

Chapter Seven

Information and Communications

The Need for Scientifically Sound Information

A recurring finding of this project is the lack of data and information that members of the scientific, management and policy communities consider to be fundamental to scientifically sound decisions regarding the withdrawal and use of Great Lakes-St. Lawrence River water resources. Additionally, numerous recommendations contained in this report address specific improvements regarding accounting of the waters of the Great Lakes-St. Lawrence River system, monitoring water uses, and assessing prospective ecological impacts of such use. Under this project, existing data and information have been assembled and characterized, and gaps have been identified. The next step in this endeavor is to organize data and information (both existing and prospective) so resource managers and decisionmakers can have ready access to it.

Directive #5 of Annex 2001 calls for “a decision support system that ensures the best available information.” The governors and premiers stipulated in the Annex that the “design of an information gathering system ... will include an assessment of available information and existing systems, a complete update of data on existing water uses, an identification of needs, provisions for a better understanding of the role of groundwater, and a plan to implement the ongoing decision support system.” The Annex 2001 implementation process is moving forward, and a governor/premier-appointed Working Group is focusing on the development of binding agreements. Accurate, consistent, well-documented and easily accessible data and information should be the foundation of the decision support system.

The design of the decision support system will need to be a collaborative effort involving representatives of all likely decisionmakers, information providers and stakeholders. Further, the information systems that support the decisionmaking process will need to be designed for wide public access. Recent developments in Internet technologies will provide essential components in this endeavor.

The Information Base for a Decision Support System

Key points to consider about data and information with respect to the development of a Water Resources Management Decision Support System (WRMDSS) are as follows:

- We will likely never have access to all the data and information that is considered relevant to water resources planning and management; hence, decisions will be made with the best available information.
- Data and information standards will need to be promoted, developed and implemented as necessary. Further, metadata (detailed records about data sets) will become increasingly important to ensure that information is accurately interpreted and used in decisionmaking.
- Hydrologic and hydraulic data vary in density, resolution, scale and temporal characteristics. Consequently, assessing changes in the water resources of a watershed is substantially different than looking at water resource characteristics on the Great Lakes. Information must therefore be structured, managed and delivered at various “nested” scales and temporal formats.
- Improvements in monitoring of water withdrawals and uses throughout the region will coincide with a need for increased sophistication in database design and maintenance. Commensurate commitments to metadata production will be required.
- Scientifically sound data and information on ecological conditions and trends are being collected under compatible programs, as evidenced by the binational monitoring programs that are evolving to implement the State of the Lakes Ecosystem Conference (SOLEC) indicator suite. This data and information should be exploited to the fullest extent possible.
- Improvements in computer modeling of complex physical, chemical and biological

processes and associated visualization tools may play a crucial role in the WRMDSS. Connectivity between computer models demands greater attention.

- Technological advancements in interoperable computer networks, geographic information systems (GIS) and wireless communications will create significant opportunities for seamless and virtual information exchange between political jurisdictions.

Evolving Technologies

When considering decision support system options, it is important to understand the way communications and technology advances have contributed to changes in water resources management decisionmaking since the signing of the Great Lakes Charter in 1985. Some of the changes include the following:

The Internet – The Internet has been, in many respects, the most significant technological advancement of recent decades. Information is disseminated almost instantaneously to any number of stakeholders. Advances in Internet technology are expected to continue unabated for the foreseeable future. The Internet will most likely be the cornerstone for data and information access for a WRMDSS.

Electronic Communications and Compatibility – The explosion of the cellular communication industry, the advent of email, and improvements to traditional phone lines are continuing to transform business processes. These new technologies provide broad access to both centrally-managed and distributed data and information.



Real-Time Data – Advances have been made in automated and instantaneous dissemination of data from remote sampling locales. Almost all water level gauging systems in the region are equipped with some mechanism for instantaneous interrogation and satellite or radio-frequency data relay. Access to real-time data influences management decisions for many of the hydropower, commercial navigation, municipal, industrial and agricultural users in the Great Lakes-St. Lawrence River system.

Integrated Data Collection – Positional and temporal detail has improved tremendously over the last 15 years. Water level data are now collected from gauging sites at 6-minute (U.S.) or 15-minute (Canada) intervals and at mobile sampling locations using backpack or hand-held Global Positioning System (GPS) units.

Remote Sensing – Satellite and airborne imagery is becoming much more affordable for operational applications. These data have applicability in classification for land use, land cover and wetlands. Images collected over time can be used to monitor change.

Data Consistency, Uniformity and Display – Although significant shortfalls exist in data and information standardization, substantial progress has been made to allow various users to take advantage of water resources data and information. Gaps in water use inventories are being identified, and reporting is becoming more uniform and recurrent. Complex processes can now be simplified and visualized due to advancements in computing and Internet resources.

GIS – Geographic Information System (GIS) technology has advanced steadily, with improvements in distributed processing and relational database management tools. A current trend is the development of large-scale multi-jurisdictional “web mapping” projects. Web mapping frequently involves cooperative data serving nodes that deliver products to clients using the Internet. This technology will likely support the analysis of information needed for water resources management decisionmaking.

Metadata – Metadata in the broadest sense is the “history” of the data, including source, scale, accuracy and processing steps. Substantial progress has been made in defining data content standards for many GIS data themes, but a more substantial production of metadata for other data types is needed. The power of distributed data access, real-time web mapping, timely computer

modeling and many other applications is compromised if metadata are incomplete.

The technological advances noted above have, in many respects, made the extraction of relevant data and information as much an “art form” as a science. Therefore, suitable resources must be invested in a careful systems-engineering assessment of the problems associated with data access, storage and retrieval.

Investments are being made in new wireless and fiber optic delivery mechanisms that should provide resource managers, stakeholders and interested citizens with improved abilities to acquire data and information across the Internet. Increases in computer storage capacities will also occur, but likely will be matched by increased data volumes. Increased computing speeds will continue to promote improvements in computer models and visualization tools.

These technological advances should promote a more open environment that improves public access to data and information. Although security considerations are likely to increase, effective “work-arounds” are likely to be found. Resource management decisions should become more sophisticated as abilities improve to acquire and analyze vast quantities of data and information, and to generate applicable options. Further, managers should be able to more effectively plan for the future, set reasonable targets, develop metrics, monitor progress and achieve desired results.

Examples of Operational Decision Support Systems

A decision support system (DSS) is a broad concept that typically involves both descriptive information systems as well as standard, prescriptive optimization approaches. It may be defined as “any and all data, information, expertise and activities that contribute to option selection” (Andriole, 1989).

The decision support process consists of three phases of decisionmaking: *information gathering*, *options design* and *choice*. The information gathering phase typically involves identifying problem situations, causes and effects, and interrelationships. The information gathering system coordinates decision situation analysis by exploring and integrating data and information from a wide range of sources. In the options design phase, the DSS typically supports decisionmakers in the development of possible alternatives that reflect various interests, objectives and evaluation criteria. The

nature of the choice phase depends upon the decisionmaker’s preferences with respect to the importance of the evaluation criteria. Decision support systems range from highly deterministic and rule-based formulae to highly interactive and participatory processes.

The objective of a computer-based decision support system is to improve planning and decisionmaking by providing useful and scientifically sound information. It is most effective in collaborative decisionmaking. Expert or knowledge-based systems, and other analytical and modeling techniques, have been used to help scientists, managers and policymakers understand the complexity of physical and biological systems.

Many examples of decision support systems designed for research applications and demonstration purposes at a regional or watershed level can be found. Most have been developed to assess the environmental impact of natural resources use including agricultural, industrial and land use activities. Others have been applied to potential contamination and site suitability problems based on maximization of multiple criteria and minimization of threshold (constraint) values. Popular DSS-based software packages, such as IDRISI GIS, STELLA, ExpertChoice and a number of ESRI extensions, allow users to evaluate a decision problem through a multiple criteria decisionmaking (MCDM) process. This common approach allows the user to assess the relationships between a set of objectives and associated attributes. Many of the software packages are becoming “web-enabled,” allowing for wider access and even multi-player gaming exercises.

The DSS framework innovatively supports resource management and planning by creating an information framework tailored to the information, communication and technical needs. In addition, it can support and promote an informed debate when multiple goals and interests must be simultaneously addressed to resolve conflicts and build consensus.

A DSS framework applied to the management of Lake Ellesmere in New Zealand identified various decisionmakers and stakeholders and educated them about differing perceptions on existing lake management problems (Gough and Ward, 1996). By concentrating on information gathering and consultation with affected parties, the framework helps improve the decisionmaking process and establish criteria for measuring desired outcomes.

The Colorado River Decision Support System (CRDSS) is a fully operational tool that enables

agencies, water users and managers to organize, assess and evaluate a wide range of information and strategies on reservoir and river operations, water flow impacts, and water allocations. Designed by Riverside Technology, the CRDSS allows decisionmakers to analyze historical and real-time hydrologic data, run hydrologic simulation models and water rights allocation models, and study the effects of potential decisions. The primary component of the CRDSS is the HydroBase database that includes streamflow, climate, water rights, diversions, well permits, dam safety and land use data. These data feed into the consumptive use model to calculate the amount of water used by different interests. The results from scenario models are central to determining present and future uses of water. By allowing all applications to use the same, consistent information, this data-centered approach ensures data integrity and minimizes data redundancy (Bennett et al., 2001).

The Québec Ministry of Environment developed an integrated modeling system prototype to evaluate the impacts of municipal, industrial, forestry, and agricultural projects on the water quality and yield of a river basin (Rousseau et al., 2000). Comprised of a relational database management system, the modeling system has the ability to use both spatial and attribute data (e.g., digital elevation model, meteorology, soil, gauge locations, simulation results, livestock production, crop management) to generate scenarios that add water quality and flow dimensions to watershed assessments.

An operational DSS has also been implemented in the Great Lakes watershed. RAISON (Regional Analysis by Intelligent Systems ON microcomputers), developed at the National Water Research Institute of Environment Canada, is designed to help Great Lakes basin decisionmakers, managers and advisors locate relevant information for toxic chemicals (Lam and Swayne, 1993; Lam et al., 1995; Booty et al., 2001). The system consists of several layers of computational modules including a database, a spreadsheet, GIS, statistics, expert system, contouring, spatial visualization and graphs. Data on toxic chemicals provides input to the database table for further statistical analysis or optimization modeling. The system integrates text, maps, satellite images and other data with a combination of spatial algorithms, models and statistics to generate specific scenarios.

Information Integration

The essence of a DSS is the integration of data, information and knowledge from different sources to improve the decisionmaking process. However, as noted below, several factors can help or hinder the development and adoption of an integrated DSS for Great Lakes-St. Lawrence River water resources management.

Quality of Data – Several issues illustrate the need for system interoperability and data consistency. Large amounts of raw data are needed that come from different collection sources (i.e., water levels, river flows, air temperature, precipitation, meteorological parameters), which must be verified and corrected for final use. These sources typically are in different formats that must be converted for use in the WRMDSS. Some data must be current, but historic information may also be crucial. High resolution spatial or temporal data may also be essential to the decisionmaking process. In some instances, geospatial data may have different positional accuracies, making them more difficult to integrate into the WRMDSS.

System and Hardware Maintenance – The development of a WRMDSS should be considered a continuous process instead of a one-time development project, and be able to respond to current needs, stakeholder interests and future demands. Experiences have shown that, when dealing with a large set of data types from different sources, database tables and their fields should be carefully designed in the initial phase of the project. The WRMDSS will require data to be frequently updated, as the system will be otherwise useless.

Leadership and Management – Leadership and management set and achieve goals and objectives that sustain the value of the investment. Leadership also coordinates and communicates between different agencies across jurisdictions. Emphasis should be placed on the importance of the WRMDSS as a communications tool that provides an information infrastructure and framework for multiple users to make informed decisions based on the best available data collected.

Modeling Interconnectivity – In Chapter five, an extensive inventory is presented on the types of descriptive models that may be needed for the WRMDSS. To quantify the range of potential ecological impacts of a particular water withdrawal, a linked modeling framework will be necessary, comprised of groundwater, hydrodynamic, surface water quality and ecological effects models.

Information Dissemination – Key Considerations

The manner in which a broad range of information is displayed and presented will be key to the success of the WRMDSS. Some key considerations follow.

Clearinghouse node – A clearinghouse node is a decentralized system of servers located on the Internet that contains descriptions of available digital data known as metadata. Metadata are collected in a standard format to facilitate query and consistent presentation across participating sites. A clearinghouse uses readily available web technology for the client side to query, search and present search results. By utilizing a standard method for these functions, a clearinghouse allows individual agencies, consortia and geographically defined communities to collectively promote their available digital spatial data.

Integrated and interoperable web pages – In promoting the availability, quality and requirements for digital data through a searchable online system, there must be integrated and interoperable web pages that provide a standard data and information dissemination mechanism to different target audiences.

Data warehouses – A data warehouse is a database designed to support organizational decisionmaking. It can be updated automatically and structured for rapid online queries. A warehouse stores historical and consolidated data (e.g., flow records, water levels, meteorological parameters) in a common format. This component is the most critical element of a DSS.

Distributed networks – A network, which functions closely with a clearinghouse node, is needed to retrieve data from multiple sources. Servers may be installed at local, regional or central offices, as dictated by organizational and logistical efficiencies. All clearinghouse servers in a distributed network



are considered “peers” within the clearinghouse activity; there is no hierarchy among the servers. This permits direct query by any Internet user with minimal transactional processing and duplication of effort in the collection of digital spatial data. Cooperative digital data collection activities are fostered as well.

Distributed GIS mapping – Web-based GIS provides a visualization mechanism that allows users to access various sources of geospatial data. An open GIS architecture should be able to assess multiple forms of data. Users of geospatial data need to share data effectively and efficiently.

Enhancing Communications

An important part of the WRMDSS project has been the development of effective communications tools to provide access to available data and information. Below is a description of these tools and approaches and how they may be applied in the WRMDSS design. This listing is not comprehensive, but illustrates the array of available tools.

- **Internet** – A Great Lakes water use website has been a centerpiece of project activity and has been finalized with electronic versions of project products and an online regional water use database. The site is extensively linked through and highlighted on the Great Lakes Commission-managed Great Lakes Information Network (GLIN). GLIN is the pre-eminent Internet clearinghouse for data and information in the Great Lakes-St. Lawrence River region and, among many other services, supports a hydro-meteorological station directory and coordinated hydrologic/hydraulic data. GLIN also contributes significantly to the water resources management community via its “Daily News” feature, an electronic “clip service” that monitors print, radio and television media coverage of Great Lakes issues. GLIN also provides secure email discussion forums for targeted groups and topics. The websites and forums would support the needs of the region’s governmental agencies during decisionmaking deliberations.
- **Intranet Portal** – An intranet portal is an internal communications tool that can be configured to include only state, provincial and federal regulatory agencies (and other key groups), in the interest of providing security and privacy for confidential infor-

mation exchange and deliberations. Some intranet functions are currently available to the WRMDSS project team via listservs and community email addresses. The intranet portal can also help researchers coordinate ongoing and prospective projects with colleagues, and provide policymakers and managers with data and information for the WRMDSS.

- **Online GIS** – The Great Lakes Commission supports new web-based GIS applications as a service to the International Joint Commission (IJC), the U.S. Environmental Protection Agency (USEPA), the U.S. Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA). The Great Lakes Commission staff is currently developing a GLIN-based framework for regional metadata clearinghouse and web-mapping applications. The GLIN website could provide an effective Internet presence for a coordinated and distributed GIS that would add a valuable dimension to the WRMDSS.
- **Conventional Hard Copy Dissemination** – The Great Lakes Commission’s Advisor newsletter is used to disseminate project information and announcements to more than 3,500 policymakers, managers, researchers and other interested parties. Additionally, hard copies of some products (e.g., water use database report) have been published, publicized and made available to all interested parties. Hard copy products will continue to be the preferred medium for many entities in the region to keep current with water resources management issues and should be factored into the WRMDSS.
- **Meetings and Conferences** – The annual and semiannual meetings of the Great Lakes Commission have been used to report on progress, receive feedback, and release interim and final reports. These forums have been convenient and cost effective given that many of the WRMDSS project participants attend these meetings. Project findings and recommendations will also be presented and discussed at other related meetings and conferences where Great Lakes issues are discussed. Face-to-face communication among agency officials and with the public should continue to be a major vehicle for information dissemination and coordination of decisionmaking, and needs to be explicitly designed into the WRMDSS.

These communication tools are proven to be effective, and should be further refined to satisfy the needs of decisionmakers, managers, scientists and other interested parties.

Findings and Recommendations

A Water Resources Management Decision Support System is essential in supporting and promoting decisions through informed discussion and debate where multiple, and sometimes conflicting, goals and interests are involved. A variety of information dissemination and communications tools can be applied and, among others, include the Internet, intranet portals, online GIS and conventional communications.

Key considerations for integrating data and information into the WRMDSS include the promotion, development and implementation of data and information standards; the variability of hydrologic and hydraulic data in density, resolution, scale and temporal characteristics; and improvements in computer modeling and associated visualization tools.

The WRMDSS design process must also include the review and evaluation of alternative decision support frameworks – or models – that organize critical, yet disparate, data and information in a way that will foster science-based evaluation of withdrawal proposals. Decisionmakers, managers and scientists should be presented with multiple WRMDSS frameworks and be fully involved in testing and evaluation. The initial research, review and assessment process should not yield a single, specific alternative, but provide multiple options that decisionmakers (i.e., the Annex Working Group) can consider in reaching their own conclusions on which option or suite of options best meets the needs of the region.

The WRMDSS should provide easy access to relevant scientific data and information, including all key data sets and other products of the project: water use data by basin, jurisdiction and sector; consumptive use information; relevant literature (peer-reviewed and “gray”) on ecological impacts; essential questions to assess ecological impacts; computer models; and data/information needed to apply a resource improvement standard.

Recommendations

1. **Develop integrated Internet web pages to facilitate data and information exchange, distribution and access.**

Commitments should be made by all federal, state and provincial governments across the Great Lakes-St. Lawrence River system to cooperate fully in the development of the web pages. Information should be publicly accessible to the greatest extent possible.

2. **Develop metadata to accompany all geospatial and temporal data used in a Water Resources Management Decision Support System.**

Metadata should be developed to accompany all geospatial and temporal data used in the WRMDSS; this will benefit decisionmaking by facilitating information discovery, networked GIS mapping, and assessment and consideration of information uncertainties.

3. **Incorporate a robust communications strategy into the Water Resources Management Decision Support System, involving a range of interrelated tools such as Internet technologies; email and online discussion groups; and conventional communications including printed materials, meetings, conferences and symposia.**

The WRMDSS should include a communications strategy. Existing and emerging Internet technologies, as well as email and online discussion groups, should be viewed as key components of the WRMDSS. Applicable meetings, conferences and symposia focused on information coordination and continued system development should also be used to facilitate communication.

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