Chapter Eight

Pulling It All Together: Project Synthesis

Introduction

The results of this two-year project have been compiled and presented in this report to ensure their immediate use and benefit to water resources managers, decisionmakers and other interested parties. Through the inventory and assessment of available water resources data and information, project collaborators have come to realize that, while much is known about the complex nature of Great Lakes-St. Lawrence River water resources, much more still needs to be learned to advance science-based decisionmaking.

With the conclusion of this effort, state and provincial water resources policy experts, managers and decisionmakers will begin to grapple with application of project findings and recommendations to the Water Resources Management Decision Support System (WRMDSS) called for under the Charter Annex and within the context of existing provincial, state and federal laws and treaties. This chapter pulls together the project's several elements and, in so doing, will help the region's decisionmakers understand and address uncertainties associated with the water resource and its ecosystem; address key data and information gaps; and design interoperable and integrated communications, data management and assessment tools.

Using Data and Information to Inform Decisionmaking

The primary purpose of this project was to assess the status of current data and information and to identify associated gaps and needs. In writing this report, a challenge has been to balance the discussion and not adopt a "glass half empty" approach when critically examining the complexities related to data and information for decisionmaking. Much of the data that is currently available, in fact, adequately addresses the purposes for which it has been gathered, but this data may be inadequate to meet all future decisionmaking needs. This does not mean that agencies and jurisdictions lack commitment or have been negligent, but points to the need for enhanced planning to identify and accommodate the evolving nature and associated needs of water resources management decisionmaking.

Water resource management decisions are made within the context of existing state, provincial and federal laws and treaties, which help establish the parameters for a decision support system. An examination of these laws and treaties, many of which were briefly discussed in Chapter one, may also help determine which data and information are most relevant for a new decisionmaking process.

Focusing on Future Needs

Water resource management efforts in the Great Lakes-St. Lawrence River basin – including laws, policies, research activities and interjurisdictional agreements – have historically focused on the physical implications (i.e., alternation in levels and flows) of water withdrawals from the open lakes and larger tributaries. Over time, however, other ecological dimensions of water withdrawals have gained increased attention. For example:

1. The issue of scale has taken on greater importance. The region has come to realize that the ecological impacts of any given water withdrawal are most discernable at the sub-watershed level. Yet, data and information gathering efforts, as well as computer modeling and related analyses, have historically focused on a larger-scale, lake-wide or systemwide basis. This suggests the need for a fundamental examination of the current water withdrawal impact assessment process in the interest of securing both systemwide and sub-watershed level perspectives.
2. Enhanced understanding of groundwater resources suggests the need for a greater focus on groundwater research, management and protection. The role of groundwater in the hydrologic cycle is increasingly recognized (though not well understood), as is its contribution to surface water levels and flows.
3. Ecological impacts associated with water withdrawals have placed new demands on scientists and managers who have traditionally approached water resources projects primarily from a hydraulic/hydrologic standpoint. This suggests the need for an

assessment and refocusing of research, and development of new multi-disciplinary partnerships for scientific inquiry and decision support.

4. A better understanding of the cumulative impacts of water withdrawals over space and time is a priority need in developing and implementing the WRMDSS.

Future needs can also be addressed by building on current data collection processes. Water withdrawal and use data and information can assist managers and other decisionmakers in anticipating and planning for future changes in demand. The development and implementation of effective and comprehensive water management programs (including elements such as water conservation and drought contingency planning) is problematic because water demand information is not readily available.

The Importance of Scale in the Assessment of Water Resources Data and Information Needs and Gaps

"How sensitive is the Great Lakes-St. Lawrence River system to impacts associated with water withdrawals and diversions, and at what level can those impacts be ascertained?" This is a fundamental yet complicated question due to a variety of factors. For example, the Great Lakes-St. Lawrence River system is no longer a natural one. Changes to the system, primarily for navigation, hydropower and riparian purposes, have permanently altered the natural levels and flows regime. Diversions (both incoming and outgoing); construction of locks, dams and controlling works; and dredging and riparian encroachment in the interconnecting waterways have created changes that are orders of magnitude greater than any changes that might occur from small-scale withdrawals, diversion or export projects, even when considered cumulatively. In addition, major changes have occurred in natural hydrologic/hydraulic streamflow regimes due to largely irreversible land use modifications such as timber cutting, agricultural and transportation development, and residential expansions. At the global scale, climate change may cause additional alterations to the levels and flows of the Great Lakes-St. Lawrence River system. Being able to discriminate between the effects of each of these "forcing functions" will be crucial for an effective WRMDSS.

Hydrologic Scale Issues

As noted in Chapter two, the variability of the hydrologic system and the limitations of hydrologic measurements are factors that need to be considered in any decision support process and in the assessment of watershed sensitivities. All hydrologic and hydraulic phenomena are variable both temporally and spatially and can be treated at different scales of time and space, depending on the water use scenarios being examined. Most of the hydrologic data are reported as long-term averages at large spatial scales, with no direct measure of uncertainty. As a consequence, different water uses and hydrologic alterations may have different space-time scales. This is particularly applicable to the water withdrawal issue. For instance, a withdrawal of a given water quantity from a large water body could have very different impacts than a withdrawal of the same quantity from a small water body or stream.

Most hydrologic issues are analyzed within a given drainage basin or watershed. Watershed boundaries rarely coincide with territorial or jurisdictional boundaries (Singh, 1992). Watersheds vary tremendously in size, literally from a few acres to hundreds of thousands of square miles, such as the Great Lakes-St. Lawrence River basin. Large watersheds are comprised of smaller drainage basins, or sub-basins, which can be more manageable units for analysis.

The ordering of watersheds begins at the largest level of the watershed. In Canada, for example, the Great Lakes basin would be considered the primary or 1st level watershed. Individual lake watersheds (e.g., Lake Superior) would be considered a secondary or 2nd level watersheds, the sub-watersheds of the individual lakes would be considered tertiary or 3rd level watersheds, and so on.

In the United States, the U.S. Geological Survey (USGS) has a hydrologic unit classification system similar to Canada's. The first level of classification divides the United States into 21 regions, one of which is the Great Lakes basin (Region 4). The second level divides the 21 regions into 222 sub-regions. A sub-region includes the area drained by a river system, a reach of a river and its tributaries in that reach, closed basin(s), or a group of streams forming a coastal drainage area. The third level subdivides many of the sub-regions into 352 accounting units, which are portions of sub-regions or entire sub-regions. The fourth level is the cataloging unit, which is a geographic area representing part or all of a surface drainage basin, a

Indiana Dunes National Lakeshore, Lake Michigan

combination of drainage basins, or a distinct hydrologic feature.

These basin levels should not be confused with the Horton-Strahler stream-ordering scheme (Dunne and Leopold, 1978), which increases numerically from headwater streams. The system of stream ordering is a method of numbering streams as part of a drainage basin network. The main stream is always of the highest order. The smallest unbranched mapped tributaries are designated first order, streams which receive only first-order tributaries are second order, larger branches which receive only first-order and second-order tributaries are designated third order, and so on.

Assessing Impacts at the Sub-watershed Level

This report has repeatedly stated that the consequences of different water withdrawals are not equal across the basin and that the impacts are most clearly discernable at a sub-watershed level. The impacts of water withdrawals must therefore be considered at various scales ranging from the Great Lakes themselves to 4th level watersheds. Actions at the local level that have not been identified or seriously considered may have impacts with regional implications. For example, a water withdrawal from a small stream may not have measurable impacts to the Great Lakes-St. Lawrence River system levels and flows, but the withdrawal could reduce stream flow to a level that jeopardizes the habitat of an endangered species that is important to the region.

Using hierarchical, or nested, watershed designs to support water withdrawal decisionmaking is one approach that provides opportunities to analyze conditions at multiple scales of resolution. Each scale is important to understand the system and the relationship between supply, use and ecological impacts. The Canada/Ontario Water Use and Supply Project has been using this approach to better understand the water use and supply and ecological impacts at the various scales, as illustrated in Figure 8-1.

An increasing level of detail can be captured and represented as the resolution becomes finer. Individual withdrawals can be assessed at a local level to identify water availability, existing uses and ecological impacts based on the local watershed's known sensitivities. This nested structure also allows water use, supply and related impacts to be aggregated from a finer scale and carried through to higher levels to better assess both individual and cumulative impacts.

Along with scale, understanding the varying characteristics of watersheds is important to assessments of impacts. Size, shape, slope, elevation, density of channels, channel characteristics (depth/width), vegetation, land use, soil type,

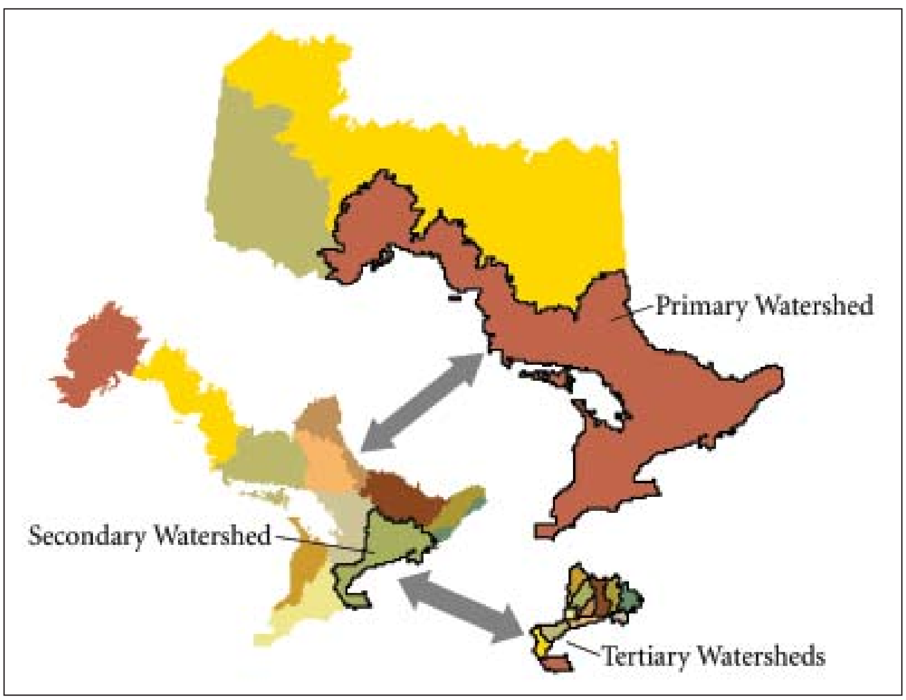


Figure 8-1
Conceptualization of nested watersheds

hydrogeology, lakes, wetlands, artificial drainage, water use and ecology represent some of the important characteristics of a drainage basin. The quality and quantity of water resources also varies among sub-watersheds of the Great Lakes-St. Lawrence River basin. The amount of precipitation, evaporation and runoff can vary significantly over relatively small spatial scales, and groundwater discharge to streams ranges from 10 percent of the streamflow to 80 percent of the streamflow (Piggott et al., 2001). Watersheds can also vary in the uniformity of groundwater flow over time, the type of land use, and the types of water uses. These natural and anthropogenic factors will all influence a watershed's ecologic and hydrologic sensitivity.

Understanding specific sub-watershed sensitivities will be important to developing informed water resource management decisions. For example, understanding a watershed's physical characteristics, current surface and groundwater supplies, current water uses, and ecological requirements could help characterize the watershed's sensitivities to water withdrawals or diversions. Water withdrawal limits, allocation strategies, or other strategies could then be targeted on highly sensitive watersheds that are already stressed by overuse. A categorization of watersheds in terms of their sensitivities may be a first step toward providing the context within which water management decisions are made.

The Importance of Groundwater Data and Information Related to Water Resources Decisionmaking

The issue of scale is also important as it relates to the availability and use of groundwater resources in the Great Lakes-St. Lawrence River system. Groundwater discharges directly into the Great Lakes and connecting channels, but also provides some tributary stream flow. Groundwater that discharges to streams supports instream ecosystems by providing base flow and moderating water temperature. It is particularly important for maintaining water quality during periods of low flows, when almost all the flow in the stream can be from groundwater.

While the importance of groundwater discharge to the health of aquatic ecosystems is recognized, significant data and information gaps concerning the region's groundwater resources remain. For instance, each aquifer that contributes groundwater to the Great Lakes or their tributary streams has a potentiometric surface. This surface is similar to the earth's surface in that it has groundwater divides that are analogous to watershed divides. Groundwater on one side of the divide flows toward the Great Lakes; groundwater on the other side flows away from the Great Lakes. Groundwater and surface water divides do not usually share boundaries, and groundwater divides, unlike surface water divides, are not static and may vary in response to groundwater withdrawals. Some aquifers in certain parts of the Great Lakes region have mapped potentiometric surfaces and groundwater divides. In the remainder of the region, the area that contributes groundwater to the Great Lakes is unknown.

On a sub-watershed scale, sufficient streamflow and groundwater data are available in some, but not all, areas of the basin to predict the likely effects of in-stream and groundwater withdrawals. Expansion of tributary stream gauging and networks for groundwater and climate monitoring, as well as water withdrawal data on a sub-watershed scale, will be critical if the WRMDSS is to support investigations in areas which have been heretofore "data poor." Also, a basinwide groundwater flow model is needed to provide information that supports decisions on proposed groundwater withdrawals in the United States and Canada.

Reliable groundwater supplies continue to be readily available to the majority of the Great Lakes-St. Lawrence River basin's population. However, in some localized cases, inadequate or poor quality groundwater supplies have caused local water supply shortages. For example, Monroe County, Michigan, located in the southeast corner of the state, relies on groundwater for drinking water and irrigation, but aquifers have been depleted due to quarry operations. Oakland and Macomb Counties, also in southeastern Michigan, likewise have recently experienced aquifer depletion due to low rainfall, higher than normal temperatures and rapid residential development. The interest in protecting groundwater resources has heightened as a result of these and other occurrences of localized groundwater shortages in various parts of the Great Lakes-St. Lawrence River basin. In addition, the recent construction and operation of the Perrier bottling plant near Muskegon, Michigan has brought this issue to the forefront of public discussion. The groundwater issue and "better understanding its role in the Great Lakes basin" is an identified priority under Directive #6 of the Great Lakes Charter Annex. These examples point to the need to consider the importance of groundwater when developing the WRMDSS.

Importance of Data and Information in Assessing Ecological Impacts of Water Withdrawals

As understanding of the complexities of the Great Lakes-St. Lawrence River system has improved, concerns have been expressed regarding the ecological impacts of water withdrawals, particularly in sub-watersheds and the nearshore zone. These ecological impacts are important as they relate to the scale issue discussed above. Chapter two, which highlights the uncertainty involved with measuring components of the Great Lakes water balance, points out that, on a lake-wide scale, uncertainties in levels and flows tend to mask the potential effects (either individual or cumulative) of any given water withdrawal.

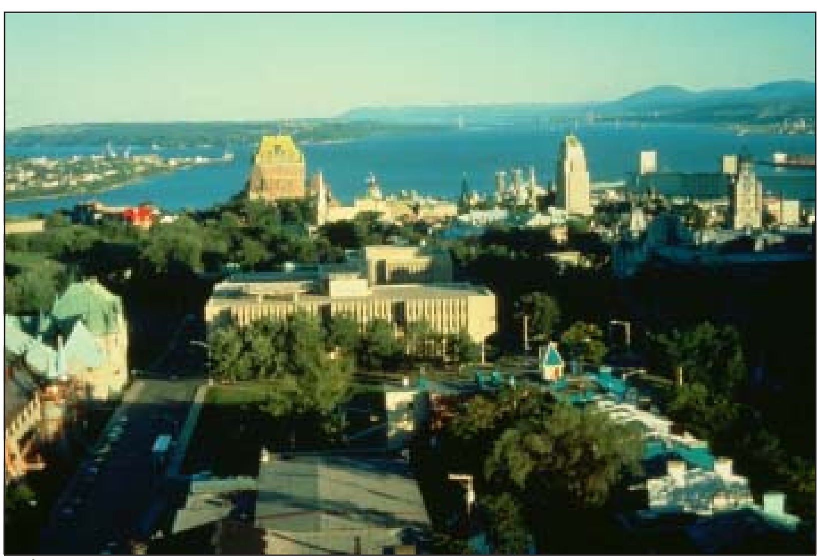
In nearshore areas, biota appears most likely to be affected by water withdrawals, rather than those organisms which inhabit the deeper portions of the Great Lakes. However, fish and other aquatic organisms that live in these deeper areas may be dependent on nearshore areas for food, spawning habitat and other needs. Also, water withdrawals may be only one factor or stressor present in certain watersheds that contribute to the measurement of impacts to an aquatic ecosystem. The impacts of a single withdrawal may not be measurable but, combined with other factors such as land-use changes, can result in significant, readily measurable impacts.

Better and more site-specific data and information on the ecological effects associated with water withdrawals are needed to support a regional resource-based decisionmaking standard (being developed under Directive #3 of the Annex). Activities pursued under this project highlight many of these data and information needs, as well as knowledge gaps. The literature reviewed under the project offers few practical approaches for addressing questions that relate to cause-effect relationships and cumulative impacts of changes in levels and flows, although some studies shed light on the establishment of monitoring protocols and agendas for scientific research. A key observation is that the lack of integrative modeling tools currently confounds the assessment of cumulative ecological impacts from multiple stressors. This observation is supported by the outcome of the model review: no single model can, by itself, quantify the range of potential ecological impacts of a particular water withdrawal scenario.

Continued research and data collection are necessary for more certain assessment of ecological impacts (particularly cumulative effects) of water withdrawals and diversions. However, these gaps in understanding and data cannot be allowed to slow progress toward building and applying tools for supporting the decisionmaking process.

The Importance of Considering Cumulative Effects

Any water withdrawal will have an incremental cumulative effect on the Great Lakes-St. Lawrence River ecosystem over space and time. An individual withdrawal will have a greater ecological and hydrologic impact locally than further downstream. An individual withdrawal, given persistence over time, will impact conditions first within its own watershed and then further downstream. Multiple water withdrawals from any given Great Lake may not have measurable ecological impacts on that particular lake, but their cumulative ecological effects may be magnified on the lower St. Lawrence River. The cumulative ecological effects will also be a function of multiple other factors, or stressors, that can range from local modifications (e.g., source water changes, channelization, sediment loading) to large-scale changes (e.g., global climate modification).



Québec City on the St. Lawrence River

The cumulative impacts of one or more water withdrawals must be considered in light of time and space dimensions and the complexities they suggest for a WRMDSS. A minor withdrawal, for example, may take place for years before its impact can be detected from a hydrologic or ecological standpoint. Further, that impact may be detected – at different points in time – at the location of the withdrawal, in the open waters of the lake basin, and/or far downstream in the St. Lawrence River.

The additive effect of multiple withdrawals is of significant concern as well. Consider, for example, a scenario in which a single minor withdrawal in a tributary is found to have no significant adverse impact on the withdrawal location or the larger Great Lakes-St. Lawrence River ecosystem. However, the cumulative impact of multiple withdrawals of the same quantity (and along the same tributary) may have devastating effects locally and measurable adverse effects on a broader scale. Hence, any WRMDSS and associated data and information gathering processes must accommodate the time and space dimensions associated with the cumulative impacts of both individual and multiple withdrawals. Mechanisms for assessing these impacts with any degree of precision have yet to be developed.

The Use of Scenarios/Case Studies to Evaluate Data and Information

Developing and working through plausible water withdrawal and use scenarios provides a valuable process for evaluating data and information needs and gaps. Two scenario evaluation exercises were convened under the WRMDSS project that helped scientists, managers and policymakers focus on key issues related to the region's ability to evaluate water withdrawal and use proposals. One exercise was convened by the Water Withdrawal and Use Technical Subcommittee (TSC 3) on September 10-11, 2001, to assist in the identification of water withdrawal and use data and information needs. Building upon this exercise, a project-wide scenarios evaluation workshop was held on May 15-16, 2002. This workshop brought a full range of interests and expertise to bear on the evaluation of three mock water projects. It also informed the discussion of the full range of data and information needs related to the hydrology and hydraulics of the Great Lakes-St. Lawrence River system, water withdrawal and use, ecological effects from water projects, and associated potential cumulative impacts. Additional purposes of the workshop were to inform the Annex 2001 implementation process about data and information needs and availability, and to begin conceptualization of informational components and characteristics of an effective WRMDSS.

Some of the observations and ideas generated at the workshop demonstrate how scenarios/case study analyses can enhance understanding of data and information needs and requirements. Samples of the observations from the May 15-16 workshop are presented below:

- The ability of current data and the state of science to inform cumulative impact assessments is limited and must be addressed in the development and application of any WRMDSS.
- The relationship between hydrologic changes and ecological impacts, particularly related to cumulative impacts in the nearshore zone, is not currently well known. For instance, data coverage for wetlands is incomplete, inconsistent, and non-periodic, making it impossible to monitor changes over time.
- When considering a WRMDSS, decision standards, data collection programs and modeling efforts should be applicable to decisionmaking both on large (entire basin) and small (sub-watershed) scales.
- Dedicated, long-term monitoring programs coordinated at the basinwide level are critical to the success of any decisionmaking process.
- Demand forecasting is a useful tool to provide guidance to any WRMDSS.
- The scenario process is a useful tool that can be further employed to identify data and information needs, test alternate decisionmaking processes, and identify and assemble the components of a WRMDSS.

Looking Into the Future: Other Issues Influencing Water Resources Decision Support

Research, management and policy activities need to anticipate and adapt to changes in the near and intermediate future that might significantly affect how water resources management decisions are made as well as the data and information requirements to support the evolving decisionmaking process. Any decision support "toolkit" needs to be as robust as possible to withstand the "test of time" and accommodate changes in the supply, distribution, quality and use of water resources. Unanticipated ecological stressors will likely arise, complicating the region's ability to manage the resource effectively. Technologies will also continue to evolve, some at a very rapid pace. A brief discussion of these issues follows:

- Climate variability is the norm for the region, not the exception. Long-term climate changes are likely to occur and will be accompanied by varying ranges of water levels and supply (Great Lakes Regional Assessment Group, 2000). Advances in climate prediction and risk assessments are needed to assist managers in anticipating these effects.
- Substantial changes in land use will continue. Residential property development will reduce agricultural lands and urban redevelopment will continue to be a societal objective. Agricultural changes are likely to continue into more selective "niches," requiring significant changes in local water demands (Thorp et al., 1998). Recreational opportunities will continue to transform the landscape (e.g., golf course development) and recreational boating will encourage greater controls of water levels throughout the system (Golf Research Group, 1997).
- Municipalities have been expanding water treatment capabilities as a major infrastructure investment (Hill, 2002). Service areas are expanding regularly. Also substantial changes have occurred in the bottled water and related beverage industries, and societal shifts from tap water to bottled water may continue (International Bottled Water Association, 2002).
- A number of ecological stressors will continue and, in some cases, will increase in relevance. Impacts of new exotic or invasive species can (and will) complicate the region's ability to discriminate between causes and effects, particularly in the indicator wetland environments (Glassner-Shwayder, 2000). Coastal wetlands are also highly impacted by adjacent land use changes, hardening of nearby shorelines and changes in sediment supplies.
- The technological advances experienced in the last decade are likely to continue. Investments in new wireless and fiber optic delivery mechanisms will provide scientists, resource managers, water users and the concerned citizenry with a greater ability to access and process data and information in an efficient manner. Increases in computer storage capacities will also likely occur to match the increased data volumes that are expected. Increased computing speeds and evolving software tools will make integrated products for resource management more user friendly.
- These technological advances continue to push resource management protocols into the public arena, and public involvement in the decisionmaking process will likely increase as a consequence. The level of sophistication of resource management will also likely improve. Managers will have the ability to access and process vast quantities of data and information and better discern options for the problems at hand. Further, resource managers will be able to embrace a "systems-engineering" perspective on problem solving, more effectively planning for the future, setting reasonable targets, monitoring progress and achieving desired results.

Concluding Observations

The numerous recommendations of this report address the need to improve the quality and quantity of data and information relevant to examining water withdrawal and use proposals and their impacts.

Some concluding points need to be made regarding the importance of data and information to guide water resources management decisionmaking:

- Existing laws, policies, programs and agreements at the state, provincial, federal and binational levels provide the context within which a WRMDSS must be developed and associated data and information needs determined;
- Understanding the uncertainties associated with available data and information can, in many cases, be as critical as the information itself;
- Data needed for decisionmaking on hydrologic and hydraulic processes throughout the system have varied characteristics. For instance, sub-watershed level analyses will likely require denser spatial and temporal detail than assessments conducted on the

open lakes or for the interconnecting waterways;

- A pressing need exists to improve the collection and reporting of accurate, consistent and uniform water withdrawal and use data;
- Much is still unknown about the region's groundwater resources. Expansion of tributary stream gauging and groundwater monitoring networks will be critical in accessing the data and information needed to support a WRMDSS;
- Using hierarchical, or nested, watershed designs to support water withdrawal decisionmaking is one approach that provides opportunities to analyze conditions at multiple scales of resolution. Categorization of watersheds in terms of their sensitivities is an important first step;
- Climate change effects could become the primary stressor to levels and flows and will influence demand forecasts, cumulative impacts assessments, and even future individual water withdrawal decisions. As such, understanding the magnitude and nature of potential climate change effects should be a research priority;
- Scientifically sound data and information are being collected under highly compatible programs and should be exploited to the fullest extent to reduce costs. The best examples are the binational monitoring programs evolving to implement the State of the Lakes Ecosystem Conference (SOLEC) indicator suite;
- Improving the base of data related to water withdrawal and use, surface water and groundwater resources, and ecological/biological effects will require substantial commitment on the part of all units of government;
- To be useful, the commitment to improve this base of data must be long-term, requiring dedicated support for programs over time;
- While data and information shortfalls are being resolved, regional water resources management decisions will still need to be made. Decisionmakers should evaluate projects using the best available information, tools and decision support options, while recognizing their uncertainties. If there is reason to believe that a technology or activity may result in harm and there is scientific uncertainty regarding the nature and extent of that harm, then measures to anticipate and prevent harm may be necessary and justifiable; and
- An implementation plan for this report's recommendations needs to be developed and implemented in consultation with relevant state and provincial officials. This should include prioritization and costing-out of recommendations and a strategy to conduct needed research and policy analysis to address and apply them as a WRMDSS is developed.

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