Synthesis of Learnings of the **Canadian Watershed Research Consortium**

Canadian Water Network

CONTENTS

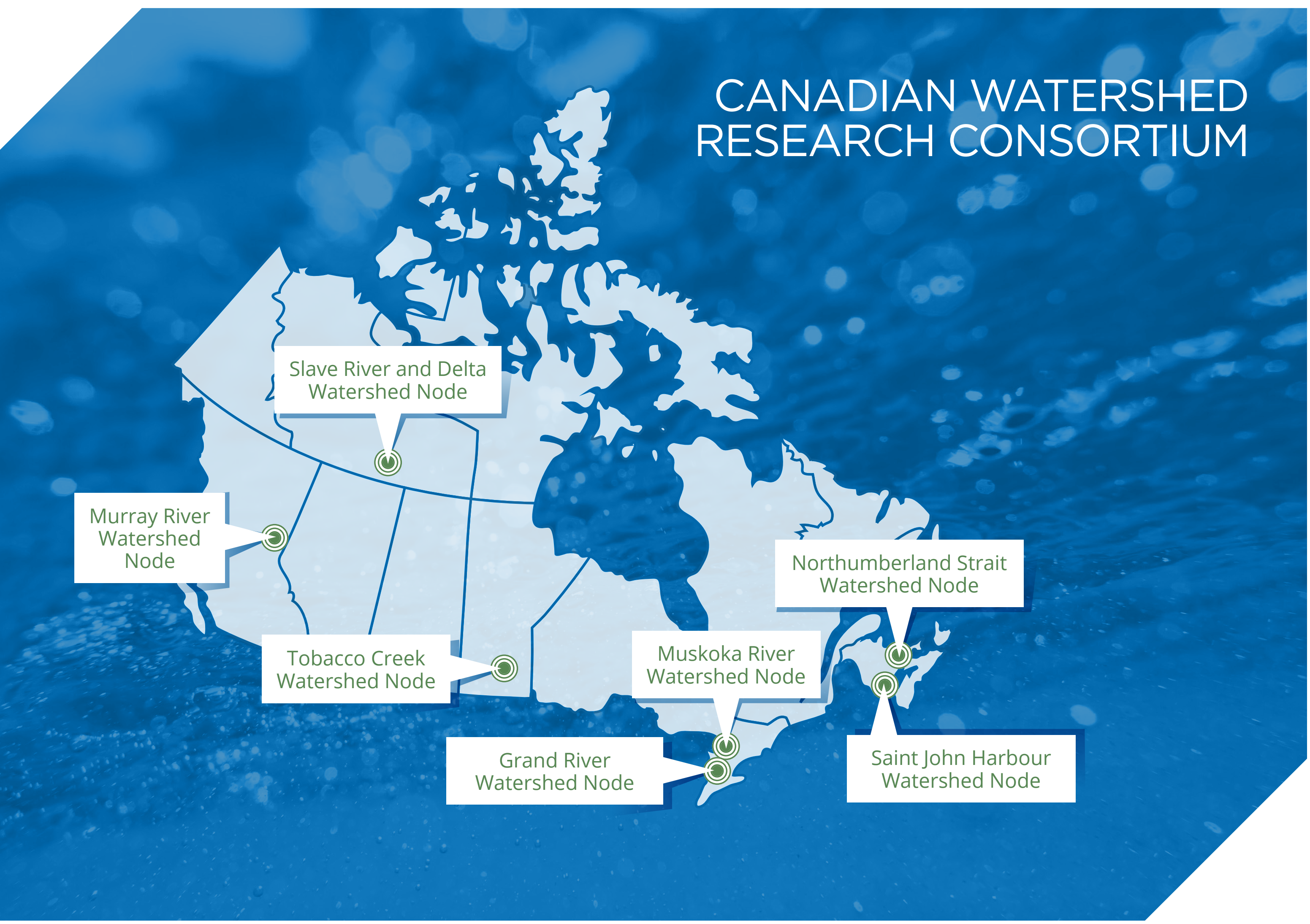
INTRODUCTION

Human activities and natural disturbances can cause impacts to the environment that accumulate over time. Within Canada, regulatory processes designed to prevent or mitigate adverse impacts or effects have often focused on Environmental Impact Assessments on a project-by-project basis. This approach has been critiqued for its lack of attention to synergistic and cumulative impacts to the environment (Dubé, 2015; Duinker & Greig, 2006). Cumulative Effects Assessment (CEA) involves monitoring, tracking and predicting accumulating environmental changes beyond any single project (Dubé, 2015). However, monitoring and predicting cumulative effects in a meaningful and actionable way has proven challenging.

Canadian Water Network's approach is to connect resources, people and knowledge to drive progress on collective water challenges. Our staff met with agencies and decision makers across the country to discuss the challenges of CEA. A collective need was identified for more consistent and effective monitoring frameworks that could enable a more sound understanding of effects beyond specific projects, as well as increasing efficiency and providing a regional basis for questions of concern.

Beginning in 2010, Canadian Water Network formed the Canadian Watershed Research Consortium (CWRC), with representatives from seven watershed-based groups across Canada. The Consortium's purpose was to support and catalyse groups to develop consistent regional monitoring frameworks that could support decision making for CEA and watershed management. By developing consistent monitoring methods, timing and locations, a baseline understanding of ecosystem conditions is being established that lays the foundation for being able to better understand variability and to develop better predictive tools.

This report provides a brief overview of the activities of the CWRC over the past five years, what we've learned about adaptive monitoring and the implementation of collaborative monitoring frameworks, as well as the potential benefits CWRC node partners foresee in using these frameworks.



ABOUT THE CANADIAN WATERSHED RESEARCH CONSORTIUM

In the early days of developing the CWRC, Canadian Water Network's consultation with end users pointed to several key priorities, including data availability and consistency, and methodology for conducting watershed-level assessments. To address these collective needs, Canadian Water Network developed an end user-driven approach to establish research nodes in watersheds across Canada, with diverse groups of local stakeholders and decision makers that were partnered with teams of Canadian water researchers. The CWRC was ultimately created to support regional efforts to design and use watershed-level cumulative effects monitoring frameworks that could support decision-making in land use management, natural resource management, impact mitigation and other areas.

An initial pilot project was undertaken in Saint John Harbour, where a previous research program with a wealth of historic data existed, and significant developments had been proposed. Once this project was established, Canadian Water Network issued a call for expressions of interest for the development of additional watershed research nodes. This process identified place-based regional partnerships with collective knowledge needs and the capacity to use the results to guide their monitoring programs. Four nodes were selected in the Grand River, Muskoka River, Northumberland Strait and Tobacco Creek watersheds.

A year later, a sixth node was added in the Slave River and Delta watershed. A project in the Murray River watershed in northeastern British Columbia was also developed following the same model, although it did not receive financial support from Canadian Water Network.

From the outset, stakeholders in the nodes such as water managers, government agencies, watershed groups, industry representatives and service and technology providers were involved as project partners. Each node identified their own collective needs for better information to support evidence-based decisions, including:

- Elements of baseline monitoring (i.e., selection of sampling and reference sites, indicators, sentinel species, sampling methods, timing and frequency)
- Descriptions of ranges of normal variance
- Triggers for additional monitoring and/or management responses when normal variance is exceeded

With support from Canadian Water Network, each node developed a tailored research call to meet its collective science needs for developing regional monitoring frameworks. Canadian Water Network administered and funded the calls for research proposals for multi-disciplinary, university-based research teams to develop recommendations for monitoring frameworks and to collect baseline information in support of CEA. The node partners then helped to evaluate the proposals to ensure that the research process was structured to support the node's decision needs (e.g. natural resource management or impact mitigation). The nodes identified which research team best met their collective needs and provided additional feedback on the proposals. The proposals also underwent technical scientific review to ensure academic excellence.

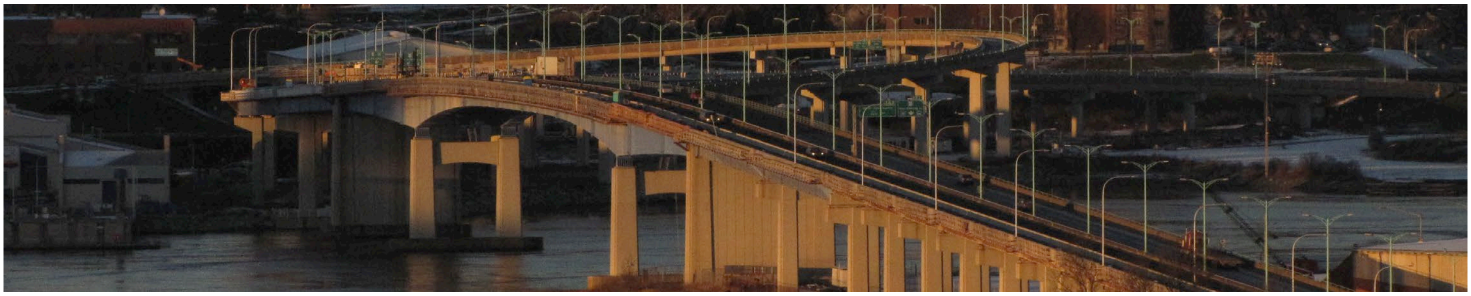
Each node tackled the questions of what to monitor for CEA. While monitoring to support CEA was the goal, and CEA provided a common foundation and longer-term goal, the focus for this stage of work was on developing better, more consistent baseline monitoring.

The section that follows provides background about each node's partners, drivers, challenges and research needs. Further details can be found at *cwn-rce.ca/canadian-watershed-research-consortium*.

Interpretations of some of the terms used by Canadian Water Network and the nodes vary. For example, the nodes used various approaches of endpoints, criteria or valued ecosystem components to focus their research.

Canadian Water Network's definition of watershed is deliberately broad to enable a regional approach at a scale appropriate for each group. For some nodes, the appropriate scale is sub-watershed, while in others the scale is multiple watersheds.

The nodes are watershed-based because context is important for the science and implementation of the monitoring frameworks. It became very apparent during this program that there is a wide range of understandings and applications of the term CEA and related terms.



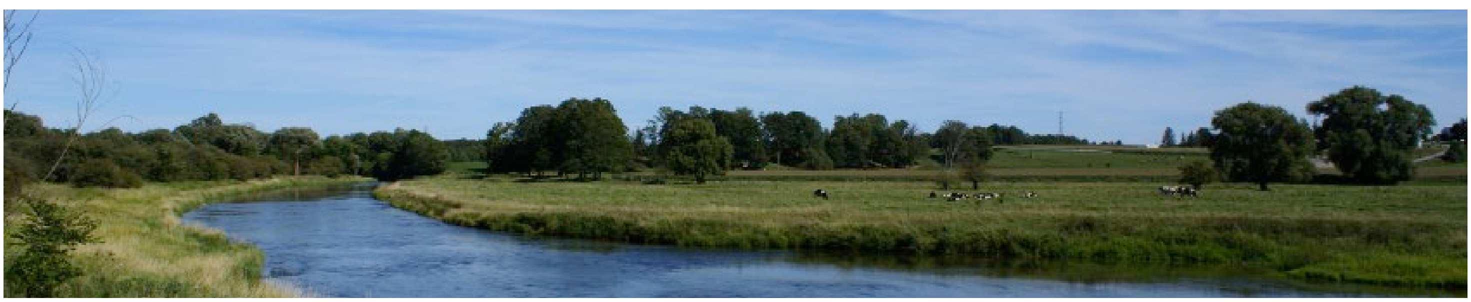
Saint John Harbour Watershed Node

Saint John Harbour in New Brunswick is undergoing significant development, which is a key driver for partner interest. A variety of groups, including regulators, government agencies, industry and non-governmental organizations have collected data related to the ecological health of the harbour. Historically, these monitoring activities occurred in silos with overlapping efforts leading to inefficiencies or redundancies, and data were not consistently collected, shared, reported or used for water management decisions. Many studies had examined the types and levels of contaminants in the harbour and the effects of development on fish and sediment-dwelling invertebrates, but this research base was not being used in Environmental Impact Assessments.

The challenge for the Saint John Harbour watershed node was to focus on developing optimal long-term monitoring programs that could be used to satisfy a range of regulatory requirements, while establishing reference and baseline conditions and thresholds against which changes of concern could be identified.

Specific research goals of the Saint John Harbour watershed node were to better understand:

- The spatial and temporal variability in contaminants found in the sediments and animals
- The macroinvertebrate community that lives in the sediments
- Sentinel species that reflect the health of the water column



Grand River Watershed Node

The physical, chemical and biological characteristics of the Grand River in Ontario are very complex and variable along the length of the watershed and over time. Pressures include a largely agricultural land base, a growing and highly urbanized population with subsequent water and wastewater impacts, and climate change. Stakeholders include the Grand River Conservation Authority and multiple municipalities, regulators and industries.

A lack of understanding of the relationships between biological, physical and chemical processes and mechanisms which affect aquatic ecosystems is a factor that constrains effective management of the watershed. Additionally, detecting change in ecosystems and aquatic communities requires an understanding of the variability induced by natural and human stressors. Identifying appropriate biological indicators (i.e., endpoints) relevant to the Grand River system and monitoring techniques that best reflect changes in the watershed are key priorities for the node.

Specific research goals of the Grand River watershed node:

- Synthesize historic and current biomonitoring research and studies in the watershed
- Develop a monitoring approach that includes biological indicators to detect changes in the headwater, central and lower river regions
- Increase scientific understanding of relationships among biological, physical and chemical processes in the river
- Develop approaches or predictive tools related to how biotic indicators respond to stressors in the watershed

Muskoka River Watershed Node

Water quality in the Muskoka River watershed in Ontario has been impacted by changes in land use, resource extraction and invasive species. Although monitoring has been widely conducted in the past, it has not been well aligned with watershed management needs. Aligning the existing monitoring activities at the watershed scale has been challenging, and the existing *Lakeshore Capacity Model* (which is used to review development proposals) has a number of limitations, with its simplistic focus on phosphorus and observed declines in water quality.

Stakeholders from the District of Muskoka and other levels of government, area lake associations and other interested parties identified calcium and phosphorus levels, climate change, acidification, invasive species and development as key priorities. Phosphorous levels and calcium levels in the watershed have both declined, with potential impacts on the health of biota in the watershed. Dissolved organic carbon and salinity have risen in many lakes and streams, with unknown impacts on nutrient availability, lake thermal properties and biodiversity.

Specific research goals of the Muskoka River watershed node:

- → Identify biological, chemical and physical indicators to characterize baseline conditions and provide benchmarks to assess lake condition
- → Begin to determine the causes and implications of changes in the watershed
- → Develop a conceptual model that associates multiple stressors and their cumulative effects

Northumberland Strait Watershed Node

Stakeholders perceived that the rivers, estuaries and coastal regions of the Northumberland Strait, which separates Prince Edward Island from New Brunswick and Nova Scotia, had been experiencing declining fish stocks and ecological degradation over the past two decades, including loss of eelgrass habitat, increased frequency and magnitude of opportunistic blooms of macro-algae (sea lettuce) and hypoxia or anoxia (i.e., very low or no dissolved oxygen) in estuaries. The development of the Confederation Bridge, extensive agriculture and other human activities were felt to be potential causal factors.

The region's estuarine aquatic plants, invertebrates and fish — all of which support coastal fisheries, aquaculture, tourism and recreation in the strait — are valued ecosystem components. Consultation with stakeholders from fisheries groups, government agencies and industry identified the influx of sediments, contaminants and nutrients from land-based activities as key priorities. The stakeholders are concerned about how human activities on land affect the watershed, and as an initial focus, the estuaries where the rivers meet the sea.

Specific research goals of the Northumberland Strait watershed node:

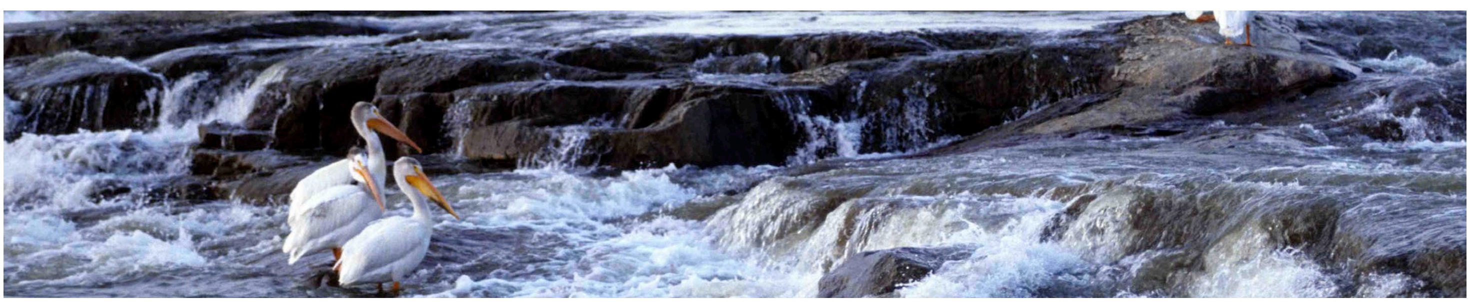
- → Develop a recommended sampling strategy to improve CEA focused on nutrients, sediments and contaminants from land-based activities on fish and fisheries, invertebrates, aquaculture and submerged aquatic vegetation in the estuaries of the Northumberland region
- → Establish a regional monitoring framework in support of CEA
- → Determine sample locations (including reference sites), indicators, sampling methods, and sampling frequency and timing

Tobacco Creek Watershed Node

Modern agriculture has come under intense scrutiny in regards to water quality and biodiversity issues in the Red River Valley and Lake Winnipeg Basin areas of southern Manitoba. Flooding, nutrient loading and the health of aquatic biota are challenges in the Tobacco Creek watershed. Substantial research has been conducted in the Lake Winnipeg basin regarding cumulative effects. However, the region lacks an integrated monitoring network that can provide baseline data, track changes over time, and determine which beneficial management practices (BMPs) are most appropriate and cost-effective for particular forms of agriculture. Evaluating agricultural and water management practices and establishing baseline data to understand the impact of BMPs and encourage uptake are the key priorities identified by farmers, municipalities, the agriculture industry and governments.

Specific research goals of the Tobacco Creek watershed node:

- Provide a monitoring framework to evaluate agricultural practices and water management schemes
- Establish ecological baseline data on water quality, hydrology, sediment and aquatic biology against which to measure the cumulative effects of natural processes and management practices
- Develop effective, region-specific biotic indicators within the context of annual and seasonal hydrologic regimes
- Develop protocols for sample site selection, sampling methodologies, sample timing, frequency, handling and analysis, and indicator selection and application
- Measure the consequences or benefits of artificial structures such as small scale dams



Slave River and Delta Watershed Node

The Slave River and Delta watershed node in the Northwest Territories includes representatives from Indigenous, municipal, territorial and federal governments, and educational institutions. They have expressed concerns about impacts on water quantity and quality due to resource extraction upstream in the Athabasca River and Peace River watersheds, changes in hydrology due to hydroelectric development, contaminant impacts on traditional foods, and changing ice conditions due to climate change. The Partnership posed three questions: Is the water safe to drink? Are the fish safe to eat? Are the plants and animals healthy? Prolonged and diverse impacts on the river have eroded the confidence of Indigenous peoples in the quality of the river's waters and related biota, which has resulted in economic, social and cultural hardship. Other priorities that have been identified by the partners include the human dimensions of aquatic ecosystem change and community-based monitoring.

Specific research goals of the Slave River and Delta watershed node:

- Assess the current situation, monitor future changes and inform decision making about the health of the waters, fish, benthic invertebrates and ice
- Incorporate Traditional and local knowledge at all stages of research design and implementation
- Develop recommendations for the design of a regional watershed monitoring framework to support CEA and adaptive management strategies. Elements to be incorporated include: hydrology, water quality, fish and benthic invertebrates, human dimensions of aquatic ecosystem change and community-based monitoring

Murray River Watershed Node

Canadian Water Network also worked with a group in the Murray River watershed in northeastern British Columbia on issues related to natural resource development. The Murray River watershed has a number of large scale developments, including coal mines, natural gas extraction and transmission, forestry and wind power. Local Indigenous communities are concerned about the scale and pace of development and its impacts on water quality and quantity and fish and wildlife. The stakeholders involved in this work sought Canadian Water Network's expertise and guidance in the development of their partnership. While this group did not receive funding to develop their monitoring framework in support of CEA, they did invite Canadian Water Network to participate in their group and sent representatives to the annual internode workshops, where they shared information on their progress.

Specific research goals of the Murray River watershed node:

- Assess and better understand the aquatic ecosystem of the Murray River watershed and the cumulative effects of development in order to inform the management actions required to improve the sustainability of the watershed
- Work together to align and combine monitoring initiatives
- Develop an aquatic CEA framework that can be used here and in other watersheds to inform future management decisions

COLLABORATING WITHIN THE WATERSHED FOR A COMMON PURPOSE

Articulation of the watershed's research needs and ongoing exploration of how to best address those needs have been the hallmarks of the various watershed nodes. The need to continuously engage and re-engage potential node partners is also a common thread. The diversity in the nodes' partnership structures illustrates that there is no one particular format that works best for every group. Many of the nodes developed terms of reference and organized consultation exercises with their partners. Other nodes used existing models or conceptual frameworks to identify key concerns, such as the DPSIR model which considers drivers, pressures, the state of the environment, impacts and management responses. The Saint John Harbour watershed node and Northumberland Strait watershed node also created science advisory committees to provide ongoing input and facilitate communication with the researchers.

At the outset, most nodes identified that research could contribute to both short- and longer-term outcomes related to cumulative effects monitoring. For example, researchers in the Northumberland Strait watershed node initially evaluated monitoring strategies for the impacts of nutrients and sediments, with a vision to develop relationships between stressors and changes in valued ecosystem components to enable decision making. The Muskoka River and Grand River watershed nodes also identified short term monitoring strategies and longer term modeling goals.

Some nodes have had their work on cumulative effects monitoring frameworks integrated into a larger process from the early stages of their work. These larger processes shaped the nodes' articulation of science needs and the activities of the research teams. For example, the *Grand River Watershed Water Management Plan* provided a collaborative opportunity that brought multiple stakeholders to the table.

WHAT HAVE WE LEARNED?

In 2015, Canadian Water Network contracted an independent expert to assess how well the CWRC met the needs and expectations of its participants, and to provide observations regarding implementation of the research that resulted (Maas, 2015). This assessment was based primarily on information gathered from the Saint John Harbour, Grand River and Tobacco Creek watershed nodes. Coupled with Canadian Water Network's insights from ongoing interaction with all of the nodes, we are now able to share some high level learnings.

Recommendations for adaptive monitoring

Begin the design process by defining a common understanding.

Although assessing environmental conditions and thresholds is dominated by science-based approaches and activities, the process of defining ecological goals, making management decisions, or determining levels of acceptable risk is based on human values as well as science. A common understanding of the terminology is an essential prerequisite for meaningful collaborative discussions and informed decision making. Given the broad range of partners at each table, breaking down silos of language, discipline or industry was critical.

An important start to any common understanding is an appreciation of the range of terminology and interpretations used in discussions. For example, the terms Environmental Impact Assessment, Environmental Effects Monitoring and CEA all have specific legal meanings, but are variously referenced in different regulations or guidance, where their scope and intent is differently interpreted. Even 'cumulative effects' is interpreted in many different ways by different players. Coming to the table together to discuss these concepts has enabled the nodes' partners to better understand each other's use of these terms.

Because it is not practical to measure everything, partners must also come to an agreement of what to measure, based on the issues facing their watershed. Identifying what to measure stems from both social values (i.e., which components are most important) and science (i.e., which indicators or endpoints are appropriate for capturing impacts of relevance to those components, as well as when and where to measure). For example, fish health is considered by partners in the Slave River and Delta to be a key component to measure, so the research team developed a fish health index that incorporated information on internal and external anomalies with contaminants found in fish, as well as Traditional Knowledge about the quality and numbers of fish (Jones, 2015).

In addition, common understanding comes from consistency in the monitoring efforts taken by the various groups within a region. The disparate monitoring methods used historically by each of the node partners were often inconsistent, even for the same type of endpoint. The CWRC's original goal of developing a consistent regional approach for sampling strategy, endpoints and protocols was intended to help coordinate monitoring efforts, reduce duplication of effort and allow data to become regionally available. Duinker and Greig (2006) contend that CEA logically is well suited to a regional scale, while Dubé (2015) argues that CEA must occur at various scales, with consistency across those scales to enable a broader picture of environmental conditions. Consistency across scales also enables a common understanding of ecosystem health amongst various partners.

The shared exploration and articulation of goals and monitoring needs was discussed not only among the partners within each node, but also among the nodes at Canadian Water Network's annual internode workshops. Participants from each of the nodes who participated in these workshops expressed the value of exploring common goals beyond the individual node level.

Establish and maintain a partner-focus to the research being done.

Collaboration is highly effective when used to address complex problems that cannot be easily solved within one organization. Truly collaborative processes are based on voluntary engagement, and involve shared authority and decision making (Jones, 2016). Involving the right people from the right organizations is challenging, but increases credibility and the likelihood that the research results will be used to inform decision making. The CWRC's node partnerships were very diverse and included interested parties both from within and outside of government. The nodes which were able to engage key decision making agencies throughout their project are optimistic that implementation of the monitoring frameworks will proceed, whereas the nodes which faced challenges keeping decision making agencies at the table have a less clear path toward implementation.

The nodes noted that collaborative processes take time, but many of the important outcomes identified by node partnerships came about because of these processes. Benefits include, "stronger, more collaborative relationships; the diversity of sectors and organizations represented in the nodes; and building of trust and ongoing dialogue" (Maas, 2015, p. 20). The independent assessment of the CWRC also concluded that, "without Canadian Water Network taking on the convening role and having the resources to do it well, these benefits would likely not have been realized" (Maas, 2015, p. 20).

> "If we did anything in these three years it is build relationships — that's been more important than any science we've done… but it is through the science these relationships have been built."
>
> Interview response, CWRC program review *(Maas, 2015, p. 17)*

One of the key learnings of the CWRC has been that it is critical to involve all relevant partners at the outset of the process. Projects have been most successful when all partners were brought around a common table at the beginning to co-create their node's monitoring vision, articulate valued ecosystem components and discuss values. It is important to define the role and participation of partners from the outset. Partners who followed this type of process noted that this set the stage for stronger ongoing relationships.

Following that first step of relationship-building among stakeholders and prioritizing of research needs, partnerships were able to participate with Canadian Water Network and external experts in running competitions to choose a research team that would best meet those research needs. Relationships were then established between the partners and research teams early in the process, and partners met with the researchers often (in some cases semi-annually) to ensure that the research remained on-track to address the needs of the partnership. Almost every research team reported that they had achieved an outcome of strengthened relationships with partners. They indicated that their close engagement with the partners has led to new areas of research and new insights, and improved the design of monitoring programs. Despite the challenges this type of research can present, many researchers felt this work to be very rewarding.

Prior to development as a CWRC node, there was a duplication of monitoring efforts in the Saint John Harbour. Bringing partners together to consider the health of the harbour has opened the door to information sharing and increased dialogue, while reducing redundancy and strengthening relationships. Members of the Environmental Monitoring Partnership have noted that their participation has demonstrated to the public that their industries are committed to environmental stewardship. One partner commented, "Getting a permit is one thing, but having social licence and showing we are taking care of the waters is huge. Within the partnership, the two things actually go hand in hand" (Maas, 2015, p. 6).

> "[This is] an opportunity to avoid reinventing the wheel and to invest collective resources in a shared system, rather than making separate investments in separate, uncoordinated monitoring efforts."
>
> Interview response, CWRC program review *(Maas, 2015, p. 5)*

Develop place-based monitoring strategies that meet the needs of decision makers.

There is no single template for collaborative, multi-actor water governance in Canada. The partners involved, the questions asked, specific results and how information will be used to make decisions are unique to each node. Place-based monitoring strategies enable more effective, targeted science that meets the specific needs of decision makers in the area.

For the Slave River and Delta watershed node, it was critical that community-based monitoring underpinned their framework, so it was incorporated in the original call for research. In the Grand River watershed node, the agencies involved in the Water Management Plan helped define the initial research goals and are logical implementers for some of the research recommendations.

While some components of monitoring frameworks are common across multiple nodes, others are very specific to the region and have only been considered by one node. For example, several of the research teams examined benthic invertebrates or stream metabolism as indicators of watershed health, while the focus on endpoints such as eelgrass or air pockets in ice are very specific to a particular region, given the importance of these endpoints to the partners in the area.

Recommendations for implementation

Monitoring frameworks should be linked to existing governance.

Monitoring frameworks should be linked to the structures and processes through which decisions are made, including regulatory requirements. De Loë (2015) identified a gap between collaborative processes and existing government decision making processes. This gap is evident for a number of the watershed nodes, as they seek to use the monitoring frameworks developed through a collaborative process. All of the nodes have found that involving groups with a mandate to make decisions regarding monitoring and management throughout the process has been important.

Some nodes were engaged with organizations with a clear mandate to use the scientific findings to influence their monitoring and management practices. In other nodes, regulatory agencies needed to agree (or will need to agree) to accept the data from a shared monitoring program in place of the individual sampling currently done by proponents.

> "If we can't tie everything to some regulatory process, and if that regulatory process can't feed into what the consortium is doing, and if the consortium is not aware of the regulatory connections, the fear is that it will just be another research exercise that gets shoved in the drawer."
>
> Interview response, CWRC program review (Maas, 2015, p. 8)

Some nodes have been able to develop a better understanding of what affects decisions at local, provincial and federal levels, while others have had significant challenges in developing relationships or keeping decision making agencies at the table that would enable them to find the mechanisms to change current monitoring practices.

In the case of watersheds, tools are needed to help find gaps in controls such as existing legislation and policies, as well as to evaluate potential management actions to mitigate cumulative effects. Bow-tie analysis is one such tool that several of the nodes have investigated to examine existing governance regimes and their connection to ecosystem management. This tool allows for the evaluation of management controls and the pathways of risks leading to undesired consequences. Bow-tie analysis can also help clarify the kind of monitoring information needed to support management decisions, and conversely, assess the value of monitoring endpoints being collected.

Direct incorporation or referencing of monitoring framework recommendations doesn't necessarily need to take place at the regulatory or legislative level to ensure connection to governance. The Grand River watershed node's connection to the recently completed *Grand River Watershed Water Management Plan* provides a clear place of entry for the research findings to be implemented. The plan is not based on legal requirements, but on collaboration to align efforts towards a common agenda. The associated Water Managers' group also provides a mechanism to move the implementation forward.

Coal mines in the Murray River watershed are required to contribute to a cumulative effects monitoring program as a condition of their provincial licence to operate. Their participation in the node enables them to meet that requirement.

Leadership capacity and resources should extend to implementation.

Sufficient human and financial resources are essential for putting the monitoring framework recommendations into practice. There must be dedicated resources to sustain the work of the node over time. The independent assessment noted, "The people engaged in the nodes are busy balancing various responsibilities within their organizations and it is unlikely that a leadership role can be sustained if it is added on top of existing responsibilities" (Maas, 2015, p. 22).

Several nodes had administrative support from one or more of their partners during the initial stage of developing a monitoring framework. However, clearly defined responsibilities over the long term, including who should do the monitoring, is needed. In some nodes, there have been champions from a partner organization who have gone beyond their institutional role to encourage, convene and promote the node's activities. However, if the role or mandate of this champion changes, momentum can falter.

Initially, the Canadian Rivers Institute provided administrative support to the Saint John Harbour and Northumberland Strait nodes during their CWN-sponsored research phases. Since then, ACAP Saint John and the Southern Gulf of St. Lawrence

> "Effectively integrating the research into governance regimes will require people and money to convene and coordinate meetings and workshops, to spend the time it takes to engage additional stakeholders in partnerships, to establish and manage tools and processes for data sharing, and to translate the often complex scientific information in ways that can be presented to a range of different audiences, from the public to politicians."
>
> CWRC program review *(Maas, 2015, p. 22)*

Coalition on Sustainability have taken on the role of providing administrative support to Saint John Harbour and Northumberland Strait nodes respectively. For other nodes, the initial organisation that coordinated the research phase was able to continue on to the implementation phase.

The Grand River watershed node will be phasing in elements of their monitoring framework over time. Similarly, the Tobacco Creek watershed node has planned a staged implementation process that takes into account the limited capacity of the partner organizations. Both nodes have noted that starting with a basic biological monitoring protocol can provide a foundation upon which to build a more comprehensive regional monitoring framework.

Don't overlook the role of communication in ensuring the project's success.

Sharing the concrete value resulting from invoking a more effective monitoring framework is important for all nodes to generate ongoing support through resources and to improve uptake by influencing decision making. Coordinating and keeping the right people at the table is critical. Communication should be tailored to meet the needs of the different groups, including both senior decision makers and a more general audience. This may involve questions like, "Can we meet with your group to determine how what we are doing might integrate with what you are doing? Is what we are doing useful to you? How could it be more useful to you?"

Senior leaders in the partner organizations — as well as local and provincial politicians, must buy into the project. It should also be noted that some node partners may be willing to implement the recommendations developed by the research teams, but may not have a mandate to make decisions.

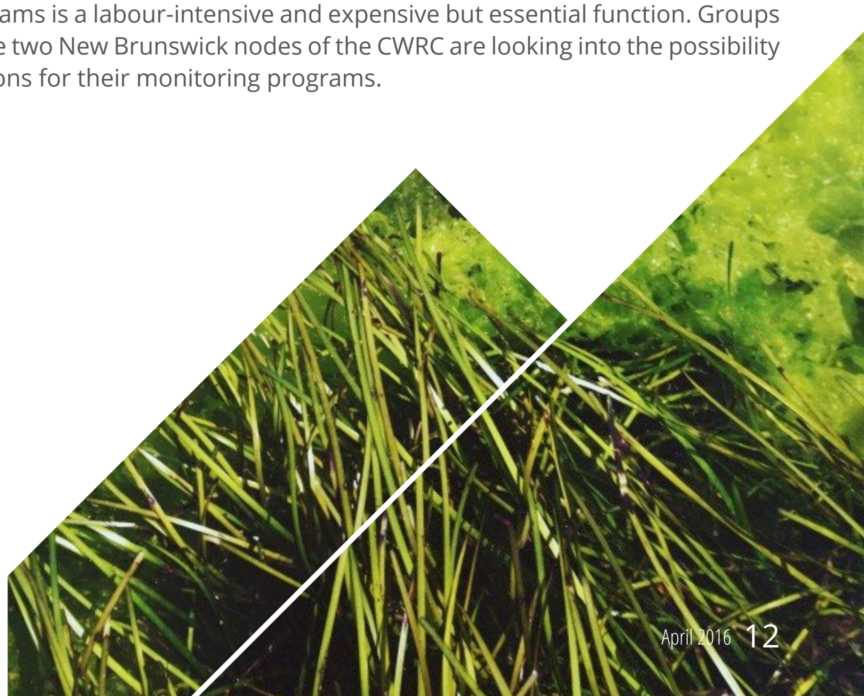
Potential benefits to decision makers could include:

- Reduced overlap and greater efficiencies from pooling information and capacity
- Relevant, reliable, accurate and precise monitoring information and models that can be demonstrated to accurately predict environmental responses to particular stressors
- Potential cost savings
- Increased scientific credibility as a result of employing world-class researchers
- Broader knowledge of overall ecosystem health for long term planning
- Success stories to share

Community members in the Slave River and Delta watershed requested communications in forms other than standard reports. In response, the research team developed an infographic and whiteboard animation, visited classrooms, organized joint field trips and shared findings at community workshops. The infographic includes six faces of Indigenous understanding within an adaptive management framework. The whiteboard animation, which was especially well-received, shares stories told by Elders about the changes they have experienced as a result of increased activities in the Slave River Basin.

Consider ownership and consistency of data.

It is becoming generally recognized that compiling, archiving, quality-checking, synthesizing and making available the very large data sets that result from environmental monitoring programs is a labour-intensive and expensive but essential function. Groups are struggling to accommodate this need. For example, the two New Brunswick nodes of the CWRC are looking into the possibility of a New Brunswick data warehouse to serve these functions for their monitoring programs.



HOW IS THIS INFORMATION BEING USED BY DECISION MAKERS?

Collecting environmental data is of no value unless the information is interpreted and used (Dubé, 2015). One basic but informative method to interpret the data gathered by the monitoring framework is to compare the monitoring results to some sort of benchmark or limit. This can help partners understand what the range of normal looks like (i.e., the baseline), the threshold beyond which monitoring results are outside of normal, and when baselines are shifting. This type of interpretation supports both decision making and long-term predictive modeling. Decision makers can set triggers for endpoints, to allow action to be taken before a particular threshold is reached. When monitoring indicates that a trigger has been reached, actions may be taken, including the implementation of additional or different monitoring or management measures (e.g., restricting access to an area).

Benefits from the development of collaborative monitoring frameworks also included enabling partners to monitor, report, learn, and apply in support of adaptive management. Partners noted that the frameworks must lead towards predictive models or relationships that link stressors or drivers to environmental changes of concern.

As their work has progressed, several of the nodes have considered thresholds. Researchers with the Saint John Harbour watershed node have been able to identify contaminant hotspots in the harbour sediments based on comparison of their early monitoring results to a number of thresholds. Researchers with the Muskoka River watershed node have identified thresholds for calcium levels in different lakes across the watershed.

A number of the nodes have identified contexts in which research results have shown potential to influence decision making:

SAINT JOHN HARBOUR WATERSHED NODE

The node's research findings have been used to support Environmental Effects Monitoring study design submissions by JD Irving Ltd, and in an Environmental Impact Assessment submission by Potash Corporation. Information on the impacts of harbour dredging are also useful to address concerns identified by the Port Authority.

MUSKOKA RIVER WATERSHED NODE

The research results indicate that some lakes are so sensitive that any timber harvesting in their catchment may cause calcium concentrations to drop below a biologically damaging threshold. It is anticipated that Westwind Forest Stewardship, a partner in the node, will use this information to guide their harvesting activities.

TOBACCO CREEK WATERSHED NODE

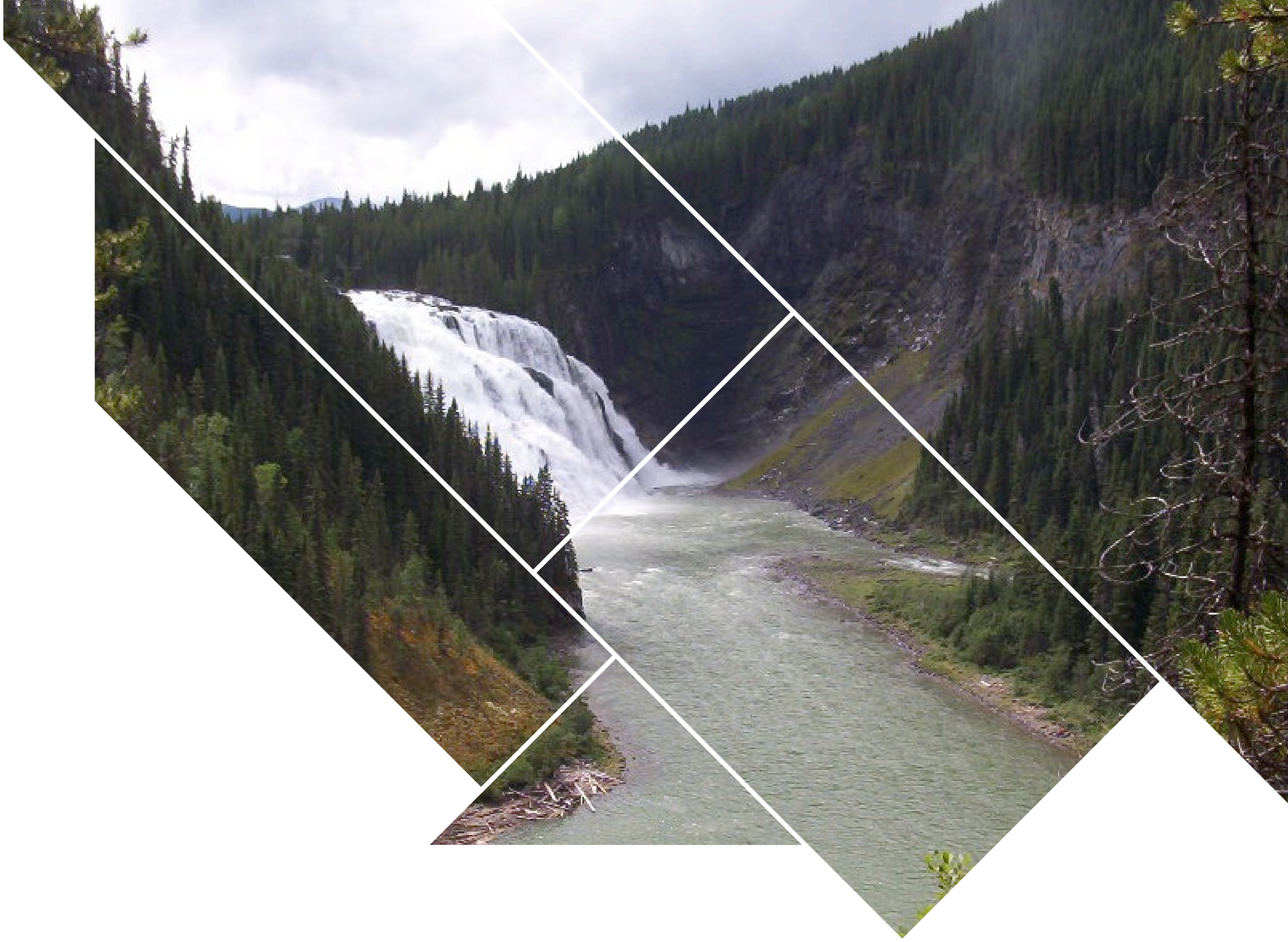
Research findings may have influenced land owners' actions regarding management of cattle and vegetation in riparian zones.

NORTHUMBERLAND STRAIT WATERSHED NODE

Fisheries and Oceans Canada is working to develop marine environmental quality indicators and benchmarks for the Northumberland Strait. They have approached the node's research team to build on the research conducted. The node and Fisheries and Oceans Canada are currently exploring options to work together on indicators and benchmarks that are intended to adjust management practices.

SLAVE RIVER AND DELTA WATERSHED NODE

Findings on changing ice conditions, including air pocket formation, have significant implications to both management and public safety. "Predicting river ice-induced natural hazards, such as ice cover breakup and ice jam flooding are important for the community to adapt to changing or hazardous ice conditions by altering means of transportation to areas reliant on river ice for access" (Jones, 2015, p. 3). This information may be useful in the daily decisions for people going out on the land.



MOVING TOWARD ADAPTIVE MONITORING AND MANAGEMENT

The nodes have completed the first step of developing a monitoring framework with consistent monitoring indicators. At this stage it is difficult to determine to what extent all seven nodes will continue the monitoring programs that have been developed. The frameworks developed by each of the nodes were designed specifically to answer questions raised by the node's partners. Some are progressing towards developing node-specific monitoring triggers. Most of the nodes have been considering adaptive monitoring and adaptive management as the logical application of their research work.

The Muskoka River watershed node has been considering how their state-of-the-environment report card can feed into an adaptive environmental management process. There is an opportunity to better align with valued ecosystem components and societal goals for the watershed, and to build on the science to improve criteria to evaluate future shoreline development beyond their current phosphorous-based model. As well, there is great interest in exploring the capacity of the developed monitoring framework to support detection of climate change impacts and efficacy of associated mitigation measures. Finally, it is noteworthy that the CWRC process has advanced our understanding of CEA. A very good example of this also resulted in the Muskoka River watershed node; researcher Chris Jones published a review of CEA principles and challenges (Jones, 2016) which was inspired by discussions held with researchers from other nodes at CWN's annual internode workshops.

"There is a strong need to apply and leverage research to:

- better understand natural processes
- set appropriate management targets
- augment the existing monitoring to assess cumulative effects relative to the targets established throughout the entire river system
- understand and target most effective actions
- operationalize new approaches and technologies."

— Grand River watershed node *(Veale, Cooke, & Bicudo, 2013)*

WHAT DOES THE FUTURE HOLD?

The Canadian Watershed Research Consortium illustrates the benefit of structuring discussions to address collective water management questions. The design of monitoring frameworks in support of CEA must consider both human values and science, and be built upon common understanding. Bringing partners and researchers together has brought the right knowledge forward to build collaborative, place-based monitoring frameworks. The science conducted over the past five years has been very successful; research teams have identified components of monitoring frameworks to address the collective needs of each node.

The context of each node's collaboration has been key. The process required identifying the right people/partners at the outset, and then identifying their unique decision needs, capacity and mandate. Partners valued the opportunity to shape research questions and agendas before any decisions had been taken, but that alone is not sufficient to successfully implement the monitoring frameworks. Putting the monitoring frameworks into action requires links to the processes or 'infrastructure' through which decisions are made (i.e., governance regimes), leadership, resources and targeted communication of the value of the monitoring frameworks.

Clear steps, roles, and responsibilities in moving towards implementation or practical use of the monitoring frameworks have not all been defined for all of the nodes. However, both the research teams and the nodes have made efforts to interpret the data developed during the creation of the monitoring frameworks, and several clear examples are available in which the science advancements have supported decision making for node partners. Nodes have indicated that using a phased approach to implementation, as part of an iterative and adaptive process, is likely to be better received than pressure to adopt all of the recommendations for a monitoring framework at once.

Nodes have benefited from their work to develop a collaborative monitoring framework, and while most nodes have not yet used the monitoring frameworks for decision making (or implemented them), some very clear possibilities exist for the process to be used in making management decisions.

Following the completion of the research funded by Canadian Water Network, node partner representatives and key implementers — including federal and provincial regulators, met to reflect on the collective learnings from the CWRC within the broader context of other activities in Canada focused on evolving the practice of CEA and related Environmental Impact Assessment. This workshop enabled the groups to learn from the collective experience and share thoughts on best next steps in the development of what were recognized as improvements in the adaptive monitoring framework approach that underpins all variations of CEA being practiced in Canada. Key learnings from the CWRC nodes were used as the basis for discussion of opportunities to develop adaptive, cost-effective monitoring approaches, within the nodes and more generally across Canada.

Looking at the experience of the last five years with the CWRC, workshop participants strongly endorsed the paradigm that had been followed by the nodes. All agreed that learnings from the nodes provided useful examples of principles that could be followed for the development of CEA monitoring throughout the provinces and territories of Canada. The best mechanisms to capture, convey and share the core principles with data-collectors, regulators, managers and politicians are now being explored by a leadership group.

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APPENDIX A: CWRC MANAGEMENT COMMITTEE, PAST AND PRESENT

Chair

William (Bill) Goodfellow Jr, MSc
Principal Scientist, Exponent Inc.

Co-Chair

Simon Courtenay, PhD
Scientific Director, Canadian Water Network (2013 - current); Professor, School of Environment, Resources and Sustainability, University of Waterloo

Kelly Munkittrick, PhD
Scientific Director, Canadian Water Network (2009 - 2013); Director of Monitoring, COSIA

Members

Alex Bielak, PhD
Founder and Chief Knowledge Broker, Alex Bielak Communications

Richard Butts, PhD
(retired) Director General, Agri-Environmental Knowledge, Innovation and Technology Directorate, Agriculture and Agri-Food Canada

Bernadette Conant, MSc
Chief Executive Officer, Canadian Water Network

Jiri Marsalek, DSc, PhD (h.c.) DrEng (h.c.), PEng
Scientist Emeritus, National Water Research Institute; Adjunct Professor, Urban Water, Technical University of Lulea, Sweden

Fred Wrona, PhD
(current) Chief Scientist, Monitoring and Science Division, Alberta Environment and Parks; (past)Director, Aquatic Ecosystem Impacts Research Division, Environment Canada

Grand River Watershed Representatives

Sandra Cooke
Senior Water Quality Supervisor, Grand River Conservation Authority

Lorrie Minshall
Water Management Plan Director, Grand River Conservation Authority

Muskoka River Watershed Representatives

Judi Brouse
(retired) Director of Watershed Programs, Muskoka Watershed Council

Christy Doyle
Director of Environmental and Watershed Programs, District Municipality of Muskoka

Isobel Heathcote
Professor Emeritus, Environmental Science and Environmental Engineering, University of Guelph

Greg Mierle
Ecologist, Dorset Environmental Science Centre, Ontario Ministry of Environment

Northumberland Strait Watershed Representatives

Mireille Chiasson
Regional Manager, Oceans Programmes, Fisheries and Oceans Canada

Cindy Crane
Surface Water Biologist, PEI Department of Environment, Labour and Justice

Tanya Dykens
Senior Water Management Specialist, Agriculture and Agri-Food Canada; Southern Gulf of St. Lawrence Coalition on Sustainability

Chantal Gagnon
(retired) Executive Director, Southern Gulf of St. Lawrence Coalition on Sustainability

Angela Douglas
Executive Director, Southern Gulf of St. Lawrence Coalition on Sustainability

Saint John Harbour Watershed Representatives

Carole Godin
Senior Fisheries Protection Biologist, Department of Fisheries and Oceans

Renee Morais
Environmental Coordinator, J.D. Irving, Limited

Tim Vickers
(current) Senior Environmental Scientist, Stantec; (past) Executive Director, Atlantic Coastal Action Program, Saint John

Rob MacDougall
Area Habitat Coordinator Fisheries and Oceans Canada

Graeme Stewart-Robertson
Executive Director, Atlantic Coastal Action Program, Saint John

Tobacco Creek Watershed Representatives

David Lobb
Co-Chair, Tobacco Creek Model Watershed Science Advisory Committee, University of Manitoba

Les McEwan
Chair of the Tobacco Creek Model Watershed

Selena Randall
(current) Associate Director, Manitoba Centre for Health Policy; (past) Research Development Coordinator, Watershed Systems Research Program, University of Manitoba

Slave River and Delta Watershed Representatives

Erin Kelly
(current) Assistant Deputy Minister, Environment and Natural Resources, Government of Northwest Territories; (past) Manager, Watershed Programs and Partnerships, Environment and Natural Resources, Government of Northwest Territories

Tim Heron
Environment Manager, Northwest Territory Metis Nation

Patrick Simon
Environmental Manager, Deninu K'ue First Nation, Fort Resolution

APPENDIX B: CWRC NODE PARTNERS

Saint John Harbour Watershed Node

- ACAP Saint John
- Aquila Tours
- Bay Ferries Ltd.
- Canadian Coast Guard
- Canadian Rivers Institute
- Canaport LNG (Repsol)
- City of Saint John
- Emera Energy Inc. (Bayside Power)
- Emera Energy Inc. (Brunswick Pipeline)
- Enterprise Saint John
- Environment and Climate Change Canada
- Fisheries and Oceans Canada
- Fundy Baykeeper
- Fundy North Fishermen's Association
- Irving Oil
- J.D. Irving Ltd
- New Brunswick Department of Environment and Local Government
- Port Saint John
- PotashCorp NB Division
- Saint John Board of Trade
- Saint John Water
- Saint John Waterfront Development
- St. Mary's First Nation
- University of New Brunswick

Muskoka River Watershed Node

- Brandy Lake Association
- District Municipality of Muskoka
- Dorset Environmental Science Centre
- Friends of the Muskoka Watershed
- Hutchinson Environmental Sciences Ltd.
- Ontario Ministry of Environment and Climate Change
- Ontario Ministry of Natural Resources and Forestry
- Three Mile Lake Association
- West Wind Forest Stewardship Inc.

Grand River Watershed Node

- Agriculture and Agri-food Canada
- City of Brantford
- City of Guelph
- County of Brant
- Ducks Unlimited
- Environment and Climate Change Canada
- Fisheries and Ocean Canada
- Grand River Conservation Authority
- Ontario Federation of Anglers and Hunters
- Ontario Ministry of the Environment and Climate Change
- Ontario Ministry of Natural Resources and Forestry
- Regional Municipality of Waterloo
- Six Nations
- Trout Unlimited

Northumberland Strait Watershed Node

- Aboriginal Aquatic Resource and Oceans Management Program, Fisheries and Oceans Canada
- Agriculture and Agri-Food Canada
- Canadian Rivers Institute
- Environment and Climate Change Canada
- Fisheries and Oceans Canada
- J.D. Irving Limited
- Maritime Fishermen's Union
- Miramichi River Environmental Assessment Committee
- New Brunswick Environment and Local Government
- New Brunswick Professional Shellfish Grower Association
- Northern Pulp Nova Scotia
- Nova Scotia Environment
- Nova Scotia Department of Fisheries and Aquaculture
- Parks Canada
- PEI Fishermen's Association
- Pictou Harbour Environmental Protection Project
- Prince Edward Island Aquaculture Alliance
- Prince Edward Island Department of Communities, Land and Environment
- Prince Edward Island Shellfish Association
- Prince Edward Island Watershed Alliance
- Southern Gulf of St-Lawrence Coalition on Sustainability

Murray River Watershed Node

- BC Ministry of Environment
- BC Ministry of Forests, Lands and Natural Resource Operations
- District of Tumbler Ridge
- HD Mining
- McLeod Lake Indian Band
- Peace River Coal
- Peace River Regional District
- Saulteau First Nations
- Shell
- Spectra Energy
- Teck Coal
- Treaty 8 Tribal Association
- Walter Energy
- West Moberly First Nations

Tobacco Creek Watershed Node

- Agriculture and Agri-Food Canada
- Central Eurasia Academy
- Deerwood Soil and Water Management Association
- Ducks Unlimited Canada
- Environment and Climate Change Canada
- Fisheries and Oceans Canada
- International Institute for Sustainable Development
- Keystone Agricultural Producers
- Manitoba Agriculture
- Manitoba Beef Producers
- Manitoba Egg Farmers
- Manitoba Hydro
- Manitoba Pork Council
- Manitoba Water Stewardship
- Migal Galilee Technology Center Ltd
- Red River Basin Commission
- Rural Municipality of Dufferin
- Rural Municipality of Lorne
- Rural Municipality of Roland
- Rural Municipality of Thompson
- Thomas Sill Foundation Inc.
- Western Michigan University

Slave River and Delta Watershed Node

- Aurora College
- Aurora Research Institute
- Deninu K'ue First Nation
- Deninu School
- Environment and Climate Change Canada
- Fisheries and Oceans Canada
- Fort Resolution Métis Council
- Fort Smith Métis Council
- Hamlet of Fort Resolution
- Indigenous and Northern Affairs Canada
- Northwest Territories Métis Nation
- NWT Environment and Natural Resources
- NWT Municipal and Community Affairs
- Parks Canada
- Salt River First Nation
- Smith's Landing First Nation
- Town of Fort Smith
- Wood Buffalo National Park

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