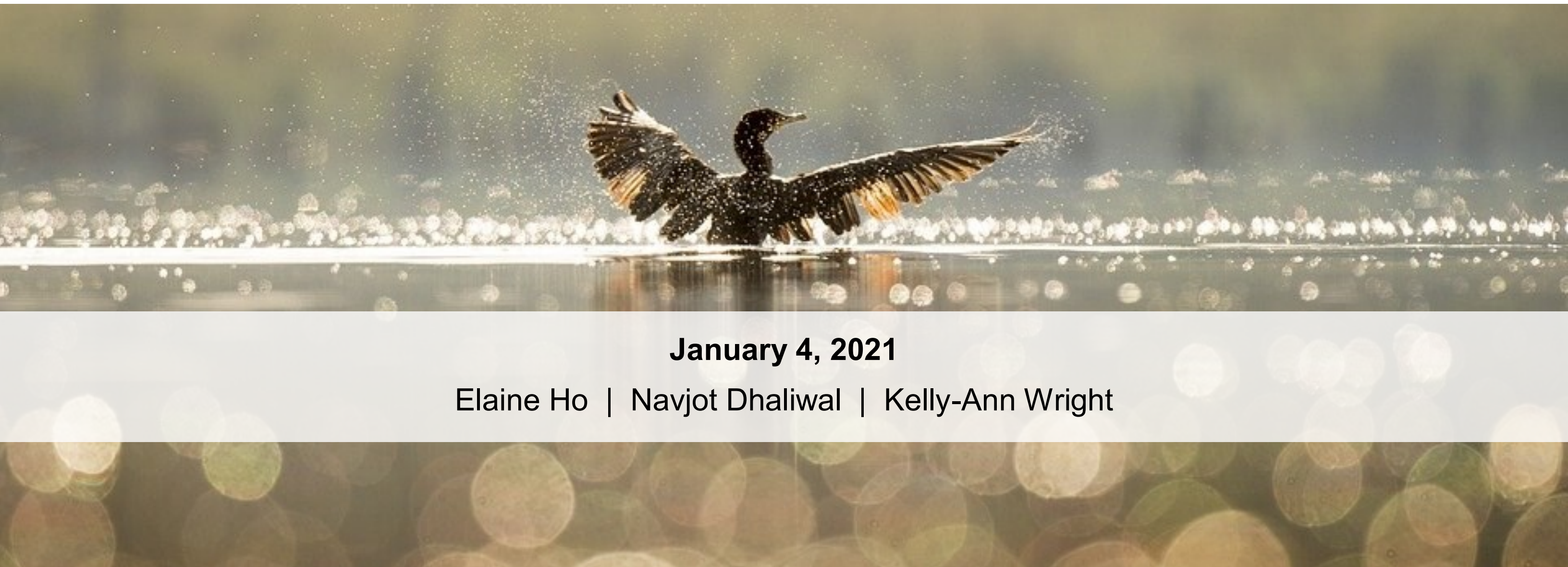
Grand-Erie Study

Practitioner Insights

on water monitoring in the Grand River estuary



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What's inside?

This document is the final outcome of practitioner interviews carried out from February to May 2019. The method, a synthesis of responses, and a summary report are integrated here.

The views expressed herein represent the collective insights from practitioner experience and are not necessarily scientific facts, official policies, or established plans. The contents of this document do not represent the opinions of the editors.

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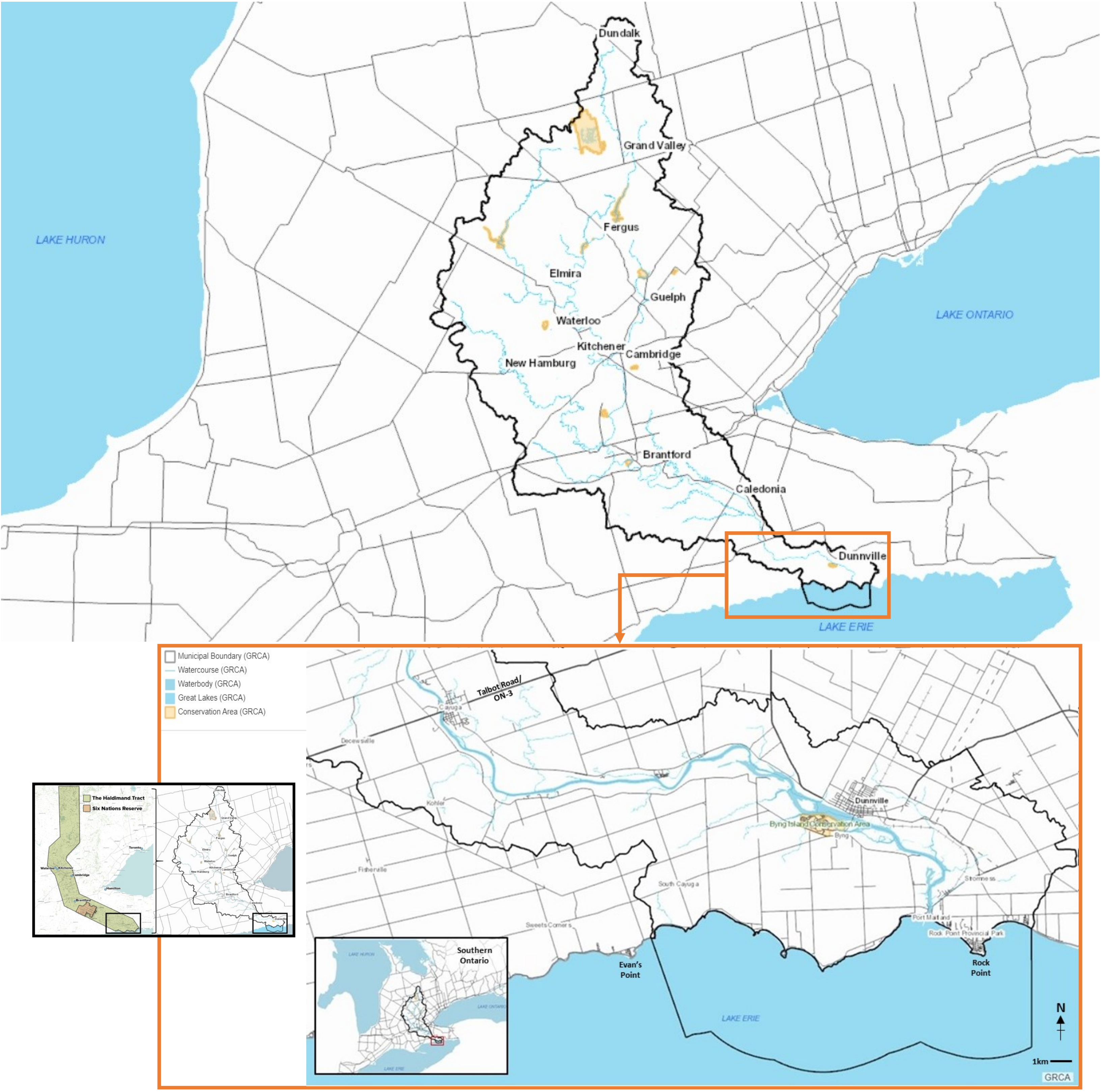


Project context

Grand River Watershed

The Grand River watershed is the largest watershed in Southern Ontario, at approximately 6,800km^2 (roughly the size of Prince Edward Island). Its headwaters are located in Dufferin County, from which the Grand River's waters run approximately 310km to Port Maitland in the eastern basin of Lake Erie (however, the combined length of all rivers and streams is closer to 11,000km). The watershed is home to roughly 1 million residents who primarily reside in Kitchener, Waterloo, Guelph, Cambridge, and Brantford. The watershed consists of 39 municipalities located at least in part within its boundaries, in addition to two First Nations territories. First Nations communities are the Six Nations of the Grand River First Nation—Canada's largest Indigenous community by population, and the only place in North America where all six Iroquois nations reside—and the Mississaugas of the New Credit First Nation. About 80 species at risk are found in the watershed, which also boasts a world class fishery; more than half the fish species in Canada are found here!

In the focus area for this research, the lower Grand River and northeast basin of Lake Erie, there are many organizations and institutions with overlapping responsibilities regarding freshwater resources. In the Grand River, the Grand River Conservation Authority (GRCA) is responsible for regional planning related resource protection, public education, and aquatic monitoring and reporting. However, decision-making powers lie almost exclusively with the Province. Local municipalities (e.g., Haldimand County) and community groups (e.g., Friends of the Grand River) share in the protection of the resource, education of the public, and in restoration projects. Most of the area surrounding the lower Grand River is either First Nation Reserve or private property (i.e., residential, agricultural, or industrial); therefore, certain decisions lie with these stakeholders.

About the study

There are national, provincial, and local demands for strengthening current monitoring efforts, improving coordination among monitoring bodies, and considering cumulative effects.

This research strives to propose an integrated monitoring and management framework for the lower Grand River and nearshore area of Lake Erie (i.e., the estuary). The research question is, “How can current monitoring be strengthened to: (1) incorporate diverse perspectives, (2) consider cumulative effects and (3) connect to management and inform decision-making?”

This study incorporates eight methods, as follows:

1. Exploratory study (Muskoka River Watershed): January-August 2016
2. Participant observation: January 2018-May 2019
3. Monitoring program review: May 2018-May 2019
4. Key informant interviews: February-May 2019
5. Public arts engagement: February-September 2019
6. Indigenous arts engagement: July 2018-March 2020 (on display until January 2021)
7. Workshops: October 5, 2020 and December 7, 2020
8. Literature and document review: ongoing

The interviews summarized in this document were undertaken to assess opportunities to strengthen water monitoring, incorporate cumulative effects, and improve data-decision-making integration in the estuary.

All documents, public recordings (e.g., conference presentations), results, and resources are posted on our research website: **www.GrandErieStudy.ca**.

Note: Since interviews were completed in early 2019, the Government of Ontario has made changes to the *Conservation Authorities Act*. This may render views about the role and strengths of Conservation Authorities obsolete. As the passing of Schedule 6 in Bill 229 — *Protect, Support and Recover from COVID-19 Act (Budget Measures)* — occurred recently, on December 8, 2020, its impacts are yet to be determined.

Acknowledgements

This research and this report would not be possible without the support of the interviewees and many individuals who consulted on the research. These individuals not only provided honest, in-depth insights, but also provided literature and facilitated connections with other practitioners in later phases of the research.

The research team provided immense support throughout the research process: supervisors Dr. Andrew Trant and Dr. Simon Courtenay, committee members Dr. Dan McCarthy and Dr. Mark Servos, the co-authors mentioned on the cover, and the research assistants who transcribed 20 of the interviews (Aalia Khan and Siobhan Mullally).

Finally, special thanks to one interviewee who provided extensive feedback on the report draft, as well as Gilbert Ho, who reviewed the draft for typographical errors.

Method

Data collection

Who's views are represented?

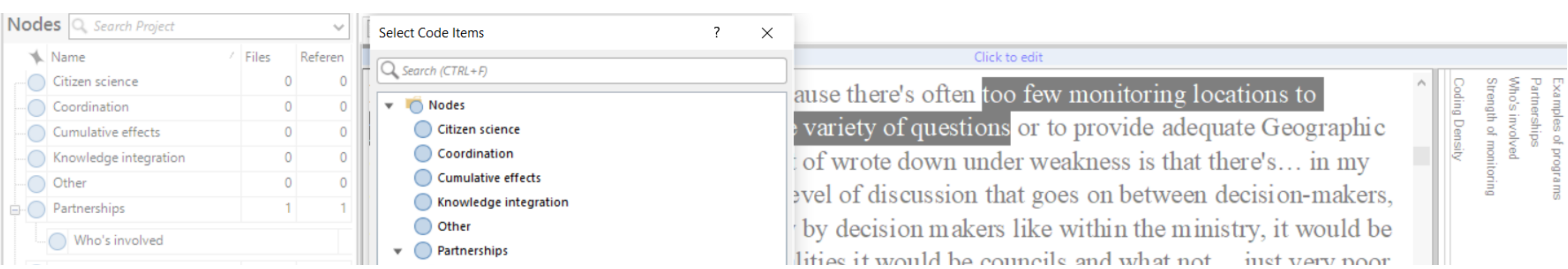
Between February 27 and May 16, 2019, 21 semi-structured interviews were conducted in person or via telephone. Participants represented federal and provincial government agencies, the local Conservation Authority (regional watershed management agencies unique to Ontario, Canada), the local Indigenous community, local, regional, and national community groups or non-profit organizations, a regional industry association, and an independent scientist. Participants spoke about water monitoring programs (water quality and fisheries), water management, decision-making, cumulative effects, and/or integrating science with policy. In some cases, citizen-science and the integration of Western and Indigenous knowledge were discussed. Individuals were identified from the literature and through consultation with those who work in the study area (e.g., scientists and water managers).

Detailed approach

Before each interview, participants completed a routing questionnaire using SurveyMonkey so that a short-list of questions relevant to their unique experience could be selected from a larger pool of questions. In addition to name and general comments, participants were asked to describe their familiarity with the study area, and whether interview questions were requested prior to the interview. Interview questions were selected from a pool of 16 questions related to general water monitoring (6 questions), cumulative effects (3 questions), and decisions and coordination (7 questions), in addition to concluding questions (3 'exit' questions). Interviews were audio recorded for transcription purposes and, if requested, each interviewee's custom question list was sent to him/her before each interview.

One researcher performed all interviews and all coding. Interview audio was first transcribed using an auto-transcription software, Transcribe Wreally. Following auto-transcription, two undergraduate students were hired to manually edit the transcripts. The researcher edited the first transcript for demonstration purposes, one student edited transcripts 2, 4, 6, and 8, and the second student edited the remaining transcripts. Interviews were analyzed using Nvivo 12, coded into seven high-level categories ('nodes') with subcategories beneath them. Files that were analyzed included 21 transcripts and one written response. The written response consisted of the typed notes from interviewee 2, included in analysis due to not having enough time to complete the interview.

Once coded, a 'Coding Summary By Code' report was exported from NVivo. This report reduced 315 pages of interview transcripts (including the 4-page response from interviewee 2) into 159 pages of organized content according to code, then by file (e.g., "Nodes\\1 - Strength of monitoring" > "Files\\Transcript 01" > [content coded]). All coded content beneath each parent node was then recoded/reorganized into topic areas, as opposed to transcript number. The coded content was synthesized to create this report, which was summarized in a modified SWOT analysis (SWOTR).



SWOTR?

Background to SWOT

The SWOT analysis is likely the most widely used management technique in the process of decision -making, normally in the context of business[1]. It is applied here due to its prominence as a method and its relevance to both management and decision-making. Though its origins are unclear, it is most often credited to Albert Humphrey, who was at minimum a major influencer of the concept during his development of the Team Action Management technique while working for the Stanford Research Institute from 1960 into the 1970s[2].

As corporate planning for change management – which emerged in the 1940s – often failed, Humphrey sought to analyze why. His team conducted 1,100 interviews with organizations over nearly a decade[2]. The process began by asking what was good and bad about the operation, followed by what is good and bad about the future. This was initially represented in a SOFT analysis: Satisfactory, Opportunity, Fault, and Threat. This was later changed to the SWOT acronym. In other words, the analysis emerged organically by inquiring about the positive and negative internal and external factors affecting a management framework, which is the core purpose of the interviews undertaken in this research.

In its original design, SWOT was the first step of an analysis process, followed by a sorting of the issues into six categories: product, process, customer, distribution, finance, and administration. The idea was that by sorting the issues into these categories, the collective agreement and commitment of those who work within those mandates would be established. This was then followed by a planning process regarding what should be done to rectify the issues. Various developments were published by Humphrey and others from 1966 into the present-day, applying and adapting it for various contexts, incorporating variations on analyses that follow initial SWOT sorting, or addressing limitations of the method.

Rationale for SWOTR

Given overwhelming support from the literature for using SWOT analyses for strategic analysis in nearly any context – including natural resource management – and given the methodological context SWOT emerged from (i.e., interviews), this study uses a modified SWOT tool as a first step for identifying what issues exist in water monitoring. In the same way Humphrey's SOFT model emerged from interview contributions, we have modified SWOT to include recommendations for maintaining or resolving the SWOT issues identified by interviewees. As the goal of this research is to develop an improved framework for monitoring, interviewees were asked for recommendations based on their extensive experiences.

These recommendations are incorporated into a SWOTR analysis (strengths, weaknesses, opportunities, threats, recommendations), which is used to highlight issues to address in the creation of this framework while integrating a high-level analysis regarding what should be done about these issues. We expect managers and other end users of this research would apply additional analyses – e.g., Multiple Criteria Decision Support methods – to strengthen the utility of SWOT for their needs[3].

1. Panagiotou, G. 2003. Bringing SWOT into focus. *Business Strategy Review*, 14(2): 8-10.
2. Humphrey, A. 2005. *"SWOT Analysis for Management Consulting"*. SRI Alumni Newsletter (December 2005). SRI International.
3. Kajanus, M., Leskinen, P., Kurttila, M., and Kangas, J. 2012. Making use of MCDS methods in SWOT analysis—Lessons learnt in strategic natural resources management. *Forest Policy and Economics*, 20: 1-9.

Given the steps initially proposed by Humphrey – sorting, categorizing based on commitments, and planning to rectify issues – our modified method of SWOTR was completed using the following steps:

1. SWOT analysis is carried out. Issues are identified by informants (e.g., stakeholders, experts, etc.) and are sorted into separate pages or rows.
2. [Optional:] If required, a review of commitments is done separately. In the context of resource management in Canada, authority and commitment are legislated, regulated, and mandated with (usually) a high amount of detail/specificity. Thus, categorization to achieve agreement and commitment is irrelevant in a context where both are determined by legislated jurisdiction and policy mandates. This step is optional since most informants would be aware of designated roles, which are inherent to many of the recommendations provided; however, for areas of overlap or unclear jurisdiction (e.g., some aspects of freshwater monitoring in estuaries of the Laurentian Great Lakes), a review of jurisdiction and mandates may be warranted.
3. Recommendations are categorized according to the issue they address. Incorporating the recommendations into the SWOTR analysis ensure Humphrey's third step – planning to rectify issues – is integrated with the identification of issues. This provides a basis for further analysis if needed to facilitate management or decision-making and blueprint for planning and action.

Synthesis

Monitoring strengths

Two aspects of monitoring were very strongly praised by most interviewees: the comprehensive data we have accumulated over the last 60 years, and the many collaborative relationships that we now have in place.

Data/information were produced from thousands of sites across Ontario over decades. These data have been applied in many ways: government regulatory evaluations; industry evaluations of downstream changes; development of critical effect sizes and triggers for decisions; characterization (that recognizes variability) of many water systems; identification of long-term trends; decisions driven by highly focused and purposeful short-term data; and the definition of many baselines that allow us to assess issues at many scales. The combination of monitoring designs – fixed stations (index assessments), stratified or random sampling programs, and contributions from citizen science – was also highlighted as a strength of our general system of monitoring in Ontario, including the Grand River/Lake Erie area of study.

Some data are very well-used and have shown a return on their investment; many interviewees have been able to observe or track changes as a result. For example, investments in sewage treatment plant upgrades in the Waterloo Region, which were implemented in part due to issues identified through monitoring, were deemed successful as a result of monitoring data that demonstrated positive changes directly connected to those upgrades. Improvements like these have helped the river's health enormously, despite the surrounding population tripling since the 1960s, returning it to something of ecologic, economic and community value.

The value of monitoring extends beyond ecological benefits. From a management perspective, the ability to quantify early warning indicators may contribute to proactive decisions that can prevent or diminish a potentially costly or otherwise devastating problem. When people have trouble agreeing, quality monitoring data can remove some of the biases, increasing opportunities for people to focus on facts and come to decisions. Medium-term program cycles (i.e., 3 years) allow for program review, evaluation of studies, and assessment of next steps. Common methods or protocols allow us to ask questions, build models or mine data for appropriate records. Many protocols are international in nature which makes data collected under those protocols comparable (important in a binational context as with Lake Erie, but also for drawing lessons or making comparisons with other watersheds). There exists much operational expertise in current water monitoring and management systems, so—in theory—there should be little need for developing knowledge capacity.

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Monitoring programs in Ontario monitor in partnership with more agencies than anywhere in Canada. Interviewees suggested partnerships are the core of success for many monitoring programs. Where partnerships function well, the burden of funding is distributed among more than one agency while organizational knowledge and expertise are enhanced due to collaboration. Targeted collaboration is well-practiced in the study area. When the right people are engaged, desired changes have been achieved (e.g., decision trees were implemented in one program to determine which industry projects should be assessed in the next review cycle, which ensured time for data use). Fortunately, most partners/stakeholders across Ontario continue to demonstrate a keen (and often growing) interest to collaborate.

Strengths of our broader system of monitoring include advances in technologies (e.g., eDNA, telemetry, higher resolution data), identification of best management practices, and that monitoring infrastructure (social and physical) is already in place. The latter makes implementing changes theoretically easier than starting from scratch – especially when considering relationships that have been built through past and present collaboration. One benefit provided by Ontario's Conservation Authority system – which was itself cited as a general strength – is the standardized approach to communicating watershed monitoring data. Watershed report cards, promoted by Conservation Ontario, have become a standard of watershed reporting as they are accessible to broad audiences. Finally, one interviewee suggested the large magnitude of the Grand river at Lake Erie has the advantage of needing fewer sites for characterization due to the lower variability of conditions.

Examples of strong monitoring practices

In Ontario, most monitoring by government agencies or Conservation Authorities contributes to one of three regional monitoring networks: the Provincial (Stream) Water Quality Monitoring Network (PWQMN), the Provincial Groundwater Monitoring Network, or the Benthic Invertebrate Biomonitoring Network. These three programs model many of the best qualities of our water monitoring systems, including purposeful activity, comprehensive datasets, and collaboration; the PWQMN in particular was highlighted by numerous interviewees. At a high level, a strong monitoring program should feed into an agency that coordinates efforts and makes sure the information is communicated. However, other traits – e.g., capacity – were also highlighted in examples of strong monitoring programs, described below.

The Region of Waterloo's monitoring of wastewater treatment plants, which began in the mid-2000s, is linked to decisions. Positive changes have been demonstrated by the data, which reinforce related management and decisions. Other examples include the Region's river monitoring program, which is provided with the financial and professional (i.e., consulting) resources it needs to ensure statistical rigor and effective quantification of impacts. The Grand River Conservation Authority was often praised for its collaborative efforts, though its historical monitoring data on sturgeon and walleye were also considered exemplary due to their consideration in decision-making and ongoing discussion (e.g., like whether the Dunnville Dam should be removed). The Grand River Fisheries Management Plan Implementation Committee (currently inactive due to COVID-19 funding diversions) incorporated roundtable news sharing at periodic water manager meetings so everyone would keep updated. In turn, the strengths demonstrated by the Implementation Committee streamlined the Fisheries Management Zones administration process. Elsewhere, prevention monitoring in Georgian Bay was highlighted as a proactive program that ensures good use of its information, while both provincial and federal departments run monitoring programs directly connected to decision-making (e.g., Ontario's Nearshore Community Index Netting, the Canada's intensive fisheries monitoring index netting).

Across Canada, the Environmental Effects Monitoring (EEM) program was cited more than once as a strong model to replicate, as were several pilot programs developed during the Canadian Water

Network's Canadian Water Canadian Watershed Research Consortium (e.g., Slave River and Delta Watershed, Muskoka River Watershed, and Grand River Watershed). On a regional scale, the Joint Oil Sands Monitoring program was described as a strong model of public-private partnerships, while the Great Lakes Nutrient Initiative has produced a tremendous amount of water quality and benthic biology data. There are also many 'internal' monitoring programs from government and industry (especially government) that have produce a lot of information. For example, benthic biology in the coastal area of Lake Erie has been quantified since the early 1990s. This program includes offshore monitoring in Lake Erie in 3-year cycles, which looks at both sediment chemistry and benthic invertebrates to get a cross-section of stress indicators to fit into stress features.

On a binational scale, the Lakewide Management program exemplifies collaboration between the relevant states, US Geological Service, Canadian government, Great Lakes Fishery Commission, and other groups, resulting in shared data between all parties. In the United States, many aspects of the Environmental Protection Agency and its monitoring programs were highlighted, including that it has an effective classification system, data indexing and metrics for reporting. Other examples of strong monitoring included the Maumee River monitoring program and the Hudson River program—the latter of which exists as a regulatory requirement for industry to lead intensive monitoring.

Monitoring weaknesses

The biggest weaknesses of monitoring are the components that feed into it (i.e., not the science itself). Inadequate resources— financial, human, coordination, databases, and interpretation—are the foundation of this section. Many other weaknesses were also described by interviewees: logistical inconsistencies; misrepresentation of data and information; ineffective or lack of communication of monitoring data and information; lack of coordination among agencies; managing expectations; and influences of politics and bureaucracy.

Funding deficiencies result in piecemeal monitoring or interrupted continuous monitoring as a best-case scenario.

Nearly all interviewees agreed the biggest issue is the lack of adequate resources allocated to programs, coupled with limited attention to their design from the start, resulting in poor operational capacity. Poor capacity was described as too little staffing, equipment, ability to perform analyses (including cumulative effects assessment), and access to laboratories. Regulatory requirements for monitoring do not leave enough time for proper program design, implementation, and capacity building. There is never a situation in which everything is put into place prior to starting studies, as the need to quickly start collecting data is not easily balanced with the need to implement appropriate systems for data analysis, review, program evaluation, and making improvements.

There is rarely any kind of peer review process for determining questions, sample locations, frequency, or selection of the best analytical methods. Funding deficiencies result in piecemeal monitoring or interrupted continuous monitoring as a best-case scenario. Even in heavily partnered examples, where funding challenges are somewhat mitigated by shared expenses and combined resources, there is often disagreement over who pays for the activation and maintenance of shared monitoring stations.

Indicators that can be measured and predicted well are not necessarily the indicators that are required for management or decision-making. Some things cannot be modeled well because of the number of variables involved and the lack of capacity to quantify these relationships. We do not monitor for emerging issues very well. Further, dealing with ‘the whole picture’ is extremely overwhelming and often requires data collection and analysis outside the scope of a specific question. Several interviewees raised operational capacity as an issue, including the ability to look at collected data and interpret them in a manner that permits mitigation. The exception is monitoring undertaken for regulatory compliance, in which interpretation and communication of data are legislated. Allowing a program to run for years without data analysis prevents us from knowing if we are getting what we need, but the capacity to analyze data is often lacking. Similarly, data are usually only analyzed at the end of a study period, not on an interim basis, which further reduces the time available to analyze, communicate, or learn from it in an adaptive manner.

Interviewees stated there is plenty of technology and equipment available (e.g., vessels with two sensor arrays that map water quality, recording instrumentation), but there is limited operational capacity—labor and knowledge—to make full use of the tools available. Frequent staff turnover results in lost knowledge and sometimes lost data or information. There is limited statistical ability to make statements with high confidence. Further, information management is not something done well; even where data are available, they are not easy to find, put together or analyze. Tracking where data are used and how (which are the things that justify why data are collected) is a major challenge and is also not done well.

Due to capacity issues, it does not make sense for all agencies to do everything in-house; however, challenges arise when deciding how much to do, who else to engage, and how much autonomy is permitted. Where volunteers contribute to monitoring, a difficulty is keeping them vested in the process. This highlights a weakness of those programs: reporting back to ensure volunteers recognize they are part of something bigger (i.e., giving them purpose). Some community groups collect their own data, which may be strongly complementary (or supplementary) to conventional monitoring programs, but they face the same capacity limitations for disseminating the data. Most communities at the mouth of the river are small and have less capacity than other water monitoring partners have (i.e., they lack a lot of equipment, don’t have the large boats). Thus, their contributions and their needs or priorities are sometimes diminished. Illustrating this point, one interviewee highlighted an example in which the fish passage at Dunnville was allowed to deteriorate after much of the monitoring and assessment done over a decade was carried out by local volunteers (at the time, some locals expressed the perception that government employees were afraid to come to Dunnville). Subsequently, the Ministry of Natural Resources (and Forestry) undertook research, and a small boat was donated to increase local capacity.

There were a variety of program logistics raised as weaknesses. For example: when balancing competing needs between temporal and geographic coverage, there usually ends up being too few monitoring locations to provide enough data to ask a wide range of questions (beyond characterization), and not a lot of biological information included in most monitoring. Despite established best practices, we cannot standardize a monitoring program design for all locations, which should undertake somewhat tailored or unique design processes to be carried out. Unique questions should be asked in each watershed, which may require unique approaches. The goal of monitoring programs is often how much monitoring can we do with a given dollar amount, rather than focus on monitoring activities that directly connect with decisions. This is partly because separate operational and characterization needs exist for continuous monitoring, on top of any issue -based needs, despite limited capacity.

When monitoring does not reflect actual conditions, the whole practice of monitoring is devalued and more likely to be defunded.

Such competing needs often lead to poor quality data and/ or data that are not able to answer current questions – especially given the lack of variability captured between seasons and across years (e.g., monitoring fish populations once every five years does not do much good). Fixed stations are a disadvantage when randomized sampling is absent. Baseflow monitoring is not representative of actual condition year-round, so high flow events must be captured as well. When monitoring does not reflect actual conditions, the whole practice of monitoring is devalued and more likely to be defunded. Long-term datasets miss a lot of variability, especially with biological data. It is worth recognizing that, in the lower Grand River, high flow events pose legitimate safety and access concerns (though, where access is feasible, high flow events are still rarely monitored in-person). Perhaps improvements to remote technologies, and capacity to make use of them, would make year-round continuous monitoring more feasible.

There are many weaknesses with data interpretation as well, which largely result from difficulties capturing interactions between multiple variables in complex systems. For example, assessing individual fish stocks is challenging enough, but it is nearly impossible to adequately consider all impacts various stocks have on each other and on the ecosystem. Where information is published, misinterpretation of high priority scientific information by the media, public forums, or social media is common. In addition, color-coded maps and other similar visuals are widely-used methods for disseminating information. Although these are designed to prevent misinterpretation by end users, this approach oversimplifies categories of health and blankets categories across whole regions of a watershed. While these maps are attractive and comprehensible, end users don't usually delve into what data went into them and how comprehensive those data are. Thus, there is a level of uncertainty and seasonality that is not usually represented. A given area could be red in some parts of the year and green in others. Or, there may be a 10% probability it's red at any time of the year, with an 80% change it's yellow and a 10% change it's green. Therefore, these visuals do not present real information, despite their wide uptake across Ontario.

Communication is therefore paramount in every stage of monitoring, from program design to knowledge dissemination; yet, this is one of the weakest aspects of monitoring. There is little to no discussion between monitoring personnel and decision-makers regarding what the key questions are, and no inventory of questions addressed by each relevant agency. As a result, there is often little thought about what decisions need to be made, what evidence is needed, and in what format evidence should be delivered. For example, across the country there is an enormous gap in fundamental habitat and food chain reporting in plain English, so reporting is ineffective.

Reporting often lacks information about implications, whether for management or individual persons in the watershed. There is little consideration about how analyses will be carried out when designing a program, which means the data that need to be collected are not always collected, even if the goal of the program is clear. There is no communication between scientists and managers about what the data will be used for, or their limitations (i.e., what the data can or cannot answer). What is perhaps most troubling is there is often little interest to even have these conversations. Professional cultures can get in the way, as transdisciplinary communication is a major challenge. Similarly, when different players are involved – industry, government, regulators, and Canadian and Indigenous communities – it is difficult to manage and achieve acceptance by all. In the context of the Grand-Erie estuary, it is often a matter of perspective how the range of temporal, spatial and biological conditions interact with each other. People often do not arrive at the same notion of the interface.

While collaboration and partnerships are strengths of monitoring, they also present challenges. When working with multiple persons, organizations, and communities. Two weaknesses are the coordination of parties and management of expectations. Knowledge of who does what, what data they have, and what they can share is almost entirely lacking. Data are managed by different agencies and are collected for different reasons, with little communication or coordination. In the past, building trust between partners for sharing data was a major barrier and there was a lack of transparency. In addition, many agencies work at odds with each other. There is not a single, widely used data repository that permits free and open data sharing (e.g., some form of nature Wiki); the Provincial (Stream) Water Quality Monitoring Network is close, but is limited by its contributing members, which do not include academia, industry or civil society. As such, data continue to be collected and not shared throughout the Grand River watershed, and elsewhere. Fortunately, current developments with Ontario's Open Data Catalogue and Canada's Linkable Open Data Environment may signify a change for the near future. Where different parties are interested in collaborating and pooling data for a shared goal, lack of standardization with past data collection is a problem. Further, private citizens cannot usually access monitoring data, or often know about them.

There are unrealistic social and political expectations of what monitoring can do and what changes we expect to see as a result (and when we see these changes). For one, confidence intervals and variability are not often accepted by decision-makers—and variances can be huge. Also, systemic silos prevent most decision-makers from thinking about the whole life cycle of certain programs or industrial development projects. Part of the reason is that issues can be entrenched in political uncertainty, controversy, and emotion (influenced by fearmongering in the media, promoting distorted versions of reality). Inadequate reporting pushes these controversial issues down the priority chain until we hit a crisis point, which is when finger-pointing begins with few willing to be accountable to act. If you do not monitor and measure issues, you cannot manage them; however, measurement is not only influenced by controversy, it is also dictated by the economy.

Everyone has a favorite watershed, a favorite issue, and jurisdictional limitations. There is usually prioritization of issues with direct societal relevance (i.e., human health and economics), and where this connection is not clear, the issues are deemed less important. Elected officials often prefer jobs and physical/hard solutions over environmental actions. Soft solutions may make a lot of sense but may be counter to their interests. Because of politicized processes that contribute to identifying priorities, monitoring data are somewhat personality driven. Whether monitoring networks can maintain integrity under different governments is unclear. As each government comes in, the sense is that a few years of addressing one issue is enough, so it is time to move on to the next issue. Sometimes, those who manage budgets may not understand why after so many years of monitoring, the programs cannot be replaced by predictive models.

There is no accountability for uninformed decision-making

Such politicized processes delay or otherwise impede monitoring programs from achieving the level of success they otherwise could. Pressures from inadequate funding are compounded by the need to constantly defend what is currently in place. Although few monitoring personnel and fewer decision-makers appreciate the need to communicate and engage with one another, monitoring programs would enjoy more efficient use of resources if communication were better. However, there are long-standing jurisdictional gaps in which people are so used to working with insufficient data—e.g., data that demonstrate a partial picture—that this practice is acceptable. There is no accountability for uninformed decision-making, and few systems to guide responses to monitoring information exist.

Determining the purpose and objectives of monitoring, and how we want to use these programs, was a major point brought up by many interviewees. Many felt that progress (from management) is too slow and that there is not enough flexibility to adapt to changes in priorities or emergent information. Linking monitoring to decision-making is challenging, unless we can implement monitoring programs that identify problems before they occur (i.e., estimate what the major stressors will be and monitor for those). However, we do not have a competent and adequate approach for understanding, interpreting, or managing coastal water quality of the Great Lakes.

...we do not have [an] adequate approach for understanding, interpreting, or managing coastal water quality...

World Wildlife Fund Canada's Watershed Report found data gaps in access and availability across Canada. Citizen science is underutilized, and open data is not yet common practice. Lack of data sharing can lead to knowledge gaps. For this reason (and others), a gap in knowledge is not justification for adding a monitoring program; we must ask ourselves: what is the question being answered? What is the change we need to observe? Are long-standing objectives clear to all parties? Do original objectives still apply, or have new ones been documented?

One interviewee suggested that Universities do a lot of the great work governments should, calling for an increase of funding to address knowledge gaps and continuous data collection. The challenge with limited funding is that monies are usually allocated to what are perceived to be the most degraded or urgently problematic areas, like a triage system implemented without a comprehensive understanding of the unique issues and phenomena of each area. There is also a fixation on standardization and comparability to other watersheds. A closer look at the issues may suggest a need for intensive monitoring rather than programs designed to look at general conditions. Statistical analyses need to be subsidized too, as detailed statistical analyses are not always within the capacity of conventional monitoring programs. Further, changes within programs—e.g., adding high flow events to long term baseflow data—make data incomparable and sometimes unusable or obsolete.

We rely more on technology and reactive solutions than mitigating or preventing water quality issues. For example, drinking water at the Six Nations Reserve is assumed to have been dealt with since a water treatment plant was built. However, the plant is a solution for some residents only. Not all residents have access to its infrastructure, so the problem remains since the issue of water quality was not addressed. This highlights the need to engage meaningfully with all parties involved. Nothing can replace personal contact—visiting people and meeting them face to face to discuss an issue. However, this is expensive and time consuming, especially when multiple points of contact are made with numerous relationships being formed (which then requires coordination). Problems also arise when one contact is relied upon to represent the general community, as was the case with a representative from Six Nations of the Grand River. Aside from one voice being unable to speak for all six nations without their input, the individual is now retired and has left a vacancy that impacts various collaborative efforts.

Historical relationships between governments and the Six Nations community play a big role today... there is little guidance on how to operationalize the necessary changes.

Systemic challenges

There are a number of systemic challenges facing the study area. For example, the Six Nations of the Grand River community is one of the most studied Indigenous communities in Canada, with a focus primarily on those living on reserve (despite roughly 60% of members living off-reserve). Not surprisingly, community members often feel overused after so much work with few benefits experienced. Historical relationships between governments and the Six Nations community continue to play a role today. Changing government requirements (e.g., to include First Nations in certain approval processes) and changing data availability (e.g., Ontario's open data approach) are positive steps towards reconciliation; however, implementation is challenging when there is little guidance on how to operationalize the necessary changes.

Due to the large size of the Grand River (Strahler classification 7), most in situ monitoring—e.g., examining fish community structure and fish movement, water chemistry, wetlands, and other water quality parameters—is challenging, especially at the estuary. Interviewees discussed not being able to gain a holistic view of the river due to sampling locations. Sampling in the middle of the river may not be representative of conditions closer to the margins. This was illustrated by a previous study which found the margins up to a third on either side of the river were completely anaerobic in some areas, while the middle had survivable oxygen levels. As well, interactions between species and trophic levels make interpretation challenging; however, using multiple biotic indicators is key as they may respond differently to some stressors while responding similarly to others, allowing us to pinpoint stressors more easily. The Great Lakes are very complex since flows change from one direction to another, so there are different logistics for sampling than in the river. In the Grand, assessments are made upstream and at the mouth, with limited consideration for what is happening in Lake Erie.

Conflicting timelines

Both the Grand River Watershed and Lake Erie cover vast areas, presenting challenges with managing, engaging with, and achieving agreement between many diverse stakeholders. There are also temporal challenges: in Lake Erie, conditions change significantly in a 5-10-year timeframe. This means that what is true today is not necessarily going to be the case in five years. The rate of change in the watershed is also variable, reaffirming the importance of using an adaptive monitoring and management regime. While a program designed for a given watershed should identify changes in system conditions, its ability to continue signaling change may be impacted if the rate of change increases or decreases—which may have implications for funding and for management response. This raises the issue that probabilistic expression of monitoring data is not common practice—e.g., "there is a 50% chance we are overfishing", rather than "we are overfishing"—despite more accurate representation of most data.

From a social-political perspective, a 5-year timeline is considered a long-term plan; however, in ecological terms, this is certainly not the case. Justifying the need to fund a program that does not benefit the incumbent office (e.g., benefits will be seen in 8-10 years) is a tough sell. Add to this the fact that monitoring is (to most) a boring and expensive investment that cannot be automated. Even 'automated' systems aren't fully automated, as budgeting is required for a person to calibrate instruments, check sensors, and more. As well, many of the goals that seem obvious—e.g., responding to water monitoring information—are not built into our governance system. Goals that do exist usually focus on meeting legislative requirements. This results in water quality being categorized as "good enough" in some areas, resulting in heavily degraded areas downstream.

Barriers to action

Goals and obligations can be difficult to achieve or fulfill when other factors prevent action. For example, a commitment to improve fish passage in the Grand River watershed would require the removal of the Caledonia and Dunnville dams. Removal of the Dunnville dam would require bringing together many opposing (but often justified) perspectives that can present ethical dilemmas (e.g., whose perspective do you favor, and why?). Decisions like these are not always based on data. Any kind of change tends to be attached to emotion, which can impede progress even when the change would result in widespread benefits (ecologically, economically, and socially). In addition, community member voices are often considered very strongly by decision-makers, even though the public is often less knowledgeable.

Jurisdictional mandates and siloed water management agencies are a major concern. Staff may have expertise on their piece of the watershed, but few have the whole system in mind. Jurisdiction also limits permissible activities each agency can undertake, despite shared benefits and common goals. For example, the Region of Waterloo is not tasked with improving surface water quality before it reaches Brantford, which sources its drinking water from the river. The City of Brantford also has limited influence on the rest of the watershed. As such, limited jurisdiction also contributes to lack of accountability. Although jurisdictional silos are accepted practice—e.g., separating fish monitoring and water quality monitoring—objectives from each department or agency cannot be achieved independently (i.e., fish community objectives cannot be realized without environmental objectives). Therefore, a systemic approach should be considered.

Interviewees considered whether arm's-length management may facilitate action from monitoring. While less politicized, it does not involve a high level of involvement from decision-makers. As a result, the information produced is less likely to inform decisions. Conversely, sometimes the agencies that have a say choose not to engage in monitoring or management processes. Progress can also become paralyzed by organizational charts and the chain of command. Unfortunately, the bureaucratic system is designed to prevent bottom-up power sharing and co-creation. It is widely known that government is good at getting things done that it is told to do, but not at innovating (e.g., building an integrated ecological information base). Another issue is that some people's jobs are only partly dedicated to monitoring, which means their interest and ability to engage with partners for this purpose is limited; or, they are dedicated only to monitoring, and not to reporting or knowledge sharing. Knowledge brokers can play a role in disseminating knowledge for those monitoring personnel. However, they may not have full confidence or know everything they need to know to make a competent statement (e.g., lack of monitoring context).

Because of the many challenges described above, data are often produced but not used (e.g., GRCA is excellent at defining recharge

areas, yet municipalities seem to disregard this information so that they can develop these areas). The need to always have perfectly comprehensive, rigorous, and fully representative data may be a problem of mismanaged expectations, as representation is not always the goal. Making use of all available data is likely to save on resources and mitigate duplicated efforts; however, this can be difficult since data are often collected for an entirely different purpose and may not be applicable to a new question at hand. As well, there is a constant re-education of end users and partners due to turnover. Cultures within management agencies can also pose a challenge. For example, social philosophies that prioritize voluntary actions to mitigate impacts can reduce our ability to facilitate change. Another example is if species are not commercially valued, they are not monitored or considered in decisions—in other words, prioritization based on human-utility.

Government agencies are typically risk averse and decision-makers are inaccessible. Interviewees pointed out that senior government officials tend to keep contentious, challenging issues off their plate, leaving the onus on stakeholders and community groups to act on those issues. As well, the highest level of decision-maker (Ministers) are guarded by a team of staff and are not usually accessible to anyone outside their team. In general, people are more comfortable with the familiar, resulting in both government and the public being resistant to change. There can be resistance to implementing new approaches since established approaches work well enough for most expectations; issues are then sidelined until a crisis results, often from outdated management approaches. Even those who agree to collaborate on an issue tend to enter the collaboration with a predetermined idea of what they want to see happen, with little will to veer from it.

Collaboration

Institutional capacities for science are dwindling across Canada, in part due to an overall defunding trend that has been ongoing for decades. Collaboration is one important key to success highlighted by nearly all study participants. In some cases, community groups (e.g., local fishery or community non-profit organization) might come forward with priorities that align with more formal organizations like conservation authorities, which may result in collaborative projects, funding, or generation of information. Other times, permitting processes can initiate collaborations where the permitting organization may help the requesting organization navigate hurdles; however, all collaborations require a shared goal or priority.

All interviewees agreed it is critical to engage with the right people and that they represent diverse backgrounds. These might include researchers, decision-makers, scientists, managers, and other users of the information. They might also include local anglers, hunters, and trappers, Indigenous persons, and community champions. Overall, interviewees felt existing collaboration in the study area is on the right path to where it needs to be, with many examples highlighted—e.g., Grand River Conservation Authority's source water and water management planning (via the water managers table), and binational work under the Lake Erie Lakewide Action Management Plan.

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Strengths and benefits

Many existing collaborations are well-established, with relatively comprehensive (and often consistent) representation and effective relationships between parties. Much of the collaboration (and coordination) that occurs today is unofficial in nature, and often unrecorded; however, potential benefits can be achieved whether formalized or not. The biggest benefit of collaboration raised by interviewees was that working with industry opens up additional funding and information otherwise unavailable. As well, there is better distribution of funding among agencies and there is increased access to larger databases with relatively little contribution from each individual party. There is also increased buy-in and, often, ownership from parties that perhaps would otherwise be opponents (e.g., Indigenous groups and industry parties).

Collaboration to develop predictive models was highlighted as a successful engagement approach. In participatory modelling, stakeholders are involved in putting together a network model that will be used for decision-making. Engaging stakeholders creates ownership and helps all parties accept the result even if the decision seems contrary to their way of thinking. Network models can be used by decision-makers and the public alike, so when a decision is being made the public can also manipulate scenarios to understand the implications of alternative decisions. Collaborative network models also allow all parties to put in their own evidence. The ability to test things themselves also puts the power and authority back into the decision-maker's hands, rather than have information selected and provided to them by others. The public also has a tool for being more informed and holding decision-makers accountable (e.g., they will be able to ask, "Why did you select option 2 instead of option 1, and what evidence demonstrates the decision is beneficial?"). Heavily partnered collaborations can be more resilient since agencies can replace any temporary or permanent loss in capacity or vestment from others, allowing programs to continue relatively uninterrupted. Collaboration offers more comprehensive knowledge, feedback, and experience to identify and implement changes before small problems become big ones (e.g., you would not want to wait until three years into a five-year project to finally understand that the data are not telling you what you needed them to).

Enabling collaboration

Where consensus is sought, standardized methods and (often) decision support tools are helpful. An example from Lake Erie fisheries is a management strategy evaluation tool. It simulates commercial fisheries, applies different management strategies, and looks at performance measures across a suite of harvest strategies. This tool has reduced conflicts among stakeholders since the facts and development of scenarios and effects are shared with all parties. Effective collaboration also requires time. All parties need to be okay with moving at whatever pace is necessary for everyone to meaningfully engage. Of course, all parties should want to be there and would ideally have a mandate to be there. One interviewee pointed out that big picture policies implemented from legislated mandates are likely to have impacts that trickle down. If there are agencies that agree to participate, perhaps in appreciation for the process, but which do not see value in the goals from the start, the process will be impeded.

It is imperative that the people who need to be there are there, and at the right time. This may change at different times of the collaboration's lifespan, so frequently building in a 'who is missing' exercise is critical to keeping the collaboration on track. Similarly, a less frequent 'who does not need to be here anymore' exercise may maintain the strength of the group, rather than allowing it to become too big with a lost focus (note: this is proposed to be less frequent because, generally, organizations that no longer need to be involved will usually self-identify before this exercise becomes necessary). Another key element is the presence of open-minded individuals who are focused on evidence-based decision-making and who also validate stakeholder experiences and needs. Finally, some form of check-in should be part of any collaborative process – e.g., an annual meeting where all agencies review what was done in the previous year and assess what will be done in the upcoming year. These check-ins are also opportunities to assess coordination.

Challenges

In any collaboration, trade-offs can be expected. These may include loss of control (e.g., one agency will not control the direction of all others) and a more difficult and/or time-consuming process for consolidating stories from all the partners. Clearly defined roles shared among many organizations may mean roles are limited compared to each organization's capacity. For example, where five agencies have the capacity to collect, interpret, and communicate data/information, two may end up collecting and interpreting data while two may communicate or broker the information, with the final agency taking a coordinating role. While redundancy in capacity creates resilience in partnerships, redundancy of activities should be minimized in well-coordinated collaborations. Further, these roles may not be in effect for all projects, and so the full capacity of each agency may be utilized throughout the collaboration's lifespan while maintaining optimized collaboration.

Given rapidly changing environmental conditions, flexibility to change priorities quickly is essential but not easily achieved – especially when multiple parties are involved. However, where roles and capacities are clear, parties may make this shift quickly (e.g., knowing one organization is currently at capacity with existing priorities, another organization with a data collection role might begin exploring a new phenomenon on behalf of the collaboration to assess what needs to be done).

Publicly shared data means there are no limitations on their use (this should be a stipulation of any central database). Oftentimes, there are competing priorities between partners that require different approaches to data collection. For example, for some members of a collaboration, index monitoring eight times per year during baseflow may suffice, while other members may require randomized sampling that correspond with high flow events. Although capacity is always a challenge, it is helpful to step back and recognize that at the end of five years, for example, everyone will have what they need to act on a shared priority, and so perhaps both approaches will need to be adopted.

Often, the people who need to be at the table are unaware they should be there, or otherwise are not as knowledgeable of the issues despite being vested. As mentioned earlier in this report, there are sometimes systems put in place to prevent others, including researchers, from engaging with

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these individuals. When it comes to Indigenous communities, another challenge is there is a lack of knowledge regarding how managers should engage with community members. Fortunately, there are some excellent resources addressing this question and more are emerging each year. Still, because these resources call for frameworks outside the realm of conventional practice, there are challenges for implementation. For example, the FUBU concept—or Us, By Us—is largely an Indigenous concept with no actual guidance for engaging persons and communities. Often, issues are analyzed and addressed through a strictly-Western data analysis lens, which is hard to overcome. A section dedicated to this challenge is included later in this report.

There are usually organizations with vested interests that are not entrenched in water monitoring or management, nor do they wish to be. This is sometimes a result of time-bound relevance of common issues on their radar. Differences in realized involvement and presence, alongside changing political landscapes, result in occasional difficulties managing relationships. Language and motivations are often different between parties (and sometimes within them). For example, regarding conservation authorities, the word 'authority' may imply different things to different parties and may cause some groups to not engage if they do not recognize this authority. Also, their mandate is to manage waters as a resource, not to be stewards of a living system; these two purposes represent opposing worldviews in the Grand River Watershed. Reconciling these views is a challenge, but one that can be overcome with understanding, communication, and a just and co-created process. A related issue is the lack of trust that exists between some parties. Finally, collaboration is often impacted by who believes they have jurisdiction over the issue(s) at hand. This can be a positive thing if the issue is directly within an organization's mandate; however, in areas like an estuary where there is no clear jurisdiction, addressing issues only as defined by legislated/policy mandates is problematic.

Building a future for everyone

To move forward in a productive way, we must first ensure data is more readily available. Collaboration would be most effective if focused on solution building on a scale determined by the problem at hand (e.g., watershed versus river-lake boundaries). We are becoming good at working together to identify what needs to be done, but we need to start implementing solutions. Importantly, engagement should occur before a monitoring program is designed so that we do not end up in a situation where one opinion is thrust upon others for feedback.

The notion of inclusivity needs to be replaced with shared, equitable, and just spaces. Inviting new perspectives into a space and processes not designed for them—inclusivity—is not an effective way to engage or co-create. For those conventional spaces that are being improved for co-creative purposes, decolonizing strategies create spaces that are not just equitable for Indigenous representation, but also for other demographics as well. We also need to recognize that inclusivity often comes with a demand to amalgamate, which results in a trade-off between being engaged and maintaining one's identity. This is where justice comes into play.

Capacity building for all partners makes everyone in the collaboration stronger. Where similar capacities or capabilities exist, diverse persons should be engaged in paid, management and/or decision roles. This includes having trained people from Indigenous and Canadian communities participate in paid work (e.g., consulting, research, analysis, brokering information) and/or authoritative roles. Training should also be extended to youth, who will then be more capable and inclined to contribute as adults. The inclusion of youth in capacity building encourages a collaborative and constructive culture conducive to both Western and Indigenous ways of doing and knowing.

Who are the decision-makers and how do you influence them?

Interview participants identified numerous positions with decision-making authority. However, there were several points raised regarding how difficult it can often be to identify who would be the authority on a given issue or context. For example, the governance hierarchy is clear in fisheries, but it is very convoluted in water quality. In water quality, the decision-maker changes depending on the issue. Leveraging the chain of command (e.g., going through management committee directors, boards, Fisheries Management Zone councils—FMZ 19 for Lake Erie, etc.) was a recommendation for facilitating vertical communication. Interviewees generally agreed that both Provincial and Federal governments should be 'at the table.' Examples of routes for influencing decisions as described by interviewees are as follows:

- International: binational committees (e.g., for yellow perch and walleye limits)
- Federal (Environment and Climate Change Canada, Fisheries and Oceans Canada): Director (e.g., on fisheries policy branch or section), who reports to his/her Director, who reports to the Assistant Deputy Minister, then the Deputy Minister, to the Minister; three individuals identified ADMs/DMs as their decision-makers
- Provincial (Ministry of Environment, Conservation, and Parks; Ministry of Natural Resources and Forestry): Ministry senior managers, Ministers, committees within Lake Erie Management Unit
- Sub-regional: Conservation Authorities, municipalities and counselors, Boards of Directors (including within NGOs)

Many parties were identified by participants as being at least somewhat engaged on a regular basis. In addition, comments on common challenges for engagement in general and tips for success in engaging decision-makers were also provided. It is immensely difficult to achieve representation of communities from community members (i.e., rather than elected officials). Identifying representative and capable individuals or groups is not only difficult, but is not often pursued using meaningful approaches. Also, while most of the right people are already engaged, they are engaged separately (on an individual basis) rather than collaboratively/together. Although individual engagement is an important part of ensuring everyone is meaningfully involved, interviewees highlighted the importance of engaging with everyone in the group regularly—separately and together—to build a common understanding of the monitoring program. Different cultures of work exist across various groups, which sometimes results in conflict or misunderstanding. One participant suggested far-reaching collaboration would need to be legislatively mandated to be successful.

Parties identified as being regularly engaged included organizations and persons from across sectors: Non-governmental/non-profit groups, industry, First Nations, all three levels of government, conservation authorities, academia, committees and other groups within organizations, and binational collaboratives (e.g., Great Lakes Fisheries Commission, the Annex 4 group under the Great Lakes Water Quality Agreement, contributors to the Great Lakes Observing System, etc.). Individuals were classified as regulators, water managers, upper management, ADMs, and community and stakeholder champions (not diverse community members, but strong communicators who are actively engaged and often serve as a knowledge broker to the community).

As mentioned earlier in this document, personal interaction is key. However, high-level decision-makers in government are extremely pressed for time and are thus unlikely to attend any kind of meeting if they do not know how it will benefit them. It is a worthwhile exercise to ensure a few minutes are dedicated to explaining shared goals and benefits to build interest in attending. Efforts to engage the general public, on the other hand, pose a different set of difficulties, some of which can be mitigated by engaging with the community earlier in the management or solution-building process. This is increasingly important the more community-specific the goal or issue is (e.g., a fishway is specific to a location or stream). Unique and successful outcomes can be experienced, highlighting the importance of pursuing these engagements. A natural heritage group described by one interviewee involved community members with knowledge of aquatic systems as well as others specializing in outreach, restoration, local actions, and related skills. The resulting plan for water quality would have looked very different if—as an example—the engineering group would have developed the plan on their own. This being said, disciplinary and subject matter experts remain absolutely critical. Teams of people with specialized knowledge and years of experience are needed for exercises like building models for management and decision-making.

Coordination and use of monitoring data

Interviewees described two types of coordination: first, coordinating priorities and linkages between knowledge creators and knowledge users (e.g., scientists and decision-makers); and second, coordinating monitoring activities between and within different programs and agencies that design and implement monitoring in the area.

Interviewees identified many efforts to improve linkages between knowledge creators and knowledge users. Examples were largely unsuccessful primarily due to poor communication practices and a lack of understanding between the two cultures of people. Those examples that were successful were usually connected to some legislated requirement, e.g., permitting, industry assessment or compliance, or commercial fishery quotas. The challenge raised was that decisions are made when they have to be made (i.e., the mandate exists), but not as easily without a clear requirement to make the decision or to engage with the right people who can eventually connect evidence to their mandate. However, legislated requirements like permitting systems may be catalysts for coordination if they require a certain format of data reporting. Therefore, mandates may provide opportunities: they are some of the biggest determinants of whether and how decisions are made and are usually clearly defined. Knowledge producers who know the mandates of their decision-makers and tailor their information to them may be more successful at negotiating desirable outcomes. The challenge is where no mandate for a given issue exists (note: this is part of the reason for resistance to Schedule 6 of Bill 229 (Omnibus Budget Bill)—passed in December 2020 as the *Protect, Support and Recover from COVID-19 Act (Budget Measures)*).

...it can take years for data to be looked at for the first time.

Connecting monitoring with management depends on having the right people engaged—especially key stakeholders/ rightsholders and decision-makers—at the right time, in the right way. Not all people need to be at every table or meeting, but may be involved periodically (e.g., committees) instead. This kind of engagement requires strong upper management involvement in coordination ensures information is used in management decisions. First Nations communities are starting to have a bigger role in decision-making in other areas of Ontario and especially Canada; however, this is lacking in the Grand River watershed, despite historical authority under the Haldimand Proclamation.

Capacity for coordination is also a challenge, as coordination of multiple partners at the watershed scale requires dedicated human and financial resources—especially true in the Grand River watershed since the estuary joins transboundary waters. One interviewee suggested that, given recent legislative changes (2019-2020) and the COVID-19 pandemic, budgetary downsizing is likely to worsen in the near future. Only two interviewees described an example in which dedicated coordination resources were present in a monitoring program. In one example, there were about 40 people whose role was focused on binational coordination in some manner, which illustrates the immense capacity required for large-scale coordination.

In both examples, coordination was mandated under Annexes (2 and 10) in the Great Lakes Water Quality Agreement. Another interviewee pointed out that in such large and diverse collaborations, coordination cannot possibly be done by a single entity and so although coordination mechanisms are built -in, they are often optional (i.e. no one driving it, parties participate out of interest). A final capacity challenge is the lack of timely data analysis and interpretation. This is largely due to a lack of staffing for this purpose. It is nearly impossible to coordinate monitoring and management retroactively when it can take years for data to be looked at for the first time. There may be opportunities for academia to facilitate coordination in this context, as researchers may have more capacity to review and interpret data sooner and with specific goals in mind compared to many monitoring agencies. A mutual benefit is that academics would not need to use their own resources to collect often duplicate information for research purposes.

Connecting monitoring with management depends on having the right people engaged... at the right time, in the right way.

Time lags and uncertainty also contribute to challenges with large-scale coordination. One interviewee recommended Buzz Hollen's work regarding adaptive environmental management approaches. This framework acknowledges the lack of time to make a decision with the best science available (i.e., to provide an absolute answer), hence the iterative process. Risks are evaluated, potential outcomes weighed, and an interim decision is implemented, monitored, and adapted as more information comes forward. Consider that in commercial fisheries, a 1% change in a quota could mean $50,000 out of someone's pocket. Thus, there are tangible and personal implications for every decision. In this scenario, adaptive environmental management may be applied alongside a collaborative risk-sharing approach that incorporates collaborative decision-making (implies the fault of a decision does not rest entirely on the Minister). Such a practice may increase risk tolerances to incorporate broader information that is accurately represented (e.g., probabilities of a scenario occurring, margins of error).

Misrepresentation and inadequate reporting, including reporting in a format that is not useful to knowledge users, diminish watershed priorities. Misrepresentation also exacerbates the lack of accountability that already exists. Accurate representation impacts the perception of risk, which then influences the use of monitoring data since the desire for absolute certainty may be used as a reason not to act. Transparency was recommended as an important factor for reducing conflicts and/or disconnects in the knowledge producer-user context. Transparency was defined as how information was created as well as not passing off political opinions or arguments as factual information.

Most decision-makers, at any level, do not generally have access to broad ecological data or information. Access of information is often determined by its complexity; however, oversimplification of information (e.g., using stoplight colors with arrows demonstrating improvements or degradation over a given timespan) is also not useful and is potentially misleading. Many decision-makers are extremely capable and also have qualified teams of people who are all well-trained in their fields, collectively representing decades or even centuries of knowledge and experience. Therefore, these people can identify, interpret and use external information of varying complexity when they need to. The challenges are identifying a need to use that information or to make the related decision, and that the decision-making system does not represent diverse perspectives as well as it could (note: while diverse perspectives are important, one interviewee pointed out they may become unwieldly towards reaching goals if without adequate focus). This is true of many decision support tools as well, which are not used extensively by most decision-makers despite the comprehensive data that contributed to the development of the models or scenarios. Often, monitoring is extremely useful at smaller scales (e.g., watershed or subwatershed), but is less useful at larger scales. This is due to the kinds of decisions made and the types of questions monitoring often answers (e.g., we can tell you about this one parameter or this set of parameters at these times at these locations; the exception is looking at high-level trends like rising chloride levels in waterbodies across Ontario).

As we know, ecological considerations are not the only considerations in decision-making, nor are they often the most important to those who make decisions. Social and economic aspects of most issues are at least of equal importance. In many cases, decisions require less monitoring than is carried out; what is usually needed is societal change or political will. In these cases, excessive monitoring may be done to justify the decision being requested (i.e., to gain political will). However, focusing communication on convincing the other person why something you think is important is important to them has not proven very effective, especially when the information presented does not fit the other person's mental model. An assumption is also made that we know enough about the area already to make decisions, which does not represent the reality of changing conditions and emerging issues like legacy contaminants, climate change, plastics pollution, and cumulative effects. As discussed in previous sections, jurisdictional challenges and limited mandates often prevent individuals and organizations from fully engaging in coordinating activities. Systemic silos agencies work within mean it is extremely difficult to identify an organization or department that has a combination of a 'big picture' understanding and the authority or mandate to lead coordination. Most interviewees were not able to outline which agencies monitor what, where, or for what reason, in any detail (one interviewee stated years of his early career were spent trying to gather this information in detail, with little success).

Regarding monitoring design, nearly all interviewees stated there is little to no coordination among the many agencies that monitor in the area, even those that collaborate regularly. However, some interviewees highlighted that data coordination is improving with better data sharing systems and technological improvements—e.g., data storage, the cloud, real-time data automation (also for decision-making). Both Environment and Climate Change Canada and the Government of Ontario are developing their open data platforms, which in Environment and Climate Change Canada's case also incorporates citizen science information (this is an opportunity to facilitate coordination between civil society and conventional monitoring programs). Still, data are usually managed in different databases by different agencies, collected for different reasons and with little communication to coordinate goals and reasons for monitoring. Even within an agency or at a program level there are challenges with coordination (i.e., there is not always clarity about why something is being collected in a certain way, at a certain location).

The only program described as being relatively well-coordinated is the Provincial (Stream) Water Quality Monitoring Network. Sites are dictated by the Province and monitoring is carried out by collaborating partners. In theory, this prevents redundancy and gaps; however, the Network has evolved over time, adding or removing indicators and updating protocols. Management plans have evolved as well to incorporate more systemic considerations of the watershed. For example, consideration of downstream impacts into Lake Erie was not an initial component of the Grand River Water Management Plan (prior to the development of the Watershed Plan). This change in thinking inevitably changes the purpose and design of some monitoring activities, which are not only difficult to coordinate across organizations but may also present challenges with coordinating data collection, resources, and logistics within organizations.

Some interviewees described scenarios of excellent coordination between multiple monitoring parties that shared a specific goal. One recommendation was to have a knowledge broker—an interdisciplinary bridge—who is capable of interpreting the messages and information from each party and who is able to observe and translate when necessary to ensure miscommunications do not occur. Even where there is no ill will, misrepresentation (misunderstandings) can occur. Knowledge brokers would also ensure information generated by the collaboration is brought to the people it needs to get to, in the appropriate format and at the appropriate level of detail/complexity.

Some interviewees suggested conservation authorities should be coordinators that experts at provincial and federal departments to identify monitoring approaches and possible funding. This is partly because of their existing (until 2019) capacity to engage with broad stakeholders, but also because they are usually the organization functioning closest to the watershed scale. Also, CAs report in both directions—to municipalities and the province—so would theoretically be looking for approaches to address resource concerns for local and regional scales.

Cumulative effects assessment

Assessing cumulative effects requires a systemic or systems-based approach (e.g., soft systems analysis). However, assessing cumulative effects may also require considering stressors from outside the system (watershed) being managed. Identifying monitoring objectives for cumulative effects assessment is a challenge that in turn affects buy-in from key partners and decision-makers. To overcome this, one interviewee described a decision matrix that was used to consider which management objectives were present, and what monitoring design would provide feedback regarding whether objectives were achieved. This matrix inspired discussion on what the long-term effects are of cumulative stressors on the whole system. However, another interviewee expressed the challenge of detecting long-term permanent impacts in a cumulative context; rather, one-off events are more easily interpreted. The more parameters are sampled, the more trends may be observed that randomly mean nothing; still, a balance can be struck where multiple indicators will provide more a complete story. One interviewee proposed the use of value of information analysis—a tool for assessing whether new information would influence a decision. Data collected for cumulative effects assessment are also most useful on a regional scale (e.g., watersheds or provincially), so it may not make sense to compare sites or information from one region to another.

Emerging issues can be identified using sampling and reporting at regular intervals. Relationships between indicators are starting to show unforeseen effects of human activities—e.g., Neonicotinoid impacts from present and past use, as well as legacy contaminants and nutrient loading. The challenge is that few monitoring programs exist that would be able to support multi-question decisions with multivariate stream data. From an ecological perspective, every effect is a cumulative effect; however, from a monitoring perspective, cumulative effects may mean carrying out multivariate statistical analyses to identify and possibly quantify different relationships. The variability of species in an area can tell a more complete story than observing long-term trends alone. Still, it is important to note that there are desired cumulative effects to manage for as well. One example was stream augmentation, where multiple reservoirs augment flows of the Grand River up to 90% in the summer. Because we had degraded wetlands at the top and bottom of the river prior to many dams being constructed, without augmentation the river might potentially not exist in a form habitable to fish of all life stages.

Climate change is a challenging stressor to assess. It is certainly recognized widely, for example when discussing extreme precipitation events and their timing; however, the quantification of climate working together with other stressors is yet to be established. Cumulative effects in the nearshore of the Great Lakes were only recently analyzed by using remote technologies, identifying different grades of conditions, and notifying communities as to what is causing those conditions. However, the program described is still in pilot stage and others like it are also early in implementation. As such, there is concern about how effective current modelling is at predicting future conditions. Alternatively, scenario analysis was proposed, as it incorporates influences of different drivers while considering risks and uncertainties. However, overall, interviewees concluded that we need better tools to assess cumulative effects.

...we need better tools to assess cumulative effects.

Definitions

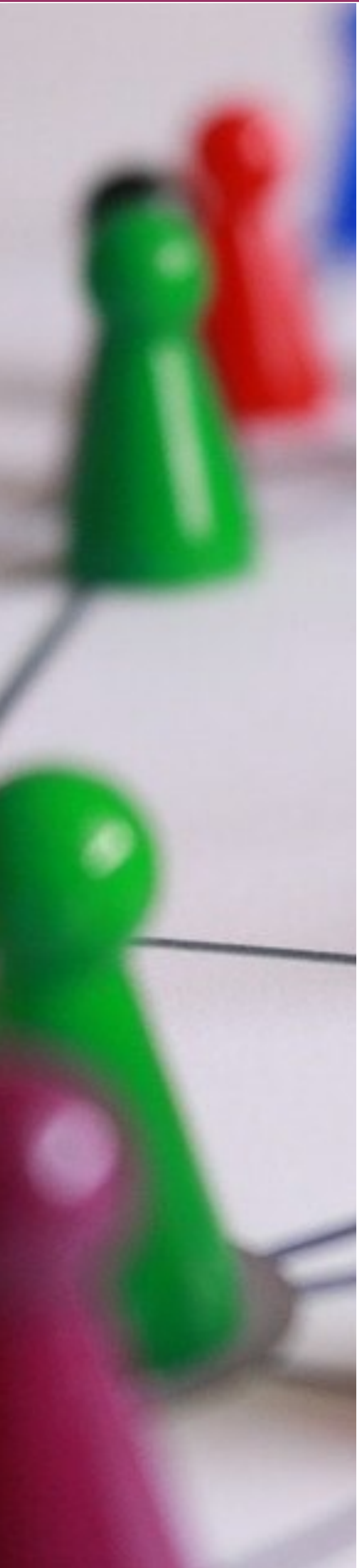
While interviewees generally had the same understanding of cumulative effects at a high level, there were subtle nuances in several of the definitions. For example, some definitions of cumulative effects included only human-induced changes in the environment, while others also included changes resulting from natural processes or stressors. Examples provided by interviewees demonstrated that cumulative effects involve a definite time scale, which ranged from under three years to at least ten years, and that there would be multiple sites within a defined geographical area (e.g., a watershed). Examples of participants' definitions are below.

"Cumulative effects are…"

- A change resulting from multiple interactions of natural and human stressors
- Interactions that occur simultaneously, at the same time and in the same area, versus interactions that occur over a timespan in the same area
- A sum of effects from past and present activities and processes, versus aggregated, collective, accruing, or combined changes to the ecosystem
- Small effects that would not have much of an impact on their own, adding up to create larger impacts – a synergistic accumulation of small stresses or impacts
- The state of a biotic community compared to a reference condition or a historical reference point
- Environmental changes caused by past and present human activities at various scales—local (e.g., thousands of homes in a municipality using water and electricity at the same time), regional (e.g., province-wide urbanization), or global (e.g., climate change)

Interviewees discussed the importance of defining the temporal and/or spatial context(s) of cumulative effects. Too short of a timeframe may not accurately capture phenomena, while too long of a timeframe may reduce the data's validity. One interviewee suggested that more than ten years of observation/data would be needed to understand effects on the environment well enough to determine the appropriate geographic scale. Another interviewee described her interpretation of physical space in cumulative effects as the area in which the waters flow. This example implies directionality of effects, from the headwaters to the estuary. The assumption in this case is that the greatest impacts are experienced in the lower watershed since they will have accumulated impacts from upstream.

One interviewee raised the question of whether cumulative effects are incorporated into decision about the monitoring program, or whether monitoring data are incorporated into a cumulative effects



management scenario. The former scenario relates to the design of the monitoring program and discussion on adaptive monitoring; the latter is more in-line with earlier definitions and is what this research was striving to explore (i.e., cumulative effects assessment). However, the question of how cumulative effects may be incorporated into the design of monitoring programs is an important one that would ideally be addressed in order for the most relevant and usable data to be collected for cumulative effects assessment in management.

Different from regular monitoring?

While many existing monitoring programs have some form of project-based or stressor-based monitoring, an approach focused on cumulative effects would be done on a regional scale (i.e., would not monitor only a single stressor). Although a commitment for long-term, uninterrupted funding is ideal for all monitoring, it is imperative for monitoring that will contribute to cumulative effects assessment. Observing more than one effect is likely required for identifying a cumulative issue (e.g., monitoring nutrient concentrations versus also monitoring water temperature and invasive species).

While everything measured in situ is technically a cumulative effect, drivers are rarely easily identified. While conventional monitoring programs may be designed to permit estimation of single-driver influences, monitoring for cumulative effects is unlikely to produce anything useful without the simultaneous consideration of other potential drivers. The whole system needs to be studied, first by looking closely at the question(s), then considering which combination of drivers may potentially be behind the effect(s). In other words, monitoring for cumulative effects is not just about measuring the endpoints, it is about measuring the drivers and their intensity of influence on the endpoints. This may not require redesigning existing programs, but rather adding capacity to assess these drivers collectively.

Cumulative effects assessment is more dynamic, with many levers that can be used to perform scenario analyses. Specific chemical and physical aspects may be narrow in scope, but there would be spatial pressures that can be incorporated into some models for analysis. A broad base of data would be required alongside a modelling tool that can identify relationships and generate predictions. The process might look something like this:

1. Define the issue in terms of which collection of parameters demonstrates that the issue is present
2. Consider drivers of the parameters
3. Model potential drivers and their influences on the parameters to see what combination of drivers results in the issue being observed. If

none sufficiently fit observations, return to the first step to see what information may have been missed, as perhaps we have misunderstood what the actual dynamics of the system are. This might require more in-depth study, incorporating systems approaches like soft systems analysis (refer to Peter Checkland's work).

Examples of cumulative effects in practice

Most programs in Ontario do not incorporate cumulative effects assessment, but there are components of current monitoring that can contribute to it. For example, there are thousands of sites where many parameters have been measured for decades—data that can be used to build models for cumulative effects assessment. Existing programs like Environmental Effects Monitoring (Environment Canada's industry assessment program) can be used to evaluate cumulative impacts of multiple projects in a region, or watershed. An example of the Sydney tar ponds in Nova Scotia illustrated historical attempts at measuring cumulative effects of a particular stressor—collective leeching of coal mining ponds—over a long time period, which succeeded in achieving (limited) action. Another example occurred in the 1980s: a gravel pit extraction at the University of Guelph gravel pit was discussed at an Ontario Municipal Board hearing, resulting in the formation of a cumulative effects committee to assess impacts of this and other developments (e.g., Highway 401 expansion) on Mill Creek. Other Canadian examples included programs in the Skeena watershed, Saint John River, and the Oil Sands. Initiatives by the Grand River Conservation Authority (e.g., simulation model from the 1970s projecting oxygen levels in response to point sources, non-point sources and background concentrations) and the Credit Valley Conservation Authority (e.g., watershed planning documents) were also highlighted. Internationally, monitoring programs in the Florida Everglades, Chesapeake Bay and an international consortium of lung associations (cumulative effects of multiple atmospheric contaminants ahead of the Beijing Olympics) were recommended as potential examples to explore.

What monitoring for cumulative effects can achieve

As with any monitoring, there are limitations to what cumulative effects monitoring can tell us, largely because of the uncertainties associate with it. For example, we are only starting to understand what controls natural variability of fish health endpoints. Efforts are strengthening to predict changes on fish health influenced by future development, climate change, etc. as well. Questions one might ask before making a decision include how to capture resulting data, how sensitive the indicator is to other decisions or activities being managed, whether the indicator can be modelled for scenario analysis, and if not, then what the relevance of the indicator is. Other questions would be around evaluating the efficacy of monitoring design for cumulative assessment. Such concerns relate to acceptable indicators for adaptive monitoring and management, standardized methods for comparability across sites, and optimal or reasonable frequencies and locations.

Despite limitations, useful predictive models are possible to generate. Historical trends and divergences in water quality over time are now better understood. We are already able to better connect effects to at least their collective stressors than in the past, and collaborative scientific efforts have generated much knowledge regarding how stressor-effect pathways develop and how to manage or prevent them. To ensure the model is useful, the scale of modelling should be chosen based on the question being asked (e.g., on a landscape or watershed scale, or whichever of the many hierarchical systems approaches is chosen by the modeler).

Examples of the influence of cumulative effects monitoring illustrate how this type of information can build resilience and support innovation. In one example, a guidance document describing cumulative effects pathways was presented to a public official, who then used it to make decisions after a river wiped out several communities. In another example, a software was developed to receive data, perform statistical analyses, and present summaries of the data (unfortunately, this initiative was scrapped despite working well, for reasons unknown to the interviewee). Studies are being conducted in Alberta's oil sands to predict future cumulative impacts of mines, pit lakes, etc. on the surrounding environment and receiving waters. This proactive effort will inform response plans developed in the event predicted effects should come to fruition. Continued monitoring will help us to assess and improve our predictions.

Other insights

Estuary conservation and management requires a greater level of analysis to ensure that well-informed preemptive steps are taken to induce effective restoration. Models can be developed to indicate key contaminants that alter estuary ecology, identifying areas for future research and data collection. Unfortunately, models developed for estuary analysis can be difficult to use as contaminant concentration data can skew considerably. These concentrations can only be measured with accuracy within a few kilometers along the nearshore, from the mouth of the Grand River to Rock point. Beyond this range, the dilution rate is erratic due to the inconsistent flow rate, increasing the chance of variable data and rendering the model inaccurate. Additional research on the volume of water discharged from the river as a function of the lake's circulation regime may be required to resolve this issue. This issue is exacerbated by insufficient data collection. Input datasets for models are collected by multiple agencies and research groups, and are generally stored in some form of database. In theory, these data are expected to be well managed and available for use in the future; however, governmental issues can result in dropping of databases, including insufficient funding. Partner organizations responsible for collecting the data are rarely consulted during this process as there is no ownership of data.

There is currently no way to track or monitor potential stressors outside regulatory mechanisms. This issue is further exacerbated due to researchers' inability to identify what depth of information is required to generate a well-informed strategy. Research indicates that a tiered approach may adequately categorize research topics dependent on their importance to aquatic ecology. Tier one would be ambient characterization; based on conservation authority current capacity, no depth regarding cause-and-effect is required. Tiers two and three would delve more into cause-and-effect relationships, and detailed statistical inferences and predictions on cumulative effects would be possible.

Interviewees suggested that sampling a series of cross-sections of vertical depths, longitudinally, every three to four weeks over several years, may be required to generate a baseline dataset. Additionally, an on-call ('SWAT') team would be required to sample any extreme events such as rain or snow, ensuring that both chronic and episodic data are collected. Unfortunately, Canada lacks the funding mechanisms available in the United States via the US Army Corps of Engineers, NOAA's National Sea Grants, USDS, benevolent NGOs and GLATOS. This has resulted in a considerable knowledge gap in the lower Grand River, reiterated by several interviewees. The building of knowledge in the eastern basin of Lake Erie has largely been pursued in the last two decades, almost from scratch. Technical and academic advances in the Grand River Watershed have been important for progress and were generally backed by municipalities.

The study area experiences an accountability problem: there is no single person or entity accountable for water quality in the estuary. One interviewee suggested this lack of accountability may be partly due to a lack of strong, visionary leadership. An example was provided in which a leader told his team what he wanted to see happen. He had no idea how to make it happen, but he knew what needed to be done so he told his team to make it happen. There was some resistance at first, but less than a year later a strong first iteration was implemented, demonstrating the possibility to implement the necessary actions should the mandate or demand be present. However, accountability is not only lacking from a leadership perspective, but all around. The cost of restoration is approximately $1,000 per square meter, and so the cost of restoration at the current scale is many thousands of dollars on a regional scale. However, people and organizations are permitted to degrade habitat with little penalty (i.e., the Grand River Conservation Authority could only charge a maximum of $10,000, and only after a court process). Furthermore, restoration never brings the area back to its pristine condition, so there are always permanent impacts that also affect other parts of the watershed. One interviewee suggested considering changes to the watershed on a spectrum, looking back from pre-European contact to an industrialized watershed that does not value the water, and determining the overall vision based on where on this spectrum we want to sit.

There was some thought as to whether the definition of monitoring will change in the future. One interviewee suggested watershed planning will always continue to be the basis of water resource management. Several interviewees directly or indirectly suggested the definition of monitoring would evolve to incorporate more social variables, which already determine the outcome of things being measured. For example, when monitoring nutrients, an interviewee was never asked about concentrations, but instead was asked how much the program was costing. This demonstrates a change from perceptions about water monitoring being limited to chemical parameters and fish. Ongoing monitoring may not be required for a comprehensive list of indicators, especially if we can wrap our heads around cumulative effects and related modelling. For example, research reveals that high concentration of contaminants within the estuary may cause an increase in Bullhead liver tumors in the lower Grand. Further research to verify whether this is a cumulative effective of upstream contamination may be required. Regulations are needed to identify and monitor potential cumulative stressors; anything outside the current regulatory system would be discounted. One monitoring program described by an interviewee eventually reduced a list of about 20 national assessment indicators to four that were determined to provide a common base upon which to customize assessments for each area covered by the program. Further, not all indicators would require ongoing monitoring. An example is the return of sturgeon up to Caledonia, as they had been before the dam, which would represent much more than the removal of the dam. It would represent the whole ecosystem is changing, being restored in a biological and ecological sense, but it would represent healing in a cultural sense as a symbol of decolonization and fulfilled commitments (i.e., in other words, good faith).

It is important to recognize the comments of one interviewee who reiterated that subsections of all Indigenous communities should be considered end users of information. A strong, accessible knowledge mobilization strategy should be implemented, which would engage with stakeholders and rightsholders before data are collected to determine what their goals are and in what form they should receive information (this echoes earlier recommendations to ask government decision-makers in what format they would prefer to receive monitoring information). However, knowledge mobilization should go two ways, so that alongside conventional data collection there would be equitable ways of engaging people to tell their stories (i.e., to incorporate other ways of knowing). In addition to enhancing the knowledge generated by monitoring, two-way knowledge mobilization is an opportunity for community members to be involved and to reconnect with the land and water (and each other; a knowledge mobilization strategy such as this would support nation-to-nation relationships and facilitate cultural and ecological healing).

...knowledge mobilization should go two ways...

An example of this healing is the story of Mill Creek, a unique cold-water stream in Haldimand County (lower Grand River). A fissure in the limestone bedrock created the stream, and there is a continuous flow of regional groundwater to the surface at approximately eight degrees Celsius. A dam at Taquanyah was removed in 2004-2005, which resulted in a study about what may have been present before the dam. The study discovered Indigenous cultural artifacts dated approximately 9,000 years ago (twice as old as the Giza pyramids). The First Nations peoples would frequent Mill Creek in the late fall and over winter because the waters were open year-round. There is a layer of chert (flint) between the limestone layers that would be used to make arrowheads and other items. Other benefits of the creek are that there was ample drinking water and game, and the people were located close to Lake Erie. As new tools were fashioned, old tools were left behind, to be found millennia later. The ‘unearthing’ of these artifacts brought the area’s Indigenous history to light and returned cultural artifacts to the community. The Grand River Conservation Authority honored this history with signage at the location to tell the story of settlers and the First Nations peoples who routinely came through the area.

Although there were some comments about an inability to measure historical improvements to the watershed, other interviewees provided information that counters this perspective. There were many examples from interviewees of intergenerational memories that have tracked and described the state of the water system since the 1960s. Observations included the color and smell of the river, the presence or lack of certain species (e.g., bald eagles, rainbow trout, sturgeon), and the impact of human development (primarily dams). Nearly all interviewees who shared memories of river improvement commented on how it has changed from an unusable water system to a much-loved resource with significant economic value. A handful of interviewees recommended this generational model—to ensure future generations can enjoy what we currently or previously enjoyed, while maintaining long-term memories (i.e., records) of how conditions changed. The importance of the watershed’s history was echoed by several interviewees, some of whom recommended bringing this history back into educational programming, monitoring reporting, and communication in a more prevalent way. Other interviewees used historical stories, photographs and data to illustrate the importance of present-day monitoring outcomes. One example of cumulative effects assessment, which resulted in simple solutions that mostly resolved the issue, used historical information (water levels upstream and downstream of a diversion) to build a model to predict lake levels. That study highlighted that, as a result of historical data analysis, average conditions should be considered along with extreme conditions because unique effects occur at the extremes.

Citizen science

Data collection is a meticulous and tedious endeavor. Ideally, monitoring is designed to answer decision-maker questions and is communicated to community organizations or community members. Where priorities overlap between managers, decision-makers, and community members, opportunities to collaborate exist. However, capacity needs to be built so that community members can collect accurate and reliable data; hiring expert consultants is often necessary, at least at the start. Expert consultants, if hired, should be engaged with the same level of care and attention as any other stakeholder or rightsholder, which increases the time required for a project.

Informally collected data from citizen science, often referred to as anecdotal evidence, can supplement ongoing monitoring or catalyze in-depth studies. In addition to enhancing data collection, citizen science is a valuable engagement tool. This method of data collection informs and educates the public, creates ownership of the process, and facilitates decision-making. Additionally, empowering community members to be part of a potential change incorporates community endorsed behavioral change techniques. This allows individuals to learn and contribute on a communal level and accomplishes the change objective with limited external intervention. Engaging with communities can also provide the monitoring program access to unconventional funding streams, increasing project resilience.

Citizen science projects have been implemented across the nation, including the Niagara Coastal Community Collaborative—a citizen science *Cladophora* monitoring program, World Wildlife Fund's STREAM program, Trout Unlimited's cold-water monitoring, and beach monitoring initiatives set up by Swim Drink Fish. In these examples, data are collected and made publicly available; however, making data available is not enough. The key is engaging with community members and local municipalities to make changes and generate solutions that are self-driven. Empowering sustainable intervention through community ownership is a more effective form of behavioral change. A major benefit of citizen science is expanded data collection capacity, though the quality of data is a concern. As the data is informally collected, it generally lacks the continuity and rigorous standardization of conventional data collection methods. Researchers have hired co-ops students to

digitize data in attempt to salvage datasets with variable success. Citizen science programs require further capacity to optimize data analysis and reporting processes. Citizen science is unlikely to satisfy monitoring needs in the offshore environment; however, in the river and nearshore environments there is a lot of potential that some organizations—e.g., Environment Canada, World Wildlife Foundation—are beginning to explore. Some practices, like the Ontario Ministry of Natural Resources and Forestry's Angler Diary program, have been in place for years, but are not formally categorized as citizen science.

It may be beneficial to develop community driven initiatives, as watershed residents have personal interests and vestments related to the water system. Many individuals who live on the waterfront, especially on the Lake, own boats and/or have knowledge of fish species identification and physiology. One interviewee mentioned an example where the agency had trouble securing insurance to have a boat take the team to a site. The agency gave up control of that aspect of the project and put it in the hands of community members, who had no problem getting insurance for their private boat. For some existing programs, like the Provincial (Stream) Water Quality Monitoring Program, citizen science is not implemented because data collection needs to be long-term and is often carried out with specialized field equipment. However, in more remote areas North of Ontario, partnerships with Indigenous groups are of interest to fill gaps in data collection. Several interviewees agreed that citizen science is worth exploring more, and that it may be a solution to increasingly limited capacity in conventional programs.

Indigenous-Western knowledge integration

Bringing multiple lines of evidence together is a skill most monitoring personnel need to build to communicate meaningfully with decision-makers. Engaging with communities at-large may help to define what a 'healthy' system really looks like; a more equitable lens of the ecosystem and more representative monitoring objectives can then be developed. Indigenous knowledge in particular tends to be an enigma to most people at most water management agencies, though interviewees expressed widespread interest in learning how to integrate Indigenous and Western knowledge forms. Incorporating diverse lines of evidence does not only generate a stronger knowledge base, but also provides an opportunity to engage with the community at various points in monitoring and management processes. For example, Western data may make sense only after Indigenous knowledge provides a narrative to contextualize the data, which requires engaging with Indigenous persons to develop and understand their contexts. Westerners need to be more informed as to what knowledge Indigenous persons can offer: cultural knowledge may involve teachings, oral history (e.g., anecdotal evidence), and ceremonial events, in addition to Indigenous-led Western science approaches. Culture defines a key responsibility to be stewards of the land and water (an entirely different spirit than management). As such, Indigenous culture not only produces cultural outcomes, but is a vector for action, as environmental stewardship is core to many individuals' identities as a result. Other knowledge has provided historical states of the water and surrounding areas that are not captured in conventional monitoring. Of course, Indigenous scientific data can align well with existing programs given the Western approaches used to collect them.

In a collaborative monitoring framework, motivations of all parties for participation or engagement should be transparent. It should be recognized that there will be priorities or indicators that matter only to one party in the collaboration; however, there will also be others that matter to all parties, which can then contribute to a shared vision or goal for the monitoring program. In an example using an indigenous community as context, one interviewee suggested there should be some sense from the community what the high-level vision is—e.g., what should the future look like here? Also, both sides should be able to steer monitoring towards emerging issues observed by either party. In addition, it would be worth exploring the capacities and capabilities of each party. For example, larger vessels, equipment, laboratories could be provided by ministries, while personnel and supplementary cultural knowledge could be provided by local communities. Academia and other subject matter experts might have a role with data analysis and reporting. Indigenous coordinators should be hired to ensure an ongoing presence and guidance throughout the project life. Further, workshops should be held to engage the community in knowledge integration and to generate ways to share information in an accessible way for all end users.

A holistic perspective is needed in order to integrate Indigenous and Western knowledge—one in which we are all part of the solution, and all affected by the problem (however inequitably, all aspects are shared). Existing models like a sustainability framework may apply, in which everything has at least three functions and in which every outcome should strive to produce twice as much energy it took to create it (therefore balancing processes and creating system self-sufficiency). One interviewee recommended reflecting upon Western knowledge limitations and epistemology prior to attempting to intertwine it with Indigenous knowledge, describing a diagram of Western and Indigenous worldviews (Figure 1). One worldview, a triangle, is the Western worldview. Animals and plants are organized in a top-down hierarchy where humans are at the top and everything else is beneath. For example, if a stream encroaches on private property, people take issue with it and try to control it. The Indigenous worldview is a circle in which humans are a part of nature, not above it. In this worldview, we are not meant to control the stream, as it knows where it needs to flow. Sometimes the path of least resistance—e.g., removing barriers in rivers to permit free flow—is the sustainable option.

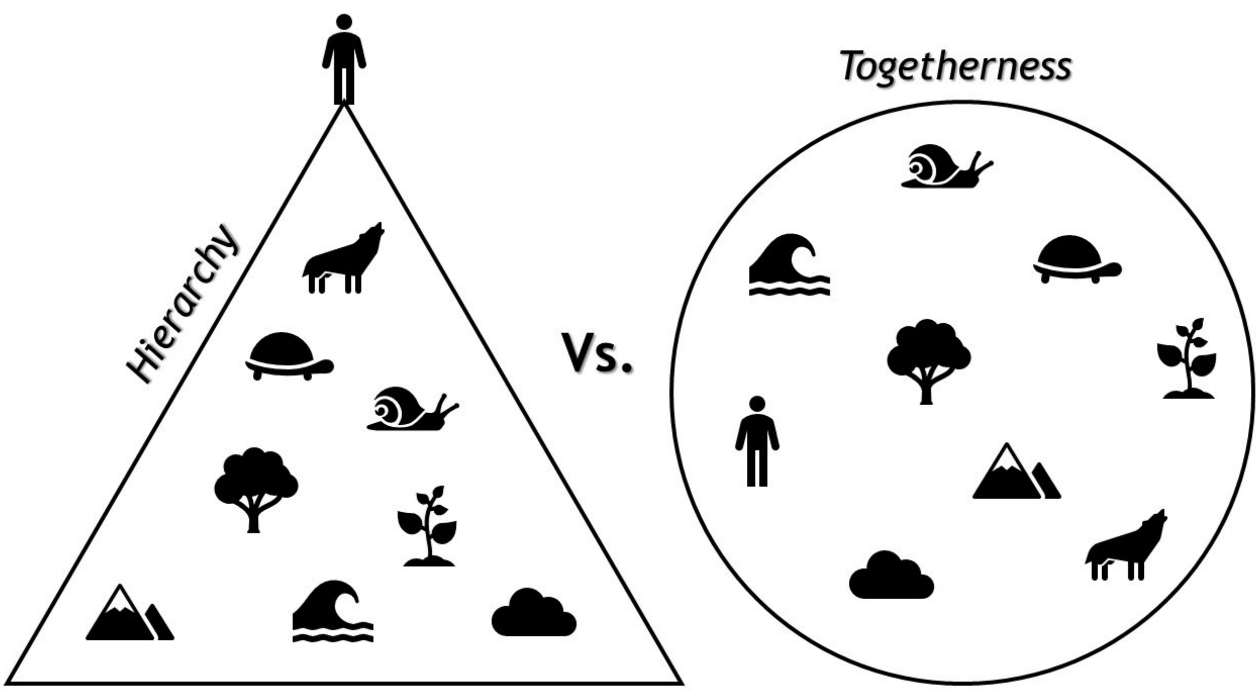


Figure 1. Western vs Indigenous worldviews (existing model described by a participant)

If collecting Indigenous or integrated data in a central database, there needs to be an overriding philosophy that everything is freely shared, that everyone can use it for any purpose. This being said, Indigenous data should be collected and used in accordance with the OCAP™ principles (Ownership, Control, Access, and Possession). If we are able to collaborate in meaningful and respectful ways, we may find achieving shared goals easier to accomplish than if we tackled the issues separately. Indigenous communities might be more adept at assessing cumulative effects, for example, as they already evaluate interconnections between people, land, and water

Recommendations

One of the main recommendations highlighted by interviews was the need to consult with all parties from the start and design monitoring together. A social network analysis on all monitoring partners may be a helpful tool for understanding where the critical leverage points are. Community champions, community groups, residents, and other communities of interest – shoreline property owners, fisheries people, etc. – should also be engaged in specific ways. For example, those who spend time on or near the water should be informed of the program's development and asked about their interest in contributing to the data. Similarly, individuals who live in the estuary may have historical, intergenerational knowledge and memories (whether Indigenous or not). Communities of interest may help drive the vision and can contribute to data collection. In any case, capacity building (e.g., tools, training) should be provided as needed.

Clear objectives should be established from the start, and expectations managed.

Clear objectives should be established from the start, and expectations managed. Mandated agency stakeholders, rightsholders and decision-makers should be brought together in a coordinated work planning exercise for monitoring design (whether coordinators are internal or external should be determined by the parties involved). As part of this exercise, decision-maker needs would be translated into monitoring questions (which will feed directly into specified decisions to be made) prior to data collection. Both decision-makers and monitoring personnel must have a clear understanding of what is to be monitored and why, which implies effective communication. End users should be asked in what format they want their evidence delivered, and what kind of integration is needed. In some cases where characterization is needed, monitoring should not be carried out just to see what is present; rather, it should be designed around a hypothesis to contribute to our understanding of what drives the system. This will increase the ability of monitoring data and information to be used in answering multiple current and future questions.

Several interviewees suggested it would be useful to set up a data analysis system prior to collecting data to ensure the data are usable in the context of necessary analyses (which implies the question being answered is known). Monitoring design should ensure natural variation is represented in the data, and the scale at which water quality information is needed should be clarified (i.e., how refine the data need to be). Both chemical and biological measures should be used, especially in long-term watershed assessments of human stressors and their impacts on water quality and biological factors (e.g., measure water chemistry, water temperature, animal life). The question(s) monitoring strives to answer should determine monitoring intensities; however, the riverine portion (high-order stream – Strahler classification 7 – with low variability) may not need to be as intensely monitored as the nearshore area (which experiences influences from both directions and offshore).

The roles of parties who are a part of the proposed framework should be based on more than knowledge and monitoring capability; for example, the ease with which organizations can adapt or change is an important consideration (i.e., governments are usually not as nimble as other organizations). People need to be in place to coordinate efforts from the start, with a clear mandate for coordination. Funding Agreements between Federal and Provincial governments and conservation authorities, with expected outcomes expressed, would be ideal. It may be beneficial to replicate existing models in which industry and government put money into Universities and get valuable research in return.

Interviewees stressed the need for an adaptive environmental management approach: assess where the monitoring tells us we missed information, make a new decision, implement it, monitor it, and adapt monitoring and management as needed. For this to be effective, open lines of communication and transparent, accessible data are required; as mentioned, any researchers should understand their data may be used by others if published. Where community groups or under-resourced groups collect environmental data, hiring a consultant to analyze and communicate the data may be an effective way to ensure the data are interpreted properly, efficiently and in a timely manner (for use in decision-making). Standardized protocols (e.g., taxonomic consistency) should be maintained, and quality assurance built in if methods or labs change partway through monitoring. Long-term datasets should be maintained for assessing general trends, while project-specific monitoring may delve into issues and can provide a basis for testing decisions. We need to create integrated ecological baselines with ongoing contributions, so that one set of baselines can serve us well enough in a variety of projects or questions.

Annual data check-ins should be implemented to track patterns, assess whether questions have been answered (and what is left to answer), ensure data are providing us with the information we hoped it would, reiterate limitations of the data (what the data cannot tell us) and what everyone realistically expects to gain from the program. Some mechanism – perhaps these annual check-ins – should also be implemented for reviewing or maintaining high level knowledge about what is going on in surrounding areas (within or outside the watershed); potential stressors or impacts outside the estuary's scope of management or monitoring could result in collaboration opportunities in the future, especially in the context of cumulative effects.

A collaborative approach and network can enable observation of interconnections and complexities associated with the Grand River and nearshore Lake Erie (e.g., its plume), as existing organizations on their own do not have the capacity for this. The collaborative should empower and enable the spirit of stewardship and responsibility within management. Public education programs should be incorporated to deliver lay information to the masses and to help them influence decision-makers, as decision-makers often cater to citizens who usually do not have all the information they need. Non-management parties also need to stand up for stronger water quality, whether leaving their watershed or entering it. Finally, rather than attempting to create an answer that involves how to collect data, a process for addressing the issue and for generating (incremental, adaptive management) solutions is most needed—essentially, how to work together to generate solutions. That is the goal of this broader research.

Ideal programs

Many of the above points were echoed in interviewees' descriptions of an ideal monitoring program. Components of ideal programs include clear questions about what monitoring can and cannot answer, direct connections to decisions being made, some form of funds-for-data model, and capacity to perform (e.g., funding, staffing, laboratory resources). Data sharing and co-ownership (between partners, e.g., community groups and academia) are strongly encouraged. An earlier recommendation to incorporate peer review in the program design was also echoed here, regarding sample method, locations, frequency of sampling, analytical methods, reporting, and a process for knowledge mobilization. There would ideally be a mix of stressor-based and effect-based monitoring approaches. Depending on the question asked/decision being made, we might want indicators that could be modelled with enough accuracy to use them in resource use change scenarios. These scenarios would consider the relative importance of different natural and human factors to determine the likely range of outcomes associated with a decision or some human activity. Modelling with the data or using it for different purposes would potentially require intensive monitoring and would require at least some automated, continuous, real-time data over a large area.

In terms of industry stressors and community development, risk assessments that gradually consider previous assessments cumulatively would make tracking cumulative effects and trends easier. Mandated agency stakeholders would determine monitoring sites based on coordinated work planning. There are many US examples of coordination and data sharing that are not bogged down with unnecessary meetings, and which have built-in accountabilities (facilitated by legislation). There would be tangible, measurable improvements related to the goals initially set out, supported by monitoring throughout the watershed that would allow conclusions to be determined with confidence. More statistical knowledge at the forefront of program design would improve chances of generating better quality data and more meaningful information. Objectives for both the river and the lake would be addressed, with water quantity and quality being integrated into one program run for the same purpose. The data would be comprehensive enough to track down emerging issues or problems for proactive management, and trends over time would represent diverse indicators and incorporate seasonal variability (i.e., would represent real drivers of the system). Any changes in protocols would require both the old and new approaches to be maintained simultaneously for a few seasons to make conversions and comparability possible later on.

There were several suggestions for mixed or joint funding models, as opposed to relying on government funding. To make use of existing data (e.g., from the York station)—which has provided a good basis for high level characterization—the ideal program would build on past knowledge using new technologies (e.g., remote sensing, LiDAR) to understand relationships between individual phenomena we've measured over time. Partners would need to work beyond conventional silos and would operate under an adaptive framework that would be gradually improved (this implies acceptance at the start that the program will not be perfect right away). Further, partners would be diverse and would be involved from the early phases of the program (e.g., scoping). Decision-makers could be viewed as monitoring partners as well, since the design of monitoring programs should be heavily influenced by decisions being made.

Bayesian belief networks (or, Bayesian networks, Bayesian decision networks if applied to decision-making) are graphical modelling tools that learn the data and demonstrate cause and effect relationships throughout the network. These types of tools should be explored for adapting the design of monitoring programs where existing frameworks are not providing the information they should. These tools can also perform a cost benefit calculation on the value of information. Evidence could be entered in real time, and graphical models can be produced to communicate information for use by broad audiences.

Several interviewees provided examples of programs they felt were close to their descriptions of what monitoring should be. These examples included oil sands monitoring, Grand River Conservation Authority (especially the Fisheries Management Plan Implementation Committee and the water managers table—neither of which were active on the publication date of this report), aspects of Lake Erie and Ontario Fisheries Management programs (Erie's use of modelling, Ontario's use of plain English communications aimed at anglers), Toronto and Region Conservation Authority's programs (funded appropriately, they have the required expertise and resources), and Environment Canada's Environmental Effects Monitoring program. One interviewee described a colleague's research well-funded short-term project as a perfect study (note: short-term designs are likely not sustainable long-term). The study collected intense data at a high frequency throughout the year, including baseflows and storm events, that are expected to produce a rich dataset to answer very specific questions.

Potential process (for designing monitoring), based on multiple discussions

1. Identify who the end users/decision-makers are
2. Identify who will do monitoring
3. Identify any other persons who should be engaged in some capacity
4. Assess needs/priorities of end users and what decisions need to be made
5. Convert decisions and needs into monitoring questions
    - Both sides should be involved in this so all understand
    - Be transparent about what can and cannot be said, what level of certainty is likely
6. Determine how data will be analyzed, identify capacity (i.e., who will do this, when, and with what funds?)
7. Confirm what format the evidence should be in
8. Design and implement monitoring (including funding)
9. Analyze, interpret data, produce information in a format per step 7
    - Engage with professional communicators or specialist technical experts
10. Annual check-in/status review
    - Bring in knowledge brokers to facilitate communication and to bring the information to where it needs to go

Current priorities

There has not been much work done in the interface of the Grand River and Lake Erie since limited Federal-Provincial collaboration in the 1980s and 90s. Years ago, the stretch of river from Caledonia to Port Maitland was once characterized internationally as the third worst component of any river in Canada, pushing most of the attention towards the upper and middle stretches of the Grand River. Now, some believe the lower section has been degraded to a point where the estuary and its wetlands are not resilient enough to self-sustain. The following are responses by 19 interviewees when asked about their priorities (individual or organizational) and values.

Process-related priorities

Interviewees identified a lapse between the queries decision-makers need answered and the associated evidence collected. Optimization of the research topic and data-collection process—including sufficient funding to achieve the objective—would introduce significant efficiencies to the process. Interviews also revealed a need for greater stakeholder engagement; namely, an improved collaborative effort with the United States for managing shared contaminants and nutrients. For this to be possible, we must improve transparency and develop transition frameworks to manage government turnover. Clearer process for water management may improve dialogue between government and the public. This could be further amalgamated with an increased focus on citizen science for greater engagement and data collection. With greater public awareness, recreational pressure may decrease directly curtailing recreational contaminants.

General priorities, commitments, and values

Interviewees prioritized a concerted effort to conserve wetlands and assess nearshore cumulative effects on habitat—primarily, those described in the Great Lakes Water Quality Agreement, Annex 7. Estuary conservation and restoration could improve the resilience of wetlands to climate change and abate water temperature rise, thus impacting climate change mitigation and adaptation efforts. The Dunnville Dam was determined by several participants to be impacting the health of the estuary and interviewees indicated that more research is required to verify implications for invasive species (e.g., sea lamprey) should the dam be removed.

Participants identified several contaminants that are detrimental to the Grand-Erie estuary due to consistently high concentrations. Regionally, plastic pollution has been identified in aquatic species and higher-level animals by both federal and provincial agencies. Evidence demonstrates bioaccumulation of Neonicotinoid pesticides in higher animals. However, there is a considerable lapse in food network and bioaccumulation knowledge within the Grand River area. Interviewees indicated regular engagement with hunters to submit meat samples may be required to verify certain contamination sources. Legacy elements such as mercury have consistently been recorded in high concentrations; whereas, chloride is intermittently present in high concentration in some Ontario streams, sporadically approaching sea water levels. Wastewater treatment plants were determined to contribute to Grand-Erie contamination, primarily via plant bypasses and other spills.

These contaminants directly endanger our water security, limiting the volume of fresh water available and decreasing the quality of drinking water. Drinking water planning is currently not at the watershed level as it has not been classified as cumulative; however, research participants voiced their opinion that it should be. Unsustainable (urban) development has degraded the health of our groundwater, a fundamental ecosystem component and a key drinking water source in the watershed. Paving over recharge areas and preventing water from returning to aquifers must be

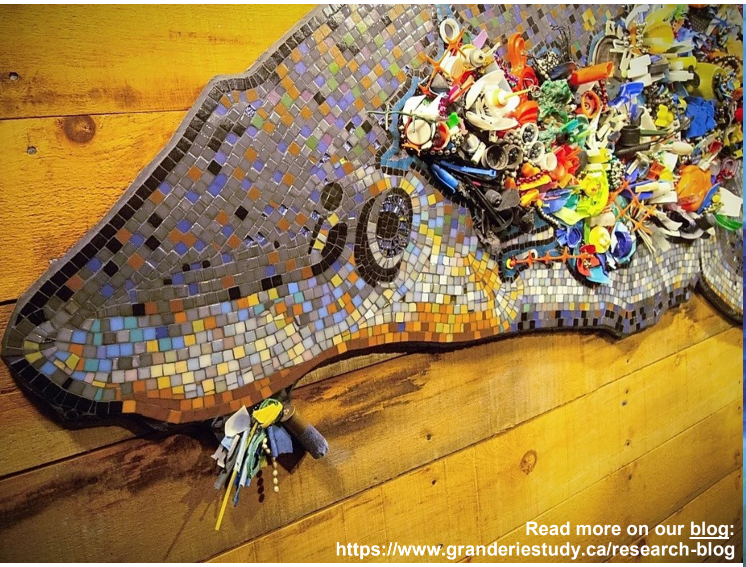
There has not been much work… since limited Federal-Provincial collaboration in the 1980s and 90s.

addressed rapidly to maintain and restore our water quality. Interviewees urged more consideration in future urban planning and development. In conjunction with above-listed contaminants, research indicates an increase in nutrients in the Great Lakes resulting in *Cladophora* algal blooms, which can cause aquatic hypoxia ('dead zones').

These aquatic contaminants have a measurably negative impact on Grand-Erie biodiversity. Fish populations like walleye and trout are struggling, limiting fishery operations due to degraded fish passages. These passages provide vital ecological benefits but are also a symbol of colonization/ decolonization due to their prominence in First Nations culture. Given the watershed boasts a world class fishery and also contributes to Lake Erie's commercial fisheries, more attention/prioritization is warranted in research and policy. Fisheries also perform contaminant monitoring and reporting services for consumption, identifying data that could be used for Grand River conservation strategies. Additional species that have been negatively impacted include mussels (species at risk), muskellunge, and sturgeon (a First Nations cultural symbol); concurrently, an increase in invasive species in Lake Erie has been recorded.

The estuary provides a plethora of social benefits. A public attraction, families frequent the ecological site while youth scavenge the area for their next adventure. Canoeing, swimming, and hiking are popular experiences. The local economy takes advantage of hunting, fishing and trapping opportunities as individuals and industry look to profit off the land and waters. Local markets, cultural and heritage buildings are tourist attractions that are frequently enjoyed by Grand River residents and visitors alike. The river has provided a regular supply of fresh water for generations, allowing small shoreline communities to flourish into large cities while providing an aesthetic value the public adores. This valuable resource demands greater protection if we are to continue to sustainably exploit it for societal gains.

The GRCA 2019-2021 Strategic Plan was developed to promote our transition towards improved health of the Grand River Watershed. Updated GRCA permit policies will focus on three key wetland



ABOVE: *Depths and Consequences*, mosaic and plastics collected from Long Point beach, community creation led by Suzanne Earls and Holly Anderson. **RIGHT**: *Plastic Beach*, ink, by Steve Johnson (part of the Grand Expressions art exhibit by Indigenous youth).

mandates: flooding, sustainable water supply and water quality improvement. To protect life and reduce property damage, the flood and erosion control initiative is attempting to update floodplain mapping. This will aid in identifying flood risk and other natural hazard areas, update infrastructure to deal with changes, and upgrade flood forecasting and warning systems. Municipalities will continue optimizing wastewater treatment plants for source water protection. Additionally, they will engage federal and provincial governments to reduce nutrient loads and work with landowners to reforest and restore natural spaces.

Future infrastructure investments will include riverside and waterfront access and trails to connect people through outdoor experiences. Public access will be further improved with construction of the new Guelph Lake Nature Centre, working with member municipalities to encourage river related activities between communities. Concurrently, the federal government will attempt to improve it's understanding of the influence of tributaries to Lake Erie's Eastern basin. Grasping the relative influence of the river on the lake and tracking their changes over time—including the estuary's relationship with rare aquatic species such as mussels and walleye—will be vital for future action. This would further develop governmental understanding of variable nutrient concentrations and their impacts on fisheries. Other parameters interviewees deemed essential to monitor include water temperature, dissolved oxygen and turbidity, all of which impact aquatic life within the estuary. A greater emphasis on Traditional Knowledge of historical hunting, fishing, and trapping in the watershed will allow researchers to develop a baseline for comparison.

Interviewees believe the river is reasonably well managed in terms of water quality and this should be maintained; we have spectacular water resources and it is our responsibility to take care of the system. Programs like the Great Lakes Coastal Wetland Monitoring program should be prioritized as we build on sustainable development practices. Remedial Action Plans are valuable ways to restore and protect the integrity of our coastal aquatic areas (though, require integrative approaches). Participants believe an emphasis on children and youth-led stewardship would appropriately motivate the next generation to maintain the integrity of our aquatic resources.

Recommended actions to do immediately

One interviewees suggested that a Land Conservation Tax credit may aid the conservation of wetlands; however, another interviewee cautioned in the use of taxes. The Conservation Tax rebates had strings attached deemed inappropriate for farmers/landowners, given other initiatives—e.g., the community-led ALUS (Alternative Land Use Services) program —are feasible options in which private landowners are rewarded for acting in the public interest (note: ALUS has strong roots in the Grand River Watershed; the Norfolk County ALUS program is the hub for Eastern Canada and is the oldest continuously running ALUS program in Canada). Uncontrolled industrial extraction must be limited by enforcing stricter regulations, especially for the agriculture industry. Current economic regulations contain significant discrepancies between stakeholders and require modifications to equally regulate all parties. New regulations must firmly enforce restoration orders and preventative measures. Restoration of fish habitats may cost approximately $1,000 per square meter; initial assessments must include figures such as these within their proposals to appropriately assess the value of extraction and restoration. Cost-benefit analyses on invasive species should focus on emerging threats and abandon conventionally ineffective strategies like attempts to manage phragmites and dog strangling vine.

Additionally, impact assessments should include pragmatism of projects; a dam in the middle of an estuary, such as the Dunnville Dam, demonstrates flawed urban planning as free-flowing (and fluctuating) water is required by downstream inhabitants for consumption, transportation and fish habitation. However, one interviewee pointed out that despite urgency being expressed from some parties, education/awareness campaigns related to dam removal take many years—even decades (e.g., 20 years to shift perspectives regarding the Springbank Dam in London, ON; some success was achieved in the Grand River Watershed when local groups like Trout Unlimited and the Ontario Federation of Anglers and Hunters supported campaign efforts). Finally, programming that addresses data gaps, including citizen science should be prioritized. For example, citizen science may be used to improve fish spawning and fish safety protocols, or can address the issue of algae by increasing the rate of detection.

Final thoughts

In the context of the developing monitoring framework, universities and similar institutions should do shorter term work (e.g., up to five years) that is largely issue-based, possibly focused on exploring emerging phenomena or issues that have been newly identified but are little understood. Government agencies are set up for more consistent, long-term monitoring. Capacities should be openly discussed, and collaborations designed around these capacities. For example, a government agency that has a large amount of equipment, but a limited mandate, may have ongoing agreements to provide other agencies with access to these resources. These agencies may have more flexibility to explore broader issues, would have the operational knowledge to operate those equipment, and would have enough 'boots on the ground' to be effective. Tiered partnerships may be feasible, in which collaborations with certain organizations (e.g., community groups like Trout Unlimited) are possible but dependent on relationships with another party (i.e., university researchers).

Summary (SWOTR)

Strengths

1. **Comprehensive data accumulated over 60+ years**

   a. Some data are well utilized

   b. Multiple benefits—e.g., ability to quantify early warning indicators and provides common basis for discussion and modelling (prediction)

   c. Combination of monitoring designs

   d. Medium-term program cycles permit review, evaluation, and planning (adaptive)

   e. Comparable data (standardized protocols)

   f. Much operational expertise exists

   g. Watershed-scale planning

2. **Collaborative relationships between monitoring agencies and other stakeholders**

   a. Benefits include shared funding burden, enhanced expertise/knowledge, achievement of shared goals, buy-in

   b. Interest from collaborators for working together remains strong across the Province of Ontario

   c. Processes for meaningful engagement are established; we are becoming good at collectively determining what should be done

3. **Standardized communication of data (e.g., watershed report cards)**

   a. Permits the public to demand accountability

4. **Regional, accessible data repositories exist**

= Priority

Recommendations

b. Impacts of data use should be tracked; annual data summary check-ins may facilitate tracking and identify gaps

c. Fewer sites are needed in the study area due to low variability of conditions

d. Adaptive management should be implemented, with open communication, transparent data, and integrated ecological baselines usable for variety of questions

e. Maintain standardized protocols

g. Maintain; drinking water planning should be on watershed scale

2. **Collaboration is critical to successful programs; consult with all parties from the start and design together (incl. USA)**

   a. Roles should be determined on more than knowledge and monitoring capacity (e.g., flexibility)

   b. Social network analysis can be done to see where the common areas of influence or authorities are; motivations, visions, and indicators should be transparent and collaboratively developed (especially with Indigenous partners)

   c. Building in stakeholder assessment exercises (e.g., who is missing, who does not need to be here) would ensure the right people are the table when you need them; engagement should occur before implementation

   a. Collaborative network models can be used to involve stakeholders in the design *and use* of models

4. **Monitoring data should feed into coordinating agency (communication, efforts); no limitations on data use**

Weaknesses

1. **Limited operational capacity**

    a. Little attention to program design, resulting in poor operational capacity

    b. Expenses of shared monitoring stations (activation, maintenance) not often discussed at the get-go

    c. Cannot analyze and interpret data in a timely way that permits issue mitigation

    d. Analyzing data only at the end of the study does not permit adaptive monitoring or management

    e. Despite plenty of technology and equipment available, too few staff or too little training to make use of it

    f. Tracking data use is not done well

2. **Some knowledge capacity gaps (e.g., cumulative effects assessment)**

    a. Peer review of program design, questions, etc. is lacking

    b. Little capacity to monitor for emerging issues; variables and their relationships are not easily quantified

    c. Frequent staff turnover results in loss of knowledge and sometimes data

    d. Information management usually poor (data hard to find, access, synthesize)

    e. Western knowledge approaches are dominant, other knowledge is lacking

    f. Building knowledge in Erie's eastern basin largely from scratch in last two decades

3. **Good scientific indicators are not necessarily the best indicators to answer management or decision-maker needs or questions**

Recommendations

1. **Agencies should review what makes sense to complete in-house, and what can be carried out by partners (note: for community partners, recognition and purpose should be provided to maintain vestment, and capacity for analysis and dissemination provided); capacity-building should be done in both Western and Indigenous ways, and all stakeholders should establish capacities to meaningfully engage**

    f. Tracking data use provides justification for continuing the monitoring program

    b. Using multiple biotic indicators may facilitate interpreting interactions between species and trophic levels and pinpointing stressors more easily

    f. Generate a baseline dataset by sampling a series of cross-sections of vertical depths, longitudinally, every three to four weeks, over several years

3. **Decision-makers and scientists co-design monitoring, translate decisions into viable questions**

= Priority

Weaknesses continued

a. Limited statistical ability to make statements with high confidence

b. People across jurisdictions are used to working with (accepting) insufficient data

4. **Monitoring design needs improvement**

   a. Unique questions require unique approaches; standardization across watersheds does not work

   b. Biological monitoring is lacking

   c. Poor quality data do not answer questions (little variability, randomness, focus on base flow, etc.)

   d. We currently do not do well at capturing interactions between multiple variables in complex systems

   e. Data analysis methods are not usually considered until after data are collected; data that are needed may not always be collected

5. **Communication needs improvement in every way**

   a. Little to no discussion between monitoring personnel and decision-makers re: questions to address

   b. Visuals—e.g., color-coded maps—oversimplify data and are not comprehensive (i.e., do not capture variability, uncertainty, or seasonality)

   c. Probabilistic language is not used where it should be

   d. Expectations may be misinterpreted or not discussed, resulting in disconnect between evidence provided and use in decisions

   e. Professional cultures may interfere with (interdisciplinary) collaboration

Recommendations continued

b. More statistical knowledge at the forefront of program design would likely improve the quality of data collected

c. High flow events in the study area pose legitimate safety and access concerns; remote sensing and other technologies (and capacity to use them) may make year-round continuous monitoring more feasible

e. Set up a data analysis system prior to collecting data to ensure they are useable in analysis context (implies known questions)

5. **Determine the purpose, objectives of monitoring early and collaboratively**

   a. Questions should be clarified at the start, discussed by both sides; end users should be asked in what format evidence should be delivered

   d. What data can and cannot deliver should be clear to all parties before monitoring (Western and Indigenous data)

= Priority

Weaknesses continued

6. **Coordination is severely lacking**

    a. Not often clear who does what, what data they have, and what they can share

    b. Lack of trust has been a major barrier in the past

    c. There is a lack of standardization between present and past data

    d. Coordinating (and communicating) priorities

    e. Coordinating linkages between those who monitor, manage, and make decisions

7. **Programs and processes are exclusive**

    a. There is not a single, widely-used data repository that contains free, open sharing of data from or by government, academia, industry. and civil society

    b. Where one individual represents diverse perspectives, engagement may not be meaningful and there is a risk of losing any diversity if that individual leaves the process

    c. Historical relationships between government, academia, and Indigenous communities

    d. Current approaches do not permit meaningful engagement from community members

8. **Management culture does not support meaningful action**

    a. We rely more on technology than we should; even 'automated' tools are not fully automated, which is sometimes not considered in budgeting

    b. We implement reactive solutions rather than mitigating or preventing issues

    c. Voluntary responses are prioritized over requiring a change in practice

Recommendations continued

6. **Improve communication; implement redundancy in roles, not activities**

    a. Utilizing all data possible is likely to save on resources and reduce duplicated efforts; frequent check-ins are recommended

    b. Evolving working relationships and approaches are increasing trust (maintain)

7. **It is critical to engage with the right people, at the right time, and that they represent diverse backgrounds**

    a. We don't need answers about how to collect data; we need a process for working together to address issues and generate solutions

    d. Changing government requirements (e.g., to include First Nations in certain approvals) and data availability (e.g., open data portals) are good steps; operationalization of necessary changes requires careful consideration to be effective; permitting processes can initiate guided collaborations

= Priority

Weaknesses continued

d. Restoration never brings an area back to its pristine condition, there are always permanent impacts that impact other parts of the watershed

9. Cumulative effects are not well-considered

a. Little operational expertise (e.g., the more parameters are measured, the more unimportant trends we are likely to see; how do we sort these?)

b. New or recent approaches (e.g., remote sensing) mean insights are yet to be seen; models are young and their predictive capacities are questionable; we need better tools

c. While high-level understanding of cumulative effects is common, important nuances (and, therefore, different definitions) exist

d. Intimate knowledge of drivers and stressors (and pathways) in the watershed is rare

10. River-lake dynamics are highly-variable and not well documented

a. The rate of change in a watershed is variable, so impacts may not be appropriately assessed if only a single normal range of variance is accepted

b. Models developed for estuary analysis are difficult because concentrations can only be measured within a few kms along the nearshore, from the mouth of the Grand River to Rock Point; dilution rate is erratic due to inconsistent flow rates, and variability of data is high

Recommendations continued

d. Consider changes to the watershed on a spectrum, from pre-European contact to fully industrialized, and determining where the overall vision is (i.e., where on the spectrum do we want to be?)

a. Define the temporal and/or spatial context; scale of modelling should be chosen based on the question being asked; assessing more than one effect is likely needed

b. Scenario analysis (incorporating influences of different drivers and considers risks or uncertainties) was recommended, at least while we hone other approaches

d. Tools like Bayesian networks should be utilized

10. Grasping the relative influence of the river and lake on each other, and tracking changes over time (incl. estuary's importance to species-at-risk), are vital for future action

a. Flexible priorities are essential; clear roles for all parties may help shift priorities quickly; adaptive monitoring and management processes are recommended

b. Additional research on the volume of water discharged from the Grand River as a function of the Lake's circulation regime

= Priority

Opportunities

1. **Advances in technology have increased capacity to investigate complex issues**

   a. Improved data sharing (e.g., data storage, the cloud, real-time data automation)

   b. Tools have been developed and can be applied to cumulative effects assessment (e.g., decision matrix, value of information analysis, etc.)

2. **Open data practices are becoming the norm (and expected)**

   a. Increasing capacity in citizen science nationwide can make use of and complement conventional data sources

3. **Reconciliation provides a mandate for meaningful Indigenous collaboration**

   a. Increasing research available for operationalizing necessary changes and bringing together multiple lines of evidence

4. **Mandates are some of the biggest determinants of whether and how decisions are made (they are clearly defined and comprehensive)**

   a. Decision-makers are extremely capable and have qualified teams

5. **Knowledge and practice are co-evolving an becoming more dynamic**

   a. Cumulative effects assessment is establishing as a field/practice; enables scenario analyses using chemical, physical, and spatial pressures

   b. The operational definition of water monitoring and management is likely to change in the future (more social variables)

Recommendations

3 **Indigenous communities should be considered end users of information; implement a strong, accessible, *two-way* knowledge mobilization strategy**

   a. Ensure community data are self-driven; Westerners need educating re: what Indigenous data are and what they offer; holistic perspective is required

4. **Knowledge producers who know the mandates of their decision-makers and tailor their information to them may be more successful at negotiating desirable outcomes**

   a. Ensure a broad base of data for identifying relationships and generating predictions, and long-term funding; Regulations are needed to identify and monitor potential cumulative stressors

   b. Ongoing monitoring may not be required if we establish cumulative effects and related modelling; generational (e.g., memories) of data should be incorporated

= Priority

Threats

1. **Capacity deficiencies**

   a. Inadequate funding

   b. Too few staff

   c. Inadequate equipment/tools

   d. Insufficient access to laboratory resources

2. **Limiting regulatory/legislative processes, policy mandates, and jurisdiction**

   a. Timelines for developing, implementing, and learning from monitoring are unrealistic

   b. Progress is too slow and

   c. Systemic silos prevent most decision-makers from thinking about whole life cycles or integrating priorities from outside their mandates; similarly, staff have little opportunity to integrate their expertise with others'

   d. Issues not obviously connected to mandates or regulatory mechanisms are not monitored

   e. There is little flexibility to adapt to emergent information

   f. Focus on legislative requirements causes some degradation to be classified as having made "good enough" progress

   g. Sometimes job descriptions include water monitoring as one of many duties; limited ability to dedicate their time and energy on collaboration, etc.

   h. No single accountable person or entity

3. **Misinterpretation may undermines progress**

   a. Published information can be misinterpreted and is sometimes re-published (miscommunicated) via the media

Recommendations

a. We should not focus on how much monitoring can be done with a dollar amount, but rather on activities that directly connect with decisions; alternatively, a closer look at the issues may suggest a need for intensive monitoring (rather than general characterization); mixed-funding models, e.g., funds-for-information (government-universities), should be replicated

2. **Community groups and other partners may collaborate to fill gaps in mandates or jurisdiction**

   d. A tiered approach for categorizing studies according to their importance to aquatic ecology: Tier 1—characterization; Tiers 2 and 3—delve more into cause/effect, ability to make detailed statistical inferences and predictions on cumulative effects

   f. A systemic or systems-based approach should be considered (as opposed to achieving objectives independently)

   h. Visionary leadership

3. **Be transparent (e.g., how information was created, not passing political opinions off as fact)**

   a. Make use of a knowledge broker

= Priority

Threats continued

or social media.

b. Issues can become entrenched in uncertainty, emotion, and controversy; results in little attention on those issues by decision-makers, until a crisis occurs

c. Appearing to make progress is sometimes prioritized over making real progress; i.e., implementing hard solutions over soft solutions is preferred

d. No accountability for uninformed decision-making and few systems to guide responses to monitoring information

4. Systemic discrepancies

a. In many cases, no requirement to respond to the information produced

b. Justifications to continue monitoring are frequently required and not always possible (e.g., if a program does not benefit the incumbent office—if it requires a few more years to provide useful information—it may not be supported)

c. Change management is not commonly practiced, which impedes progress despite possible benefits

d. Decisions are not required to be science-based; community member voices are often considered strongly even if the public is not knowledgeable

e. We are experiencing increasing unforeseen challenges; predictive approaches need improvements

f. Sometimes, progress is impeded by other actions that cannot proceed (but which are required)

Recommendations continued

b. Include open-minded individuals who are evidence-based but who also validate stakeholder needs

d. Public education should be incorporated as part of dissemination of monitoring information

e. A mechanism (perhaps annual data check -ins) is needed for reviewing high-level knowledge about what is occurring in surrounding areas (outside the watershed); this could catalyze collaborative opportunities

f. Restore/conserve the estuary's wetlands—requires consideration for removing the Dunnville Dam

= Priority

We thank our experienced contributors for the perspectives shared in these interviews!

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