A Climate Change Guidance Framework for IJC Boards

A guide for IJC control, watershed, and pilot watershed boards to address climate change within their mandates

February 27, 2017

This document is meant to initiate a larger effort to design an International Joint Commission (IJC) strategy to supports its control, watershed, and pilot watershed Boards' efforts in addressing climate change as it pertains to Board mandates. This draft was reviewed by IJC staff and members of the Climate Adaptation Working Group (CAWG) to identify the issues that need to be addressed within the CAWG during face to face discussions in a workshop November 9-10, 2016 in Ottawa, ON.

There already has been a substantial amount of work done on this subject by IJC Boards, some of it advancing the state of climate science and decision making. There are also IJC climate change initiatives underway now. This proposed framework would encompass information sharing in an effort to connect all this work so the contributions in each region could be made accessible to all Boards.

Executive Summary

As part of its ongoing International Watersheds Initiative, the International Joint Commission (IJC) held a workshop in April 2016 at which its boards identified the need for a framework that would help them prepare for climate change. This document provides a review of the implications of climate change for the IJC and proposes a general framework including a recommended planning guidance method that could be used by IJC control, watershed, and pilot watershed boards. The framework is presented in broad terms; actual implementation of the framework will require further detailed development and piloting.

The goal adopted for the framework is to provide clear guidance to the boards for addressing climate change in IJC policy and operations using the best available institutional and organizational science and stakeholder inputs available to the boards. The purpose of the framework is to provide a process for the IJC to maintain, to the extent reasonably possible, the resilience of IJC's responsible systems such as the ability to continue to maintain ecosystems, economic and social benefits and impacts within preferred ranges in the face of future change and uncertainties.

Discussions held with the IJC, including the IWI April 2016 workshop, helped produce a set of desirable climate change framework attributes. The framework should:

- Be consistent with work conducted at the last two IWI workshops and should complete a baseline review of the existing climate change activities of all IJC boards;
- Consider the social, economic, and ecological impacts triggered by climate change across the transboundary basins where IJC has a mandate, particularly any emerging impacts not currently addressed by IJC Boards. The framework should prioritize the assessment of impacts related to the mandates of IJC Boards using risk analysis and/or other appropriate methods by providing a one framework that can be applied to many boards;
- Identify needed action items for boards by completing a gap analysis – in other words, compare the priorities relative to existing IJC Board activities;
- Develop an adaptive management plan for each board to monitor progress, document and share lessons, and adjust activities and strategies as appropriate.

This document was commissioned for the Climate Adaptation Working Group (CAWG) to consider and discuss.

The framework proposed here has three elements:

1. A recommended planning guidance method;
2. A shared information pool; and
3. Assistance in establishing adaptive management.

The Planning Method

The planning method is central to the framework; the other two elements (i.e. a shared information pool and assistance in establishing adaptive management), will support each Board's successful planning. Many approaches have been used for climate change impact evaluation and adaptation planning in the last twenty years. An initial emphasis on projecting future climate has given way to approaches that focus on first understanding the responsiveness of the system to climate change, describing the context with regard to the full spectrum of possible future uncertainties, and using climate science to inform the analysis, rather than serving as the starting point and focus. The contrast between the early and later approaches is captured in the terminology; downscaling focused on developing local climate projections from global models, decision-scaling starts with an assessment of how climate change might affect outcomes and then considers the plausibility of those changes occurring.

There are a growing number of adaptation or resilience planning methods offered by government agencies or nongovernmental organizations. These methods generally follow common planning approaches, including identification of the problem, cataloging of options, evaluating comparative performance of options and selecting a plan. Examples include the US Climate Resilience Toolkit and the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) "Implementation Framework for Climate Change Adaptation Planning at a Watershed Scale." These provide helpful resources for planners and serve as a basis for the process described here, which is a distillation of the best of these existing planning methods, tailored for application to IJC Board responsibilities, and strengthened with advanced approaches for addressing the uncertainty associated with climate change.

Decision-scaling is designed to make the best use of potentially helpful climate information. It recognizes the uncertainty and hazards of using climate projections and is designed to maximize the useful and credible information that can be gained from them. Given the inevitable importance of climate change to IJC Board activities, and the accompanying inevitable uncertainty, it fits well with the IJCs management responsibilities. Decision-scaling starts with the identification of the most important impacts from climate change, determines the plausibility of those impacts occurring and then frames the evaluation of alternative ways to reduce those risks.

The proposed planning method consists of 4 primary steps: Organize, Analyze, Act, and Update. In the organization step, each Board would formulate its climate change-related objectives and assess what information was available and what was needed to prepare to meet those objectives successfully under a changed climate. The Analysis step includes the formulation, evaluation and ranking of actions each Board might take towards realization of their stated objectives. The Action step includes taking those actions, with whatever changes are necessary to support them. The Update step is adaptive management, the structured improvement of actions based on evidence acquired systematically over time. Specific tasks within each step provide the needed detail for practitioners to implement. When fully developed, the framework would also serve as a resource for implementation by pointing the user to available tools and information sources for assistance in completing each step. This planning method is proposed to be a useful decision-making tool for IJC control, watershed, and pilot watershed boards to propose actions that could be pursued in order to address climate change within their basins and within their mandates.

The Boards need more than climate science to do their jobs. They work with stakeholders to carry out their responsibilities, and the effective communication of climate change management issues and positions will be essential in gaining stakeholder support for climate change initiatives. Trend analysis is often important in monitoring the onset of climate change; the framework must also facilitate Board access to accurate data. It will also be helpful to develop or provide expertise in planning, decision support, and risk management. Some Boards have this expertise, and it could be supplemented at the IJC level, so that all Boards could have access to it.

This document begins by setting the context for this work, the IJC's International Watershed Initiative and summarizes the principles articulated for this work from an April 2016 IWI workshop. A very brief overview of relevant climate change issues is followed by a background description of how water management has evolved to be able to address uncertainty. The next section of the report covers issues more specific to the Boards' missions and related ongoing activities sponsored by the IJC. An outline for the IJC framework is then proposed based on the previous assessments, including a section on the four-step process, along with a process for refining it and carrying it to fruition.

The purpose of this document was to provide the CAWG a starting point for the design of a framework for preparing for the impacts from climate change. The document went through some revisions before being sent to CAWG members before the November 9-10, 2016 workshop in Ottawa. This final document is based on comments made at the workshop as well as on comments and edits provided since the workshop.

The Shared Information Pool

Information exchange has been flagged as an important part of dealing with a large-scale issue such as climate change both at the previous April 2016 Workshop and by the CAWG. This framework promotes the facilitation of the exchange of information across boards to support successful planning by sharing scientific and technical knowledge, pilot projects, and lessons learned in order to identify tools that are currently available to address the impacts of climate change on water quality, as well as tools that may need to be developed to better address this issue. This may be in the form of an online 'information hub' that is accessible to all IJC Board. This 'hub' could allow for an exchange of ideas and as a platform to promote discussion and collaboration among boards on issues being faced from climate change. The role of each IJC board would include updating on their climate change research and activities when possible so other boards are aware of the efforts on the landscape and have an opportunity to discuss and make linkages/comparisons amongst the various efforts occurring across the transboundary.

Assistance in establishing adaptive management

Because change is inevitable and there may be surprises, there is a need to monitor performance and provide feedback to the operation policies so that course corrections can be made. Thus, decisions can be effectively incorporated into adaptive management approaches that allow the performance of the system to be maintained even if it requires transformation of different aspects of the operating policy. This framework discusses adaptive management assistance that could be established to support the Boards' ability to manage climate change.

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I. Introduction: the context for developing this framework

International Joint Commission (IJC) Boards assist the IJC in carrying out activities under references, orders of approval, treaties and agreements. The way the Boards have operated has changed over time as water management generally has become more open and multi-objective. An important milestone in that progression was the creation of the IJC's International Watersheds Initiative, introduced by the Commission in its 1997 report The IJC and the 21st Century.

Back in April 1997, the Canadian and United States governments asked the IJC to propose strategies on meeting the environmental challenges of both countries in the 21st century. Even then, climate change was one of the concerns, along with other drivers such as growth, urbanization, and energy demands. The governments were concerned about a variety of impact categories including water supply, air pollution, toxic chemical use and release, habitat loss and biological diversity, exotic species, waste management, and infrastructure needs.

The Commission responded to this request from governments in its 1997 report "The IJC and the 21st Century" which included five proposals, the first of which was a request for a reference to establish ecosystem based international watershed boards from coast to coast to address boundary disputes about the environment.

It was also in this 1997 report that the IJC introduced the concept of the International Watersheds Initiative (IWI). The initiative addressed in this document is part of the larger watersheds policy initiative.

The governments asked the Commission to further define the international watershed board recommendation. The Commission provided an initial feasibility analysis in December 2000 and a discussion paper in 2005. The IJC's premise in its reporting was that local people, given appropriate assistance, were best positioned to resolve local transboundary issues and that supporting that capability would reduce the need to involve the governments and IJC in more formal dispute resolutions. Through these reports that were fueled by consultations with federal governments, relevant states, provinces, tribes, First Nations, and local interests, the concepts of the IWI and an international watershed board were further developed. In the 2005 report, the IJC also named three boards as the most promising for initial development of an International Watershed Board; the St. Croix, Red River, and Rainy River. In 2007, the Souris River Board was added to the list of pilot boards.

As of 2016, along with the three pilot boards and St. Croix River International Watershed Board, the IJC has an additional nine standing boards and a committee that can carry out IWI-supported projects to help manage resources, promote communication, and conduct scientific studies within their Board mandates.

The third report to governments on the IWI produced in January 2009 included this assessment:

> *IJC Commissioners and staff have been working to strengthen the capacity of these boards, providing catalytic funding for selected projects involving activities such as developing harmonized transboundary watershed maps and geographic information system (GIS) data; modeling river and reservoir hydraulics; and expanding outreach to*

the public. The St. Croix River board has made the greatest progress so far, and in April 2007 was designated the first full-fledged International Watershed Board.

The decision to develop this document stems from an International Watersheds Initiative (IWI) Multi-board Workshop that took place in Washington, D.C. in April 2016. About sixty people, including IJC Commissioners, members from all the IJC's control, watershed and pilot watershed Boards, and Commission staff participated in the workshop at which actions to address impacts from climate change on water quantity and quality in transboundary basins were suggested. There were two breakout group discussion groups, one for water quality and the other for water quantity, but their ideas were very similar and consistent with the IWI perspective. A workshop report that summarizes these discussions is available on the IJC website.

Relevance of this Guidance Framework to the Great Lakes Advisory Boards and the Health Professionals Advisory Board

This climate change guidance framework is intended to support IJC control and watershed boards in their efforts to address climate change as it pertains to their respective board directives. Outside of these boards, there are other boards that fall under the purview of the IJC that may benefit from what is achieved through the framework. Two of these boards are derived from the Great Lakes Water Quality Agreement – the Water Quality Board and the Science Advisory Board (which is composed of two committees, the Science Priority Committee and the Research Coordination Committee) – and one, the Health Professionals Advisory Board, is the result of the reference letters to the IJC. Respectively, their role is to advise the IJC on matters related to the water quality of the Great Lakes and human health concerns along the transboundary region assigned to them in their directives from the IJC. These boards are expected to be made aware of efforts by control and watershed boards consistent with the climate change guidance framework and, where applicable, collaborate on issues of shared concern.

Guiding principles articulated in the April 2016 IWI Workshop

One result of the discussions from both the water quality and water quantity discussion groups was to create a first draft of a climate change framework, which can be used by the IJC's control, watershed and pilot watershed Boards using the following approach:

- Build upon work conducted at the last two IWI workshops and complete a baseline review of the existing climate change activities of all IJC boards;
- Identify and synthesize the social, economic, and ecological impacts triggered by climate change across the transboundary basins where IJC has a mandate, particularly any emerging impacts not currently addressed by IJC Boards;
- Prioritize the social, economic, and ecological impacts relative to the mandates of IJC Boards and the use of risk analysis and/or other appropriate methods;
- Identify needed action items by completing a gap analysis – in other words, compare the priorities relative to existing IJC Board activities;
- Develop an adaptive management plan to monitor progress, document and share lessons, and adjust activities and strategies as appropriate.

The workshop included breakout discussions focusing on water quality and quantity that supported the summary statements above.

IWI Workshop Statement on Impacts from Climate Change on Water Quantity

The water quantity group reviewed a list of actions various Boards have suggested to address climate change identified to date (Table 1) and discussed the utility from their Board's perspective. Many of the projects submitted by the Boards to capture their climate change-related activities were Board specific, so the group shifted gears and started contributing to a new list of work that was broader in nature and would have utility for multiple Boards.

The group identified the work they thought was important for addressing climate change impacts on water quantity. This work was then prioritized (each participant had three dots for voting purposes) with the priority work being identified in bold:

- Implications of climate change on droughts and floods.
- Baseline of climate change activities in the Boards, gap analysis, next steps.
- Climate change impacts on precipitation patterns and timing (snowfall, rainfall, flood parameters).
- Application of Regional Climate Model to all transboundary watersheds.
- Broad framework that focuses on climate change impacts, and how this relates to Boards mandate.
- Systematic monitoring of water temperature and other pertinent parameters (temperature, ice, wind) for assessing impacts from climate change.
- Risk analysis framework to assess implications of changing climate (United States Army Corps of Engineers has such a framework that could serve as a model).
- IJC to coordinate with key agencies to ensure standards and usability of these important data in transboundary basins.

- Tracking socio-economic and environmental changes due to climate change.
- Assess how systems are adapting to climate change.
- Cross-reference issues of concerns with existing IJC mandate (Review of Orders, References).

After further discussions, the group determined that the work items could be structured sequentially as they were interrelated. This resulted in the following order and refinement of the proposed work.

- Perform a baseline review of climate change impacts and related Board activities.
- Assess hydroclimate shifts that will trigger ecological and socio-economic changes in the basin.
- Perform risk analyses of the impacts to address the implications of these climate change-related triggers with respect to Board priorities.
- Develop an IJC/Board response of action items for addressing the prioritized impacts associated with a changing climate relative to water quality.

Breakout Session on Impacts from Climate Change on Water Quality

- Facilitate an exchange of information across boards to share scientific and technical knowledge, pilot projects, and lessons learned. This exercise would help identify tools that are currently available to address the impacts of climate change on water quality, as well as tools that need to be developed to better address this issue.
- Complete a binational baseline study of the impacts from climate change on water quality. This study should integrate indigenous knowledge and should be performed basin-by-basin when appropriate considering the Board's mandate (see Text Box on Elements of a Baseline Study).
- Document, as part of the baseline study, socio-economic impacts to communities, particularly indigenous communities (including impacts to culture, human health, and traditional livelihoods).
- Capture and share best practices for adaptive management in responding to the impacts from climate change on water quality. Some, if not most, of this information could be generated through the exchange of information mentioned above.

The participants consistently referred to several key concepts to inform and shape a comprehensive, practical climate change strategy. They were:

- Employ a "Research to Action" approach to develop and implement a comprehensive IJC/IWI climate change strategy that can be appropriately adapted to individual watersheds.
- Complete an inventory of "what we know" and "what we do not know" as the foundation of any baseline study; this exercise will shed light on "what we need to know" to move forward.
- Harvest lessons from recently completed, ongoing, and future pilot/demonstration projects within selected basins to share knowledge, lessons, technology, and so on with other boards.
- Invest in "action items" that are consistent with existing IJC references and are genuinely bi-national in purpose and scope.
- Integrate the objectives and methods of adaptive management (learning!) in everything IJC does.

Table 1 Actions proposed at the April 2016 IWI workshop to prepare for climate change

Actor	Proposed Action
IJC	Incorporate the most current climate science and climate scenarios from advanced regional climate models into its recent water regulation plan reviews to ensure the robustness of the revised plans to address a changing climate. The Commission will continue this practice as it proceeds to update the orders of approval for all the remaining water control structures (*i.e.,* dams) under its jurisdiction.
	Collaborate with federal agencies and research institutions in the application of advanced regional climate models to transboundary basins to support its boards in understanding climate change impacts on key issues such as water apportionment, nutrient loading and aquatic ecosystem health.
	Implement an adaptive management approach to climate change.
Red River Board	Monitor flood preparedness & mitigation actions identified in "Living with the Red" report.
	Identify in-stream flow needs and establishing minimum flow criteria.
St. Mary and Milk Rivers Accredited Officers	Improve methods for estimating natural flows that consider climate change.
	Simulate altered flows conditions due to climate change; build on existing routing models.
Osoyoos Lake and Columbia River Boards	Improved understanding of climate change impacts on flows and water levels and the implications on regulation (A study addressing climate change impacts was completed in 2011 as part of the Review of Orders).
Rainy-Lake of the Woods Watershed Board	Need a better understanding of how climate change will impact water levels in the system.
Great Lakes-St. Lawrence River Adaptive Management Committee	Develop a strategic plan to guide future climate change investments.
	Need a better understanding of hydro-climatic conditions in the basin.
	Improved understanding of socio-economic and environmental sensitivity to fluctuating water levels is changing in the system.
	Maintain existing predictive tools and develop new ones regarding the impacts of fluctuating water levels.
	Better understanding of how to improve decision making related to transboundary water management through adaptive management.
St. Croix Watershed Board	Climate Change and sea level rise. Analyzing water level data collected at the USGS tide gage would be extremely useful to document trends over time and capture real time storm surges at the mouth of the river.

The workshop participants also recommended that an ad-hoc working group be established to further develop and implement this climate change framework.

Subsequently, the CAWG was formed, including Board members, IJC staff, and Bill Werick and Casey Brown, who have worked on climate change planning issues including some involving the IJC. The current CAWG members are listed in Table 2.

What are the aspects of climate change that are relevant to the Boards' orders and objectives? What techniques have been developed and tested for dealing with other uncertainties? These subjects are introduced on the next two pages and discussed in the body of the document.

Relevant Climate Change Impacts

IJC Boards must consider how climate change could affect the outcomes related to Board responsibilities. Climate change could affect the quantity and timing of water flowing into a basin, the temperature of the water and hence ice cover, evaporation, and suitability for plants and animals including nuisance and invasive species. More severe storms could affect sediment runoff and water quality. Photoperiodism, the response of organisms to hours of sunlight may not synchronize with water and air temperatures as they have, which could disturb life cycles. Climate change may affect evaporation from lakes and reservoirs because of changes not just in temperature but also in cloudiness or wind speed and direction. It may be that increased evaporation reduces the risks of lakeshore flooding, while increased storm severity will increase the risk of flooding along river banks. Higher temperatures will reduce snowpack, which will reduce safe yields of western water systems but may also reduce spring flooding. Exotic species may migrate northward seeking preferred weather and vegetation as weather and vegetation migrate because of climate change. Development pressures may increase as people abandon areas that have become too hot or dry and move to these areas as their warm season extends and the winters become milder.

Table 2. IJC Climate Adaptation Working Group Members

Member	Role
Bruce Davison	Accredited Officers for the St. Mary-Milk Rivers, Canadian representative
Christopher Hilkene	Great Lakes Water Quality Board, Canadian member
Wendy Leger	Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee, Canadian co-chair
Dr. Laurie Chan	Health Professionals Advisory Board, Canadian member
Dr. Pierre-Yves Caux	IJC Ottawa, Director of Sciences and Engineering
Samantha Klaus	IJC Ottawa, Environmental Officer
Dr. David Fay	IJC Ottawa, Senior Engineering Adviser
Dr. Wayne Jenkinson	IJC Ottawa, Senior Engineering Advisor
Dr. Glenn Benoy	IJC Ottawa, Senior Water Quality and Ecosystem Adviser
Dr. Mark Gabriel	IJC Washington, Engineering Advisor
Dr. Mark Colosimo	IJC Washington, Senior Engineering Advisor
Brian Maloney	IJC Washington, Special Assistant
Dr. Jeffrey Arnold	Osooyos Lake Board of Control - U.S. Army Corps of Engineers Representative
Bruno Tassone	Osoyoos Lake, Columbia River, and Kootenay Lake Boards of Control, Canadian Co-Chair
Teika Newton	Rainy-Lake of the Woods Watershed Board Community Advisory Group, Canadian member
Charlene Mason	Rainy-Lake of the Woods Watershed Board, US member
Suzanne Hanson	Rainy-Lake of the Woods Watershed Board, US member
Gregg Wiche	Souris River Board, US member
Shelley Weppler	Souris River Board, US member
Dr. Bob Lent	St. Croix River Board, US member
Bill Appleby	St. Croix River Watershed Board, Canadian Co-chair
Marc Hudon	St. Lawrence River Board of Control, Canadian member
Dr. Casey Brown	University of Massachusetts, Professor
Bill Werick	Water resources planner

Planning and Uncertainty

Planning is about the future and so always about acting despite uncertainty. Although managing water in a changing climate is a relatively new field, there are many useful and informative precedents in the history of water resources planning. For example, water resources planning guidelines in the United States since the 1930s have considered methods to deal with uncertainty quantitatively. Much, but not all of this conceptual approach can still inform climate change decisions.

Relevant history

Although the Corps of Engineers had been controlling floods on the Mississippi since the 1800's, the 1936 Flood Control Act imposed a condition for Federal involvement, which was that "the benefits, to whom so ever they accrue" must be "in excess of the estimated costs." Benefit cost ratios implicitly required estimates of uncertain future impacts. In the late 1940's, Congress found wide differences among agencies in how they did this. In 1950, Congress developed standard methods in the "Proposed Practices for Economic Analysis of River Basin Projects" (often referred to as "The Green Book").

These standards were challenged and improved. The Water Resources Council helped develop Senate Document 97 (1962), which revised standards for benefit-cost analysis, and after the great Eastern Drought of the 1960s, new multi-objective planning methods were developed, leading to the Principles and Guidelines (1973) and Principles and Standards (P&S, 1983), rules supported by numerous technical manuals on every aspect of planning, including how to estimate the future severity and frequency of floods. P&S required an iterative, six step planning process. Evaluations were based on four objectives: national and regional economic development, environmental quality, and social well-being.

II. Climate Change: What do we know

A changing climate creates a challenging context for water resources management and planning. Traditional water resources engineering practice utilized assumptions related to stationarity - that the historical record was indicative of what would be experienced in the future, and that the statistics of the historical record could guide designing for the future. Improved understanding of the potential impacts of climate change have caused grave questioning of these assumptions but not clear guidance on how they should be replaced. First, a better understanding of the specifics of climate change at locally-relevant scales is needed to answer that question.

There are three primary sources of information related to climate change and its future evolution: historical observations, theory, and climate change projections. Historical observations are probably the most important source of information, as they provide evidence of what his happening on the ground in any particular location. Trend analysis, frequency analysis, and other statistical methods are used to extract information about how climate is, or is not, changing. Theory is the scientific rationale that explains why we may expect to see specific changes based on our understanding of the earth's climate system. For example, scientific theory provides the strongest basis for explaining why global temperatures increase as greenhouse gas emissions increase, why the timing of streamflow peaks may change with warming temperatures, and why warming could possibly lead to more intense precipitation. Finally, climate change projections are simulations from global climate models (GCMs, also called Atmosphere-Ocean General Circulation Models) that represent the most advanced model representations of the earth's climate system. These simulations attempt to provide some indication of how the earth's climate may evolve in the future.

The scientific literature provides evidence of climate change and possible future changes based on all three sources. For the purposes of decision making, this overview gives the highest credence to observation-based studies, followed by theoretical studies and finally GCM-based studies. This relative ranking is based on extensive evaluation by the authors of the credibility of climate simulations from GCMs at scales relevant to water management. When all three sources of information indicate a change is likely to take place, this provides the highest level of credibility for a particular impact.

Studies of the border region between the US and Canada provide a clear signal of currently observed climate changes. Those changes with clear observational, theoretical and model-based evidence include:

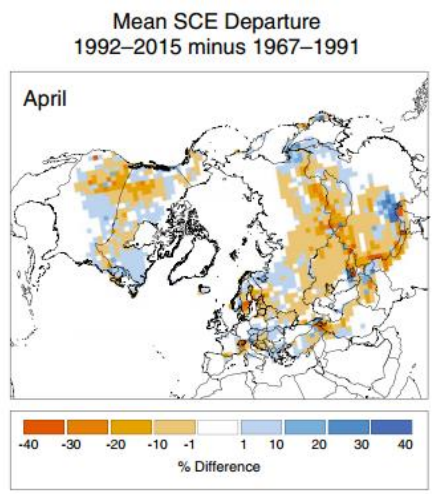


Figure 1 Change in snow cover extent, 1967-91 period compared to 1992-2015

From Trends and Extremes in Northern Hemisphere

Snow Characteristics (Kunkel *et al* 2016)

Comparison of April snow cover extent over Northern Hemisphere lands between the first (1967–1991) and second (1992– 2015) half of the satellite data record.

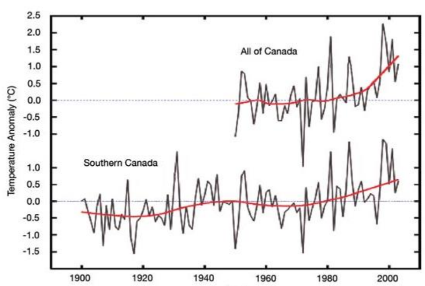


Figure 2 Temperature trends in Canada ([Natural Resources Canada](#))

- the region has been warming in all seasons; most pronounced in winter and spring; largest in west and north (Figure 2, Figure 6);
- precipitation increasing (Figure 3), less snowfall in the Pacific Northwest (US) and parts of south western Canada (Figure 1);
- spring snowpack is declining; and
- changing in the timing of spring peak flows in many watersheds due to warming temperatures that melt snow earlier.

Other climate changes may be anticipated but do not have a strong evidence base at this point. For example:

- no clear pattern in heavy rainfall; and
- no clear signal for changes in total runoff other than timing changes.

There are also other climate related impacts that have been experienced in some places or are consistent with theory, such as:

- warming temperatures causing warmer streamflow temperatures, impacting cold water fisheries; and
- warming temperatures causing warmer lake temperatures that are more conducive to harmful algal blooms.

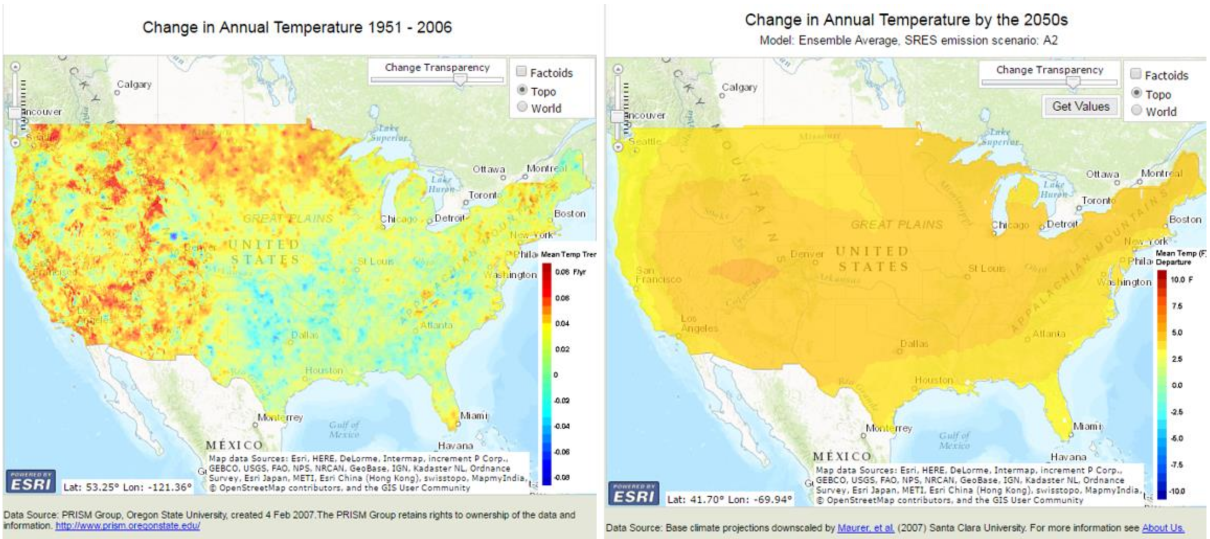


Figure 3 Maps of past and future changes in annual temperatures

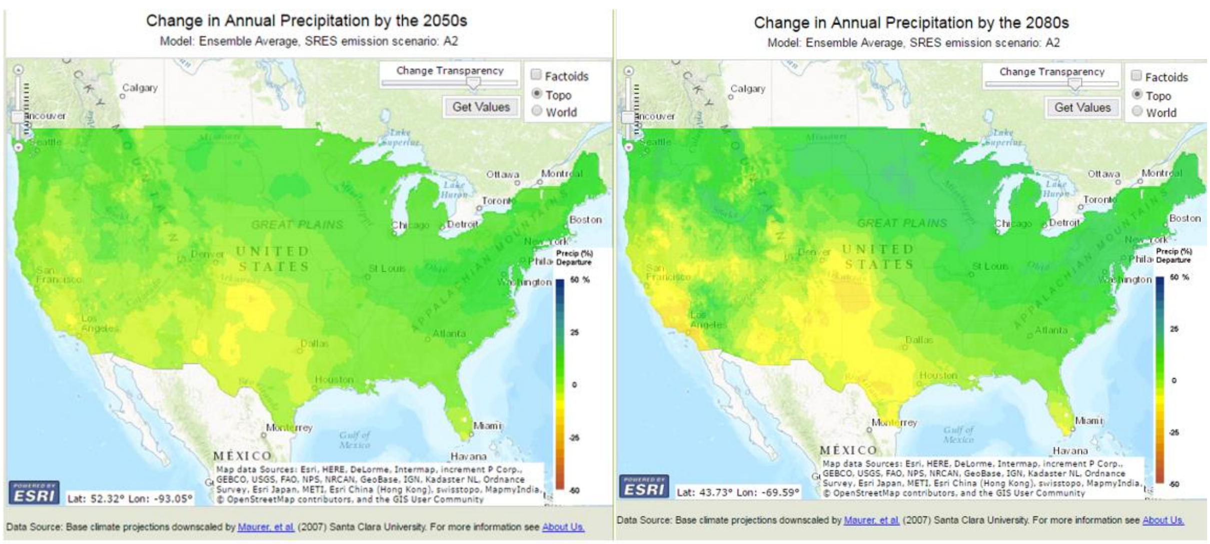
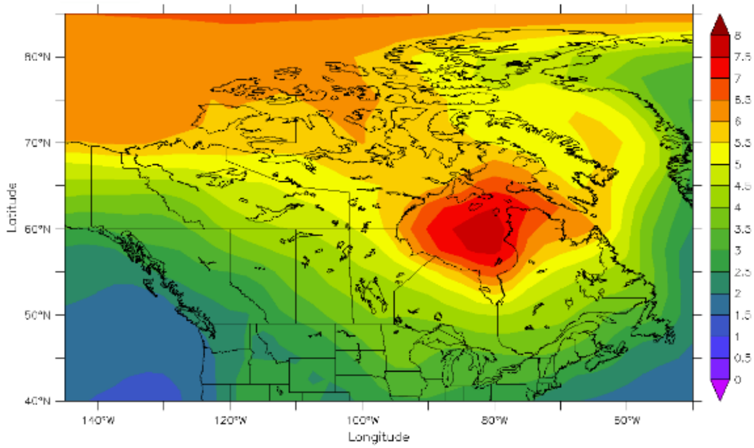


Figure 4 Maps of annual precipitation changes by 2050 and 2080

Sample Scenario: Significantly Warmer Winters



By the middle of this century, winter temperatures are expected to rise dramatically in Canada. This scenario was produced by an ensemble of climate models (*mean winter temperature change, 2041-2070 as compared to 1961-1990, SRES A1B, using IPCC AR4 climate models).*

Helping Decision-Makers Adapt

Climate change will affect Canada's water resources, energy demands, infrastructure and a host of other social and economic sectors. In many sectors, there will be significant impacts, and decision-makers need to plan now for future change. However, some uncertainty remains about how Canada's climate will change, particularly on a local or regional scale.

To assist resource managers, policy advisors and other decision-makers, Environment Canada researchers, working in partnership with Canadian universities, have developed a series of plausible scenarios of future climate. Using these scenarios, decision-makers can develop a range of adaptive strategies, and determine the most effective approach for their sector.

Figure 5 Sample Web Display from the Canadian Climate Change Scenarios Network

The effects of climate change on the Great Lakes, in particular, have been a long studied topic. The results of such study are emblematic of the climate change planning challenge generally. The large number of studies have revealed various changes taking place, but the combination of strong natural variability and many other anthropogenic influences beside climate change makes projecting the future of the lakes persistently challenging. There are several interesting climate and non-climate related challenges to water management on the Great Lakes:

- Observed historical variability of lake levels represents some of the largest range of changes of any coastal system.
- One third of the Great Lakes basin is under water (94,250 square miles water surface area. 308,926 sq. mi. drainage basin), meaning observations of inflows determine a small part of lake level variation.
- Lake levels exhibit low frequency variation, meaning long periods, up to decades, of lower and higher levels. This makes distinguishing between trends and variability very difficult.
- Glacial Isostatic Adjustment influences lake levels.

- Throughout the observed record, land use has been continually changing in the basin watershed.
- Evaporation from the lake surfaces is poorly observed, and plays a key role in future lake levels.

Despite these complications, the studies to date have provided some insights:

- Lake ice cover has been decreasing (Austin and Colman, 2007, VanCleave, 2012, Wang, 2010).
- Many climate model-based Great Lakes studies have probably overestimated evaporation from lake surfaces, leading to projections of lower lake levels (Lenters *et al*., 2013).
- Lakes Superior and Michigan-Huron were not long ago at or near records lows, while lake temperatures have been higher than average (Gronewold *et al*. 2016, VanCleave *et al*., 2014).
- Forecasting the future lake levels remains difficult (Lenters *et al*., 2013, Gronewold and Fortin, 2011).

The recent observed changes, and anticipated possible change in climate of the border region provide water managers with much to contemplate. Clear changes, such as warmer temperatures and reduced snowpack will create different conditions than management systems have been designed to manage. These changes, and other changes that are difficult to anticipate, will require adaptive actions. For example, changes to the timing of runoff, and changes to streamflow temperature will cause difficulty for native fishes. This will likely result in the need to alter water infrastructure management, such as flow release policies and reservoir rule curves to accommodate impacted species. Efforts to develop new operating policies will need to provide for the possible impacts of climate change, and are likely to become overwhelmed by the wide range of those impacts. The traditional approach of seeking solutions through more scientific analysis to reduce uncertainty are not likely to yield results. Therefore, guidance for making these decisions is needed.

Information about the regional manifestations of climate change can now be much more easily obtained from websites developed by NOAA, USGS and Environment and Climate Change Canada. Universities and climate research centers also produce such information. A few examples are illustrated with screen captures in Figure 3, Figure 4, Figure 5 and Figure 6. No comparative analysis of climate change assessments was performed as part of the development of this document; these sites are offered as examples of assessments by recognized governmental science agencies with simplified geographical displays of potential impacts from climate change. In fact, the inclination in decision-scaling would be to treat all projections from agencies such as NOAA, NASA, ECCC or USGS as plausible. Once a Board has done an initial assessment of its possible responses to climate change, it may need to reconsider the plausibility of particular projections if only those projections support future scenarios that require responses that are costly or environmentally damaging.

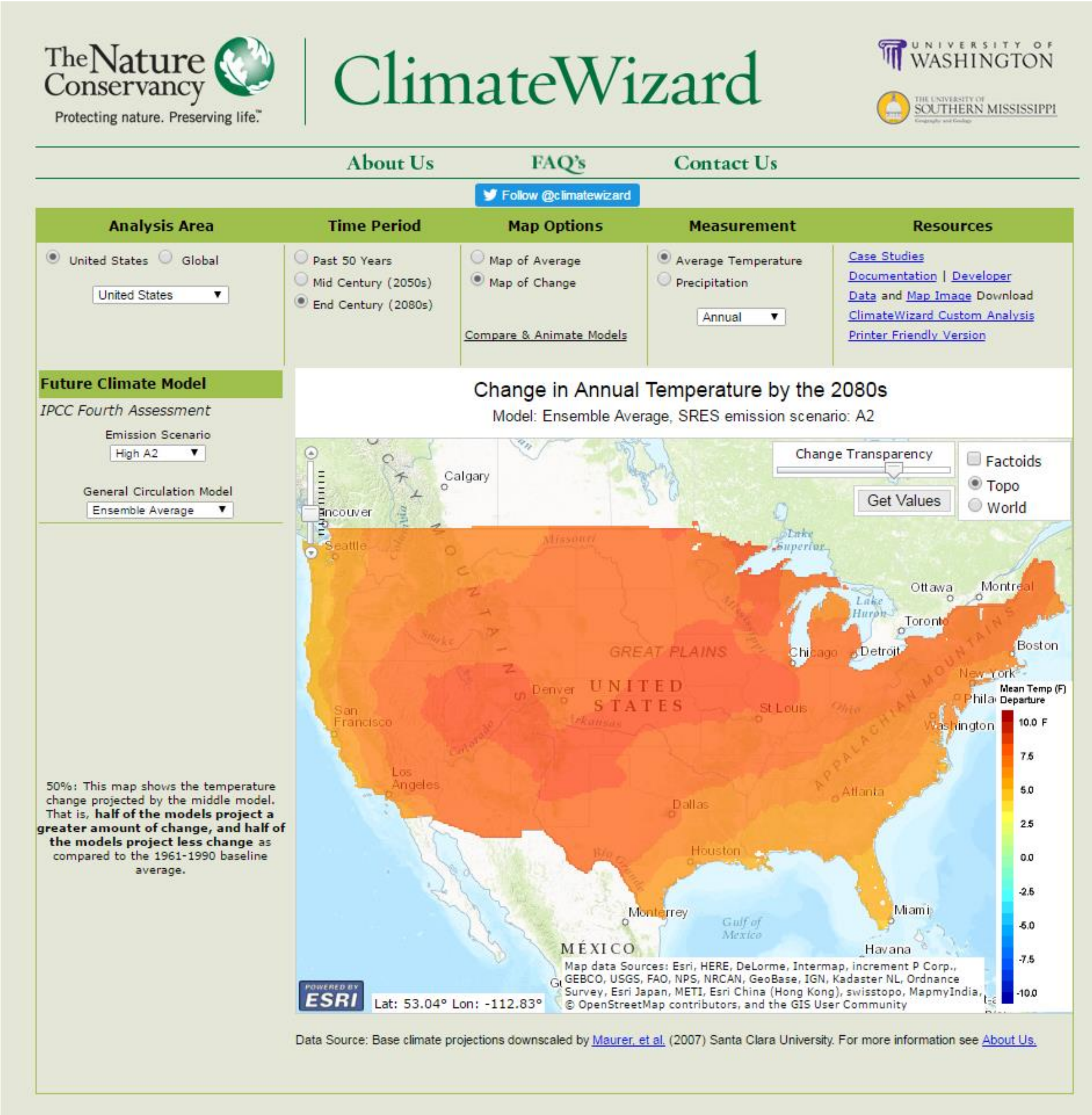


Figure 6 Nature Conservancy Climate Wizard Website

III. Water Management at the Onset of Climate Change

Until the 1990s, the methods to decide whether the benefits of a proposed project would exceed its costs, how high to build a levee, what diameter a culvert should be, or setting the "safe" yield of a water supply, were based on the assumption that climate did not change noticeably over the span of a lifetime. The rational-analytic methods were based on projections about what would happen in the next thirty to hundred years after the decision was made, and water managers used statistical methods to quantify the likely consequences of the decision because the next and last hundred years were samples from the same statistical population.

Statistical textbooks are very likely to use certain illustrative examples such as the rolling of dice. Another is socks in a drawer; for example:

> *A pairs of socks is picked blindly from a drawer and returned. This process is repeated another 19 times. Ten times white socks were selected, ten black. What is the likelihood that 15 or more of the next 20 such selections will be black?*

In water management, the drawer was climate, the 20 selections were the historical record and the probability of picking 75% black socks part of statistical hydrology. Bulletin 17-B instructed federal water managers on how to estimate flood frequencies. The diameter of culverts in road design were based on similar statistical projections of some of the largest flows that would go through that pipe.

If climate was changing, then the contents of the "drawer" that was used in this teaching analogy was changing; imagine a conveyor belt for a drawer bottom, or someone inside the drawer changing the mix. The important thing was the assumption that the future could be foretold statistically was undermined, and the degree to which statistics were useful was some unknown function of how and how fast climate was changing.

In the 1990s, both climate change and climate variability spurred analysts to develop new methods for making decisions about the future.

The first was natural climate variability. The consideration of federal investments in a pump to reduce flooding damage around Devils Lake in North Dakota was undermined by the finding that there might be a continuing natural variability in the lake size, demonstrated by paleologic evidence. Devils Lake levels had a natural tendency to be high for decades, and then be low for a long time, with no way to predict when the shift would come. In fact, these so called "quasi-periodic" cycles could also be seen in the Great Salt Lake in Utah and other closed basin lakes around the world. Great Lakes water managers believed that the lakes went through wet and dry cycles and that the dry period in the 1960s had been followed by persistence wetness in the 70s, 80s and 90s. At about the same time, there were many reports about how the presumption of stationarity had misled planners, most notably on the water allocations from the Colorado River and Corps flooding projects on the American River in California. In these cases, there was no identified periodic shift; it was just that frequencies before and after mid-century were distinctly different.

The second challenge to planning based on stationarity was the growing awareness that global climate was changing because of the increased emission of carbon into the atmosphere. The United Nations established the "Intergovernmental Panel on Climate Change (IPCC) in 1988, and since then the phrase "climate change" has been used to signify changes to climate caused by mankind.

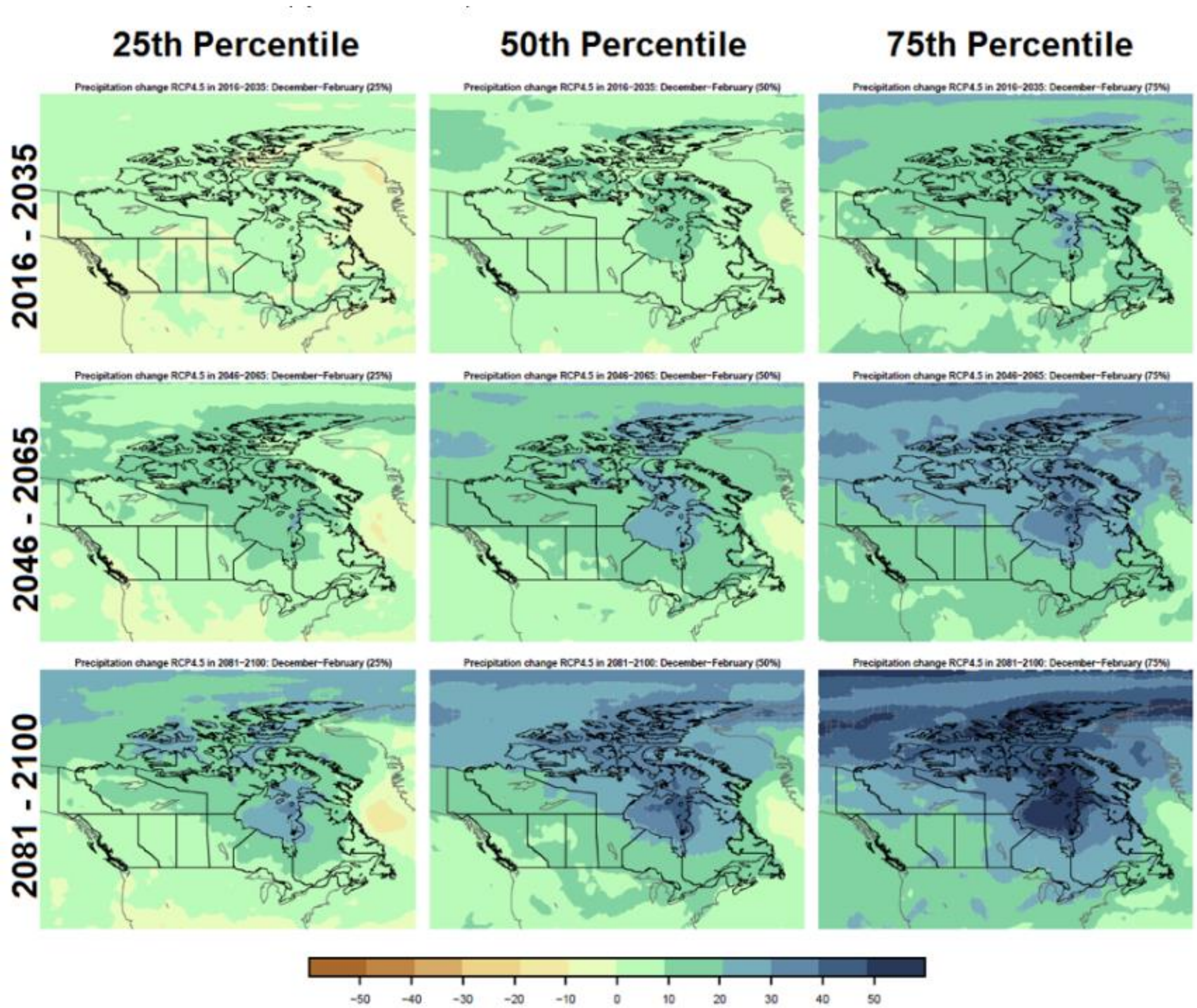


Figure 9 – Maps of winter precipitation change projected by the CMIP5 multi-model ensemble for the RCP4.5 scenario, averaged over December–February. Change is computed relative to the 1986–2005 baseline period. As in the IPCC Atlas (IPCC, 2013), the top row shows results for the period 2016–2035, the middle row for 2046–2065, and the bottom row for 2081–2100. For each row the left panel shows the 25th percentile, the middle panel the 50th percentile (median), and the right panel the 75th percentile. The colour scale indicates precipitation change in % with positive change (increased precipitation) indicated by green colours and decrease by yellow to brown colours, consistent with the colour scale used in the IPCC AR5 Annex I (IPCC, 2013).

Figure 7 Projections for winter precipitation in Canada for three future periods, three non-exceedance frequencies

http://ec.gc.ca/sc-cs/default.asp?lang=En&n=80E99404-1&offset=2&toc=show

In 2008, the journal Science published a paper called "Stationarity Is Dead: Whither Water Management?". The authors were leading hydrologists from the United States Geological Survey (U.S.G.S.) and academia around the world. By the time the paper was published, experiments in how to plan with no faith that stationarity applied had been going on for a decade, some by these authors, particularly Professor Dennis Lettenmaier. He and others had been trying to quantify the risks from climate change using a method called "downscaling" which was a series of steps starting with Global Circulation Model (GCM) results. GCMs modeled the movement of the world's atmosphere or oceans or both, in "coupled" models. The models used an underlying grid structure; cells of a certain size in a web covering the planet. Downscaling is the use of GCM predictions of climate change for a particular area with other models, such as rainfall-runoff models, to produce inflow datasets that represented inflows the basin could expect under climate change.

However around 2008, an alternative to downscaling called decision-scaling was suggested by Dr. Casey Brown. Decision-scaling inverts downscaling, and in doing so, provides a better test of system vulnerability.

In a traditional downscaling process, inflows are produced and then system vulnerability is tested in evaluations using those inflows. The evaluations can show whether the managed system is vulnerable based on these specific inflows, but it does not address the question of whether the system would be vulnerable under other plausible inflows.

For those global or regional climate models whose projections are used to produce inflow datasets that are perturbed versions of the historical data, the inflows are defined completely by the thoughtful manipulation of climate and hydrology, without any consideration of the impact changed inflows would have on people and the environment. Although the manipulations are thoughtful, they are easily challenged because of shortcomings in both the GCMs and the downscaling processes. The datasets produced may not be as severe as some future generated stochastically based on a stationary climate. Downscaled inflow data provide a limited sample of potential future inflows. If the selection is made solely on the basis of climate information, there is no assurance that there are other, plausible inflows that would cause problems.

Decision-scaling starts with thoughtful consideration of how impacts might change if climate changed, and once the scenarios of concern are identified, the planner asks whether those inflows are plausible considering what is known about climate change in that region. The inflows provided by decision-scaling are more useful than and just as defensible as those produced by decision-scaling. They are more useful because they test systems based on known vulnerabilities. The real test of any forecast is in the future, after its usefulness has past, so no projection of climate change impacts used for planning will be validated for use. Downscaled hydrologic datasets may be used in decision-scaling, but other approaches may be used, too. Some important characteristics of lakes and reservoirs – safe yield, minimum releases, lowest levels - may be more dependent on the persistence of wet and dry periods, something that is not typically considered in downscaled datasets. A six year historical drought followed by a seventh year which is normal may be transformed in downscaling into a more severe six year drought with a seventh year slightly below normal. Longer term records synthesized from paleological evidence such as tree rings may show evidence of much longer droughts. For example, the IJC's Upper Great Lakes Study report on climate and hydrology shows a much wider range of wet and dry cycle durations than are evident in the recorded history (Figure 8).

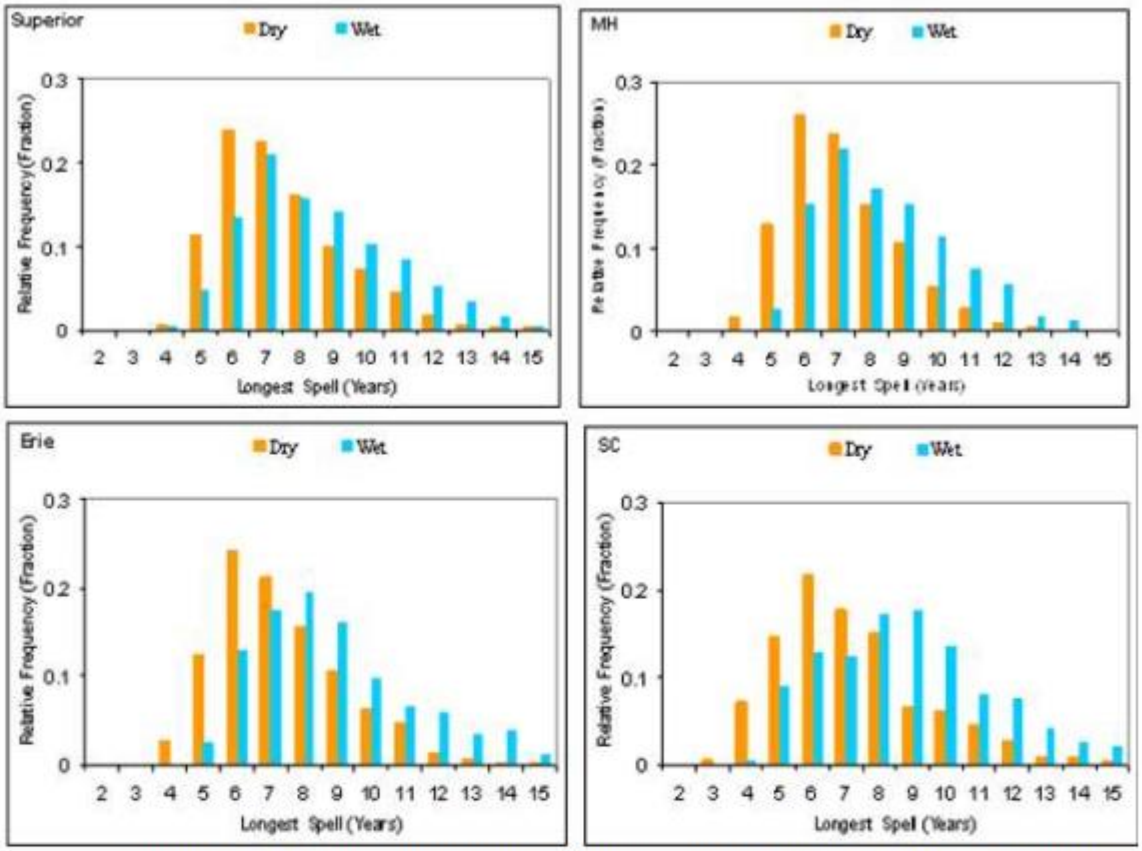


Figure 18 - Relative Frequencies of Uninterrupted Dry and Wet Years, by Lake

Figure 8 Frequencies of wet and dry periods of different lengths on Lakes Superior, Michigan-Huron, Erie and St. Clair

The IJC's study of Lake Ontario-St. Lawrence River regulation relied on downscaling whereas the IJCs Upper Great Lakes Study used decision-scaling. There have been some attempts to develop planning guidance to address the risks posed by climate change, but there is no universally accepted guidebook.

In this context, a robust rule curve or regulation plan is one that performs about as well as any other no matter which plausible inflow dataset it is tested with.

Robustness may be sacrificed for better performance with inflows that are considered more likely. For instance, a very low minimum release preserves water in the lakes if the future climate creates longer and more severe droughts, but it reduces flows to the river during more common dry periods. There is no "optimal" minimum release; even if the impacts could be precisely quantified in one common metric (which they cannot), the probability of plausible future droughts of record severity and length cannot be estimated statistically.

Finally, every decision is viewed as ultimately provisional. Because change is inevitable and there may be surprises, there is a need to monitor performance and provide feedback to the operation policies so that course corrections can be made. Thus, decisions can be effectively incorporated into adaptive management approaches that allow the performance of the system to be maintained even if it requires transformation of different aspects of the operating policy.

Unable to divine the perfect choice, a decision making Board will endeavor to use the information available to explain their recommendations. The Board will “practice” making these recommendations with stakeholders so as to be open to their opinions and insights and so the Board’s decision process is as transparent as possible. Finally, the Board will consider whether the uncertainty can be better managed adaptively. For example, as time goes by and more is known about where climate is trending, rule curves could be modified according to the emerging assessment of robustness.

IV. Board Responsibilities Affected by Climate Change

Different IJC Boards have different responsibilities. Climate change makes several of these responsibilities more challenging.

The Impact of Climate Change on Water Level and Flow Management

Six of the sixteen IJC Boards play some part in the regulation of water levels and flows: International Lake of the Woods Board of Control, the Lake Superior Board of Control, the Osoyoos Lake Board of Control, the Rainy-Lake of the Woods Watershed Board, the St. Lawrence Board of Control and the St. Croix Watershed Board. In addition, the Accredited Officers for the St. Mary – Milk Rivers monitor and apportion flow in the St. Mary and Milk rivers and three Mile River tributaries, Frenchman River, Battle Creek and Lodge Creek and the Souris River Board also monitors and apportions flows of the Souris River at its two international boundary crossings, the Kootenay Board measures flows and determines apportioned shares and the Niagara Board oversees water levels regulation in the Chippawa-Grass Island Pool and installation of the Lake Erie-Niagara River Ice Boom.

Climate change is expected to change the timing and quantity of water flows in all the transboundary basins, and so water control Boards may face all these issues described in “IV. Board Responsibilities Affected by Climate Change” starting on page 18. During the November 9-10 workshop in Ottawa, the authors of this document acknowledged their familiarity with Board operations was limited mainly to water control boards, and that this section is useful mainly to trigger more informed and specific reviews board by board. One of the conclusions from the workshop is that Step 1 of the proposed preparedness process (described starting on page 29) should be applied in a consistent way across all Boards to generate a more useful assessment of the Board responsibilities that will be affected by climate change.

There are climate change issues particular to water supply that water control boards must consider:

- To the extent that climate change induces longer or more severe droughts, minimum flows or releases may have to be re-examined. These flows are often set based on a balance between instream flow needs for fish or water quality and the desire to retain water in the reservoir for longer droughts. Water control planners may have to consider whether maintaining higher minimum flows which would increase the risk of running out of water and being unable to supplement flows in longer droughts is worth reducing the minimum flow to preserve long-term storage.
- Droughts may also reduce water depths available for shipping and recreational boating and may imperil drinking water intakes.

- Droughts may make it more difficult to meet firm hydropower yields;
- Low lake levels could disrupt the free passage of fish between the lake and its tributary streams. Gravel streambeds will eventually erode to lake water surface levels, but the impediment may persist if there are box-culvert bridges near the mouths of those tributaries that would create miniature waterfalls.
- Very high water supplies may overtop and damage spillways and flood hydropower plants.
- Increased inflow variability increases difficulty in maintaining levels and flows within narrow specific ranges, or expected ranges.

The Impact of Climate Change on Water Quality

Climate change will affect water quality directly and indirectly for better and worse. In concert with other trends, climate change will affect not just the impacts of pollution but also the sources of pollution. Climate change impacts to water supply may have significant impacts on water quality.

- Extreme rain events and flooding may lead to source water contamination
- Wildfire in watersheds may increase source water contamination
- Warmer waters promote growth of harmful algal blooms

Newer water quality concerns, such as microbeads and pharmaceuticals, will be part of the mix of concerns.

Climate change impacts on the sources of pollution

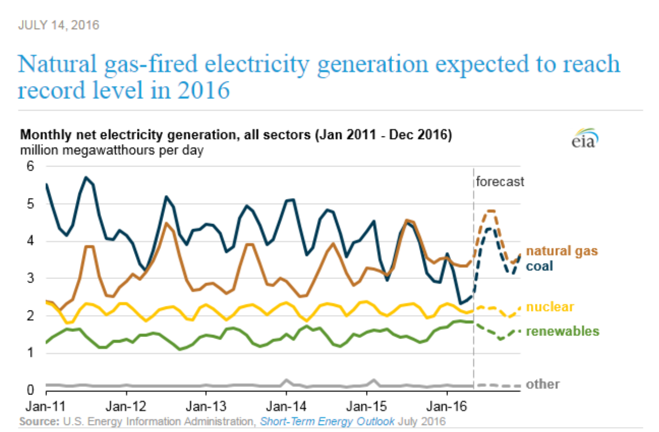


Figure 9 Monthly U.S. electrical production by generation type 2011-2016 and projected (U.S. Energy Information Administration)

One of the greatest water quality concerns in U.S.-Canadian waters has been the accumulation of mercury in fish. Coal-fired power plants in the western continent have been the primary contributors to mercury contamination. The increased production of natural gas in the last ten years has reduced gas prices by about half, and natural gas is replacing coal as the leading generation type (Figure 9). Solar, wind and other renewable power prices have dropped 70 percent since 2009, and although there are other impediments, solar generation is also expected to increase its share of production. Climate change may help accelerate these trends because of the greater demand for clean energy and because of incentives to avoid carbon emissions.

Another significant water quality concern comes from non-point nitrogen and phosphorus contributing to the growth of harmful algal blooms (HABs). HABs can harm aquatic ecosystems, the enjoyment of coastal resources, and human health. A recent UNESCO report shows HABs are a global issue, but one that requires local and regional solutions. Changes in temperature and precipitation from climate change may change the agricultural production patterns, increasing or reducing the nutrient load in any one basin. Warmer water promotes the growth of HABs.

Climate change impacts to water supply that affect water quality

Policy analysts have long criticized the separation of water quality and quantity given the physical connections between the two. Climate change will expose more of these connections. Some examples include:

- Climate induced changes in water levels can move the location of the water-land interface, which can translate to a different near-shore bathymetry, changing the area of near-shore susceptible to HAB infestation. Warmer temperatures in the near shore may exacerbate the problem.
- Reduced water supplies may make it more difficult to provide minimum instream flows mandated to reduce the concentrations of pollutants.

The Impact of Climate Change on Ecosystem Management

Some Boards have been charged explicitly with advising the IJC on how governments are addressing environmental objectives pursuant to the Great Lakes Water Quality Agreement, and on current and emergent environmental and health issues in the Great Lakes region (Great Lakes Science Advisory Board, Great Lakes Water Quality Board, Health Professionals Advisory Board, Air Quality Advisory Board), but over time the water control Boards also have also had to consider environmental objectives in the decisions they make. This may become increasingly important as climate changes and other effects put increasing pressure on vulnerable populations, causing increasing pressure or expectation that IJC Boards respond appropriately to preserve these populations.

Climate Change on Data Management

Many Board decisions are based on assumptions grounded in a stationary climate and it may be that those decisions would change if the timing and extent of the climate change could be known. Tradeoffs between providing flood storage and water supply and ecosystem management, for example, might be adjusted if the threat of flooding has changed, but the decision to adjust is dependent on reducing the uncertainty around whether the flood risk has been lowered. Because investigations of the onset of climate change so often are based on trend analysis, there is a concern that uncertainty and errors in the data the Boards use may mask or exaggerate nascent trends.

The International Upper Great Lakes Study (IUGLS) was designed in part to determine whether the conveyance of the St. Clair River has changed. The IUGLS investigations exposed in practical terms what was always known in theory, that the “data” that IJC Boards rely on are estimates, some more uncertain than others. Lake levels are considered the most reliable, but even these are affected by winds and isostatic adjustment. Water balances on any IJC reservoir can be accounted for using an algebraic summation of the components (precipitation, evaporation, runoff) or an estimate of the sum of those components derived from changes in lake levels (the “residual” method). Residual estimates require an estimate of the volume of water added with each centimeter of lake elevation change. Estimates of runoff at any gaged site is typically based on a rating curve that related the measured water surface elevation with a flow, and there can be runoff below a gaged station or from an ungaged basin. Only recently has evaporation been measured rather than modeled, and on-lake precipitation is often derived from nearby land stations. In sum, recorded “data” include a variety of uncertain estimates. In the case of the Great Lakes, there was a substantial difference between the estimates of net basin supplies, indicating that there were errors in the data. Since the completion of IUGLS, the Great Lakes-St. Lawrence River Adaptive Management (GLAM) Committee has attempted both to improve these estimates and make the data more readily available.

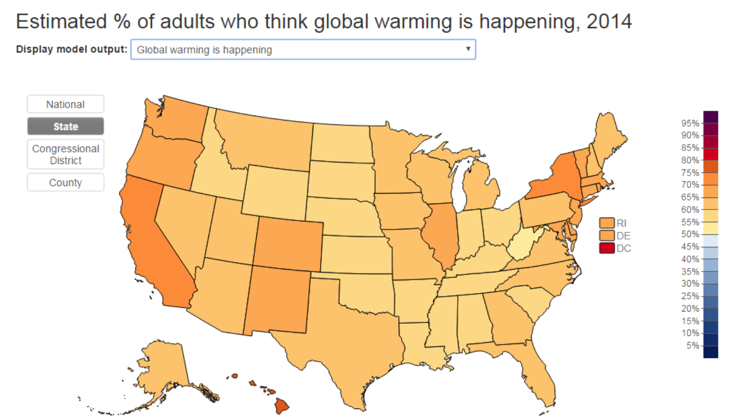


Figure 10 Percentage of people by state who believe the world is warming

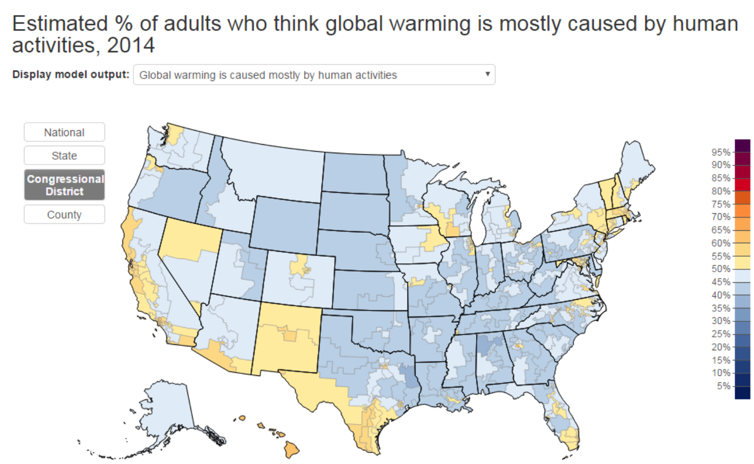


Figure 11 Percentage of people by congressional district who believe climate change is man-made (Yale Project on Climate Change Communication)

The Impact of Climate Change on General Management Issues

The Boards are already and will increasingly reply to questions from governments and the public on how they are considering climate change in their decision making. As Figure 10 and Figure 11 show, public attitudes about climate change vary considerably and those divisions are often tied to deep and divisive political differences, with even some governments unwilling to affirm scientific consensus or even factor concerns about the risks from climate change into their statements, budgets and programs. Disagreements about climate change can disrupt the working relationships that Boards must have with governments and the public. An IJC framework should help Boards manage such disputes.

The Unknown Unknowns

The uncertainty surrounding the impacts of climate change become more uncertain as they accumulate in conjunction with other factors. Most certainly, temperatures will rise as will oceans; these are evident already. Warmer temperatures will almost certainly reduce water storage as snowpack, in effect reducing overall basin storage in parts of western North America. Again, recent data show this has already begun. Climate change is expected to increase storm intensity, which should increase risks from riverine flooding, but because warmer temperatures reduce ice cover and increase precipitation, climate change may reduce lake flooding. But to what degree will that be offset by greater variability of precipitation? There may be changes in wind speed and direction that affect coastal damage, shipping and mixing. Species are already migrating northward (Figure 12); what cumulative changes will that cause as these species consume, predate and compete? Among the migrating species may be humans, with more developmental pressure on these boundary waters. Will the production of hydropower be more or less valuable than it is now?

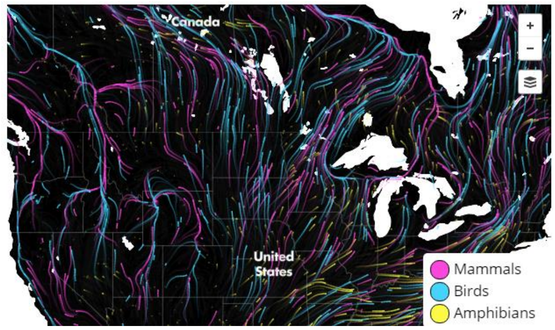


Figure 12 [Species migration because of climate change]

An IJC framework should include procedures for noticing and considering the vulnerability to newly recognized climate induced phenomena. The GLAM Committee, for example, is developing a "surveillance" program that uses experts in three fields to alert the committee to new findings that might affect IJC responsibilities in the Great Lakes.

V. Other Considerations in Designing a Framework

The previous section describes the kinds of impacts a climate change preparedness framework might have to address. This section summarizes the characteristics CAWG members described as important in a climate response framework and describes ongoing IJC activities that are relevant to the design of the framework.

The April 2016 IWI Workshop Summary captured the suggestions of participants for the framework. They said that the framework should:

- Include a strong communication strategy because outreach informs stakeholders and lets them help mitigate impacts.
- Provide clear connections where applicable between water quality and quantity
- Include the best solutions to recognized threats, not just the emergent threats, to allow the Boards to respond quickly.
- Be more than monitoring, it must guide a response.
- Use an ecosystems approach, including the terrestrial domain
- Develop a method for valuing the adaptive management of climate change and publish it as a benefit that repays costs; one indirect measure might be how widely these practices are used

- Advocate coordination with the Great Lakes Water Quality Board and Science Advisory Board. Annex 9 to the Great Lakes Water Quality Agreement of 2012 even though the IJC does not manage land
- Include an Information Management element that would pool available skills and resources.
- Address the uncertainty in climate change preparation
- Leverage the substantial amount of relevant work both governments have already done, and harmonize those efforts to create a bi-national approach.
- Build on the success individual Boards, such as the Health Professionals Advisory Board has had in getting relevant climate information.

Related IJC Activities

The IJC has addressed the issue of how to manage its responsibilities under climate change outside this CAWG effort. In addition to extensive work on past studies, there are two ongoing and relevant efforts.

Great Lakes St. Lawrence River Adaptive Management (GLAM) Committee

This is an international committee appointed by the IJC to manage the monitoring, modeling and assessment needed to support on-going evaluation of the regulation of water levels and flows. The Committee reports to the International St. Lawrence, Superior, and Niagara Boards of Control. The report of the Great Lakes-St. Lawrence River Adaptive Management Task Team (2013) provided the basis for the GLAM Committee. Knowledge gained during the Lake Ontario-St. Lawrence River Study (2000-2006) and International Upper Great Lakes Study (2007-2012) will be updated and used by the GLAM Committee to provide on-going information on how the regulation of water levels and flows affects socio-economic interests and the environment. As more is learned and as conditions change over time, this information will help determine whether changes to regulation should be considered.

An adaptive approach is considered the best way to address the uncertainty regarding when and how climate change will affect the Great Lakes. The IJC recommended new regulation plans for Ontario and Superior that were designed to perform well under climate change. The GLAM committee has a decision-scaling perspective, prioritizing its adaptive workload based on the risk that decisions by the Superior and St. Lawrence Control Boards could impact stakeholders.

Great Lakes Water Quality Board Great Lakes Climate Adaptation and Resilience Workshop

The Great Lakes Water Quality Board (WQB) has already undertaken a similar initiative (Figure 13) specific to the Great Lakes. The IJC Framework should make it easier for such efforts to cross-pollinate with experts and ideas, and build on existing work.

The WQB includes an Emerging Issues Work Group that has identified the growing impact of climate change on the Great Lakes as a priority issue.

The Board had examined the impacts of climate change in 2003, advising the IJC then that an adaptation strategy was necessary. After their latest assessment, the WQB wrote the IJC recommending three actions:

> Recommendation 1: The Federal Governments of Canada and the United States should demonstrate global leadership by jointly developing, in cooperation with other

governments and organizations across the Great Lakes basin, a Binational Approach to Climate Change Adaptation and Resilience in the Great Lakes. Such an approach would include a shared vision, coordinated action, creation of a network to share science, information and knowledge, including Métis, First Nations and Tribal traditional ecological knowledge if offered, and the commitment of adequate funding to carry out these objectives.

Recommendation 2: Investments in research, information sharing and knowledge management are needed to carry out a Vulnerability Assessment, to engage stakeholders and rights holders, and to identify priorities for responsive actions in the Great Lakes region. The assessment should include due consideration of the vulnerabilities to the chemical, physical and biological integrity (including biodiversity) of the Great Lakes in the context of water quality, and the related potential vulnerabilities for Great Lakes coastal communities, commerce and public health at small enough geographic scales that can be of material use to communities and local decision makers.

Recommendation 3: A staff-supported Network of Networks (or augmentation of an existing network) needs to be created to collect, aggregate and share information that can support climate adaptation response strategies at federal, regional, state/provincial, and local scales.

The network's function would be to build on and amplify the work of the many scientific, regulatory, and regional structures and activities already addressing some aspects of climate adaptation and resilience in the region and within federal agencies. The network hub could serve as the coordinating point for knowledge management, communications, and potential for technical resources that could support community-level strategies and actions.

International Joint Commission
Canada and United States

Commission mixte internationale
Canada et États-Unis

GREAT LAKES WATER QUALITY BOARD

Great Lakes Climate Adaptation and Resilience Workshop:
Developing a Binational Approach for Planning and Action

July 12-13, 2016
Holiday Inn & Suites, 1855 Huron Church Road, Windsor, ON

Purpose of the Workshop: This workshop, convened by the Emerging Issues Work Group (EIWG) of the International Joint Commission's (IJC) Great Lakes Water Quality Board (WQB), will bring together approximately 25-35 experts. The purpose of the workshop will be to draw on the knowledge and experience of these experts to explore and more fully develop a recommendation that the WQB may present to the IJC for consideration: Namely that the IJC advise Canada and the United States to demonstrate global leadership by jointly developing a Binational Approach to Great Lakes Climate Adaptation and Resilience.

Workshop Objectives:
At the end of this workshop, participants will:

- Briefly review the state of climate change adaptation and resilience in the Great Lakes
- Design potential key elements of a Binational Approach to Great Lakes Climate Change Adaptation and Resilience
- Contribute to identifying challenges and considerations, and shaping possible approaches to implementing such a binational approach

Figure 13 Notice for a Great Lakes Water Quality Board Workshop on Climate Adaptation

VI. Draft Outline for an IJC Framework

An institutional capacity across the IJC to support the Boards' ability to manage climate change is envisioned. It would begin with an overall IJC adaptive management policy on dealing with climate change that could provide living guidance and would be improved through learning in and outside the IJC. Access to this capacity would be simple and open; it would be easy and natural for useful information from one part of the IJC to be shared with others. The framework could include these elements:

- An Overall IJC Policy for addressing Climate Change,
- A Guidance Report Website (rather than published report, so that it could be continually updated).
- An IJC wide Adaptive Management Initiative that supports and facilitates the efforts of individual Boards in these areas:
    - Information management,
    - Reporting on relevant research,

- Linkage to regional climate planning resources that apply GCMs and RCMs to predict changes in precipitation and temperature,
- Communication support,
- Planning support,
- Online training modules.
- Evaluation of water quality and quantity management decisions and approaches to see whether and when new approaches are required by climate changes

The proposed IJC Framework for Climate Change is based on the following premises:

- Each of the water bodies that the IJC oversees are complex social-ecological systems that are only partially understood. They are dynamic and constantly evolving in ways that can only partially be anticipated.
- The Boards have different mandates and resource capacities, and the challenge will be to implement a framework that is both consistent and tailored to each Board.
- The IJC relies on the support of other government agencies in carrying out its duties, but the kind and level of that support varies and the framework will have to accommodate that.
- Insights from scientific observation and model-based studies help to understand specific parts of these systems but are typically inadequate to create a necessary understanding of the whole.
- Models and understanding are insufficient for making accurate predictions about the future and how it will affect these water bodies and their dependent communities. It is not possible to "predict" the way to needed answers.
- The framework must be able to accommodate change and surprise, must be adaptive and iterative, and dynamic when needed in response to change.
- There is an enormous, existing scientific effort to observe, experiment and build knowledge regarding many of the phenomena of interest and this should be fully leveraged. However, the results of these efforts are unlikely to benefit the IJC Board to their full potential without a carefully planned framework for ingesting the results that is consistent and coherent across the IJC.
- The disaggregated nature of the many efforts related to the IJC Boards requires a strong communication approach to fully benefit both the Boards and the communities with which they work
- Adaptive management and resilience are core concepts for guiding the IJC Climate Change Framework

Given the above considerations, the proposed IJC Climate Change Framework has been designed to be responsive to the conditions of uncertainty, change and widely distributed observation and scientific systems. It is based on a philosophy that while efforts are needed that attempt to look ahead, they will be insufficient without focusing on better understanding of how these systems are changing and evolving in real time. In addition, because ultimately the IJC serves its governments and the public, decisions must be informed by public preference and levels of satisfaction with the state of the water bodies for which the IJC is responsible.

Review of Existing Climate Change Processes

Given recognition of the potential impacts of climate change on various societal interests, there has been a growth in processes developed to assist planners in addressing these concerns. As discussed above, initial efforts focused on providing climate change projections so planners had a view of what might happen. Due to the irreducible uncertainties associated with climate change, and recognition that many other factors are changing as well, it has become apparent that climate projections alone are not necessarily helpful for planning for the future. Instead, a process that guides planners through a planning process for climate change was needed.

In response to this need, a number of government agencies and nongovernmental organizations developed planning processes for climate change. Table 3 illustrates two of them. Some of these, such as Structured Decision Making (USGS), and CRISTAL (IISD) were based on existing planning processes with climate projections substituting for probabilities used in the past. Consequently, they do not provide the analyst guidance that addresses the wide range of climate futures that are typically encountered. Recent additions, including the "US Climate Resilience Toolkit" and the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) "Implementation Framework for Climate Change Adaptation Planning at a Watershed Scale" provided updated philosophies, adopting approaches more similar to decision-scaling, but still struggle to guide users through the large set of potentially conflicting but potentially useful climate products that are out there.

Each of these processes share some clear commonalities. Primary among them are steps we summarize as: Organize, Analyze, Act, Update. Not all existing processes include a clear "Update" step, meaning the establishment of a monitoring approach and routine for integrating new information to improve and re-evaluate decision making, even though this is considered an essential part of a resilience strategy. In addition, there were a variety of steps and approaches within these broad categories. Another key attribute of the best processes, such as the US Climate Resilience Toolkit, is an online guidance resource, which explains each step of the process and provides a collection of resources that assists the analyst with the completion of that specific step. The Toolkit also uses a decision point at the end of each step to consider whether the process should continue.

A weakness of each of the existing processes is in attempting to create a "one size fits all" process, they potentially create "one size fits none." Specifically, while the general logic of some frameworks is solid, it becomes unclear how to implement specific steps at a particular location. This is a challenge that can be overcome in the development of a decision-scaling process that begins with an assessment of Board responsibilities and then incorporates more general climate information.

Table 3 Steps in two processes designed to climate change preparedness

US Climate Resilience Framework	**OCCIAR Implementation Framework**
Step 1 – Explore Climate Threats • Establish team • Investigate your regional climate • Identify key assets and threats • Define the scope of your project • Decision Point – Do weather and climate represent a threat to assets you value?	Step 1 – Initiate Adaptation Process • Examine and set context • Build awareness • Identify a champion or leader • Define and build team • Engage experts • Develop a record keeping system
Step 2 – Assess vulnerability and risks • Identify climate and non-climate stressors • Consider the potential tipping points • Determine the vulnerability • Characterize the risk from climate impacts • Decision point – can you accept the risk climate presents to your assets?	Step 2 Increase Knowledge and Collect Data • Evaluate and increase climate change knowledge • Gather historical data • Develop baseline data and indicators • Obtain future climate projections • Develop an inventory of climate change impacts
Step 3 – Investigate options • Brainstorm potential solutions • Learn from others • Evaluate potential solutions • Refine goals • Decision point – are stakeholders committed to implementing the group's favored solutions? • {That question doesn't seem to match the previous steps}	Step 3 – Assess Current Vulnerability • Determine the degree to which the watershed is sensitive and exposed to climate • Determine the adaptive capacity to address historic and current climate change impacts • Assess vulnerability • Review results and communicate findings • Update the record-keeping system
Step 4 – Prioritize actions • Consolidate actions into a cohesive plan • Estimate the expected value for each action – problematic – how to do so without probabilities? • Evaluate trade-offs and Plan the project • Decision point – Have you developed a solid plan outlining the best actions to protect what you value?	Step 4 – Assess Future risk • Conduct risk analysis • Conduct risk evaluation • Communicate findings • Review results
Step 5 – Taking Action • Implement your plan • Monitor your results • Iterate as needed • Share your story • Decision point – is implementation of your plan increasing climate resilience?	Step 5 – Generate Adaptation Solutions • Establish goals and objectives • Identify adaptation options • Evaluate adaptation options • Review and communicate results Step 6 – Implement adaptation solutions Step 7 – Monitor and Review

The preparedness process proposed here is consistent with the strategies outlined in Table 3 and consists of the following components:

<u>A Statement of Purpose</u>: Any attempt to prepare for climate change would benefit from a clear statement of its purpose. Different actors could have different purposes, such as, "improving the understanding of climate change and impacts for stakeholders"; or "making predictions of future climate conditions"; or "curating the latest climate science". However, based on the stated concerns of the IJC and its partners, a draft purpose might be: *To provide clear guidance for addressing climate change in IJC policy and operations using the best available science and stakeholder inputs*

In addition, a set of goals and objectives are also needed for clarity for the design of the framework. For example, the goal of IJC policy and operations regarding climate change may be to: *Maintain, to the extent reasonably possible, the resilience of IJC's responsible systems, meaning the ability to continue to maintain ecosystems, economic and social impacts within preferred ranges in the face of future change and uncertainties.*

<u>An Analytical Approach</u>: There are many possible approaches to conducting analysis when attempting to address climate change and each will have various strengths and weaknesses, and most appropriate application contexts. For example, in some cases, attempting to use the best available models to predict the future climate may be an appropriate analytical approach. In view of the concerns of the IJC related to climate change, a "bottom-up" based approach to addressing climate change is likely to be the best approach. A bottom-up approach (otherwise known as decision-scaling) focuses on understanding the dynamics of the system of interest and the goals for a system, understanding how sensitive these are to climate change, and then evaluating options available to mitigate vulnerabilities or other concerns that are identified through the sensitivity analysis. The following four steps – similar to other processes shown in Table 3 – can be applied across the variety of Board missions and objectives, but the degree to which the steps must be shaped to Board responsibilities and trimmed to available resources will only be known through trying. An iterative approach, with more detailed assessments coming after broad, preliminary assessments and in which Step 1 is applied to all Boards as soon as possible, would not only provide the IJC with an initial assessment of how well prepared it was for climate change; it would also show the degree to which boundary-wide consistency and Board-specific usefulness can be maintained simultaneously.

Step 1 - Organize

What are the objectives the Board is trying to achieve?

It's important to begin a self-analysis with a clear, complete, shared understanding of the objectives that the board is trying to achieve. This creates a context within into which climate change can be purposefully considered. What is the ultimate objective of the board and what are the roles they have and actions they can take to achieve them? For example, an objective might be to maintain lake levels or releases within a range that satisfies regulatory requirements and stakeholder preferences. Are there indicators or metrics that are currently used to evaluate whether the objectives are being met? For example, for water quality the indicators might already be identified, regularly collected data on water quality parameters. This organization step also helps identify gaps in information and data collection. The end product from this step is a consensus statement of how climate change may challenge the Board in carrying out its responsibilities. The first iteration will challenge the Board to think through implications for different responsibilities; later iterations can be better quantified and prioritized.

Step 2 - Analyze

Estimate how a change in climate might produce different outcomes from Board activities

This step is based on the Board's responsibilities and includes direct and indirect or cumulative impacts. For example, a Board charged with making releases to create hydropower, would consider direct impacts in terms of energy production and indirect impacts, such as the potential for brownouts.

For this step the analyst could use general climate change information products (such as those shown in earlier figures) that give some large scale guidance of what kinds of changes they should consider. For example, there is general confidence in warming, and warming causes reduced snowpack, early snow melt, etc. What does this mean for each watershed? Changes in precipitation on the other hand, are less certain. But what is plausible? Boards might consider what might happen if precipitation increased or decreased, on average, and what might happen if extreme precipitation became more intense and frequent.

Which of those outcome changes are most important, for better and worse?

The Board would rank or more likely categorize the outcomes from Step 1 according to the magnitude of the impact, independent of the likelihood of occurrence or degree of control the Board would have over it. For example, brownouts might go into the important category in this step, but in step 3 the Board might find that nothing they do would change the odds of brownouts, or in step 4 they might determine that no climate projection suggested there was a chance of flows getting low enough to cause brownouts.

How plausible is that climate will change in the way required to cause these outcome shifts?

The Board would create a chain of causality for each notable outcome shift; for example, brownout is likely with these extra-basin conditions plus this much less hydropower from the IJC influenced facility. That loss of power would result from this head and flow, which wouldn't be a problem until flows were this low for this long, which is a x% departure from the worst drought on record, which is considered plausible or not based on this or that climate assessment. The brainstorming professional judgment iteration would err on the alarmist side. For instance, if brownouts seemed to require flows half that of the worst drought on record, and there was evidence in paleo studies that flows this low were possible, then the Board might continue to the next steps, asking, if this is a plausible but unlikely outcome, can we prevent it, and if so, what are the other consequences of those actions?

In later iterations of this step, the Board would consider a range of climate information, including past observations and different projections. For example, if there is a trend in the observations and the same trend is evident in the projections from climate science, that would be strong evidence of plausibility, a reason to bear costs to avoid those outcomes, even though they were not certain.

There is a hierarchy of certainty in climate projections. There is confidence that temperatures are warming because of observations and sound scientific theory supporting it. There's some evidence precipitation extremes are increasing, but projections vary across the border and storm severity is more important in river flooding than lake flooding. The confidence in warmer temperatures creates a concern that evaporation will increase, but the process is more complicated so there is less certainty. On the other hand, the impact of warmer temperatures on snow pack is clearer, and the impact of less snowpack on water supply and flooding is well documented.

When climate was considered stationary for the planning horizon, planners would evaluate decisions using expected values, the product of the magnitude of an impact times the probability of it. Absent stationarity, the expected value of outcomes cannot be calculated, but it still must be estimated. It may be that most climate change issues Boards face can be resolved with little doubt, but there is a possibility that a costly alternative might be the only way to avoid a very bad outcome that is plausible, but barely.

Step 3 - Act

Which of those potential outcomes could the Board change? What are the possible actions the Board could take to address the concerns identified?

In the brownout example provided above, when the Board determined that brownouts might be caused by flows of less than x cfs through turbines, there might be inflow conditions for which no Board decisions would provide flows greater than x cfs, meaning there is nothing the Board could do to reduce the chance of a brownout. There might be other future inflow scenarios for which there was no concern over brownouts. In these two cases, no action would be required from the Board. But in-between there would be inflow conditions that differed from the historical by little enough that the frequency and severity of brownouts could be changed based on what the Board did. To the extent to which the Board determined that these inflow conditions were plausible, the Board would have to consider taking actions to prepare for them.

Formulation and evaluation of alternative climate preparedness actions

The Upper Great Lakes Study provides good examples of how this can be done for lake level regulation. The elements of that process that transfer to other management objectives are the creative development of a wide range of alternatives, and the estimate of how those actions affect outcomes under different climate scenarios.

What would be required for the Board to carry out this work?

In some cases, the Board has all the power it needs to develop alternatives that produce good outcomes under the plausible range of future climate scenarios. But that may not always be true. For example, land management decisions may be the only way to meaningfully reduce flood risks or improve water quality. In that case, the Board might consider actions that it is not prohibited from taking – for example, meeting with local governments and sharing pertinent research – that might mitigate the worst outcomes. Mention element of communications with local stakeholders from Section V, for example.

Step 4 – Update

After even the first iteration of the first three steps, Boards may decide that based on the plausibility and magnitude of impacts and the costs of preventive measures, that some proposed alternatives should not be undertaken. But the Board may at the same time determine that if the scenario became more plausible, or the costs reduced, or a new alternative was offered, that they would revisit the decision. The only safe way to assure this revisiting of decisions based on new information is to create an institutional context for doing so. In simplest form, this might be a short review every five years to ask whether there is any reason to go through the steps

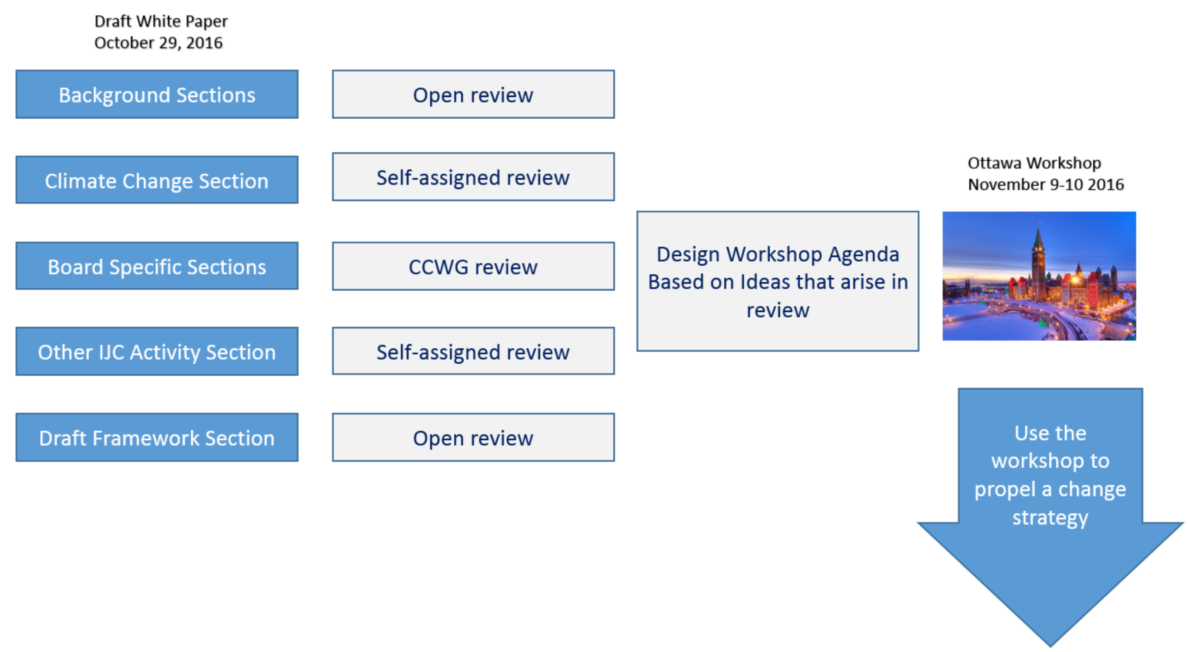


Figure 14 Work flow to create an IJC Framework for managing climate change issues

again. In many cases, a formal adaptive management process could be designed at a scale proportional to the cost, risk and uncertainty. Again, this has resource implications. If it is going to happen, there needs to be a way of ensuring it can happen. So I think what this step is, is the designing of an AM process.

VII. A Review of the Process for Implementing the Strategy

In the conception defined above, the Framework must be embraced by the Commission and integrated into the extensive efforts they have already made to address climate change. For that to happen, the commissioners would have to be made aware of the trajectory of the CAWG as soon as possible. The simple work diagram shown in Figure 14 shows what led to a workshop November 9-10, 2016 in Ottawa. A quick summary of the results was presented to the Commissioners in Washington during their December 2016 meeting. Commissioners were asked and they granted time on their January 2017 meeting for a longer briefing with some options for next steps. At the January 2017 meeting, Commissioners approved an approach to implement a pilot project of the Strategy within control, watershed, and pilot watershed boards. The pilot project would introduce Step 1 of the 4-step planning process to boards at board meetings or another convenient time for the boards. The pilot project would also introduce the entire 4-step planning process to one control, watershed, or pilot watershed board. This pilot project will provide a robust set of lessons learned that will be used to update the guideline document as necessary.

VIII. Findings, Conclusions, Recommendations

The Board representatives on the CAWG have clearly identified a need for support to the Boards on the issue of climate change, a need also identified by participants at the last 2 IWI workshops. This document proposes a preliminary framework for addressing those needs.

There already has been a substantial amount of work done by IJC Boards in advancing the state of climate science and decision making. There are IJC climate change initiatives underway now. The proposed framework would encompass and connect all this work so the contributions in one region could be used by all the Boards.

This paper explains why a decision-scaling approach is well suited to the IJCs management responsibilities. Decision-scaling starts with the identification of the most important impacts from climate change, determines the plausibility of those impacts occurring and then evaluates alternative ways to reduce those risks.

The Boards need more than climate science to do their jobs. The Boards work with stakeholders to carry out their responsibilities, and the effective communication of climate change management issues and positions will be essential in gaining stakeholder support for climate change initiatives. Trend analysis is often important in monitoring the onset of climate change; the framework must facilitate Board access to accurate data. Access to planning, decision support and risk management assistance will also be helpful.

The framework outlined in this document will be tested and improved through facilitated debate within the CAWG and through lessons learned from implementing a pilot project across control, watershed, and pilot watershed boards.