Integrated Modelling for Canada

First Annual General Meeting Report

July 18-19, 2018

Executive Summary

IMPC held its first annual general meeting on July 18-19th, 2018 at National Hydrology Research Centre, Saskatoon. This was an opportunity for members of the IMPC team, as well as the Global Water Futures (GWF) Core Modelling Team, to present, evaluate, and discuss their progress and engage in insightful discussions with various stakeholders. Strategies for user-engagement and knowledge mobilization were also discussed.

Nearly 90 people from academic, regulatory, and industrial sectors attended the meeting in-person or online. Attendees included researchers, students, collaborators, and representatives of various indigenous, municipal, provincial, and national stakeholders from 16 organizations, including the University of Saskatchewan, University of Manitoba, University of Waterloo, Environment and Climate Change Canada, Natural Resources Canada, Prairie Provinces Water Board, Government of Saskatchewan, Saskatchewan Water Security Agency, SaskPower, Partners for the Saskatchewan River Basin, Alberta Environment and Parks, City of Calgary, Manitoba Infrastructure and Transportation, Manitoba Hydro, Yukon Department of Environment, and Cumberland House. Martyn Clark, from the National Center for Atmospheric Research in US, was the featured speaker for the meeting.

In addition to presentations by lead researchers, the meeting was designed to provide additional opportunities for user communities to engage in discussions via café discussion tables and a modelling panel, and also for Highly Qualified Personnel to showcase their work through poster and interactive presentations. Two members of the IMPC/GWF team who recently passed away, Ric Soulis and Ric Yanowicz, were remembered during this meeting as well.

Concluding remarks from the strategic advisor to GWF, Professor Howard Wheater, highlighted a great start and exciting prospects for IMPC, along with some scientific and management challenges and opportunities for it in future. Some of the notable remarks include:

- The significance of creating a community of researchers and end-users by IMPC
- The significance of including the indigenous communities in the research
- A need to find strategies to optimize communication and knowledge mobilization efforts across all projects and models at different locations
- A need to start integration of various program components at a pilot basin
- An advice to think beyond water, and consider the entire food-water-energy nexus
- A requirement to bring experts from various disciplines together to identify plausible future scenarios

This report provides a list of participants, followed by a synthesis of discussions under each section. The workshop agenda is provided in the appendix. A copy of the final report, all presentations, and posters can be found on the IMPC webpage at :
https://gwf.usask.ca/impc/resources/Meetings.php#FirstAnnualGeneralMeetingJuly2018

Thank you to all who participated and contributed to making this meeting a big success!

Amin Haghnegahdar
IMPC Program Manager

Hayley Carlson
IMPC User Engagement Specialist

Saman Razavi
IMPC Principal Investigator

Nearly 90 individuals from 16 academic, regulatory, indigenous and industrial organizations attended the IMPC First Annual General Meeting July 18th-19th, 2018.

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Integrated Modelling Program for Canada
Global Water Futures

List of Participants

- Laurie Tollefson (Agriculture and Agri-Food Canada)
- Khaled Akhtar (Alberta Environment & Parks)
- Anil Gupta (Alberta Environment & Parks)
- William Chaboyer (Cumberland House Cree Nation)
- Kevin Gawne (Manitoba Hydro)
- Fisaha Unduche (Manitoba Infrastructure and Transportation)
- Bin Luo (Manitoba Infrastructure and Transportation)
- Gary Carriere (Mistik Lodge)
- Alain Bishoff (Northern Village of Cumberland House)
- Bob Halliday (Partners for the Saskatchewan River Basin)
- Mike Renouf (Prairie Provinces Water Board)
- Tricia Stadnyk (University of Manitoba)
- Masoud Asadzadeh (University of Manitoba)
- Parya Beiraghdar (University of Manitoba)
- Su Jin Kim (University of Manitoba)
- Ajay Bajracharya (University of Manitoba)
- Jay Famiglietti (University of Saskatchewan)
- Vincent Vionnet (University of Saskatchewan)
- Karl-Erich Lindenschmidt (University of Saskatchewan)
- Luis Marin (University of Saskatchewan)
- Brandon Williams (University of Saskatchewan)
- Zhaoqin Li (University of Saskatchewan)
- Sujata Budhathoki (University of Saskatchewan)
- Graham Strickert (University of Saskatchewan)
- Anuja Thapa (University of Saskatchewan)
- Amin Elshorbagy (University of Saskatchewan)
- Mohanad Zaghloul (University of Saskatchewan)
- Simon Papalexiou (University of Saskatchewan)
- Carl Gutwin (University of Saskatchewan)
- Ehsan Sotoodeh (University of Saskatchewan)
- Pat Gober (University of Saskatchewan)
- Yanping Li (University of Saskatchewan)
- Richard Agyeman (University of Saskatchewan)
- Zhenhua Li (University of Saskatchewan)
- Howard Wheater (University of Saskatchewan)
- John Pomeroy (University of Saskatchewan)
- Kevin Shook (University of Saskatchewan)
- Chris Marsh (University of Saskatchewan)
- Zhibang Lv (University of Saskatchewan)
- Youssef Loukili (University of Saskatchewan)
- Siqiong Luo (University of Saskatchewan)
- André Bertoncini (University of Saskatchewan)
- Holly Annand (University of Saskatchewan)
- Zelalem Tesemma (University of Saskatchewan)
- Dominique Richard (University of Saskatchewan)
- Al Pietroniro (University of Saskatchewan)
- Mohamed Elshamy (University of Saskatchewan)
- Fuad Yassin (University of Saskatchewan)
- Shervan Gharari (University of Saskatchewan)
- Elvis Asong (University of Saskatchewan)
- Jefferson Wong (University of Saskatchewan)
- Daniel Princz (University of Saskatchewan)
- Saman Razavi (University of Saskatchewan)
- Mohamed Abdelhamed (University of Saskatchewan)
- Leila Eamen (University of Saskatchewan)
- Seyedmohammad Ghoreishi (University of Saskatchewan)
- Kasra Keshavarz (University of Saskatchewan)
- Razi Sheikholeslami (University of Saskatchewan)
- Mustakim Ali Shah (University of Saskatchewan)
- Reza Bahremand (University of Saskatchewan)
- Andrew Slaughter (University of Saskatchewan)
- Nhu Do (University of Saskatchewan)
- Stephanie Merrill (University of Saskatchewan)
- Chris DeBeer (University of Saskatchewan)
- Jared Wolfe (University of Saskatchewan)
- Hayley Carlson (University of Saskatchewan)
- Sarah Foley (University of Saskatchewan)
- Amin Haghnegahdar (University of Saskatchewan)
- Roy Brouwer (University of Waterloo)
- Jorge Hernandez (University of Waterloo)
- Bryan Tolson (University of Waterloo)
- Juli Mai (University of Waterloo)
- Hongren Shen (University of Waterloo)
- Kamrul Hossain (Water Security Agency)
- John Fahlman (Water Security Agency)

Presentations on Day One

Principal Investigator Saman Razavi opens the IMPC Meeting.

The first day of the annual meeting was allocated to the latter research themes of the project, Themes B, C and D. The morning provided time for lead researchers to introduce the project and provide an overview of progress during year one of the IMPC and GWF research programs. The afternoon included brief reporting on project management and user engagement activities, followed by interactive Café Discussion tables which provided opportunities for informal discussion between researchers, HQP and collaborators around five subjects.

Discussions for Themes B, C & D

Hydro-economic modelling and multi-objective operating rules

During the discussion for research themes B, C and D, Howard Wheater highlighted the challenge of acquiring limited Canadian data to use in hydro-economic modelling. To Roy Brouwer he inquired about establishing a dialogue with Statistics Canada (SC) and Environment and Climate Change Canada (ECCC) around the current status of economic data and modelling and future developments. Roy Brouwer pointed out that SC is already working on water economics; to his knowledge they are particularly interested in a system of environmental-economic accounting for water developed by the statistical office of the United Nations and the Federation of European Accountants (FEE) accounting framework. This work however, is just beginning. Roy believes the main challenge we need to address in the coming years is that the SC water accounts are very specifically related to certain economic activities and not presented in an input-output modelling framework that we are interested in. While SC is interested in water economics, there is limited

Presentations

- **Welcome, IMPC Overview, Meeting Agenda** (*Saman Razavi)*
- **Global Water Futures: Year One Progress** (*John Pomeroy)*
- **Remarks from the Strategic Advisor to GWF** (*Howard Wheater*)
- **Water Management Challenges, Scenarios and Decision-Support** (*Pat Gober)*
- **Water Resources Modelling** (*Saman Razavi*)
- **Water Resources Modelling: Manitoba and the Nelson-Churchill** (*Masoud Asadzadeh*)
- **Hydro-Economic Modelling** (*Roy Brouwer*)
- **Cultural and Environmental Flows, and User Engagement** (*Graham Strickert*)
- **Advanced Visualization Tools** (*Carl Gutwin*)

capacity to work on water accounting within the organization. According to Roy, one of the major contributions we can make is to demonstrate how useful data and information is. Without demand around high-level data collection from different communities, there will not be very much funding available for these assessments.

Bob Halliday asked a question about using a multi-objective reservoir operating framework where in addition to a single dominant economic factor, societal preferences are also considered. Roy Brouwer replied that one of the most important steps is to collect data that shows the economic value of different operating systems, and potentially using this method as a way of prioritizing water allocation in times of scarcity. Whether that approach will impact decision-making is a very political decision. Roy noted that he is not as familiar with how water allocation rules are determined in Canada, but in Europe in many cases the government has rules regarding where water should go if there is an insufficient amount. Roy also emphasized that the European framework is based on multiple indicators; they are advocating for GDP in combination with other biophysical indicators, which goes very far from a multi-objective perspective.

Saman Razavi added that from an engineering point of view, quantifying hydropower generation from an economic perspective is very straightforward, while considering societal preferences is quite challenging. If we could derive a method to generate some definitive functions for societal preferences, we could include them and consider trade-offs. There are many technical issues associated with this approach. These are what the IMPC and Core Modelling team has been looking at, and they hope to bring societal preferences into the framework and make use of those data.

Trish Stadnyk noted that it is very difficult to understand the trade-offs when we don't fully understand the impact that regulation has if it was not currently in effect. There is a lack of recognition that pre- and post-dam construction hydrographs are from different periods in time and different climates. A more accurate picture around trade-offs emerges when we operate the model during the same period in time and simulate flows in absence of regulation. Trish would like the team to get to that point in the modelling.

Stakeholder Engagement and Influencing Decision-Making

Jay Famiglietti highlighted that while it is a real goal for all of us to get stakeholders and decision-makers to utilize our data, information or software in decision-making processes, it is difficult to track our impact. It is important that we have mechanisms to quantify our impact in this way. He provided an example of work in California around groundwater depletion that resulted in deciding to put the sustainable groundwater management act on the ballot. Years later people on the State Water Board noted that his presentation made a huge impact. Many times the work that we do is just one small piece of a larger information stream that decision-makers take in.

Along the same line, Pat Gober pointed out that this is a difficult and long term social process. In her case study, they've been asking the same stakeholders for 13 years, and have been lucky enough to have 3 rounds of funding from the National Science Foundation to observe the big picture and changes over time. A significant challenge to influencing decision-making emerges when funding models support a small science project, that only allow researchers to give limited advice to stakeholders and a publication two years down the line. It is about having the time to build these relationships, make mistakes, learn from those mistakes, address them and keep working. In Phoenix Pat's research team did a water simulation for the region as a whole, as they were interested in the sustainability of water supplies and demands regionally. After 2-3 years, the 120 different water providers in metro Phoenix said they wanted a WaterSim for each of those communities. Her team went back and spatialized WaterSim so it could be used on a community-level for

long-term water planning, but this took time - they had to put in the water rights for each of the 40 separate communities that have different water rights based on the historical time of development. In conclusion, Pat noted that influencing decision-making and working with stakeholders is a long-term process, which is why she wanted to share the mistakes that are inherent to the process in her presentation.

Graham Strickert explained that one of the things that they are interested in is making value-decision links. If a link between values and decisions can be made, what happens if we insert evidence into the decision-making process for people of certain values who we think are likely to make certain kinds of decisions. When we insert different forms of evidence - and this might be scientific or stakeholder uncertainty or a story from a Elder that has traditional knowledge - does that change the way people make their decision? This is not easy to do, but Graham and his team are facilitating workshops with stakeholders in order to make these links. Large data sets are required.

Bryan Tolson and Saman Razavi had a discussion about finding and measuring robust solutions with respect to performance levels or in terms of optimal decisions (in the sense that the decision itself can be sensitive to performance levels). Bryan suggested that when we think about robustness we could assess how variable the performance metric is under uncertainty, but that we should also consider how variable a decision would be across performance levels. Trish Stadnyk also added that it's not about optimal performance, but really about which performance metrics do we actually consider, because this represents different decision variables and thus different decisions will be made. She emphasized that these metrics must be defined by stakeholders - it's not really up to us as the modellers to make those decisions.

Piloting Integration

John Pomeroy appreciated the very enlightening presentations, and suggested that it is beneficial at this point to pursue a pilot project to start to combine some of these elements of water resources modelling, economic modelling, cultural and ecological flows, and visualization together, and see what modifications are needed before expanding to the larger scales. Trish Stadnyk seconded this point, and added that we need to try coupling components to make sure that everyone knows the outputs that one group or theme is generating and the inputs of the others.

Comments from Knowledge Mobilization Oversight Committee (KMOC)

Bob Halliday, Board Chair
Partners for the
Saskatchewan River Basin

"In the development of this project, we had what I tend to think of as embedded client support groups, and by that I mean the Ontario Conservation Authority and Manitoba Hydro, groups like that that were part and parcel of the development of the project. And I think for Hayley Carlson [IMPC's User Engagement Specialist] and that group, communicating with those people is a different challenge than communicating with others and engaging with others because those embedded people really have an understanding of the project and shape where it's going. And the challenge for us I think is to expand the commons, so we engage more and more people, and bringing the people who have some knowledge, have personal knowledge, and so on. That's an ambitious task, and I think it's a daunting task in many cases. Because how do you communicate with people? When do you communicate? And you don't want to say, "We're

going to solve your problem next week," and know you're not going to solve it for five years at least. So that is a challenge and we need to work through that and get a better understanding of what their needs are and how we go about it.

The other part of this is that many of these anticipated clients have made significant investments in doing what they do now, and it takes a bit to get them off of that, and I think we have to be recognize that. If you approach a client and say, "we have the solution to your problem", their first reaction might be, "we don't have a problem." So working through that and getting the clients engaged to see there could be a different way of doing things, and not only that but a better way is a real challenge in itself. So that's what I see as a real challenge going in to this.

One of the other things about modelling I've always thought is that one of the roles of modelling is to help the user to find reasonably feasible alternatives. And many times the public or even a professional working in a water agency might have a sense of the range of alternatives. But when you actually do the work and the modelling, you say that their range of alternatives is about half as wide as you think it is. So helping them through that kind of process is important.

Then I go into the idea of explaining risk and uncertainty. Many of you are aware that the U.S. was committed to using the private sector to put astronauts up in space. And the program is delayed, and one of the reasons it's delayed is that NASA says in order to use the private sector to put an astronaut on the space station, the chance of failure has to be less than 1/200. So I said to myself as I saw that: "the design flood risk in MB and BC is 1/200. So are we asking floodplain residents to be astronauts?" Explaining risk in a way that people can get their heads around is really important. Adding to the risk is a question of uncertainty. Mike Renouf, Wayne Jenkinson, and I are all enjoying the process of going to get a bunch of engineers talking to social scientists. I think it's a useful exercise and I certainly encourage you all to answer Hayley's phone calls. We are trying to do something useful that will help you in the long run."

Mike Renouf
Executive Director
Prairie Provinces
Water Board

"*I encourage all of you as investigators to work with Hayley to get your Participatory Working Groups established and up and running and working. I have had communications with a lot of individuals through my contacts who were interested at various points in the project, and my contacts were maybe a little bit early. And there were a lot of people who are anxious to get going, and they've been asking, "when am I going to be contacted?" and "how can I interface?" and "should I be approaching people?", and those kinds of questions. So there is a community that wants to participate in understanding the work that is going on and providing input based on their perceptions and experience. So again, I encourage you to get them up and running. How they may function and work maybe specific to each of those groups, or may have to have variants within each of those groups. I don't think the KMOC has had a chance to discuss a template or an approach that will work for everybody; you each have to learn your own way. You should remember that the knowledge movement should be going back and forth, maybe all the way around the circle within the groups that are there, not just between a group and the researchers, but between members of the group themselves. For many people learning is limited in the time scope that you're able to retain that information. So sometimes you need to dribble that information out and find different ways. Those would be my messages back to you: 1) get your groups up and running, and 2) be adaptive and be divers."*

Café Tables Reports

Table 1: Water Management and Hydro-Economic Modelling (Saman Razavi and Roy Brouwer)

Roy Brouwer reporting:
We decided not to use the given questions and tried to come up with three main questions that we could address in 20 minutes. The first was that we asked different participants to share their most relevant water management questions that our models should be able to address. Secondly, "What information would be needed to answer the question?" And finally, how can we improve the development of these models through end-user engagement?

In the five groups, most of the discussion was about the first question. There was a lot of discussion at local levels, as it matters a lot where you are to what the relevant questions are. We also tried to transcend and get the discussion at a higher, abstract level and come up with general criteria of what the models would need to have to address some of the main concerns of the people at our table.

I will give a short overview of some of the more generic issues, the more local issues had more to do with SK, and historic licensing for example, and they still were driving the allocation of the water. We were talking about the MB floodway as well. We learned about SK, MB, and there was someone here from AB who gave us a lot of insight about managing and sharing information and flow data, especially the private sector. Because they have commercial interests, it will be a big challenge for our integrated modelling to get that sort of information.

Most importantly, people agreed that integrated water management modelling should be able to reflect the interconnectedness of the water system and that relates both to the physical aspects to what you do upstream and how that can impact water use and availability downstream. But also altering the water flow has consequences for water quality and overall ecosystem integrity. And finally the relationship between water use and the economy.

Another important aspect that came up was the spatial scale. We have to address water management issues at the appropriate scale. Someone said administrators don't have really a clue about the hydrological boundaries of water systems; they're primarily interested in their own administrative geographical unit and it is very difficult for them to make decisions with full scale consideration of the impacts downstream. Having models address the appropriate spatial scale is considered very important, but at the same time and as an authority said "the size of the basins in Canada are massive," and trying to achieve something at a pan-Canadian scale is perhaps a bit of an illusion. What we need is basin models, which present us with notes or information about supply and demand at key points along the river system. So there does not seem to be a one-size-fits-all solution for all the different basins in Canada because we have to take into account the hydrological realities of these different basins—you cannot compare what happens in the western part of the country with the eastern part.

There was a comment that a lot of the discussion has been about how much water is there going to be in the system under climate change. This person made a plea for much better estimating demands and that demands is not static in space now and forever. The models have to be able to address competing demand and use and inform political decision-making relating trade-offs between these competing demands.

There was an issue of non-stationarity, and that climate change is real, and the current generation of modelling should reflect that already. The model should be able to accept the probability alternatives in terms of their robustness. There was also a discussion about the extent to which we will be able to capture all the runoff values in a basin in one and the same model. And to what extent these models will be monetized. It is not only models that play a role, but also cultural/ecological values are very important to take into account and they may not all fit under the overall holistic model.

There was a few more comments about the data and information in addition to the issue mentioned about the private sector, where there is no data sharing. There are a lot of series of reservoirs that are in public and private hands with different ownership, and there is no coordinated effort, for example, to minimize flood risks.

When it comes to end users it was mentioned that it is important to show what people are actually experiencing, so that's what these models are perhaps supposed to be able to do. For example, how models are useful for more efficient design of floodways. One last thing is that the voice of Indigenous people is not captured in these models so we have to learn what the models can and cannot do in this respect.

Table 2: Knowledge Mobilization and User Engagement (Hayley Carlson and Stephanie Merrill)

Hayley Carlson reporting:
We had a lot of different discussions and each group was different. In the first group we had a discussion of how do we optimize our Knowledge Mobilization efforts with each other across all projects and models. Because we have a lot of different modellers in different locations with different tools.

We also had an interesting comment from a collaborator on how the objectives from an investigator community doesn't match up with the collaborator community. The investigator community might be interested in publishing papers whereas the collaborator community is concerned with what they'll be getting out of the tool and sometimes those things can work hand-in-hand and sometimes they won't.

We also talked about the important point, maybe the fundamental point, that people don't necessarily make decisions based on model results; We tend to not want to think that way, we know that and the literature shows that as well. So how do we mobilize knowledge in order to appeal emotion and values that are actually going to make a difference in decision-making, rather than just producing more and more information that isn't necessarily going to influence decision-making? The point we came to there is to incorporate perceptions and beliefs into the modelling rather than building the modelling and trying to apply where perceptions and values are really having an impact on real-life decisions.

So another conversation was around how we want to provide periodic updates to the community and that came through in our user engagement survey, and they agree with our early, strong message that many of these people have pre-existing relationships, and they have established ways of working together. So they have a specific point in their research where they need information from a collaborator, or they're facing a critical decision-point where they need to reach out, and that's really where the communication happens. So having a monthly regular meeting really wouldn't be that helpful from that perspective.

One group that we're not capturing right now is the consultant community. They play a large role in guiding decisions around resource management, and how can we bring consultants and people from consulting

agencies, into our research. They'll specifically act as sort of a boundary group between the research community and the collaborator community.

Someone asked if we've thought about how we're mobilizing knowledge across the Canada-U.S. boundary, because there are very different cultures between Canada and the U.S. That may be a problem as many of us are doing work across the international border there.

In the latter two groups we talked more specifically about engagement, particularly in Manitoba and Alberta. There was a discussion about how MB might be a bit more interested in engaging since they're downstream, whereas AB is upstream, so they have a lot more freedom around getting engaged. But Alberta is doing some work on different tools that they're using and asking to communicate with their audiences and how that's working for them and not working for them, and how we might be able to apply these tools.

Table 3: Cultural/Environmental Flows (Graham Strickert)

Graham Strickert reporting:
The first question asked was "How should the flow in the river be?" And there were some folks in the room that immediately took issue with "should" and "what should be". And overwhelmingly, there was a pretty common response about the natural flow. That it should be a way of how it should look in different places for different seasons. Depending on where people were working there might be different characteristics or different stakeholders that they're accountable for. So we had some different views coming from hydropower sector versus folks who are more concerned about ecosystem services in a river delta for example.

We also asked about "How the flows in the river effect different animals?" And some people had never even really thought about that, or they didn't know how to incorporate it into the models, or what assumptions should go into that process. But we heard, of course, about the impact on fish and that different water levels was a dead giveaway, water levels get too low then the fish have no habitat but we had more detailed discussions of if the water levels get too low, then the temperature can go up and that can cause fish death. It can also disrupt the timing of the spawn, so if water levels fluctuated during the time of the spawn up or down, that can disrupt that entire generation of fish being born.

We also talked about "How much variation different animals can tolerate?" Different animals have different levels of adaptive capacity, so someone mentioned, humans get cold and we put on a coat. If you're a fish it's not so easy. But there is the aspect that fish can move, but not if they have nowhere to go. If the water draws down and they're stuck in a pool, they can get trapped in that pool. Or if they're in the habitat that they really want to be in and the water goes up too fast, then they might get flushed out of that place. And certain fish species will only spawn in certain areas, and they'll go back to a specific area over time, and if they get cut off from that area they won't spawn.

We also talked about how flows effect communities. The first and most common response was about flooding. People commonly hear about flooding and interface with flooding, but what also came up was drought. And people don't think about drought until they're in a drought. But also that if we are talking about the natural flow regime, and the natural flow actually means that the river dries up, a lot of people get upset about that. We have to be able to cope with the fact that most of the systems that we're dealing with are under flow control, the flows are moderated, people have to be able to empathize with the people who have the controls on those levels because oftentimes it doesn't matter what they do, people are going to complain.

Another interesting point was the issue of surprise. The river can always surprise. We can predict and forecast what the future might look like, but the rivers can always surprise us. Then we asked people to think about what would the river, whichever river you work in most, look like if it was fully restored? That brought out some interesting comments going back to the natural flows; Higher water going into the spring and summer, drawing down slowly through time and then low flow in winter. That's what flows would look like at fully restored, along with all the animals and ecosystems.

Finally, one of the comments on the best way to engage the whole community was to focus on engaging with the kids, and getting them to engage with tactile things, and then maybe they bring that home to their parents. That was one of the comments.

Table 4: Decision Support Systems and Visualization (Carl Gutwin and Bob Halliday)

Carl Gutwin reporting:
There was a wide range of discussions. We talked about issues related to sharing data and uploading your data to some site like the one we saw this morning, and the potential problems with making that data available to other people, either with the desire to keep that protected for whatever reason, the data's proprietary, or because the owner of the data wants to avoid people coming to incorrect conclusions because they don't understand the way the data was built. So I guess providence is becoming a big deal in a lot of these large scale information systems, and that could potentially become an area to look at if we're going to allow this.

Another issue is simple differences in visualization, such as representing rivers as blocks of 0.5 degree, which is very different than showing the branching structures of the river.

It was mentioned that there are in fact no tools for some of the big questions. Many of the questions that people are trying to deal with they're trying to create tools to take account for all of the inputs in the system that they're working on. They're actually still not at the point where we have the tools we just need to visualize it.

There were some great datasets that came out, such as snowcast.ca, which apparently needs better visualization.

Discussion with the group that has some of the end users from Cumberland House about physical models of hydrological systems, apparently used to be common. We talked about one that used to be the whole Frasier River Basin that is now in the parking lot. These might be really useful form those that can see the terrain but may not be interested in visualization. We talked about some of the ways to take advantage of technology through virtual reality. Apparently, these things are being made for engineers to see what part of the bridge is going to wash away.

Another thing that was suggested as an important possibility for future visualization systems was the ability to go back and forth between two scenario outputs, like those slider things. This is great, something I've never seen before in a visualization system.

Other possible things that should be included is the ability to compare model outputs to real data, to be able to show error values or even confidence levels in the data itself.

We talked about not trying to reinvent the wheel because there are a lot of good visualization tools, such as R libraries that are community-based rather than just specific to a certain project. There was a good suggestion that we conduct a survey of people to find out what visualization tools and modelling tools are currently being used and then build a catalogue of what's there and available so that everyone can use what's there and we can attempt to cherry-pick all of the best features of these tools or just reuse libraries.

Lastly, the use of visualization as a way of doing QA/QC to these big data sets was also mentioned, which is a nice precursor to modelling itself. A question was also raised about the process to QA/QC the huge amount of data produced and/or collected within GWF and IMPC. This is something that GWF management committee should discuss and will likely be relied both on investigators and on the data management team.

Table 5: Future Scenarios: policy, land use, climate, and infrastructure (Patricia Gober and Howard Wheater)

Pat Gober reporting:
We had a session on scenario development and adaptation planning. First of all, I was mightily impressed with the range and the depth of adaptation efforts and scenario planning among the participants of all five sessions. People are in the game of visioning the future and thinking about what they need to do to adapt to an uncertain future, and this kind of mindset is prevalent across the participants in this project. I think if I were in a similar group in the U.S., I would not find the multiplicity of examples and experiences as what I heard in the café sessions.

The limits to visioning the future and decision-making under uncertainty are the politics of climate change. There might be some inherited services in the operator and management community where they say "we've got this figured out, and we're not ready to talk about a future where the rules of the game are fundamentally different from the rules that have served us so effectively in the past."

We heard also that water is local, and that people are engaged and want to talk about water, but as a local resource, and most of the water resource challenges that we've talked about so far are larger scale. So the scale mismatch of where people are interested and dealing with water and where the water challenges really lie are another impediment to scenario planning and adaptation efforts.

We also talked about the process of adaptation as being top-down or bottom-up processes. One way to look at it is to take the results of the climate models, and fit those in to the hydrology models, and fit those into the water resource models, and come up with alternative visions of the future to present to stakeholders. An alternative way, and frankly a way that bypasses some of the climatic uncertainty challenges, is more of a bottom-up approach, which emphasizes the social design and vulnerability in particular systems. We heard a clear preference in some groups for the top-down way of formulating scenarios that I can see, and an alternative way would be to figure out the problems facing the existing systems, and might challenge the system in the near future and getting to adapt and adjust those.

There was discussion about water decision-making as a multi-stakeholder decision process. We're not going to build scenarios and we cannot seriously talk about adaptation efforts if we're grappling with what people think and how they value environmental flows, economic activity, water quality, and agricultural productivity. The trade-offs in these are an important part of these scenarios as we move forward.

We also had a discussion about the role of science in scenario development and scientists have, to a certain extent, or as depicted in our discussions, led the scenario development exercises. But sometimes we don't have science and the assessment tools that will allow us to find the knowledge that is necessary for generating models for thinking about the future from a decision perspective.

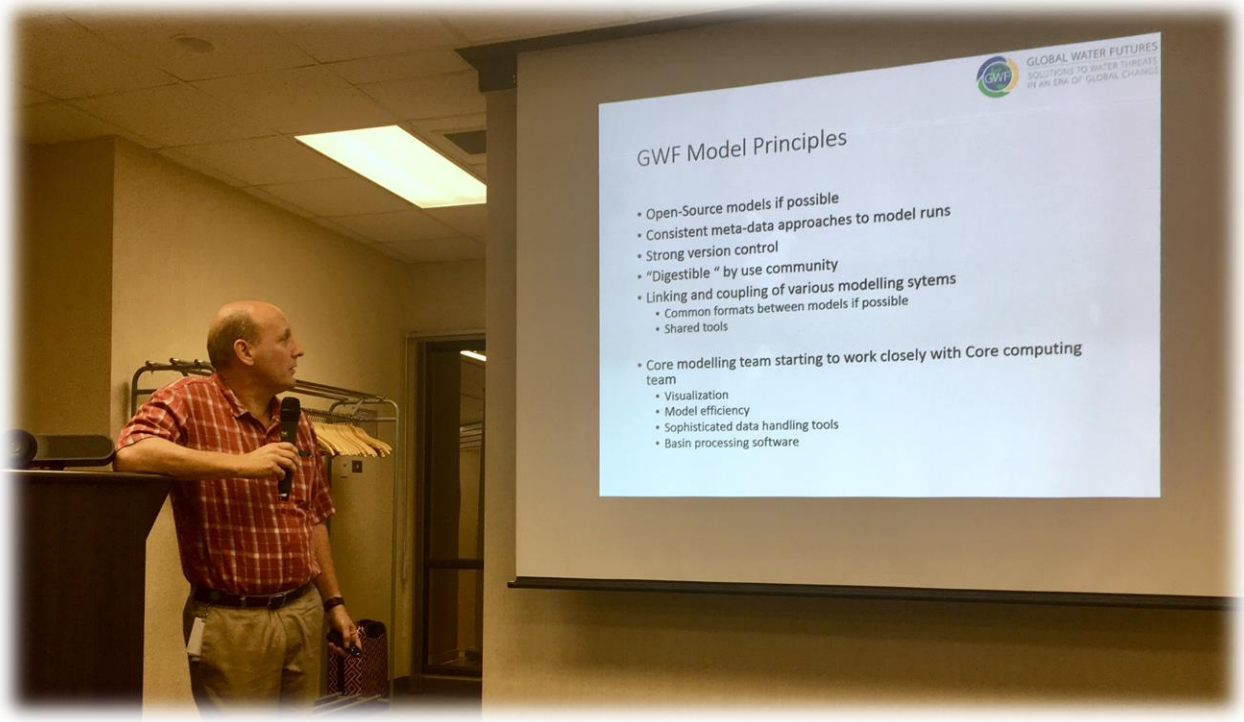
Howard Wheater reporting:
One of the things that came out from one of the hydropower companies is how far reaching adaptation issues are for their business? They are not only concerned about the future of water flows but the future of energy markets, both in Canada and the U.S. So there are really a lot of different aspects of the adaptation problem.

Al Pietroniro brought some of the realities where science gets to and politics takes over, and one of the messages from what he said is that if we need to capture enough confidence in our projections to be really convincing in the political arena, we need to be somehow be sure about the range of uncertainty around our projections, which is very difficult given the complexity of our models and the large scale we deal with.

There's a point raised from CCRN (Changing Cold Region Networks) group about building scenarios. To build future scenarios takes us well beyond our modelling capability, so we have to look at what our climate will respond, the water will respond, agriculture will respond, how human management will respond. That takes us into the process of facilitating discussions between experts and bridging gaps between distant disciplines. The experience from the CCRN is that focussing on the challenges in 50-years time frame is really a good way to bring communities together and talk about what we can share. It's a real positive, integrated question that can help us bring the community together.

Presentations on Day Two

The second day of the IMPC annual meeting opened with a remembrance for Ric Soulis and Ric Janowicz, two members of the extended researcher and collaborator community that recently passed away. Then, Martyn Clark, a researcher with the National Center for Atmospheric Research presented his vision for continental hydrological prediction. The day continued with lead researchers for Theme A – Integrated Earth Systems Modelling – providing an overview of progress during year one of the IMPC and GWF research programs. Similar to Day One, the afternoon focused on interactive sessions including a Poster "Speed Dating" session for HQP to showcase progress and a modelling panel made up of collaborator and investigator representatives.



GWF Core Modelling lead Al Pietroniro discusses GWF Modelling Principles.

Discussions for Theme A

Al Pietroniro discussed how the GWF team is pursuing similar work to those projects mentioned by Martyn Clark on modelling, but suggested that we should do them in a more systematic way for better results. He also noted that we can benefit from some of the possible correlations between geomorphological and land cover features in setting up our models.

Howard Wheater mentioned that the biggest source of uncertainty in all our modelling is input uncertainty and the community is trying to recognize that. This uncertainty is quite profound especially with future climate products where there are also biases involved. This uncertainty really drives the characterization between different weather products and is one of the most profound challenges we have in the science of modelling.

Bryan Tolson highlighted the work at University of Waterloo where input uncertainty is being addressed using ensembles of a product. Martyn Clark agreed, noting that we are considering developing a probabilistic product in Canada where GEM-CaPA can be used as the base.

In response to question by Graham Strickert, Karl Lindenschmidt explained that he is still conducting numerical experiments to capture a fairly dangerous ice-jam flooding event on the North Saskatchewan River about 3-4 years ago, where a surge reached a dam and raised the water levels up to half a meter.

Presentations

- **Vision for Continental Hydrological Prediction** (*Martyn Clark)*
- **GWF Core Modelling Team (***Al Pietroniro)*
- **High-Resolution Atmospheric Modelling (***Yanping Li)*
- **Improving Hydrologic Process Representations** (*John Pomeroy)*
- **Water Quality and River Ice (***Karl Lindenschmidt)*
- **Model Inter-Comparison and Multi-Model Analysis (***Bryan Tolson)*
- **HYPE Modelling in the Nelson River basin: A multi-model assessment (***Trish Stadnyk)*
- **GEM-Hydro (***Vincent Vionnet)*
- **MESH (***Dan Princz***)**
- **VIC** (*Shervan Gharari*)
- **Floodplain Mapping (**Amin Elshorbagy)
- **Uncertainty Characterization in Modelling** (Saman*Razavi*)

In response to a question by Trish Stadnyk, John Pomeroy pointed out that there was a substantial effort several decades ago in the Mackenzie GEWEX study on modelling the frozen soil, with tests in the Yukon and Saskatchewan. The results have been incorporated into MESH and are shown to dramatically improve the results, especially over the South Saskatchewan river basin. He also mentioned that Andrew Ireson is conducting active research to improve algorithms for frozen soil. John also added that there is ongoing work on permafrost representation in CRHM and MESH that are being tested at some sites around Inuvik.

Howard Wheater emphasized the strategic need within GWF to consider a formal structure for incorporating small scale algorithms into large scale applications. Algorithms developed at a small scale can't simply get embed into large scale models, because (a) they're complex and time-consuming, and (b) very often for such models at large scales we don't have the appropriate supporting data and the uncertainty is large. He also mentioned that while this was a goal of the Changing Cold Regions Network, it was never reached, mainly for logistical reasons. He suggested many publications can originate from such work addressing process complexity vs. large scale model applications. John Pomeroy and Al Pietroniro agreed and suggested follow up meetings to consider this. Along the same lines, Martyn Clark added that representing the spatial complexity of the real world efficiently given its computational cost is also a big challenge.

In response to Bin Luo's point about some communities being interested in riverbed scour, Karl Lindenschmidt mentioned this is something that can be considered as the next step if there is a pressing need from many people.

In response to a question by Simon Papalexiou on why parameter estimation is a physics problem, Martyn Clark explained that there is normally two extreme approaches; one that considers parameters responsible for representing physical characteristics of a system in contrast to the engineering type of approach to model calibration, where parameters are considered as a bunch of knobs in our models that we can tweak to fit the hydrograph, but not necessarily getting the right answers for the right reason. The question then becomes how we can move beyond that taking advantage of physical understanding during parameter calibration. There are two approaches that we can use; one is to explicitly simulate the dynamics of change using geomorphological theory or vegetation growth for example. The other approach involves using the available data and conducting a process-oriented calibration framework to reduce the parameter uncertainty in our

models. Examples of that is the diagnostic signature approach, where we can define diagnostic signatures for various model components and use that during parameter estimation. This approach moves away from the idea that we treat optimization as a black box and tries to introduce physics into the process.

Bryan Tolson raised the issue that by formulating the calibration problem differently with signatures and everything, the optimization problem becomes harder. Martyn Clark agreed with that but added that many of linkages between model parameters and model processes in optimization need to be considered in advance. He also mentioned that when numerical methods inside the models are improved and models are implemented correctly, it can have a great impact in optimization that was not available before.

Along the same lines, John Pomeroy also explained that this is an ecological process as well. Because we don't have continuously variable parameters across the landscape that are grouped together in any specific way. In many parts of Canada, we have a natural environment or a human environment that's been managed in particular ways - there may be pine trees over sand, spruce trees over clay, or large trees in wetlands. These are certain assemblies and we can cluster certain eco-zones and certain environments and certain groups of parameters that tend to occur together and this helps tremendously. This is kind of the concept behind the Group Response Unit (GRU) approach, and we use what we call the ecozone approach to design the model structures and select parameters as well. This allows the successful transfer of a parameter 1000 kilometers from one research basin area to a model application somewhere else. While this is not the nearest parameter, it is similar it is in its function. We also have to consider the hydro-ecology of these systems to use this approach, and that usually involves observations and understanding rather than modelling at this point, and we have a wealth of these things around the country.

In response to a question by Fisaha Unduche, Al Pietroniro clarified that there is a budget in ECCC for a many initiatives including infrastructure, recruiting, and predication, which on the federal side is in the $25 million range. This budget means a new, permanent set of staff in the CMC that will actually work on hydrological prediction, or the water cycle. He mentioned there is no capacity within ECCC to look at model structure per se, and they lean heavily on the group here to help building infrastructure into the models to make sure that the wiring is good, and they're going to reach out to the provinces over the next five years and make sure that the models are meeting their needs. The federal government is not developing a flood forecasting system, it is working with the provinces to develop one.

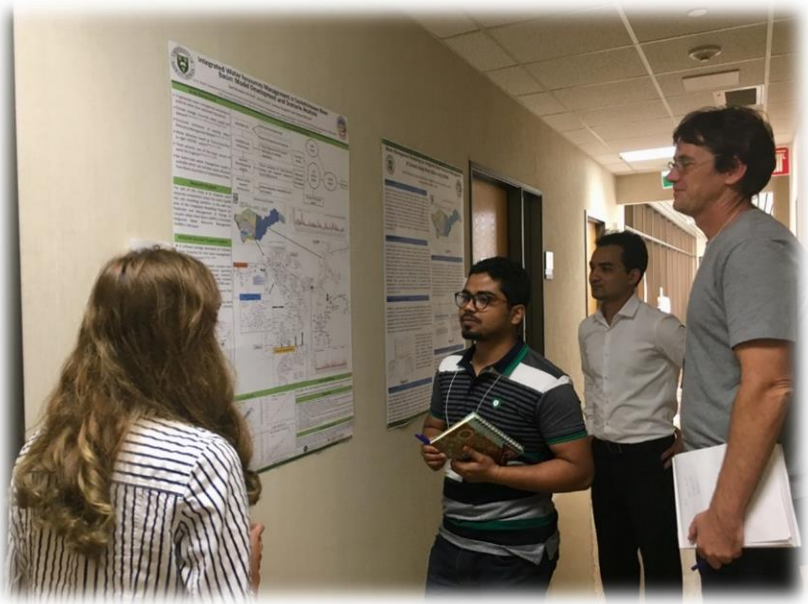
In response to a question from Pat Gober about how we can effectively communicate about uncertainty with the public and stakeholder community, Martyn Clark pointed to a 7-yr project, where the funding organization, representing a stakeholder community, found the wide range of uncertainty very debilitating and upsetting. In that project the impact of some methodological choices were evaluated around the portrayal of climate change and it was found that the choice of downscaling mixed with the choice of spatial downscaling and the choice of hydrological model, in terms of model structure and how it's parameterized, can change the sign of climate change. Martyn explained that is why the messaging was really important because the uncertainty has always been there and no uncertainty was added to the problem, but communicating this is important to prevent over-confidence in the risk assessments. Also, evaluating a wide range of storylines is very important. That is part of the reason why his group developed the multiple hypothesis modelling framework, and also because the human cost of implementing multiple models is extraordinary. This framework can mimic the behaviour of multiple models under one framework, and then provide a wide range of hydrological storylines.

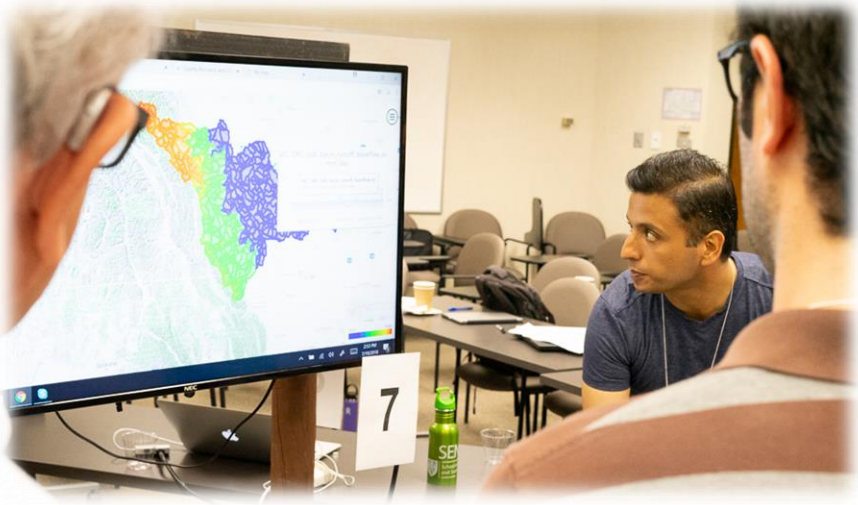
Two main challenges were discussed on flood frequency analysis between Amin Elshorbagy and Howard Wheater. The first one is that simulated flows will always have less variability than the observed flows, so it

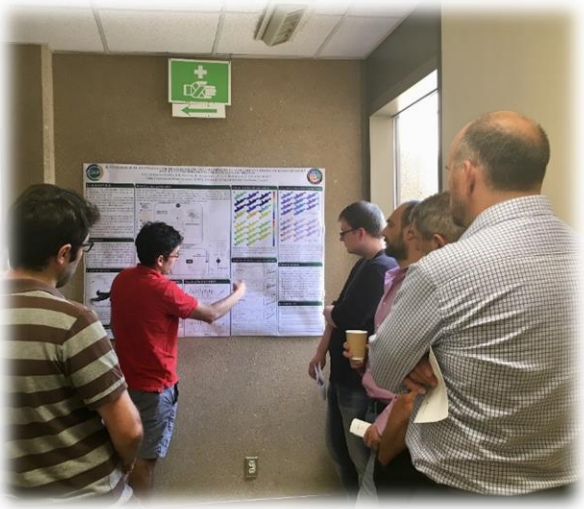
would be important to somehow preserve the variance of observed flows. The other one is that finding the relationship between floods and some other variables such as soil moisture and rain on snow condition is not always easy because there is not enough historical data available.

In response to a question on CaPA from Fisaha Unduche, Vincent Vionnet explained that the 2.5 km CaPA product integrates data from gauges and can improve as more data become available. There is also a CaPA reanalysis data being generated that extends back to about 30 years for better analysis purposes. Al Pietroniro also mentioned that ECCC is trying to make CaPA consistently available and can perhaps think of a software where people can modify CaPA data as they need.

“Science Speed Dating” Poster and Presentation Session







Modelling Panel (Investigator and Collaborator Representatives)

Panelists:

- **John Fahlman**: Vice-president of Technical Services, Water Security Agency of Saskatchewan. Area of service include hydrology, hydrogeology, forecasting, hydrometrics, dam safety, infrastructure, and engineering services.
- **Al Pietroniro**: Executive Director, National Hydrological Service for Canada, which includes the Water Survey. Also the GWF Core Modelling Team Lead.
- **Anil Gupta**: Director, Integrated Environmental Analytics and Predictions, Monitoring and Science Division, Alberta Environment and Parks, Calgary.
- **Bin Luo**: Senior Hydrologic Engineer, Manitoba Infrastructure.
- **Amin Elshorbagy**: Professor, Water Resources, Dept. of Civil Engineering, University of Saskatchewan.

Facilitator:

- **Saman Razavi**: IMPC Primary Investigator, Assistant Professor, Global Institute for Water Security, University of Saskatchewan.

Question 1: What do you see as the biggest challenge in prediction and management of future water resources in Canada?

John Fahlman: The biggest challenge in prediction and management of future water resources would be trying characterize the variability and non-stationarity. This is something we have been doing for the past 30-40 years, especially in Western Canada. The better we can nail that down going forward, the better we can make decisions based on that. So my question is always: “The bounds are changing, what are the new bounds?”

Al Pietroniro: We have had kind of a fragmented approach over the years where, as Howard Wheater phrased it, Modeller A is modelling Model B on Basin C, and Modeller D on basin E. I think the biggest challenge, which I’d argue we’re addressing at least within GWF and in Canada, is trying to bring that all together somehow into one framework. Also, to make sure we’re dealing with the users’ needs, which is what I really like about GWF as well.

Anil Gupta: There are two main trails for scenario prediction: climate change and land-use and land cover change due to natural or anthropogenic activity. Using these predictions, we will be able to develop better environmental policies, and adaptation and mitigation strategies. So the biggest challenge, I think it is to have a multi-model approach, because some people might not agree with the predictions done by one model or one group. So if we have, right from the start, a good understanding of what kind of modelling framework we are going to use for these kind of predictions in the future, then I think we will be able to make some kind of helpful strategy.

Bin Luo: My idea is quite similar to Anil. I think the big challenge is how to project the future under global change in environment, in climate, and in the world’s economic landscape. One example of climate change that is very recent in Winnipeg, is simultaneous flooding in both Assiniboine River Basin and Red River Basin. This was similar to what happened in June 2014 when peak flow was generated and a second rain storm hit in the Winnipeg River Basin, which created a record peak flow that the city was not prepared for. We are spending $600 million to expand the floodway and this is a half-billion dollar question. The second part is the

global change in the economy. About 30% of GDP is export of agricultural products, and like in Manitoba and Kelowna, 80% goes to Asia. So as the population grows in developing countries, they start to consume more food. So then you need to upscale the agricultural drainage system and water quality system, and perhaps pump some water from the U.S.A. This is why we need to gain better understanding, but it's still uncertain in the future.

Amin Elshorbagy: We have good models that sometimes answer good important questions such as streamflow forecasting. But our models fall short in answering some important questions for some policy-makers or even for some technical people. In SaskPower for example; it's not SaskHydro and the tradeoffs between irrigation and hydropower is not as important for them because they use natural gas and coal. So our current work falls short of analyzing their situation. Because they would like to put that in the bigger frame of their own economy. People, especially politicians, integrate information sources and they need to ensure there are water, food, and energy resources to people and water is just providing a service here. We run our water resources models as supply-driven, but we need to think in demand-driven and show people how we can make a difference to the water, food and energy nexus.

Bin Luo (Manitoba Infrastructure) speaks during the Investigator-Collaborator Panel in the IMPC Annual General Meeting. From left to right: Amin Elshorbagy, Bin Luo, Ani Gupta, Al Pietroniro, and John Fahlman.

Question 2: From your organization point of view, what are the most important things to achieve in the next year for IMPC and GWF in general?

John Fahlman: The Water Security Agency is interested in applied science, in a technical, social, political world. So what's the most important thing is just keep moving things forward towards the integrated modelling. For example, for operating Lake Diefenbaker, let's look at the water supply, hydrometrics, economics, environmental flows, and cultural aspects from Cumberland House. So, every five years there is another operational manual out. We'll put the first one out and in the next five years with the initiation of integrated modelling we'll start working on making it better.

Al Pietroniro: From National Hydrological Service's perspective, we're going to start developing a national water model, and we're partnering with the provinces on this and so we got 5 years to do this; that's what

cabinet asked us to do. Part of the reason we partnered with GWF is to have the intellectual capacity to do this, because we don't have a federal team. The way I'm looking at it now, we're going to have to narrow this down into something that's doable for us form an Environment Canada perspective, and really just figure out the design characteristics we want from our GEM-Hydro and MESH systems. The real challenge is to scope it down in terms of the model development over the next five years, to ensure we're choosing the right pieces with the right model design. That's the grand challenge for us, and this is the place, this is the group here to make that happen.

Anil Gupta: From an Alberta Environment and Parks perspective, one of the things that comes to mind is raising the profile of modelling with decision-makers. Senior leadership teams in different organizations should become aware of the power of modelling and how modelling can support some different decisions in the terms of policy or writing policy. The second thing is to integrate some kind of baseline data for various modelling practices that would be a huge benefit to all. Without knowing the limitations and how those data types are created, we just go and grab the data and use those data in hydrological model and produce some outputs. That doesn't provide any confidence to the decision-maker because they get different results from different models and they don't know what is right and what is wrong.

Bin Luo: Our department is largely an engineering and operational unit. So we want to use the models you develop as a quickly as possible, and lobby our opinion and continue the support of research and development. This is very important. Every year they cut funding and we say, don't do it. And then they cut it again.

Amin Elshorbagy: From my point of view, as emphasized by others as well, the most important thing to focus on taking some case studies and show that what our final integrated output will look like. Then our partners will be able to give us some solid feedback if this is useful or not and this will direct me.

Question 3: How do you think we should incorporate uncertainty into the decision-making and how, in general, do you think we should talk about uncertainty?

Amin Elshorbagy: In Canada, there is this approach called PPC, Public Infrastructure Evaluation of Vulnerability. They use a chart with X and Y; X is seven categories of probability of the event, and Y is the severity of the consequences from 1 to 7. So, if you end up with 49, 7 by 7, that's something that requires immediate attention. So, I think no matter how thorough and sophisticated our uncertainty analysis is, if we can translate it to a chart like this, anybody, even administrative municipalities, everybody will be able to look at this and understand it. This simple chart founded on solid science, is a way to communicate uncertainty very well; i.e., using discrete categories instead of probability distributions.

Bin Luo: For our department, in terms of my work, we have become more conservative, for example we raised our flood protection from a 100 year event to a 200 year event. The second is for bridge design, we used to design for a 50 year event and now we use a 100 year event. And now we use instantaneous peak as opposed to daily peak because it is much higher. So we add a lot of money to the system, and have become more conservative.

Anil Gupta: With respect to uncertainty in decision-making, I don't think a decision can be made if things are uncertain. I don't think decision-makers realize we are not sure. So we need to translate uncertainty in terms of a risk framework, for example to human health, to damaging the property, etc. And then the risk function

can be used for decision making. If it is a high risk, decision-makers will be cautious making some kind of decision. If it is low, doesn't matter.

Al Pietroniro: I agree with the previous speaker; the last thing you want to tell a politician is that you're not sure. Because they'll say: "Why do I pay you?" So you really have to articulate what we understand from an engineering perspective as something uncertain, to a decision-making framework where they can ask "what do you know?" So we really have the task to say this is what we know, these are some of the risks we see down the road, and we're going to give you three options. And one is always a political one. So our job is to take uncertainty, communicate the engineering options with the associated risks with a certain degree of certainty, and then let the political machine make the decision. On the hydrometrics, I'm really pushing hard in our program to put uncertainty bands on our flow measurements, which is really difficult to do, but we need to do it.

John Fahlman: I think the people that went before me did all the answering. But I was thinking "which uncertainty?" We have technical uncertainty, we have economic uncertainty, we have social uncertainty, we're dealing with them all the time. We're quantifiable in making these risk assessments objectively in our Dam program. It's a way of tracking whether the money you're applying to a program is delivering results. We're relying on our human professional experts and institutional knowledge and experience, heavily weighted toward risk aversion and probably biased towards our own personal values. How can models facilitate adaptive management? By quantifying the risk assessment. People will make reasonable decisions based on scientific fact and knowledge. If I quantify uncertainty and risk, then I can explain that to a decision-maker, they might accept it. And it can depend on how you frame it.

Follow-up questions and comments from the audience

With regards to communicating uncertain results, Bob Halliday made a comment that as scientists and engineers, in many cases, if you are the person who knows, you owe it to the person you're talking to, to give them your best professional opinion. Sometimes all the politician or the senior official wants to hear can be your best professional judgement. We shouldn't get too dug into giving an answer within a couple of sigma.

Along the same lines, Amin Haghnegahdar advocated for a harder push from scientists to bridge the gap with decision-makers and politicians to make a better impact, and suggested framing the work around 3 elements of environment, economy and society as an effective strategy for this purpose. This is something that can be achieved as a key aspect of integrated modelling.

Al Pietroniro also commented that a lot of decision-making is based on trust. There's a lot to be said for engagement and trust-building with decision-makers. And I think that's not seen with politicians. There is also an element of due diligence that you have to go through with these studies. We've got to be able to go and say we looked at the best possible models we could to come up with a bunch of different scenarios for reservoir management to work with our partners to come up with something and say we did the best we could. So trust and due diligence are critical in decision-making at the working level, and that translates up to others.

In response to Fisaha Unduche regarding GWF activities internationally beyond Canada, Al Pietroniro mentioned the program is Global Water Futures— so the idea is to go global. It is early days in the program, but we've got a lot of uptake from various countries, and John Pomeroy mentioned the connection with

GEWEX. We'll influence globally in two ways: one is through publications, papers, and meetings. And the other is an outreach component, where we're looking to work with other agencies in least developed countries or in modern countries. I think that's going to mature over the next 6 years or so and that's part of the hope with the CFREF program spinoffs; maybe down the road there are consultants coming out of this, and I think there's a bit of an expectation on the federal government side with the CFREF funding.

Furthermore, Howard Wheater added that there's a lot going on that has not been reported particularly in this meeting. GWF is part of the Global Climate Research Programme, and they're very interested in Northern environments, so we have a lot of data and observations available for that community. Some of the work we've been doing with large scale models is part of that global program. John Pomeroy is leading International Network for Alpine Research Catchment Hydrology initiative that brings together alpine catchment hydrology from around the world. His partners include most of Europe around the Alps and a couple countries in South America, the Himalayas, the southern plateau, and the U.S. and Canadian Rockies. So there's quite a community there to understand the changes in mountains and increase the capability to predict. In terms of the water management side, we have ambitions as a global program to collaborate with the Future Earth program on some activities around sustainable water management. We're also trying to do joint projects in China, India, and Iran, and a couple other countries.

In response to another point raised by Fisaha Unduche on dealing with drainage issue in Saskatchewan and the fact that this is also changing over the years, Al Pietroniro pointed to the Souris River Basin study where drainage is always a tough issue and there was a lot of public engagement. People wanted to know how we deal with drainage and our take on it for the study, which was an extremely complex, site-specific issue, which is difficult to resolve with the current suite of models that we have. We'll do a state-of-the-art map of drainage in Souris study but we're not sure how to look at it systematically with the scales we're working at GWF and IMPC. We are not trying to deal with it explicitly in the model because it's too complicated at thit stage. Al envisions this as something for phase two of GWF where we could look at it more seriously. There's also the sub-surface drainage issue predominant in Manitoba and a lot of Ontario and Quebec, and we do have to deal with it as well.

John Fahlman mentioned that land use and its effects on hydrology is one of the non-stationarities, and as practitioners we don't have a good handle on it. We work with historical data not accounting for non-stationarities from land use change. As far as drainage goes, there has been extensive drainage developed over the decades, especially in Saskatchewan and Manitoba. The difference between Saskatchewan and Manitoba is that Manitoba is already drained. That's another opportunity for integrated modelling to look at the hydrology and the water quality of drainage, tied to economics and cultural and environmental impacts. See who's benefitting and who's paying the cost of this. And then you get a dialogue out there based on fact and reason.

Howard Wheater pointed out that GWF is a large program. There is the Core Modelling Team and IMPC specifically about modelling. But there are 13 other user-led projects dealing with different issues. One of those is on agriculture, and one of those is on the Prairie landscape, with quite a strong focus on drainage. So one of the challenges we've got is that they are not represented here, so maybe that's something we should think about in the future.

Hayley Carlson asked panelists to identify water management challenges in the Nelson-Churchill Basin that have a lot of disagreement between stakeholders around how they should be addressed.

Bin Luo: One challenge is we have a lot of issues with First Nations groups, especially with my group. So as the government, we are the stewards and the judge between communities and hydrological corporations. It's a long-term problem that cannot be solved with money or in court. The second is that our waterways are highly regulated in Manitoba, and this will have a long-term impact on ecosystems, especially in lakes, and swamps. We drain all the water and it's gone. Some people say we should let the lake fluctuate naturally, otherwise the lake will be dead in 100-200 years like in other countries. This is a huge problem, we don't know how to do it, nobody knows.

John Fahlman: I completely agree on the First Nations aspect. It seems we're getting better at engagement, but I don't know what the next level is. A lot of it is just treated as checking a box and then you're done. But what's next after that? We need some help with that. One other thing I can think of, anything within the Nelson-Churchill that crosses borders still requires a lot of cooperation on many levels; we can always do better, so anything that helps us integrate decision-making would help.

Simon Papalexiou raised the issue of variability versus change and the fact that some of the changes that we observe are perhaps just part of a natural variability.

Al Pietroniro: We are in the land of extremes. The Souris River Basin is probably the most extreme in Canada by far. Everything is a distribution here, you go from two months of drought to two months of rain, and stuff we've never seen before. I don't know how you deal with that from a climate perspective because only about 120 years of data are available. And the other characteristic here is that it's a very recently deglaciated landscape, so there's a lot of things that we just don't understand about hydrology as well. I don't know how to articulate these things, but change is what we live with, change is what we deal with all the time, whether climate change or climate variability, however you want to phrase it. We've seen such extremes historically, we know they've existed from tree-ring analysis, but climate change wraps around all that. It's more extreme than all of that.

John Fahlman: That's great that you mentioned that, because we are one of the craziest hydrological landscapes for variation. There was that variation long before carbon fuel. I remember way back when I was a young grad student, and climate change science was just getting going, I got a question—someone was writing a paper out of Ryerson and they were asking us practitioners, "what are you going to do about climate change?" and my boss came to me and I said, whatever, "we deal with variation like this." Everything we do to deal with variability now, well it might add to that. In the prairies at least the variability of water has been dealt with since we've been dealing with water. We just have to ramp it up.

Bin Luo: I deal with hydrology, the whole system and infrastructure you have is based on probability. But the question is what of the future would look like? The hydrology is a cycle, but we don't have long enough data to properly analyze that. If it's a cycle, what's the mechanism to control that cycle? Why does it work in this cycle? I think these questions are the ones the scientific community can answer.

Anil Gupta: We don't have a long enough history on record, whatever changes we are detecting, that might just be natural variability and might not be climate change. And with climate change we are also talking about climate variability. I don't think we have a good understanding of all the variability that's going to happen in the future.

Fisaha Unduche then pointed out that we have both variability and change. If we look at the Assiniboine River in last 110 years, we see a shift in snowmelt time but also the natural variability with wet and dry cycles.

In conclusion, John Fahlman noted that in his perspective as a collaborator with the project, the best way to engage with people is to make it about them and try to solve their problems in real world. User engagement should be about how your initiative is going to help your stakeholder in their world.

Inspiring Remarks from Gary Carriere, Cumberland House Community

"I'm going to take this opportunity to thank you for the invitation, and I see the importance of becoming partners. I'm very thankful that I'm here, and I'm very thankful that the Saskatchewan River Delta is part of the modelling. Millions and millions of birds depend on that lake and billions and billions of aquatic creatures depend on that lake. People, we're the ones who came and invaded the wildlife and their land. And I think we have to respect that. Us people have water treatment plants, but the wildlife don't. And we keep pumping a lot of chemicals into the river systems. I've been working with scientists for 35 years and I hear a lot of stuff. So I know that the drought is coming, and irrigation is happening, and a lot more things are going to happen in the future here. I know we've learned from our end. It is a wake up call to realize how small this world is. Seven billion people are living now and where are we fifty years from now? And there are so many important things to be modelled. This modelling is so important. No matter how hard we try to be as friendly to the environment as possible, we know the world will always be impacted by us. I'm thankful that there's some people out here who are trying to bring awareness to the rest of the world on what's happening to the planet. I know these things are going to happen and then we start realizing how sacred that water is. And I know you guys have come to realize that, but there's still a bigger group of people that don't understand that and we need to reach out to. I thank you for this opportunity and keep up the good work."

Concluding Remarks by Howard Wheater

"*It's been a spectacularly good two days. I just wanted to emphasize a few things:*

- *The first thing is that we've really created a community here, I'd like to express our thanks to all those that are here wearing a stakeholder hat for giving us their time, it's been a really rich experiences from their insight and comments from them.*

- *Pat Gober set the scene for how important it is to see things from a decision-maker or stakeholder perspective. And then we've worked through the two days, and finished up with a panel re-emphasizing those points. So we can fuss, and we do fuss, about uncertainty in our hydrological models and how many angels are dancing on the pinhead of methods of modelling uncertainty, but ultimately it's communication with stakeholders. And we have to think of simple language, and to make things real for people. So we've been hugely enriched. And it's been really nice to have Gary from the Cumberland*

House community here with his very heartfelt remarks. We're not really talking about abstract here, we're talking about people's lives and communities and cultural heritage. So it's important stuff.

- *A lot of the challenges in the GWF program and the modelling aspects are bringing people together, and the integration is a big part of the title of IMPC. We've started on that road, and I hope that, like me, you've learned a lot. So we've talked about integrating stakeholders and they've been embedded in the discussions and providing useful guidance. But we've started to learn about different parts of the research community and how they can contribute to integration. For example, Roy Brouwer told us about the first steps in moving forward in hydro-economic modelling and the real challenges that we've got in providing essential data sets to allow that work to move forward.*

- *We also had some very interesting insights from the users about how wide-ranging some of the decision processes are. Two examples came out from the hydro sector, that when they're thinking about uncertainty, they're certainly thinking about climate and water, but they're also thinking about uncertainty in demand and how that plays out in a regional and even an international context because that effects their market. So there's a lesson for us that we mustn't bury our heads in the sand, we really have to recognize that many sectors of our communities and certainly commercial and agricultural sectors are dealing in global markets. And that's an element that we have to reflect in our decision-making. There was a plea, I think, for our models to be more useful, because they fail to tackle some of the important problems and that's a challenge for us.*

- *I was struck by the fact that we had a lot of hydrology, and the focus on water resources was still quite limited. The focus on economics was quite limited too and we really had no water quality. Not because we don't want water quality, it's quite critical, but it's partly because delay in staffing up our program, but also because we don't have just the core modelling and IMPC. We have more people working and we didn't have them all today. So maybe a challenge for the future is how to make sure we connect with some of the other programs that are relevant.*

- *I think a big domestic challenge is how to integrate our efforts, because we've got fantastic resources, but we're still in danger of doing Research A with Model B in Catchment C. We should start pulling people together on case studies, and really that's the way people start working together and understanding each other and making progress.*

- *I'll just close with a wise remark from Bob Halliday and Al Pietroniro. It's all about building trust, and how when you stand up in court, you're giving your professional opinion. I think in the modelling community we tend to get stuck in the weeds of our models, and we know that our models are wrong, and the question is how useful are those models and how credible? When we start to think into the future, we are structuring those models way beyond where they can go. So if we want to know more about future flows in the Mackenzie Basin in 2080, we're thinking about permafrost thaw, landscape change, most of the glaciers will have gone, the shrub tundra will have greened, the composition of the boreal forest will have changed. And we can't model all those things. We have to bring in experts to communicate with other parts of the scientific community to draw on that expertise, and ultimately it's our best shot. We have had very insightful conversations about uncertainty from the user community: keep it simple.*

- *We've had a great two days. IMPC has its challenges, there are scientific challenges, there are management challenges, but we've made a great start and the prospects are really exciting."*

Agenda

Integrated Modelling Program for Canada (IMPC) First Annual Meeting
July 18-19, 2018
National Hydrology Research Centre
11 Innovation Boulevard, Saskatoon, SK

Day 1: Wednesday, July 18th, 2018		
8:00-8:30	**Registration and Refreshments**	
Opening, Chair: Razavi		
8:30-8:45	Welcome, IMPC overview, meeting agenda	Razavi
8:45-9:00	Global Water Futures: Year one progress	Pomeroy
9:00-9:10	Remarks from the Strategic Advisor to GWF	Wheater
9:10-10:00	Water management challenges, scenarios and decision-support (C1) (Presentation and Interactive Session)	Gober
10:00-10:20	**Coffee Break**	
Themes B-D, Chair: Stadnyk		
10:20-10:35	Water resources modelling (B1)	Razavi
10:35-10:50	Water resources modelling - Manitoba (Nelson-Churchill)	Asadzadeh
10:50-11:05	Hydro-economic modelling (B3)	Brouwer
11:05-11:20	Cultural and environmental flows, and user engagement (D1)	Strickert
11:20-11:35	Advanced visualization tools (D2)	Gutwin
11:35-12:00	Discussion	Stadnyk (Moderator)
12:00-13:00	**Lunch Break**	
Management & Knowledge Mobilization, Chair: Brouwer		
13:00-13:15	User engagement and knowledge mobilization	Carlson
13:15-13:25	Report from knowledge mobilization committee (KMOC)	Renouf/Halliday
13:25-13:30	Café discussion table explanation and break-out	Carlson
13:30-15:10	Café discussions for Theme B-D (see instructions on page 3)	All
15:10-15:40	**Coffee Break**	
15:40-15:55	Project management	Haghnegahdar
15:55-16:30	Report back from Café tables – Starting from Table 1	Table Leaders
16:30-	Closing Remarks, Day 1	Razavi
17:30 – Dinner @ Louis'		

Day 2: Thursday, July 19, 2018		
8:00-8:30	**Refreshments**	
Theme A, Chair: Pomeroy		
8:30-8:40	In memory of Ric Soulis and Ric Janowicz	Pietroniro, Pomeroy
8:40-9:10	Vision for continental hydrological prediction	Clark
9:10-9:20	GWF core modelling team	Pietroniro
9:20-9:35	High-resolution atmospheric modelling (A1)	Li
9:35-9:50	Improving hydrologic process representations (A2)	Pomeroy
9:50-10:05	Water quality and river ice (A3 and A4)	Lindenschmidt
10:15-10:30	Discussion	Pomeroy (moderator)
10:30-10:45	**Coffee Break**	
Theme A (Cont'd), Chair: Pietroniro		
10:45-11:00	Model inter-comparison and multi-model analysis (A5)	Tolson/Mai
11:00-11:20	HYPE modelling in the Nelson River basin: A multi-model assessment (A5 and A2)	Stadnyk
11:20-11:30	GEM-Hydro	Vionnet
11:30-11:40	MESH	Princz/Pietroniro
11:40-11:50	VIC	Gharari/Razavi
11:50-12:05	Floodplain mapping (A6)	Elshorbagy
12:05-12:20	Uncertainty characterization in modelling (A7)	Razavi
12:20-12:35	Discussion	Pietroniro (moderator)
12:35-13:30	**Lunch Break**	
13:30-14:30	'Science Speed Dating': Poster and Presentation Session	HQPs
14:30-15:00	**Coffee Break and Poster Follow-Up**	
15:00-16:00	Modelling Panel (Investigator and Collaborator Representatives)	Fahlman, Luo, Gupta, Pietroniro, Elshorbagy
16:00-16:30	Discussion and Synthesis	Wheater (moderator)
16:30-	Concluding Remarks, Day 2	Razavi