SCIENCE STRATEGY
June 13, 2024

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1. CONTEXT

In Article 302 of the Great Lakes - St. Lawrence River Basin Sustainable Water Resources Agreement[1] (Agreement), the Great Lakes Governors and the Premiers of Ontario and Québec "commit to provide leadership for the development of a collaborative strategy with other regional partners to strengthen the scientific basis for sound Water management decision making under this Agreement." A similar commitment is included in Section 1.4 of the Great Lakes - St Lawrence River Basin Water Resources Compact[2] (Compact).

The Agreement/Compact requires the management of water resource withdrawals at a Great Lakes Basin and Watershed of a Great Lake or St. Lawrence River scale to protect the applicable Source Watersheds (see definition in Glossary). This is led through activities undertaken by the Great Lakes-St. Lawrence River Water Resources Regional Body (Regional Body) and the Great Lakes-St. Lawrence River Basin Council (Compact Council). Management, led by individual jurisdictions, also occurs at the local or regional scale to ensure withdrawals cause "no significant individual or cumulative adverse impacts to the quantity or quality of the Waters and Water Dependent Natural Resources." The Science Strategy, in line with Regional Body/Compact Council responsibilities under the Agreement/Compact, focuses on activities at the Basin and Source Watershed scales, as defined in the Agreement/Compact (see definition of scales in Glossary). Science activities in support of management approaches and decisions and assessment of impacts at the local and regional (sub-Source Watershed) levels are important but are not intended to be addressed directly through this strategy. Rather, they will be addressed through ongoing information sharing between the Great Lakes - St. Lawrence States and Provinces.

Substantial work has been performed to date to meet these commitments. In 2013, a Science Strategy was put forward by the Regional Body and the Compact Council, and several actions were taken pursuant to advance that strategy. In 2019, this strategy was updated by the Great Lakes - St. Lawrence Regional Body and Compact Council science team after 10 years of Agreement/ Compact implementation to provide a clearer context for the strategy and to better articulate the needs, challenges, and priority actions. The Parties undertake a Cumulative Impact Assessment every five years to understand the impacts of changes, including consumptive uses and diversions, to the Great Lakes water balance at a Source Watershed and Great Lakes Basin scale. Three Cumulative Impact Assessments[3] have been performed since the Agreement and the Compact came into force. These are the first Cumulative Impact Assessments that have been performed on a watershed the size of the Great Lakes St. Lawrence River Basin.

[1] Agreement: https://www.glslregionalbody.org/media/uvlnnp5d/great_lakes-st_lawrence_river_basin_sustainable_water_resources_agreement.pdf
[2] Compact: https://www.glslcompactcouncil.org/media/nmzfv5jq/great_lakes-st_lawrence_river_basin_water_resources_compact.pdf
[3] Assessments: https://www.glslregionalbody.org/media/2cenkigj/2013-cumulative-impact-assessment-12-4-13.pdf ; https://www.glslregionalbody.org/media/yxmjkffk/2019-cumulative-impact-assessment-12-8-17.pdf; and https://www.glslregionalbody.org/media/s4lnxt3p/cumulative-impact-assessment-2016-2020.pdf

Accordingly, improvement of the Cumulative Impact Assessment is a primary driver for this Science Strategy, and many of the priority actions listed below are included with the intention of improving future iterations of the Cumulative Impact Assessment.

In addition, water use information reporting to the Great Lakes Regional Water Use Database[4] has substantially improved since 2012, with ongoing coordinated activities that have both improved the rate of water use reporting compliance as well as the quality of data that is reported. Furthermore, various focused studies have been undertaken, including a report on the potential changes in water use resulting from retirement of thermoelectric power plants in the Great Lakes Basin[5] and an article on public water use trends in municipalities throughout the Basin and potential drivers behind them.[6]

As a result of the recommendations in the 2019 Science Strategy, and previous cumulative impact assessments, to address the significant uncertainties in the Basin water balance, the 2023 Cumulative Impact Assessment of Withdrawals, Consumptive Uses and Diversions 2016-2020, includes a summary of the evaluation of using a modeled approach to developing the Basin water balance. The 2019 and previous cumulative impacts assessments identified the need for more reliable data and information regarding the Basin water budget and how consumptive uses are measured or estimated. To date, the cumulative impact assessments have used data that has significant uncertainty associated with it. To address the significant uncertainties in the Basin water balance, the Regional Body/Compact Council contracted with researchers from the University of Michigan to develop the large Lake Statistical Water Balance Model, which uses a statistical method, historical data, and millions of modelling iterations with the help of a supercomputer, to effectively close the water balance. This work has shown that this model can be used to significantly reduce the uncertainties associated with the water balance components of this cumulative impact assessment and the Regional Body and Compact Council plan on using this method for the water balance components in the next cumulative impacts assessment. The final report and a summary of these findings is included in the 2016-2020 cumulative impact assessment.

As outlined in Article 302 of the Agreement/Section 1.4 of the Compact, the intended purpose of the Science Strategy is to guide the collection and application of scientific information to support:

a. An improved understanding of the individual and Cumulative Impacts of Withdrawals from various locations and Water sources on the Basin Ecosystem and to develop a mechanism by which impacts of Water Withdrawals may be assessed;
b. The periodic assessment of Cumulative Impacts of Withdrawals, Diversions and Consumptive Uses on a Great Lake and St. Lawrence River watershed basis;
c. Improved scientific understanding of the Waters of the Basin;
d. Improved understanding of the role of groundwater in Basin Water resources management;

[4] https://waterusedata.glc.org/
[5] https://www.glslregionalbody.org/media/obcd3k4x/2017-thermoelectric-powerplant-report.pdf
[6] https://www.sciencedirect.com/science/article/pii/S0380133023002368

e. The development, transfer and application of science and research related to Water conservation and Water use efficiency.

Furthermore, because of past reports and ongoing scientific work, this updated Science Strategy aims to strengthen scientific understanding on a continuing basis, address data gaps and reduce uncertainties by prioritizing actions that will improve the implementation of the Agreement/Compact, with a particular emphasis on improving the Cumulative Impact Assessment, the estimation of consumptive uses and the water conservation and efficiency programs. The priorities include:

1. Embed Science Team in Regional Body/Compact Council Work
2. Improve the Assessment of Cumulative Impacts
3. Promoting Water Conservation and Efficiency
4. Enhancing Organizational Collaboration
5. Addressing data, monitoring, and science gaps (Research Needs)

The Science Strategy addresses water managers involved in the Agreement/Compact, Tribes, First Nations and Métis and any organization or research institute concerned with managing to conserve and restore the Waters of the Basin. It starts by identifying *needs and challenges* (Section 2) related to improving scientific understanding from which a series of *priority actions* (Section 3) are then detailed. A timeline for implementing the Science Strategy and *reporting* (Section 4) on priority actions is proposed. A *glossary* of terms and a list of bibliographic *references and appendices* can be found in Sections 5 and 6 at the end of the document.

2. NEEDS AND CHALLENGES

The Science Strategy highlights a variety of needs and challenges to better implement the Agreement/Compact and, more specifically, to improve the accuracy of future cumulative impact assessments. Some needs and challenges focus on improved water quantity data collection and scientific analysis for the Waters of the Basin (see definition in Glossary). Some are related to improved tools for management decisions regarding consumption, conservation and efficient use, whilst several address overarching issues like climate change, indigenous engagement, and outreach.

2.1 Surface Water

Developing an improved estimated Basin-wide water budget is a key component in increasing the accuracy of cumulative impact assessments. Surface water impacts are currently assessed by comparing inflows (surface water runoff, precipitation, interbasin diversions.) to outflows (withdrawals, evapotranspiration, interbasin diversions and consumptive uses). Although water elevation in the Great Lakes can be easily recorded, there are still many challenges and difficulties in estimating a water budget that accurately captures the spatial and temporal variability of Basin water levels whether associated with the variability in hydrologic and climate estimating techniques or with climate change. A water budget at a temporal scale finer than annual may also be needed to capture hydrologic patterns and seasonal variation for each Great Lake. Quantifying outflows like evapotranspiration remains a challenge. While the work undertaken by the University of Michigan in developing the Large Lake Statistical Water Balance addresses the need to reduce water balance uncertainties, it has yet to be fully incorporated into the Cumulative Impact Assessment.

Some key challenges are related to the lack of long-term stream gage data in some parts of the Basin. Improved monitoring coverage is needed to develop detailed and accurate modelling tools and improve understanding at local and regional scales from the perspective of both water quantity and quality. In turn, this will support a better understanding at the Lakes and Basin scales required for Agreement/Compact management decisions. In the meantime, in the absence of stream gages, robust estimates need to be updated.

Many of these same challenges apply to jurisdictions at the sub-watershed scale in determining whether existing or proposed water withdrawals may create individual or cumulative adverse impacts to inland lakes, ponds, and wetlands, however, the necessary data to characterize the geologic and hydrologic settings of these surface water bodies doesn't exist in many areas. In addition to the hydrologic and ecological concerns, other uses of the water body (e.g., navigation, dockage, recreation) and the rights or interests of Tribes, First Nations and Métis must be considered.

2.2 Groundwater

Groundwater is an important element of the water budget and for maintaining chemical, physical, and biological integrity of the Great Lakes Basin. Direct groundwater discharge to the Great Lakes is a small proportion of the overall water budget, however indirect groundwater discharge to Great Lakes tributary streams is a significant portion of the streamflow in many Basin tributaries. Groundwater discharge at the local scale is also responsible for maintaining streamflow and inland lake levels, particularly during the summer and fall months and during droughts (Grannemann G, Van Stempvoort D. (Eds.), 2016). Groundwater discharge at the local scale is also linked to supporting aquatic ecosystems and groundwater serves as an important resource for drinking water supply, agricultural irrigation, and industrial use across the basin.

Our understanding of the availability and extent of groundwater resources stored and flowing through aquifer systems across the Great Lakes Basin is comprehensive in some locations, but can be improved in others. Additionally, it is well understood that groundwater – surface water are closely linked in many aquifer systems. However, the details of how to evaluate the impacts of a specific groundwater withdrawal on a specific water resource are an area of active research, and there is a need to better understand the contributions of groundwater at a basin-wide scale. This information is critical in determining whether water is available and sustainable in the Great Lakes Basin to meet demands for drinking water, agricultural, industrial, and other uses, and to support healthy ecosystems (IJC, 2018). The identification and delineation of gaining and losing reaches of major Great Lakes tributaries is both critical to understanding groundwater – surface water interactions and especially challenging given the dynamic nature of these processes.

As part of the water budget used in the cumulative impact assessment, indirect groundwater discharge is captured in the calculations of tributary surface water discharges to the Great Lakes. A more refined understanding of the geography of the groundwater – surface water dynamic along these tributaries is needed to better assess the proportion and origin of indirect groundwater discharge as part of the overall tributary discharge to the Great Lakes. Direct groundwater discharge to the Great Lakes has not been included to date due to limited estimates available. When estimates of direct groundwater discharge have been made, it is a relatively small component of the Great Lakes water budget and is less than the uncertainty associated with major inflows and outflows of the Great Lakes (Feinstein, 2010).

A continually improved understanding of groundwater flow to the Great Lakes and tributaries, and groundwater – surface water interactions is needed to better determine what type of water management is needed. Furthermore, understanding of regional groundwater flow patterns is important to assess Intra-Basin Transfer and Diversion proposals and meet the Agreement/Compact requirements. These requirements include evaluating water supply alternatives as there can be a potential for groundwater outside of the topographical Great Lakes Basin to have a hydrogeological connection to Waters of the Basin.

2.3 Flow-ecology Impacts

As recognized in the 2017 Cumulative Impact Assessment, cumulative impacts of water withdrawals should consider ecologic impacts in addition to hydrologic ones. Changes in water flows, discharges, and levels, over and above natural fluctuations, can lead to significant individual or cumulative adverse impacts on ecosystems (or Water Dependent Natural Resources). Likewise, a greater understanding is needed of how water quantity can impact water quality and in turn ecosystem health, for example relating to the dispersal of aquatic invasive species. There are multiple challenges related to flow-ecology relationships which are not only to collect and analyze information but also to transpose local or regional scale data to a Lake or Basin scale and include this in future Cumulative Impact Assessments.

2.4 Consumptive Use

Consumptive Use (see Glossary for definition) is small compared to natural flows at Basin scale. The hydrologic effects of consumptive use on water levels are likewise small and are less than the uncertainty associated with major inflows and outflows of the Great Lakes. Accurately estimating the size of consumptive uses is important as it is directly related to the management of Great Lakes Basin and a key component of the management structure of the Agreement/Compact. On a local scale, jurisdictions may consider consumptive use looking at impacts of withdrawals on source groundwater and surface water that are not returned to the aquifer or returned to the same surface water system from which they are withdrawn.

Consumptive use is seldom measured directly and instead is based on a range of coefficients developed for use at Basin scale that are not necessarily applicable for tributary surface water and groundwater supplying the surface water discharge to the Great Lakes. Consequently, Parties make independent management decisions and apply a variety of coefficients. Consumptive use is then reported annually to the Great Lakes Commission as part of the States' and Provinces' annual water use reports.

Accordingly, consumptive use coefficients should be reviewed for each water use sector included in the Regional Body/Compact Council's water use reporting protocols[7] estimated for subcategories and reviewed for regional variation, like the exercise carried out for the thermoelectric sector (Nicolas, J and Posthumus, E. 2017).

2.5 Water Conservation and Efficient Use

The duty to protect and manage the waters of the Great Lakes Basin is identified as one of the findings and purposes of the Agreement/Compact. The Regional Body and Compact Council adopted Water Conservation Goals and Objectives in 2008 and each Party also adopted water conservation goals and objectives. The Agreement/Compact also calls for each Party to implement a water conservation and efficiency program and report on these programs annually. As the regional goals and objectives state, "efficient and responsible water use is a cornerstone of sound water management policy, whether the resource is considered abundant or scarce."

Water use in each jurisdiction has generally stayed steady or decreased from 2018 to 2022 (Great Lakes Commission, 2023). Despite this, there remains a lack of knowledge on Conservation and Efficiency programs that exist and their effectiveness, particularly for sectors outside of public use. Continued improvements in water conservation and efficiency can be made by focusing on key water users and the specific challenges to the development, transfer, and application of water use conservation and efficiency measures for these users. In recently reported data, the top three largest consumptive use sectors include public water supply; industry; and irrigation. These three sectors account for 80% of the consumptive water use and over 92% of the groundwater withdrawals (Great Lakes Commission, 2023) in the Basin. Identifying how much water is available for use in hydrologic, economic, and ecological units is a critical but complex step for jurisdictions. Factors influencing the amount of water available for use range from climate conditions (i.e., current and future), water quality, and how efficiently we use water that is permanently or temporarily removed from the Source Watershed.

Challenges to understanding and increasing water use conservation and efficiency also include identifying specific and measurable water use conservation and efficiency metrics for each sector and promoting research on how to increase water use conservation and efficiency in each sector, with a particular focus on those who consume the most.

[7] Protocols: https://www.glslregionalbody.org/media/5xadvqcb/water-use-reporting-protocols-12-8-16.pdf

2.6 Climate Change

In understanding and managing for long-term water sustainability, the integration of information about the impacts of climate change on the Great Lakes Basin water balance is a key challenge. Given the potential impacts of a changing climate on major components of the Basin's water cycle, including precipitation, temperature, evaporation, and evapotranspiration, it is imperative to have a greater understanding through modelling of groundwater, surface water and their interactions (both quantity and quality) under present day climate conditions (see 2.1 and 2.2 above). An initial assessment of climate change impacts to the Great Lakes conducted by the University of Michigan and included in the supplementary materials of the 2016-2020 Cumulative Impact Assessment indicates that precipitation and evaporation are both likely to increase over the coming decades. While Great Lakes water levels are unlikely to be significantly higher or lower than historical averages, there is likely to be a greater degree of variability over shorter periods of time. This assessment is an important step forward in understanding the likely impacts of climate change on the Great Lakes to inform management activities. Implementation of the science strategy should build on existing climate change work to inform Great Lakes management about the potential impact climate change may have on changes in population, and both surface and groundwater water use across the Great Lakes St. Lawrence Basin.

2.7 Indigenous Engagement and Traditional Ecological Knowledge

Ongoing Indigenous engagement is an important first step that will allow for better integration of Traditional Ecological Knowledge (TEK) - knowledge that is generated and passed on by Indigenous communities from generation to generation. TEK, in complement to Western science, will contribute to a better understanding of our environment and the Science Strategy will be all the richer for it.

To that end, the Great Lakes Indian Fish and Wildlife Commission has highlighted how TEK can contribute to understanding how changes to water quality and quantity can potentially impact ecosystems. Therefore, involvement and collaboration with members of the Federally recognized Tribes in the U.S., First Nations, and provincially recognized Métis communities in Canada, will be key to better engagement, demonstrating the benefits of the Agreement/Compact to Indigenous communities and understanding how TEK can be approached with appropriate respect and combined into the priorities of the strategy.

2.8 Outreach

Part of the challenge in a region with abundant water resources is to acknowledge and communicate that water, while a renewable resource, does have limitations to its sustainable use in certain areas and under certain circumstances. By using the principles of sustainability and adaptive management the Agreement/Compact does acknowledge that water is a limited resource, and this is reflected in the references to water conservation and efficiency in the Agreement/Compact.

Regional water use data is reported and made available through the Great Lakes Commission's Regional Water Use Database[8]. Continued improvements to the format and accessibility of the regional water use data are needed, including improved connection to jurisdictional water use data, particularly spatial information. The Parties should also improve communication and outreach to the public about the scientific resources available now and in the future.

3. PRIORITY ACTIONS

3.1 Embed the Science Team in Regional Body/Compact Council work

Since the 2019 Science Strategy was adopted, each of the Great Lakes St. Lawrence States and Provinces have identified a member of the Science Team. Biennial meetings of the Science Team have taken place and continue to take place, providing an important forum for sharing information between the jurisdictions, and hearing from those outside of the jurisdictions on a variety of issues.

There remain important ongoing actions that should continue to be undertaken to advance the Regional Body/Compact Council's Science Strategy. Such actions include:

- Continue to confirm the important role of the Regional Body and Compact Council's Advisory Committee, Resource Group and Observers, as well as Tribes, First Nations and Métis representatives at the annual meeting of the Science Strategy to assist with the ongoing implementation of the Science Strategy.
- Continue to chair an International Association for Great Lakes Research (IAGLR) session based on the annual priority identified in the Science Strategy (call for proposals each fall, submit a proposal to IAGLR, and hold the proposed session at IAGLR, which is hosted each year in May or June).
- Share the Science Strategy with other groups that are working in similar fields on an ongoing basis, encouraging them to advance the Priority Actions through their own independent research. A particular focus area would be to share the Strategy with:
    - Individual universities and academic consortiums
    - Federal Agencies in both the U.S. and Canada, including:
        - U.S. Geological Survey
        - U.S. National Oceanic and Atmospheric Administration
        - Environment and Climate Change Canada
        - International Joint Commission

3.2 Improve the Assessment of Cumulative Impacts

The Regional Body/Compact Council completed its most recent assessment of the cumulative impacts of withdrawals, consumptive uses and diversions on the Great Lakes Basin in 2023, covering the 5-year period 2016-2020. Included in this report was a supplementary report

[8] Regional Water Use Database: https://waterusedata.glc.org/

(Gronewold *et al*., 2022) outlining an approach to reducing uncertainty in historical Great Lakes water balance components. Improved estimates of the historical water balance permit greater insight into temporal trends in different water balance components and their relation to both observed and expected future changes in regional climate. Further recent work by Environment and Climate Change Canada (2022)[9] has emphasized the degree to which increased variability in lake-scale water balance components is anticipated under climate change, making this a critical area for future research.

Actions that would improve future cumulative impact assessments and advance the Regional Body/Compact Council's Science Strategy include:

- Continue to refine estimates of consumptive water use coefficients and further standardize applications of these coefficients by the Parties;
- Continue to develop methods to constrain and reduce uncertainty in components of the Great Lakes Basin water balance, such as work with the Large Lake Statistical Water Balance Model;
- Integrate methods of assessing groundwater – surface water dynamics into overall Great Lakes Basin water balance;
- Develop tools to assess the impacts of new or increased withdrawals on water quality and aquatic ecology at multiple scales;
- Continue to improve measurement methodologies for over-lake hydroclimatic variables (precipitation, evaporation) to understand how spatial and temporal patterns may differ from land-based monitoring data;
- Explore methodologies and tools to forecast water demand and consumptive use under future conditions, including consideration of climate change, for key sectors such as agricultural irrigation, to consider including in future Cumulative Impact Assessment reports;
- Communicate linkages between changes in local-, lake-, and Basin-scale water balance components and known or likely social and economic impacts in future Cumulative Impact Assessment reports;

3.3 Water Conservation & Efficient Use

This priority includes understanding water conservation and water use efficiency successes and further opportunities specifically in the Great Lakes Basin, developing and evaluating alternative conservation methods and best management practices, and benchmarking water use by various sectors (e.g., per capita residential water use, maximum to average day ratio, water foot printing, etc.). This priority aligns with Section 2. e. of article 302 of the Agreement / Section 1.4.2 e. of the Compact. Actions include:

- Develop a list of comprehensive resources for reducing system water loss for all water use sectors.

[9] Environment and Climate Change Canada. 2022. Future Hydroclimate Variables and Lake Levels for the Great Lakes using data from the Coupled Model Intercomparison Project Phase 5. Cat. No.: CW66-778/1-2022E-PDF.

- Develop best management practices for water conservation and efficiency, including opportunities for on-site water storage (e.g., rain barrels or cisterns, or ponds/reservoirs) and reuse, in agricultural settings. Collate existing effective practices for a humid Midwest climate and conduct additional research to identify effectives strategies for agricultural water systems to be more efficient with water use.
- Lead discussions with Science Team members and external partners to identify metrics that measure water use efficiency for public water supply, irrigation/agricultural uses, and industrial water use.
- Discuss and determine potential water conservation and efficiency benchmarks that could be used by jurisdictions for evaluating water conservation efforts. For example, for the public water supply sector these benchmarks may include unaccounted water, water use intensity metric and maximum day to average day ratio.
- Support research, whether at Basin scale or jurisdiction scale, that integrates water demand forecasts, potential climate change impacts on water availability and timing, and water conservation and water use efficiency measures.
- Discuss the seasonal or temporal impacts of water withdrawals (e.g., can storage be used to alleviate the impacts of withdrawals during periods of low water availability).
- Support social science research aspects of water conservation and efficiency to address what methods are helpful to drive successful behavioral shifts, assess the cost effectiveness, and ability to replicate in other jurisdictions.
- Identify past water conservation success stories from the individual jurisdictions to be used as case studies.
- Identify opportunities to tie water efficiency measures to energy efficiency, including leveraging available funding resources for energy reduction to achieve water efficiency.

3.4 Enhancing Organizational Collaboration

The Science Strategy adopted by the Regional Body and Compact Council will only succeed if there is improved collaboration with organizations that are engaging in the scientific research that has been identified in this strategy. The goal of such meetings and collaborations will be to inform the collaborating organizations of the Regional Body/Compact Council research priorities as well as member State/Provincial research activities; and, to inform the Regional Body/Compact Council members of the collaborating organizations research activities that may be of value to the Regional Body/Compact Council members. Actions include:

- Improved communication/collaboration with the U.S. Geological Survey (USGS)
  - Organize quarterly conference calls with the regional USGS office directors located in the Great Lakes-St. Lawrence States.
  - Invite USGS National staff to present at the biannual meetings of the Science Team.
- Improved communication/collaboration with IJC
  - Participate in the International Joint Commission's (IJC) science collaborative to develop a plan to implement the IJC science strategy.
  - Invite the IJC to present at each of the Science Team's biannual meetings.
- Improved communication/collaboration with Natural Resources Canada

    - Invite Natural Resources Canada to present at each of the Science Team's biannual meetings.
    - Develop relationships with Natural Resources Canada staff
- Indigenous Engagement and Traditional Ecological Knowledge
    - Presentations on indigenous lead research projects
    - Invite local indigenous groups to present on either ongoing research projects or research needs at in-person meetings of the Science Team.
- Identify and invite other organizations that focus on Science Strategy priorities to participate in Science Team meetings, provide briefings and webinars, and otherwise provide additional research results to the Science Team members.
- Explore developing a new repository for sub-watershed/local level climate, geology, GW, SW, and lake level data accessible to all parties.[10]
- Coordination across States/Provinces on Science Related to Groundwater Withdrawal Impacts on Aquifers and Surface Water Bodies[11]
- Sharing best practices, latest scientific research, and other tools to identify "hot spots" where large quantity groundwater withdrawals are causing concerns for impacts to drinking water supplies (public or private), aquifer sustainability, and/or surface water bodies. Investigating the degree of hydraulic connection between deeper glacial and/or bedrock aquifers and surface water bodies is another research need.[12]

3.5 Addressing Data, Monitoring, and Science Gaps (Research Needs)

The Regional Body/Compact Council have a variety of research needs to advance water quantity management at the Great Lakes Basin scale and implement the Agreement/Compact. In addition, jurisdictions have a variety of research needs to assist with implementing

[10] The Michigan Department of Environment, Great Lakes, and Energy (EGLE), has environmental data that is siloed in multiple databases and/or in hard copy files in the various EGLE programs. Other states and provinces may have similar data storage practices. EGLE staff in multiple divisions and the Michigan Department of Technology, Management, and Budget (DTMB) participated in a Lean Process Improvement project to address data storage and access issues. DTMB and EGLE staff are currently reviewing bids to create the EGLE Groundwater Data Management System. A contractor should be selected, and work started by the first quarter of calendar year 2024.

The Groundwater Data Management System would be populated in a phased approach, beginning with uploading existing data in electronic format and scanning and uploading hard copy data in subsequent phases. The initial phases will focus on groundwater and geologic data, but future expansions will include other environmental media (e.g., soil, surface water, sediment). The Groundwater Data Management System will be designed to accept new data generated by EGLE staff but also data submitted by external parties (e.g., regulated parties, consultants, researchers, other agencies).

The Groundwater Data Management System would be linked to geographic information systems (GIS) to display data, the Michigan Hydrologic Framework (a framework being developed to house computer models), as well as having links to external databases (e.g., the U.S. Geological Survey's National Ground Water Monitoring Network). Future links could be established with external data repositories at the state, national, and international levels.

[11] Sharing best practices, latest scientific research, and other tools to identify "hot spots" where large quantity groundwater withdrawals are causing concerns for impacts to drinking water supplies (public or private), aquifer sustainability, and/or surface water bodies. Investigating the degree of hydraulic connection between deeper glacial and/or bedrock aquifers and surface water bodies is another research need.

[12] Another example of a groundwater "hot spot" is an area where over pumping of glacial and/or bedrock aquifers draws in brines from deeper bedrock formations, adversely impacting water quality. There are some areas in the Great Lakes Basin (e.g., central Ottawa County in Michigan's Lower Peninsula) where poor groundwater quality prevents drilling deeper vertical wells, forcing water users to rely on shallow horizontal or vertical wells which have a greater impact on nearby surface water bodies.

management programs at the jurisdictional level. The following is a list of topics that would assist in the implementation of the Agreement/Compact at either the regional or jurisdictional scale. The broader research community across the Great Lakes - St. Lawrence River Basin is encouraged to undertake activities that advance these research needs. The Regional Body/Compact Council may consider reviewing and prioritizing these research needs based on feasibility from technical and cost perspectives. Actions include:

- Assess gaps in stream flow measurement networks at different spatial scales considering the purpose of the stream flow measurement network. These assessments will improve the Regional Body/Compact Council 5-year Cumulative Impacts Assessment streamflow estimate for the water budget. Assess gaps in stream flow measurements at finer scales to assist individual jurisdictions with determining adverse resource impacts at the sub-watershed scale or determining cumulative downstream depletion from withdrawals at a watershed scale.
- Investigate groundwater withdrawal impacts on aquifers and surface water resources. Jurisdictional management under the Agreement/Compact evaluates groundwater withdrawals for impacts related to public and private drinking water supplies, aquifer sustainability, and surface water resources. Additional research on these topics as well as hydraulic connectivity between aquifers and surface water resources, fracture flow, uncertainty analysis, cumulative impacts analysis, ecological impacts from groundwater withdrawals and the connection between groundwater withdrawals and groundwater quality issues will all support jurisdictional groundwater quantity management.[13]
- Develop tools to assess groundwater/surface water interactions at scales ranging from the Great Lakes Basin to individual Great Lakes' basins, states or provinces, major watersheds, down to sub-watersheds. Focus on delineating the gaining and losing reaches of major tributaries and assessing how these features fluctuate in response to seasonal patterns. As part of developing these tools, identify and fill data gaps.
- Characterize aquifers that are shared amongst jurisdictions with three-dimensional geologic mapping to better understand groundwater flow directions, barrier conditions, zones of recharge and discharge, aquifer yields, and aquifer sustainability. Groundwater modeling and aquifer pumping tests are additional tools that can be used to aid groundwater management decisions for withdrawals that may affect aquifers in multiple jurisdictions.
- Develop groundwater flow models throughout the Basin topographic boundaries to delineate the hydrogeologic divide of the Basin vis a vis its topographic boundaries. The presence of multi-aquifer systems is a complicating factor and must be considered on a case-by-case basis.
- Refine Great Lakes or Source Watershed scale consumptive use calculations and estimation methodologies on a sector specific basis.[8]

[13] GW/SW Interactions. Models at various scales should be able to be nested within model frameworks (e.g., the Michigan Hydrologic Framework) and be able to interact with other models (e.g., climate models, other models in the same framework). Data availability will be a limiting factor in calibrating these models. Data gaps need to be identified and additional data collection projects designed to address those data gaps. The purposes of the models need to be clearly identified in metadata for potential users.

- Refine return flows in water budget analyses and in cumulative downstream depletion tracking including better characterizing the degree of hydraulic connection between deeper glacial and/or bedrock aquifers with surface water resources. [14]
- Determine the feasibility of an overarching hydrologic/hydrogeologic framework for the entire Great Lakes Basin. At the Great Lakes Basin scale, an overarching hydrologic/hydrogeologic framework is needed to understand the degrees of hydraulic connection between glacial and bedrock aquifers and the Great Lakes to assist in determining the degrees to which proposed water uses are consumptive, and the risks wells pose to the Great Lakes Basin hydrologic system.
- Conduct social science research on effective methods for communication to public and private sector audiences about water conservation and efficiency.
- Evaluate the efficiency gains of various water conservation and efficiency measures for different water use sectors.
- Evaluating the benefits of those water conservation and efficiency gains to the hydrologic system, climate, etc.
- Evaluate the impacts of water conservation and efficiency measures on groundwater and surface water availability and water use, by water use sectors, at the Great Lakes Basin and individual jurisdictional scales.
- Integrate research on water demand forecasts and potential climate change impacts on water availability at the Basin and jurisdiction scale.

4. REPORTING

The Science Team will report on advances for each priority action. Reporting will be submitted to the Great Lakes - St. Lawrence River Water Resources Regional Body / Great Lakes - St. Lawrence River Basin Water Resources Council secretariat on an ongoing basis. Reporting will be disseminated on the Great Lakes - St. Lawrence River Water Resources Regional Body / Great Lakes - St. Lawrence River Basin Water Resources Council public webpage as appropriate.

The proposed timeline for implementing the Science Strategy and priority actions is as follows:

[14] Return flow and consumptive use coefficients is often poorly understood and ignored in many groundwater models that estimate stream flow depletions caused by high-capacity wells. Deeper regional groundwater flow may discharge to surface water further downstream in major watersheds.

Return flows and consumptive use coefficients vary between water use sectors and even within a specific water use sector. One example is agricultural irrigation. Center pivot irrigation systems will have different return flows and consumptive use coefficients than drip irrigation systems. Relying on old "rules of thumb", e.g., 10% return flow, is too imprecise. The example of an irrigation system must consider water loss through evaporation, transpiration, crop uptake, overland runoff, adsorption in the vadose zone, and infiltration into the saturated zone.

5. ANNUAL FOCUS TOPICS

The following are annual focus areas for webinars, hosted research presentations (e.g. IAGLR), and Science Team discussions.

2025: Agricultural water use and water efficiency
2026: Quantifying Groundwater resources in the Great Lakes St. Lawrence River Basin
2027: Projecting water demands and cumulative impacts by water use sector.
2028: Tools for identifying drought and triggering drought response.
2029: Updates to this Science Strategy

6. GLOSSARY

The following definitions are primarily taken from Article 103 of the Agreement; and, Section 1.2 of the Compact.

Basin or ***Great Lakes—St. Lawrence River Basin*** means the watershed of the Great Lakes and the St. Lawrence River upstream from Trois-Rivières, Québec within the jurisdiction of the Parties.

Basin Ecosystem means the interacting components of air, land, Water and living organisms, including humankind, within the Basin.

Consumptive Use means that portion of Water Withdrawn or withheld from the Basin that is lost or otherwise not returned to the Basin due to evaporation, incorporation into Products, or other processes.

Cumulative Impacts mean the impact on the Great Lakes—St. Lawrence River Basin Ecosystem that results from incremental effects of all aspects of a Withdrawal, Diversion or Consumptive Use in addition to other past, present, and reasonably foreseeable future Withdrawals, Diversions and Consumptive Uses regardless of who undertakes the other Withdrawals, Diversions and Consumptive Uses. Cumulative Impacts can result from individually minor but collectively significant Withdrawals, Diversions and Consumptive Uses taking place over a period of time.

Direct discharge of groundwater means the discharge of groundwater directly into a Great Lake through the lakebed into a Great Lake

Indirect discharge of groundwater discharge means the discharge of groundwater into streams, wetlands or inland lakes that flow into the Great Lakes

Scale:

Lake scale means the scale of a Great Lake or the St. Lawrence River.
Sub-watershed scale means the scale of a watershed within a Source Watershed.

Local scale means the scale equivalent equal to a community.
Regional scale means the scale equivalent to multiple states and/or provinces.
Basin scale see definition of ***Basin***.
Jurisdictional scale means the scale of a state or province.

Source Watershed means the watershed from which a Withdrawal originates. If Water is withdrawn directly from a Great Lake or from the St. Lawrence River, then the Source Watershed shall be considered to be the watershed of that Great Lake or the watershed of the St. Lawrence River, respectively. If Water is Withdrawn from the watershed of a stream that is a direct tributary to a Great Lake or a direct tributary to the St. Lawrence River, then the Source Watershed shall be considered to be the watershed of that Great Lake or the watershed of the St. Lawrence River, respectively, with a preference to the direct tributary stream watershed from which it was Withdrawn.

Water Dependent Natural Resources means the interacting components of land, Water and living organisms affected by the Waters of the Basin.

Water of the Basin means the Great Lakes and all streams, rivers, lakes, connecting channels and other bodies of water, including tributary groundwater within the Basin.

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