Indigenous Engagement** (*Graham Strickert*)
- **User Engagement and Knowledge Mobilization** (*Hayley Carlson*)
- **Project Management** (*Amin Haghnegahdar*)

Including Water Quality

Kristin Bruce from the City of Saskatoon noted that she enjoyed the presentation on visualizations and appreciated how the team is trying to bridge the gap between academia and policy. Another attendee asked how the team is addressing modelling water quality and how a reduction in water supply may affect pollution. Dr. Baulch mentioned that there is a lot more uncertainty associated with understanding water quality impacts, and while it is on the agenda, in terms of modelling and visualization, we may only be able to model a limited number of water quality parameters well at this time. Dr. Pomeroy noted that good progress has been made so far, and the next step will be integrating MESH into the MODSIM framework. This will help the team answer questions that many end-users are interested in, such as the effects of glacier decline or reservoir evaporation.

Hydro-Economic Modelling

Dr. Pietroniro remarked that the hydro-economics work presented by Dr. Brouwer and his team is very valuable, and there has always been roadblocks for doing this kind of work nationally. The basin-by-basin approach works well because each basin is unique and requires different treatment. He suggested several things to consider for the future. First, the examples shown are great boiler plates for what GWF wants to do in every region across the country, and some thought should be put into how we apply this in a Pan-Canadian context. For example, it would be nice to do the same kind of economic analysis that was shown for the prairie provinces in the Okanagan Basin. Secondly, there should be more consistency with the models in relation to change projections that are being applied. Dr. Brouwer agreed with these remarks.

Integrated Modelling Program for Canada

Global Water Futures

Kristin Bruce from the City of Saskatoon asked how we reconcile the concepts of water not being priced but having value, and willingness to pay. Dr. Brouwer replied that the important concept in economics is the price elasticity of water demand (i.e. how sensitive demand for water is to a change in price). Much of the work that occurs within GWF is around supply, but it would be good for the research team to consider the usefulness of economic policy to influence demand and behavioural change to promote sustainable water use.

An attendee asked a question about how the hydro-economic modelling framework handles water 'users' like SaskPower, which may manipulate water (e.g. holding water back in a reservoir, generating power) rather than 'using' it per se, if a charge for water was to be applied. They also asked if the model could analyze a scenario for a dry period, where water is moved from lower valued uses to higher valued uses to mitigate economic losses. Leila Eamen replied that the linked water resources and economic framework considers the amount of available water and water supply for each sector, and these types of firms are considered as part of the utility sector. These firms are still impacted by changes in water supply in terms of their ability to generate power or play other functions. Dr. Brouwer added that a basic principle of the economic model is to examine the marginal productivity of water (i.e. how much dollar value is generating in different economic sectors by every cubic meter of water). Economists generate the "shadow price" for water and these drive allocation. If a constraint is posed on the water supply, the model will try to allocate water in the most economically beneficial way given the shadow prices. The existing payment structure is also something that needs to be taken into account as well, and researchers can manipulate prices to resemble different policy instruments. Dr. Pomeroy noted that is would be a great opportunity to analyze trade-offs between flood control, water for food and power production in this basin. Other regions that experience water shortages such as southern Ontario and the Okanagan, would also benefit from this type of research.

Harmonizing water resources modeling with Indigenous ways of knowing

In regards to Dr. Strickert's presentation, Dr. Razavi asked if this research will provide something quantitative that could be plugged into the modelling. Dr. Strickert mentioned that quantitative indicators will be part of the closely related work package led by Dr. Jardine on environmental flows. Further, the photos being produced will be geo-located. For example, the person who takes the photo might tell us "we want the water to be three feet higher than this level," so that gives us an indication of what we need to get the level of water three feet higher in that area in order to satisfy that user. The large-scale modellers can tell us what the upstream trade-offs are to satisfy those needs.

Dr. Standyk asked if it would be possible for the IMPC team to host a workshop led by Dr. Strickert on how to present scientific information in a relatable and transferable way to some of these communities. She asked if there is a way to be able to share the photos and the community-level information with the researchers. Dr. Strickert replied that the team is not sharing photos unless they have permission from community members. The process is about building trust, because sometimes data that is collected is used against them.

Dr. Pomeroy noted that connecting photos back to the modellers is critical, but the modellers may not be able to predict water level. There may have to be some hydrodynamic work either in the project or outside it, because it is not trivial. Dr. Strickert noted that it is indeed not trivial, and right now they are trying to respond to the request from the community to visualize things in a certain way which is very difficult.

User Panel Discussion

The panel discussion included representatives from prominent IMPC stakeholders to primarily discuss user expectations from IMPC and GWF, identify measures of user engagement success as well as areas of improvement going forward.

Panelists:

- Laurie Tollefson, Agriculture and Agri-Food Canada
- Tom Tang, Alberta Environment and Parks,
- Tricia Stadnyk, University of Manitoba and Manitoba Hydro
- Mike Renouf, Prairie Provinces Water Board

Question 1: What are the top priorities, in your opinion, a program such as IMPC and GWF should address?

Mr. Laurie Tollefson emphasized that the agriculture sector is particularly vulnerable to climate change and extreme events such as floods or droughts. So, one priority, he said, is to understand the role of climate change and increasing water scarcity and be able to forecast extreme impacts of climate change on water availability. "*Having dependable knowledge and accurate information*

of trade-offs has consequences for multi-million dollar decisions we make regarding projects", he explained. He further highlighted the need for enhancing collaboration efforts between Environment and Climate Change Canada and Ag Canada, while appreciating initiatives such as Ag-Water Expo as good examples of research interface efforts.

Dr. Mike Renouf of Prairie Provinces Water Board pointed out that he's not aware if models presented in the AGM are currently being used by PPWB, but that many participants and communities associated with the Board could certainly benefit from work done at IMPC. This would help communities address questions and challenges around water quantity and water-sharing between jurisdictions that, in turn, have implications for ecosystem health and water management practices. Hence, priority for IMPC, he said, should be to "strengthen stakeholder engagement with users who may be able to utilize tools and models beings developed." He challenged the project to measure the success and value of the quality of stakeholder engagement, noting his observation that the number of stakeholders attending these meetings has been decreasing over time. This is despite that fact that the number of partners and participants in IMPC engagement activities have, in fact, significantly grown over the course of project progress, indicating that there exists a perception of declining stakeholder engagement.

Dr. Tricia Stadnyk represented her own views as an academic and her views from Manitoba Hydro's perspective since she closely works with their representatives. First, she highlighted the facilitation role IMPC could play between Manitoba Hydro and SaskPower since both are partners of the project. She also seconded Dr. Renouf about the need to measure success of engagement, noting that only one-third of meeting attendants are stakeholders, whereas the rest are academics. Third, she emphasized that there are a lot of opportunities for academia to facilitate linkages between projects in the form of data sharing and collaboration for modelling and analyses to avoid redundancy in effort and move forward more efficiently.

Dr. Tom Tang elaborated on the need to directly address stakeholder needs in Alberta especially in the context of climate change and coupling models on water quality and water resource management.

Question 2: What should we do as a team to further promote engagement of the stakeholder community and co-creation of knowledge? How should IMPC prioritize increasing quality of partnerships rather than increasing quantity of partnerships?

Dr. Tang saw two-way exchange of knowledge and expertise as a means of promoting engagement at different levels where users also get a chance to provide information that the technical IMPC team may not possess. "*You may have to choose and select, but you have to be clear about your milestone deliverables so they can align their inputs with your deliverables and you can cater to their need as well*", he outlined.

Dr. Stadnyk highlighted student internships as a valuable engagement strategy where students can gain experience and organizations get to potentially mentor a future hire. As for the second part of the question, she urged to prioritize deliverables by identifying a niche for them and thus,

"*target stakeholders that can best help [IMPC team] achieve that deliverable like no else in the world*." She expressed that the primary responsibility of prioritizing stakeholders this way could probably be best done by Dr. Pomeroy and Dr. Razavi who both have a better idea of the long-term vision for the GWF projects. Mr. Tollefson agreed.

And Dr. Renouf, on the other hand, emphasized that there is no secret way or proven solution to increase collaboration. *"Relationship-building combines trust and empathy and that takes time and effort… it may seem that it's slowing the project down but at the end, you will end up with a better product overall."* He ended with his support for ideas about a travelling interface or roadshow with the goal of researchers showcasing their work to users and stakeholders. This, he emphasized, could better show the link between the 39 GWF projects more broadly, which he considered to be a gap rarely addressed in IMPC meetings.

Question 3: What do you think are the most important things to achieve in the next year for the IMPC and GWF in general?

Mr. Tollefson suggested that this is a good time in the project to evaluate progress and scope outcomes going forward based on successes and set-backs so far. Along the same lines, Dr. Renouf suggested for IMPC to "take stock" of its progress, identify roadblocks, and "potentially set new directions and achieve as much as we've envisioned within things going forward". Tracking progress, he said, will also help with getting funding for the next phase by demonstrating value in return on investments in the first phase.

Dr. Stadnyk reiterated Dr. Graham Strickert's speaking points from his presentation on how trust-building depends largely on consistently delivering on commitments made to stakeholders. She pointed out that observation and data gathering can become endless cycles, and that there is a need to break that loop and move on to thinking about what we can conclude from that data and where we can apply the theories and models developed. She considered this essential given that pillar three of Global Water Futures is concerned with concrete applications of research. "*Behind the scenes, we can continue to refine and develop and improve those models, but if we don't demonstrate that we can apply them and achieve and measure success of certain outcomes, our stakeholders will lose trust*", she explained.

Question 4: What is your vision for what our modelling capability should look like by end of August 2023 (the end of the GWF program)?

Dr. Stadnyk called for an integrated hydro-climate water resource management model applicable to regions from the headwater of Alberta down to Manitoba, from Manitoba-hydro's perspective. "*Integrated can mean many things, but I think it has to have the elements of being capable of responding to climate change. Which means you have to have the link between the climate and the hydrologic model that can be fed into the water resource management model with realistic scenarios*". She also mentioned that water quality can also be added to the model down the road once we have water quantity models running. Dr. Renouf carried her comment on water quality forward, insisting that it's a growing area of concern in the prairies with non-

point source pollution posing "monster challenges". Hence, there is a need for "tools that link our economic decision-making and political decision-making with our technical understanding of the impacts of those types of decisions", he said.

Mr. Tollefson appreciated the work done so far and urged to continue building on that work. He saw the Ag-Water Expo as a great example of enhancing collaborative efforts that link water research with agriculture, reiterating the need to improve forecasting capabilities for climate change related threats to the agriculture sector.

Questions from the audience:

Question from Dr. Razavi: IMPC is unique in the sense that we've had a team especially for user engagement from the project's inception, but it's a collective effort from the entire team and we rely on our stakeholders to guide us do better. So where should we set our expectations and goals for our second phase to better engage stakeholders?

Speakers repeated some of their previous suggestions on measuring success to know if IMPC has done enough, for example, measuring whether the models developed are being used or implemented by stakeholders through surveys or continued engagement to find out if stakeholders find research outcomes valuable in their work. Dr. Stadnyk suggested that IMPC can connect various stakeholders within the project better, for example, a wiki or "stakeholder map" of sorts that depicts who's on the table, what they're doing, and what they're offering.

Dr. Pomeroy pointed out that not all stakeholders want their information to be public or to be transferred to someone else, hence, GWF project investigators and staff need to be very careful with proprietary stakeholder information. Having said that, he underlined that the very purpose of setting these annual meetings and events is so that stakeholders get a chance to connect and exchange knowledge across disciplines. He further highlighted his observation that stakeholder turnout to GWF and IMPC events has been increasing over the past couple of years. He elaborated, "*this wouldn't happen 10 years ago, it would have been a scientific meeting and that's it… having one third of stakeholders and users is fantastic, because this is what we would call in the past a 'sausage-making meeting' where you see the gut of our models and we talk about what we put in this algorithm or that algorithm. And everybody wants to see that*".

Final Discussion

The final discussion of the two-day IMPC annual meeting focused on integration and the future vision, particularly in regards to Phase II. Dr. Razavi began the conversation by inviting Dr. Pomeroy to comment on the potential to form a taskforce committee around integration. Dr. Pomeroy noted that because IMPC, and the GWF program it is part of, is so large, there is a need for more meetings with Principal Investigators to better understand what models are being used

and how projects can be better supported. There is also a need to formalize links with other GWF projects.

Dr. Brouwer noted that it would be helpful to have a committee or a panel of people that would work specifically on how the different components of the project are linked together. He noted that because of the size of the project, it is difficult to see the connections between the projects. He asked how the Co-Investigators can help Saman prioritize and plan for the upcoming Phase II proposal.

An attendee mentioned that it might be useful to collect everything and bring it to the stakeholder for feedback at this point. Another attendee suggested that it might be a good time to go look at initial documentation for the project such as the Inception Report or Proposal to assess how IMPC is progressing against the initial plan and strategically plan for Phase II.

Hayley Carlson noted that if GWF is continuing along with the Pillar 1, 2 and 3 model, where Pillar 3 is user-question led projects, it may be that the user questions that guided the programs inception are a good framework for integrating the models. How can these models be brought together to address the questions that were the framework for the project at its beginning? Dr. Pomeroy suggested that it might be useful to focus on a particular event like a large drought or flood, or water quality episode. This helps orient the research around a particular issue or set of questions, rather than all water-related questions relevant to Canada.

Dr. Asadzadeh mentioned that it might be good to revisit the integration of the MODSIM set up for the Saskatchewan River Basin, and the one set up for the lower Nelson, by the end of summer. His team works closely with Manitoba Hydro, and while they are happy with the system that have operated with linear programming for decades, they are also interested in other models that are capable of simulating the non-linearity. Another problem they experienced occurs during winter when the ice formation is happening and they lose a lot of their capacity to produce power. His team is looking forward to integrating the Manitoba MODSIM set up with the Saskatchewan MODSIM set-up.

Tom Tang, from Alberta, encouraged the team to work closely with Alberta Agriculture and Forestry, Irrigation Districts, and municipalities if possible. There also is a water quality modeler in Alberta Environment and Parks that could be a valuable connection for the team.

Dr. Razavi concluded the meeting by thanking all for attending and asking to keep in touch.

Agriculture-Water Expo

Agenda

Day 1: Wednesday, June 12, 2019		
8:00-8:30	**Registration and Refreshments**	
Theme A, Chair: Stadnyk		
8:30-8:45	Welcome, IMPC Overview, Meeting Agenda	Razavi
8:45-9:15	GIWS vision for Integrated Large Scale Modelling	Famiglietti
9:15-9:30	Global Water Futures: modelling progress, and new opportunities for international modelling and prediction	Pomeroy
9:30-9:45	GWF Core modelling Team: Progress, Challenges and Opportunities.	Pietroniro/Clark
9:45-10:00	High-resolution atmospheric modelling (A1)	Li/Lintao
10:00-10:20	Progress in model couplings for water quality & river ice modelling (A3 and A4)	Lindenschmidt
10:20-10:35	Discussion	Stadnyk/Famiglietti (moderator)
10:35-11:00	**Coffee Break**	
Theme A (Cont'd), Chair: Lindenschmidt		
11:00-11:15	Improving large scale models through representation of cold regions processes: advances and next steps (A2)	Pomeroy
11:15-11:30	Canadian Hydrological Model – status and prospects	Marsh
11:40-11:55	Progress with HYPE hydrological modelling	Stadnyk/Awoye
11:30-11:40	Progress with MESH/GEM-Hydro	Princz
11:55-12:05	Model inter-comparison and multi-model analysis (A5)	Mai/Tolson
12:05-12:15	Data Management in GWF: Information for Modellers	Peterson
12:15-12:30	Discussion	Lindenschmidt/Pomeroy (moderator)
12:30-13:30	**Lunch Break**	
Theme A (Cont'd), Chair: Mai		
13:30-13:45	Does one Distribution fit all? Proof of concept on streamflow across Canada (A6)	Elshorbagy/Zaghloul/ Papalexiou
13:45-14:00	Overview of VARS-TOOL for sensitivity and uncertainty analysis (A7)	Razavi
14:00-14:45	Lightning Talks (Theme A/Core Modelling HQP)	HQPs (*see the list)
14:45-15:30	**Coffee Break and Poster Follow-Up (*see posters list)**	
15:30-16:00	Café table discussion	All
16:00-16:30	Café table reports	Haghnegahdar (moderator)
16:30-	Concluding Remarks, Day 1	Razavi
17:00	**Dinner @ University Club**	

List of Day 1 Lightning Talks (14:00-14:45, 2 minutes each)

1	Razi Sheikholeslami	*Advances in handling high-dimensional models and model crashes*
2	Nhu Do	*Advances in handling correlation effects between model parameters*
3	Amin Haghnegahdar	*A Multi-method Generalized Approach to Assess Sensitivity of Complex Watershed Models*
4	Mostofa Kamal	*Understanding Extreme Precipitation Characteristics over Western Canada*
5	Xiao Ma	*The Analysis of Convective Indices using Convection-Permitting Regional Climate Simulations*
6	André Bertoncini	*From the Ground to Space: An Analysis of Satellite Solid Precipitation Estimates based on Multi-technique Ground Observations.*
7	Zhihua He	*Hydrological responses in a boreal forest basin to climate and land cover changes*
8	Abbas Fayad	*Assessing the MESH Model's Ability to Simulate Mountain Snowpacks*
9	Zhibang Lv	*Assimilation of snow interception information into a cold regions hydrological model.*
10	Diogo Costa	*Hydrodynamic modelling of snowmelt flooding events and nutrient transport in the Canadian Prairies using the FLUXOS model*
11	Brandon Williams	*Calibration of an Ice Jam Flood Forecasting System for the Lower Red River, Manitoba.*
12	Prabin Rokaya	*A physically-based modelling framework for operational forecasting of river ice breakup*
13	Sujata Budhathoki	*Improving hydrological simulations in the Prairies using in-situ soil moisture information*
14	Luis Morales Marin	*Advances on water quality and river ice modelling in large-scale catchments*
15	Youssef Loukili	*Lhù'ààn Mān - Kluane Lake, Yukon Territory, the impending hydrological fate after Slims River piracy*
16	Ajay Bajracharya	*Analysis of Soil Moisture Accounting in Nelson Churchill River Basin using HYPE*
17	Hervé Awoye	*Hydrological modelling in the Lake Erie and Nelson-Churchill River Basins using HYPE*
18	Sajad Khoshnod	*Analysis and Prediction of Land Cover Changes (Hable-Rud, Iran)*
19	Julie Mai	*THE CUIZINART – A Tool For Automatic Subsetting of Large Gridded Datasets and Data Dissemination*

Posters List (Poster Session on Day 1 14:40-15:30, Day 2 15:00-16:00)

1	Razi Sheikholeslami	*Advances in handling high-dimensional models and model crashes*
2	Nhu Do	*Advances in handling correlation effects between model parameters*
3	Nhu Do	*Integrating water allocation models into a unified model, performance indices, and the scenario analysis tool for water supply and demand*
4	Amin Haghnegahdar	*A Multi-method Generalized Approach to Assess Sensitivity of Complex Watershed Models*
5	Mostofa Kamal	*Understanding Extreme Precipitation Characteristics over Western Canada*
6	Xiao Ma	*The Analysis of Convective Indices using Convection-Permitting Regional Climate Simulations*
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12	Brandon Williams	*Calibration of an Ice Jam Flood Forecasting System for the Lower Red River, Manitoba.*
13	Prabin Rokaya	*A physically-based modelling framework for operational forecasting of river ice breakup*
14	Prabin Rokaya	*A stochastic framework for ensemble ice-jam flood modelling*
15	Zhaoquin Li	*Surface Soil Moisture Content retrieval using Multi-temporal Radarsat-2 images*
16	Zachary Lang	*Water Quality Modelling of Heavy Metals in the lower Athabasca River*

17	Sujata Budhathoki	*Improving hydrological simulations in the Prairies using in-situ soil moisture information*
18	Luis Morales Marin	*Advances on water quality and river ice modelling in large-scale catchments*
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22	Sajad Khoshnod	*Analysis and Prediction of Land Cover Changes (Hable-Rud, Iran)*
23	Julie Mai	*THE CUIZINART – A Tool For Automatic Subsetting of Large Gridded Datasets and Data Dissemination*
24	Mustakim Ali	*Development and testing of water allocation models for all Saskatchewan River Sub-Basins*
25	Kasra Keshavarz	*Stochastic generation of water supply scenarios by a weather generator with perturbed weather properties*
26	Mohammad Ghoreishi	*Understanding Human Adaptation to Drought in Bow River Basin: Agent-Based Agricultural Water Demand modeling*
27	SuJin Kim	*Coupled hydrologic-operations modelling for the simulation of hydropower operations in the Lower Nelson River Basin*
28	Azza Mohammadiazar	*Harmonizing Water Resource Modeling with Indigenous ways of knowing: A Collaboration in Water Stewardship of Saskatchewan River Delta*
29	Venkat Bandi	*DSS Tool Pilot – Delta Display*
30	Trish Stadnyk	*HYPE C3S Showcase – Delta Display*
31	Leila Eamen	*The Economic Response of the Saskatchewan River Basin to Water Supply Restrictions due to Climate and Policy Change*

Day 2: Thursday, June 13th, 2019		
8:00-8:30	**Refreshments**	
Themes B-D, Chair: Elshorbagy		
8:30-9:00	Razavi: *Overview of Water Resources Modelling and Challenges (B1)* Lightning talks: - *Development and testing of water allocation models for all Saskatchewan River Sub-Basins* (Ali) - *Integrating water allocation models into a unified model, performance indices, and the scenario analysis tool for water supply and demand* (Do) - *Tree-ring-based water supply scenarios for the Saskatchewan River Basin* (Slaughter) - *Stochastic generation of water supply scenarios by a weather generator with perturbed weather properties* (Keshavarz) - *Understanding Human Adaptation to Drought in Bow River Basin: Agent-Based Agricultural Water Demand modeling* (Ghoreishi)	Razavi Ali Shah Do Slaughter Keshavarz Ghoreishi
9:00-9:15	Future demand scenarios from policy discourse (C1)	Carlson/Gober
9:15-9:30	Web-based Decision Support System (D2)	Gutwin
9:30-9:45	Asadzadeh: *Water resources modelling - Manitoba (Nelson-Churchill)* - *Coupled hydrologic-operations modelling for the simulation of hydropower operations in the Lower Nelson River Basin* (Kim)	Asadzadeh Kim
9:45-10:00	Discussion	Elshorbagy (moderator)
10:00-10:30	**Coffee Break**	
Themes B-D (Cont'd), Chair: Brouwer		
10:30-11:15	Brouwer: *Challenges of Model Integration and Overview of the IMPC Hydro-Economics Approach (B3)* - *Hydro-Economic Model for the Great Lakes Basin* (Garcia Hernandez) - *Hydro-Economic Model for the Saskatchewan River Basin* (Eamen) - *Integration of Monitoring Data into a Pan-Canadian Water Quality Valuation Model* (Pinto)	Brouwer Garcia Hernandez Eamen Pinto
11:15-11:30	Environmental flows and hydro-ecologic metrics (B2)	Lento/Jardine
11:30-11:45	Strickert: Indigenous Engagement (D1) - *Harmonizing Water Resources Modeling with Indigenous ways of knowing* (Mohammadiazar)	Strickert Mohammadiazar
11:45-12:30	Modelling Integration Plenary	Brouwer (moderator)
12:30-13:30	**Lunch Break**	

Management & Knowledge Mobilization, Chair: Razavi		
13:30-14:30	User Panel: Vision and Future Planning	Tollefson, Tang, Stadnyk, Renouf
14:30-14:45	User engagement and knowledge mobilization	Carlson
14:45-15:00	Project Management	Haghnegahdar
15:00-16:00	**Coffee Break and Poster Follow-Up (*see posters list)**	
16:00-16:30	Open Discussion and Closing Remarks, Day 2	Razavi (moderator)