Appendix for the

Information and Indicators Strategy Team (I&IST)
Great Lakes Regional Collaboration (GLRC)

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Observing and Monitoring

Background

The binational Great Lakes – St. Lawrence system has a long history of programs for the collection, analysis, storage and archiving of physical, chemical, biological and cultural data. However, these programs are managed by a variety of agencies, organizations and academic institutions for varied purposes with limited coordination occurring among them.

The terms observing and monitoring are often used interchangeably, although they are not synonymous. For the purpose of evaluating Great Lakes community needs under the context of the GLRC strategy development, the following definitions highlight the distinctions between these terms within this context:

Observations – The act of measuring or recording of an event, state, condition or phenomenon, with instruments and the notation of these facts. In the context of the GRLC strategy development, observations are referred to as individual measurements collected by single sensors or systems of multiple measurements from fixed stations (e.g., buoys, stream gauging stations), networks of measurement sites (e.g., precipitation radar systems), airborne and satellite platforms (e.g., airborne snow surveys, LIDAR terrain mapping, satellite surface temperature measurements) and marine platforms (e.g., water chemistry samples, hydrographic surveys).

Monitoring – The systematic tracking of changes in conditions and progress toward meeting a management objective. In the context of the GLRC strategy development, monitoring is almost always referred to as the primary emphasis of programs to assess the ecological viability of species or habitat and the external stressors that can adversely affect them. Monitoring programs frequently require regular or ongoing observations of specific properties (e.g., monitoring of municipal drinking water for impurities). Monitoring is a critical element in the design and implementation of all indicator programs. In adaptive management, the effects of a management action are measured (or observed) and evaluated (or monitored) against established protocols and these results are applied to future decisions.

Problem Statement

The need for better coordination, integration and enhancement of observing and monitoring activities has been recognized for quite sometime. The Great Lakes – St. Lawrence system has a complex network of data collection programs, reporting requirements and monitoring strategies. Only limited resources have been made available to inventory these activities and even less have been invested to identify observing and monitoring needs. Nevertheless, there is currently a renewed emphasis being placed on developing integrated solutions from global, national and regional perspectives.

Current funding levels and federal manpower commitments are not sufficient to address the increased needs for environmental and social data to support Great Lakes ecological protection and restoration needs. Without additional investment to support more cohesive and comprehensive implementation, the current observation/monitoring status may actually decline, since operational costs constantly increase. Examples of these shortcomings are numerous.

For instance, streamflow information, vital to the understanding ecological trends, will be particularly problematic. Currently, stream flow data are collected for only 60% of the U.S. Great Lakes drainage basin. The current U.S. gauging station network of 372 stations will be diminished within three to five years, as short-term gauges are discontinued.

Operations and maintenance of buoy systems that provide important observations of subtle changes in the lakes' physical, chemical and biological resources are extremely limited. Ice-cover monitoring, a key indicator of climatic variability and a major factor in nearshore habitat processes, is too coarse to discern impacts for almost half of a year for some locales. Improvements in monitoring lake and interconnecting waterways' circulation patterns using advanced hydrodynamic models have only been modestly achieved and likely will not be used for operational forecasting unless additional resources are found.

Biological information resources are highly fragmented across different federal and state agencies, compromising science-based water resources management decisions for the basin. If these issues are not addressed robustly and comprehensively, inconsistent, incomplete, non-uniform and unreliable observations will continue to be the norm.

Desired State

In a perfect world, funding constraints would not limit the region's stakeholders from systematically, comprehensively, and repetitively monitoring the hydrologic, hydraulic, geologic, biologic, ecologic, and social condition of the Great Lakes and its tributary watersheds. Achieving this will require comprehensive and detailed data collection and analyses, state-of-the-science modeling and fully integrated information systems at all levels of government. However, it is not reasonable to expect that funding will ever be unlimited and, thus, a reasonable vision needs to be proffered, one that may be achievable if consensus occurs that significant increased resources can be applied over the next 30 years.

Under an improved scenario, the integrity of the U.S. stream gauging network would be restored and enhanced to provide more complete coverage for the 109 major U.S. Great Lakes tributary watersheds. Additional instrumentation would be added to these gauging stations to collect information on abiotic parameters (water temperature, dissolved oxygen, conductivity, etc.). Detailed streamflow simulation modeling would be completed for all watersheds, with no watersheds remaining ungauged. Programs would be fully funded to compile information on biological and cultural resources in all riverine areas and to assess anthropogenic changes to natural stream dynamics.

Substantial improvements would be made in monitoring and modeling the Great Lakes water balance. Reductions in uncertainties associated with overlake meteorological processes would be minimized by the production of daily over-lake and evaporation estimates derived from improved satellite and in-situ observations. These data would be used as direct inputs to continuous water balance modeling.

Additional instrumentation would also be added to coastal water level gauging stations and off-shore buoys and structures to monitor abiotic conditions such as temperature, salinity, conductivity and dissolved oxygen. Substantial advancements would be made in monitoring nearshore ice and wave conditions and modeling their effects on nearshore ecological processes. In-situ flow metering in the interconnecting waterways, St. Lawrence River and all major diversion canals would occur to support continuously running hydrodynamic models. Current simulation models for the open lakes would be expanded to include all embayments and enhanced for greater spatial detail in nearshore environments.

The enhanced observation goal includes collection of higher resolution terrain data (0.5 meter contours) for all coastal zone environments including below the water surface and of the topography. These observations would be repeated whenever necessary to detect changes in landform and sediment supply to the littoral system. In addition, the land cover/use characteristics of the U.S. coastal zone would be monitored on a 5-year repeat cycle using satellite or airborne multispectral imagery. This would include detailed mapping of the extent, composition and vigor of Great Lakes coastal wetlands. Sediment

monitoring would be fully operational for all major tributary streams and a comprehensive sediment budget analysis would be conducted for each lake basin to assess anthropogenic impacts over time. Under this improved scenario, observational data would be easily discoverable and accessible. Entities collecting data would establish strong partnerships to eliminate duplication of costs, time and effort.

Assessment of Ongoing Efforts

Most observing networks across the system are operated by U.S. federal agencies, with a few minor exceptions. Standing bodies coordinate data collection, information exchange, common datasets and data archival between agencies and with Canadian counterparts binationally.

Meteorological observations, overland and marine forecasts are made by the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) and coordinated with Environment Canada (EC). Water level gauging networks are operated by NOAA and the U.S. Army Corps of Engineers (USACE) and coordinated with observations made by the Canadian Department of Fisheries and Oceans (DFO). Geodetic control networks are coordinated between NOAA's National Geodetic Survey (NGS) and Geological Services of Canada (GSC). Stream flow gauging networks are maintained by the U.S. Geological Survey (USGS) and infrequently coordinated with provincial interests in Canada. Figure 1 shows the historic coverage of observations stations over the Great Lakes, highlighting the collection of lake level, streamflow, weather, and open-lake observations.

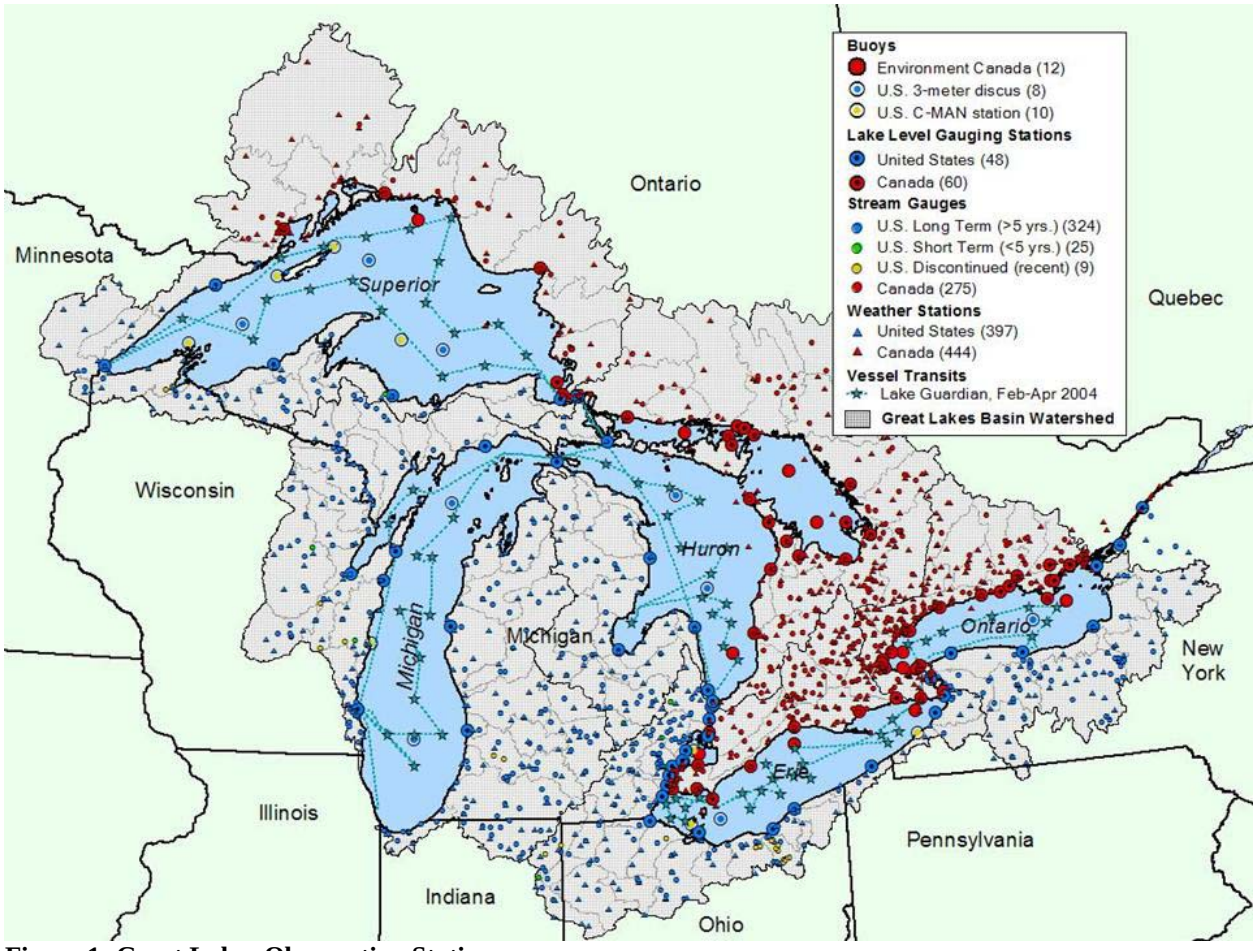


Figure 1: Great Lakes Observation Stations

The major coordinating bodies for physical data for the Great Lakes system are the Coordinating Committee on Great Lakes Hydrologic and Hydraulic Basic Data, (including representatives from all U.S. and Canadian federal agencies involved in these activities) and the Binational Executive Committee (BEC) (primarily represented by the U.S. Environmental Protection Agency (USEPA) and EC).

Fishery monitoring and research is coordinated by the Great Lakes Fishery Commission (GLFC), a binational compact agency. Biological data are collected by the U.S. Fish and Wildlife Service (USFWS), the USGS and each of the eight Great Lakes states, with substantial support provided by academic institutions. Scientific vessel coordination is conducted by the International Joint Commission (IJC). In addition, the NOAA Great Lakes Sea Grant Network (GLSGN) coordinates information collection/delivery with particular thematic emphasis (e.g., invasive species).

GEOSS/IEOS

A large, international effort to collect and share geospatial data of land, sea, and air from around the globe is currently underway. In February 2005, 61 countries agreed to implement the Global Earth Observation System of Systems (GEOSS) to network existing and new observational hardware and software and enhance global monitoring for ecological protection and economic development. The U.S. and developed nations have a unique role in developing and maintaining the system, collecting data, enhancing data distribution, and providing models to help all of the world's nations. The U.S. contribution to GEOSS is the Integrated Earth Observation System (IEOS). Seventeen federal agencies comprise the Interagency Working Group on Earth Observations (IWGEO) that developed a plan for the IEOS. To accomplish the purpose and vision of the U.S. Integrated Earth Observation System, the agencies will:

- Identify current and evolving requirements in the full range of societal benefits.
- Prioritize investments, including for new requirements, as necessary.
- Utilize available and/or develop new technologies, instruments, systems, and capabilities to meet the identified requirements and priorities.
- Streamline and sustain existing Earth observation systems that are necessary to achieve societal benefits.
- Establish U.S. policies for Earth observations and data management, and continue U.S. policies of open access to observations, encouraging other countries to do likewise.
- Expand existing governmental partnerships at local, state, regional, tribal and Federal levels, and develop new long-term partnerships with industry, academia, the K-12 education community, non-governmental, and international organizations that further the realization of these strategic goals.
- Develop human and institutional capacity to enable the translation of observations into societal benefits.

By Executive Order in May 2004, the President of the U.S. established the Great Lakes Interagency Task Force (IATF), which in turn has initiated the GLRC strategy development process. The IATF has been directed in the Executive Order to “ensure coordinated government development and implementation of the Great Lakes portion of the Global Earth Observation System of Systems.” In the U.S., the Great Lakes observational network will likely involve several separate but interrelated observing systems and monitoring networks, including the Great Lakes Observing System (GLOS) and the National Ecological Observatory Network (NEON). The Canadian contribution to GEOSS is currently in a planning phase.

IOOS / GLOS

Under the all-encompassing GEOSS umbrella to collect measurements of the air, water, and land from the ground, air, or from space, one area of focus has been the development of an integrated system to observe and monitor of the world's oceans. Over the last ten years, concerted national and international efforts have taken place to develop the Global Ocean Observing System (GOOS). The primary U.S. component of GOOS is the Integrated Ocean/Coastal Observing System (IOOS). GLOS is a regional observing system being established under the U.S. Integrated Ocean Observing System (IOOS) program initiative. The national IOOS has been developed to address seven "societal goals", all of which are relevant to the Great Lakes as a subsystem:

- improve predictions of climate change and variability (weather) and their effects on coastal communities and the nation;
- improve the safety and efficiency of marine operations;
- more effectively mitigate the effects of natural hazards;
- improve national and homeland security;
- reduce public health risks;
- more effectively protect and restore healthy coastal marine ecosystems; and
- enable the sustained use of marine resources.

The GLOS Business Plan, in final draft, has been developed by a 24-member steering committee representing major U.S. federal and state agencies and academic institutions that are involved in collection of physical, chemical, geological and biological data for the system. The GLOS steering committee also includes representatives from major user groups, including navigation interests, municipal water systems and the GLSGN. The GLOS Business Plan outlines the goals and objectives; anticipated benefits; subsystems and components; product development, evaluation and marketing; data management priorities; educational components, funding requirements and a recommended governance approach. The draft GLOS Business Plan can be found at: http://www.ocean.us/documents/docs/glosbusiness_plan.doc

GLOS will provide real-time access to a range of physical, chemical and biological Great Lakes data collected by multiple agencies and organizations. The primary goals for GLOS as a regional observing system include:

- enhance and expand observation resources – this involves several categories of activity, including enhancements to individual lake observation systems, expanded integration between the various lake observation systems in the region, and integration with observation systems that focus on terrestrial components such as NEON, air emissions and deposition programs, etc.;
- foster integrated ecological forecasting on a regional scale – target expansion and improved coordination of research and forecasting programs, including interrelationships between biological, physiological and social factors and influences;
- education and outreach that incorporates this material and reaches the broadest possible set of audiences – this includes education and training resources for all levels from elementary school through college and outreach material to encourage its use;
- communication with users to ascertain their needs for observations, monitoring and research;
- regional monitoring and modeling of public health parameters;
- regional-specific modeling and analysis of economic impacts and benefits, and provisions for the use of observing system resources to support regional economic activities, e.g. transportation systems and invasive species; and
- support and enhancement of management and policy development networks and initiatives.

The Great Lakes, as a closed basin, is heavily impacted by conditions along its shorelines, in its tributary watersheds and the interaction between the terrestrial, aquatic and atmospheric components of the ecosystem. Thus, GLOS is expected to be substantially engaged with numerous land-based and atmospheric observing activities in the region, including those conducted by Canadian authorities, the USGS, USEPA, NOAA, and others. Each of the following paragraphs briefly describes a GLOS subsystem focus.

Open Lake Observations – Understanding the Great Lakes – St. Lawrence River system requires observations drawn from a network of fixed stations that can take consistent measurements for integration with nearshore and mobile components. The GLOS open lake observation subsystem would include existing assets and deployment of new research buoys or buoy arrays. The GLOS open lake observing subsystem will gather meteorological data and sub-surface measurements of chemical, biological, and physical parameters.

NOAA's Great Lakes Environmental Research Laboratory (GLERL) has developed an integrated prototype for an environmental buoy system that is capable of providing real-time observations of chemical, biological and physical parameters. The system provides for data collection during extreme weather events, facilitates monitoring during episodic events and supports long term ecological research on zooplankton concentrations. The system also provides multi-point and relay functions for an array of sensors, including streaming underwater video, meteorological observations, and Acoustic Doppler Current Profilers (ADCPs).

Other buoy systems have been designed, tested and operated by various academic institutions across the region. Dependable observations of over-lake precipitation are also required to support water quantity management of the Great Lakes. The GLOS open lake observing subsystem will include generation of overlake precipitation estimates from terrestrial radar systems operated by the NOAA NWS.

Science Vessels – Science vessels allow seasonal sampling of sites and investigation of short-term and localized phenomena. In addition to supporting coordination and long-term management of the Great Lakes fleet, GLOS would act as a central access point for data collected by science vessels, providing repository services where needed. The science vessels operating on the Great Lakes serve as mobile research and data collection stations. They travel to and operate at a variety of sites over the course of a research season, which is in marked contrast to buoys and other fixed sensor platforms. While that reduces the time period during which vessel-derived data can be collected, it allows seasonal sampling of sites that could not support or do not justify other sampling methods.

The Great Lakes Association of Science Ships (GLASS) lists 65 research vessels active in the Great Lakes. The average Great Lakes research vessel is 31 years old and about 58 feet in length. The majority of the vessels conduct fisheries or water quality work for the States and Provinces, but all levels of government, universities and private industry are represented. During the past decade, only a few of the oldest ships have been replaced, and maintaining an aging fleet continues to be a challenge. A September 2001 report prepared for the GLFC's Council of Lake Committees concluded that only 56 percent of vessels over 30 feet in length will be able to meet the needs of agencies and researchers during the next 20 years unless action is taken.

The GLASS (www.CanAmGLASS.org) has organized in an effort to improve communications, coordination and utilization of this resource. However, in addition to improved management, fleet modernization must be provided for in order to best serve regional science needs.

Interconnecting Waterways Observations – Flows in the interconnecting waterways of the Great Lakes and St. Lawrence River affect commercial navigation, water supplies, recreational opportunities, and

production of hydropower for the Great Lakes region and the majority of North America's eastern seaboard. The collection of detailed and timely observations within these highly productive river courses has been extensive in the past, but numerous additional observations are warranted. The water level gauging network on the St. Marys, St. Clair, Detroit, Niagara and St. Lawrence rivers is sufficiently dense, but little continuous information is collected on flows in these major river courses. This GLOS subsystem should include deployment of *in situ* flow meters throughout these waterways, coupled with real-time continuous flow models.

Generally, water level observation networks do not need to be densified in the interconnecting waterways and St. Lawrence River, with a few exceptions. In a collaborative effort between U.S. and Canadian federal agencies, two-dimensional (2D) hydrodynamic models are being developed for each of the five interconnecting waterways on the Great Lakes. While models exist for each waterway, they are not run on a real-time basis, nor are they extended to applications for sediment transport studies or oil and toxic spill response support. In addition, there is a constant need for real-time monitoring of flows at key locations in these waterways as acquired by in-situ ADCPs or Acoustic Velocity Meters (AVMs). The same technologies are well suited for measuring inflows from all major tributaries to the Great Lakes to improve water balance modeling of the system.

Nearshore Observations – The U.S. Great Lakes – St. Lawrence River system has more than 6,500 miles of shoreline. The collection of detailed and timely observations over this domain has been inconsistent in the past and is of critical importance. Continuation and enhancement of the existing water level network is needed, including adding definition in major embayments of the system and adding meteorological and water chemistry parameters to the observation data streams.

GLOS will work on supporting the following enhancements: expansion of the existing geodetic control network to provide essential positioning information for electronic navigation in all weather conditions; additional instrumentation on buoys plus land-based high-frequency radar to provide critical information on the direction, magnitude and frequencies of nearshore waves and current flows; and integrated coastal airborne mapping involving periodic acquisition of high resolution imagery. The latter is critically needed to provide long-overdue detail on changes in nearshore landforms due to littoral processes and determination of habitat extent, composition and health. Nearshore wave energy information has been collected sporadically over time and space across the region. This information is critical for predicting shoreline habitat change, coastal erosion and flooding.

Although existing buoy systems provide measures of wave height and period, they do not provide necessary information on the directional components of wave energies. Nearshore currents in the open areas of the Great Lakes and in the interconnecting waterways are generally not known, even though they affect public safety, recreational and commercial boating, spill response and the swimmability of beaches.

Moderate-resolution surveys of the complex nearshore of the U.S. Great Lakes – St. Lawrence River system were completed by the early 1970s. However, little work has been conducted since to update these physical characteristics, even though many areas are affected by erosion, sedimentation and other littoral processes. Further, coastal habitats, the most ecologically productive part of the system, are poorly mapped in spatial and temporal detail. As one example, encroachment by human development and by aggressive invasive plant species has substantially transformed the natural wetlands along these coasts. No comprehensive, detailed and consistent coastal wetland map base currently exists to support emerging restoration and protection initiatives. A monitoring strategy for coastal habitat changes is needed with a minimum five-year repeat cycle.

Atmospheric Observations – The air monitoring network currently in place across the Great Lakes region does not include sufficient monitoring over the lakes or at their surfaces and does not collect observations

of some critical substances. Improvements are needed to monitor over-lake atmospheric characteristics such as meteorology, atmospheric pollutant concentrations, persistent bioaccumulative toxics (PBT) concentrations and contaminant deposition using instrumentation on monitoring buoys, research vessels and shoreline/nearshore structures. Within GLOS, output from this subsystem would be combined with data regarding water characteristics, contaminant interactions and contaminant transport via tributaries to expand and improve computer based models. The atmosphere also transports significant quantities of chemical contaminants to the waters of the Great Lakes.

Over the past decade, substantial investment has been made in designing, implementing and operating an international air monitoring network across the region — for example, on the U.S. side over 1100 monitoring sites collect data on air pollutants within the eight states that border the lakes. However, that system does not include sufficient monitoring over the lakes themselves and does not collect observations of some critical atmospheric substances. Data integration with regional monitoring networks will be another significant part of the GLOS atmospheric subsystem. The Integrated Atmospheric Deposition Network (IADN), established in response to Annex 15 of the Great Lakes Water Quality Agreement (GLWQA), has been the central focus of atmospheric PBT monitoring in the basin. Other projects, such as the Mercury Deposition Network, do some monitoring of mercury or other individual substances in the region. However, numerous chemicals of major concern, including dioxins and furans, brominated flame retardants and mercury, are not measured adequately and data that do exist are often poorly integrated.

Remote Sensing – Satellite and airborne remote sensing technologies play a major role in efforts to study and understand the mechanics and functions of the Great Lakes – St. Lawrence River system. Recognizing this, GLOS would support acquisition and archiving of imagery, calibration efforts related to regional data parameters, development of new tools and data analysis processes, improved/increased data access capacities, and broader user awareness and distribution of derived products. These efforts would include development of near-real-time lake surface evaporation estimates for use in outflow control management. Satellite and airborne remote sensing technologies allow features in the landscape to be mapped and analyzed; characteristics of the atmosphere, land and water to be determined, compared with previous data to detect change, and incorporated into modeling tools to forecast future conditions; and many vital and dynamic environmental parameters to be monitored, facilitating regulation and response.

Remote sensing technologies provide the ability to monitor the dynamics of the Great Lakes – St. Lawrence River system at a wide range of scales in near real-time. An integrated remote sensing system requires data at multiple resolutions from several levels: spatially, spectrally and temporally. The causes and extent of the recent resurgence of the macroalgae *Cladophora* in Lake Michigan that threatens to close beaches and water intakes this summer can be noted as an example. Remote sensing at fine resolution can help to accurately define spatial distribution, extent, and the possible causes of the phenomenon while coarse resolution measurements help with initial identification and placement within the larger context.

NEON

NEON is a continental scale research program managed by the National Science Foundation (NSF) consisting of geographically distributed infrastructure, networked via state-of-the-art communications. NEON is expected to include cutting-edge lab and field instrumentation, site-based experimental infrastructure, natural history archive facilities and/or computational, analytical and modeling capabilities, linked via a computational network. NEON is expected to transform ecological research by enabling studies on major environmental challenges at regional to continental scales. Scientists and engineers would use NEON to conduct real-time ecological studies spanning all levels of biological organization and temporal and geographical scales.

In September 2004, a NEON Coordinating Consortium and NEON Project Office were established to develop a blueprint for the network and a plan for its implementation. The Great Lakes region would be included in NEON under the Great Lakes and Central US Ecological Observatory (GLACEO), including all of Michigan and Wisconsin and including Northeastern Minnesota, Northeastern Iowa, Northern Illinois, Northern Indiana, Western Ohio and Western Lake Erie. It appears that the Eastern Lake Erie and the drainage basins to Lake Ontario and the St. Lawrence River would be in another region, which would create a disjointed function that should be corrected.

The NEON structure within the region is in an early conceptual phase, with little identification of the scope of observations to be conducted and only preliminary assessments of funding requirements.

Monitoring Coordination

Monitoring inventories have been compiled by the BEC and by the Great Lakes Commission (GLC) for the entire Great Lakes – St. Lawrence River system which identify all observing systems currently in place or with historic information available, and various monitoring programs that are underway in both the U.S. and Canada. These monitoring inventories will be combined to provide one Internet accessible information base.

The majority of sampling programs are found at the state/provincial level, followed by federal government, local government, university, nongovernmental organizations and private organizations. In total, 480 programs were reported for the U.S. portion of the Great Lakes basin, with 56 programs reported for the Canadian portion of the basin. Results indicate that while state agencies manage the largest percentage of reported U.S. monitoring programs, the majority of monitoring by Canadian organizations was reported from the federal sector. The combined U.S. and Canadian monitoring inventory results indicate fairly even geographic distribution of monitoring efforts across the Great Lakes. Common protocols for the monitoring of Great Lakes ecosystem components have not been established between the U.S. and Canada or between the states and provinces. Some encouraging developments have, however, occurred. Consistency in monitoring protocols and coordination of activities will considerably enhance the quality of the information base for development and reporting of indicators.

The GLC recently developed a report based on its monitoring inventory that assesses gaps and overlaps in observing systems and monitoring programs. This report includes policy recommendations to address these gaps and improve the effectiveness of monitoring efforts (GLC 2005). The gap analysis compares results from the monitoring inventory to monitoring needs identified through the State of the Lakes Ecosystem Conference (SOLEC) indicator process. The gap analysis summarizes monitoring efforts for 21 areas, reviewing the combination of current efforts, highlighting potential gaps in monitoring coverage and providing recommendations for improvement.

A core set of Great Lakes monitoring needs was established to serve as the foundation for analyzing gaps and overlaps in Great Lakes monitoring programs. Using the SOLEC indicators as the basis, 21 monitoring needs were identified for the Great Lakes basin. These needs include fish consumption, drinking water, beach safety, air, fish population health, wildlife ecology, non-native species, benthic & invertebrate ecology, coastal wetlands, plant ecology, habitat and community, atmospheric deposition, nutrient management, land use, erosion, urban issues, water quality, sediment quality, soil quality, groundwater and climate/weather.

Evaluation of Alternatives

Status Quo, no change in resources available

Currently, monitoring programs are in place for a number of physical, chemical and biological components. Monitoring programs are typically conducted by federal and state agencies with little or no coordination or regular data sharing. Few monitoring programs have been modified to better support implementation of the SOLEC indicator suite, let alone new indicators identified by the GLRC strategy teams assessing priority issues. New indicator development would require that additional observations be taken and new monitoring protocols be developed for implementation. Progress would be slow on all these fronts (if at all), since personnel and funding resources are limited within responsible agencies.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- copious spatial and temporal gaps in critical data coverage;
- inconsistent availability of data;
- inconsistent timeliness of data;
- observation needs for Areas of Concern (AOCs) would continue to be largely unaddressed;
- no additional restoration or protection programs to be established;
- SOLEC indicator reporting would continue to be incomplete; and,
- Great Lakes Basin ecosystem will continue to be vulnerable to current and future threats.

Reduced Resources from present levels

With reduced resources (personnel and/or funding), observation stations would be even more compromised, data gaps in observation networks would increase both spatially and temporally, monitoring programs would be reduced to basic elements (e.g., state regulatory or compliance functions only) or eliminated altogether (e.g., large research vessel operations for open water data collection). There would be heavier reliance on historic information collected for other purposes that may not adequately support decision making. Priorities for observation and monitoring would likely shift from Great Lakes Basin ecosystem assessment to local areas (e.g., AOCs). Large scale spatial and temporal trends would be more difficult to assess within acceptable margins of uncertainty.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- area-wide trends would become increasingly more difficult to assess;
- resource management decisions would become less scientifically defensible;
- scientific consensus would become more difficult since assumptions would increase; and
- the Great Lakes Basin ecosystem would be more vulnerable to new threats.

Same Resources Available, rationalized observation and monitoring

A limited increase in efficiency could be achieved with better integration of observational activities and monitoring programs. Better federal-state-local collaboration would reduce redundancies in data collection programs. Improved information management and data sharing would be critical. Diversion of resources might result in fewer physical, chemical or biological processes being monitored. Those that would be monitored, however, would have reduced levels of uncertainty (greater scientific defensibility).

The consequences affecting resource management for the Great Lakes system under this scenario include:

- some spatial and temporal data gaps would be filled, while others would increase;
- data availability would increase;
- some ecosystem components would be better assessed, while others would be less defensible;

- many decisions would continue to be based on incomplete information or faulty assumptions; and
- new threats to the Great Lakes Basin ecosystem would likely not be identified soon enough.

Improved Observations and Monitoring; additional resources provided

A high priority would be placed on addressing the most significant data collection gaps identified through a formal analytical process (e.g., USGS Gap Analysis Program (USGS 2005)) and benefit-cost assessments involving a cross-section of stakeholders. These strategic assessments are critical to successful implementation of the Great Lakes observational components for the GEOSS. Additional data collection would be established at currently unobserved or under-observed sites, including nearshore areas, tributaries and other watershed ecosystem components. Additional observations would be made at AOCs for determining current conditions and recovery trends. Existing monitoring programs would be improved and new monitoring protocols could be established, since this scenario includes hiring of additional personnel and exploitation of emerging information technologies for improved information discovery and access. Federal, state, local and tribal monitoring programs would be better aligned with needs for indicator data.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- better coordination of federal, state, local and tribal observations and monitoring protocols;
- better information integration under a comprehensive information management strategy and decision support framework;
- substantially reduced uncertainties in outcomes, since decisions would increasingly be based upon known facts instead of faulty assumptions; and
- enhanced abilities for mitigation of new threats to the Great Lakes and their watersheds.

Fully Funded Observational System and Monitoring Programs

This scenario is difficult to define, given necessary trade-offs between the costs of large-scale observational programs and benefits that can be assessed using largely qualitative measures. Nevertheless, most data collection gaps would be filled, including those identified by the GLRC strategy teams for nearshore areas, tributaries and other watershed ecosystem components. Existing monitoring programs would be improved and new monitoring protocols could be established, since this scenario includes hiring of additional personnel and exploitation of emerging information technologies for improved information discovery and access. All accepted indicators would be monitored fully and repetitively. This activity would be managed under a cooperative arrangement between stakeholders and compose the Great Lakes observational components for the GEOSS.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- better interagency coordination of data collection activities and monitoring programs;
- full implementation of the accepted indicator suite;
- integrated information discovery, evaluation and access;
- new or continuing threats to the Great Lakes basin ecosystem could be identified earlier and averted or mitigated; and
- better assessments of human health and well being.

Recommended Actions

Overarching Recommended Action

To provide accurate, complete and consistent information, the Great Lakes region must increase and better coordinate the collection of critical information regarding the Great Lakes ecosystem. The Great Lakes Interagency Task Force and other stakeholders need to implement the U.S. contribution to the Integrated Earth Observation System (IEOS) and the Integrated Ocean Observing System (IOOS) as part of the Global Earth Observing System of Systems (GEOSS). Monitoring must be better coordinated through the existing Great Lakes management entities, both at a lake-wide and region-wide basis.

Rationale: Observing systems and monitoring programs are the primary means for gathering information on the chemical, biological and physical characteristics of the Great Lakes ecosystem. These programs are needed to take the pulse of the Great Lakes, assess natural variability, drive ecosystem forecasting models, and assess the progress of restoration efforts. Monitoring and observing systems require continued improvements to adapt to changing technologies and informational needs of Great Lakes resource management. Initial activities should be focused on implementing the Great Lakes Observing System (GLOS) as the regional component of IOOS. Efforts should be continued to establish IEOS within the Great Lakes region.

Cost: $28 million for 5 years

Specific recommended actions imbedded in the overarching recommendation are described below.

Detailed Action 1: GLOS should be implemented to provide for integrated observations and monitoring over all lake surfaces and coastal zone areas of the U.S. Great Lakes - St. Lawrence River System.

The GLOS business plan outlines the goals and objectives for integrated observations, anticipated benefits, subsystems components, products, data management priorities, educational activities, funding requirements and a recommended governance approach. The GLOS is expected to be a non-profit organization with federal, state, academic and end user members.

The GLOS business plan identifies that additional open lake, nearshore, interconnecting waterway and atmospheric observations will cost $ 18 million at a minimum over the next five years. NOAA should be the U.S. lead agency for implementation of the GLOS Business Plan, relying upon the regional association that will be constituted to represent all regional stakeholder interests.

Detailed Action 2: The Great Lakes coverage under the Integrated Earth Observing System (IEOS) should be designed, coordinated and implemented as soon as possible to provide for integrated terrestrial observations needed to support the GLRC priority issues

Although the Great Lakes Observing System (GLOS) is currently under development, observation and monitoring efforts need to be expanded in the region to include terrestrial and atmospheric measurements as well. Therefore, the Great Lakes component of IEOS should be developed to include all of the drainage basins for lakes Erie and Ontario and the St. Lawrence River effectively covering all terrestrial components within the basin. Over the next five years, the development of initial planning and implementation of prototype observations is expected to cost $8 million.

Detailed Action 3: Organize and support binational Great Lakes monitoring coordination on a lake-wide basis. Leadership should be provided by the LaMPs and Lake Committees.

Concerted action to address lake-wide and basin-wide problems requires consistent and coordinated information collection across municipal, state and national boundaries. U.S. agencies must lead the way in expanding and coordinating ecosystem-based and issue-focused monitoring programs including protocols, scientific rationale, and integration of indicators. Such coordination should be done on a binational basis for each lake through the Lakewide Management Plans (LaMPs).

The tasks of the coordinated lake-wide monitoring efforts would include the following:

- review the set of Great Lakes indicators on a recurring basis to identify information needs from monitoring programs or other data collection efforts;
- review the inventory of Great Lakes monitoring programs to identify those programs that can support the data needs of the indicators;
- identify opportunities for cooperation and collaboration among various monitoring programs;
- identify opportunities for coordination and information exchange with national or international monitoring programs; and
- oversee development of common monitoring protocols for evaluating indicators.

This recommended action would cost $2 million over five years. The USEPA should be the prime U.S. federal lead for this endeavor, with substantial input from numerous state, academic and NGO entities.

Table 1: Observing and Monitoring Needs and Recommended Actions for GLRC Priority Issues

Aquatic Invasive Species

- Immediately require monitoring, reporting, and public dissemination of all ship ballasting activities, prevention practices, and outcomes such that progress toward the goal is measurable and enforcement practical. Implement consistent and continuous assessment of: 1) inoculation pressure from ships; 2) populations of NAIS, and 3) rates of NAIS introduction and spread.
- Initiate statistically valid sampling of Great Lakes/St. Lawrence Seaway harbors, interconnecting waterways and ships.
- Develop and implement comprehensive AIS monitoring plans for the canal vector.
- Fund assessment, monitoring, and rapid response planning in Great Lakes canals through NOAA. IL, NY, OH, NOAA, USGS, GLFC and USFWS. Develop AIS rapid response plans for the Chicago waterways, New York State Canal System and Ohio canals for species of concern;
- Develop and implement a system of enhanced observations and ecological surveys for the Great Lakes at locations with high risk of AIS invasion as a cooperative effort involving state, tribal, local, port, and other federal entities.

Areas of Concern

- The "Federal-State AOC Coordinating Committee" that should promote Data collection and sharing as one of its priority activities. This committee should move specific projects forward through technical assistance to States, tribes and local AOC councils.
- Increase observing system capabilities and improved monitoring programs for measuring progress towards AOC delisting targets and assessing the effectiveness of remedial actions at AOCs.
- Acquire additional funding to improve monitoring programs for beneficial use impairments (BUIs) that are not typically monitored under State programs and where more frequent observations are needed to verify a change in status (e.g., whether an AOC is improving enough to be delisted).
- Whereas most AOCs are monitored on a five-year cycle, more extensive data collection is required to measure the effectiveness of specific remedial actions. Once an AOC has been restored, continued monitoring on a five-year cycle should be sufficient to ensure conditions are maintained.

Coastal Health

- Improve monitoring of wet weather sewage system overflows into Great Lakes waters.
- Increase measurements of contaminants in environmental media, fish and human tissues to better monitor human health and improve consumption advisories for Great Lakes fish.
- Monitor substances known (or suspected) to be of concern in wastewater treatment plant effluent and sewage sludge.
- Measure and report nonpoint contamination at beaches.
- Conduct satellite and limnological surveys of nutrients, zooplankton and phytoplankton to determine precursor conditions leading to harmful algal blooms (HABs).
- Improve observational capabilities at water intakes across the basin to monitor drinking water quality.
- Measure the biological, physical and chemical properties of nearshore waters without beaches to assess how different sources affect non-beach areas, including monitoring near CSO/SSO outfalls, monitoring near AOCs, industrial discharges, and toxic chemical sources.
- Support the development, testing and implementation of the forecasting models through enhancing observation systems for rainfall, spatially explicit watershed hydrology models, hydrodynamics, HABs, toxic substances and bacteria.
- Conduct a thorough review of Great Lakes States' ongoing wet weather control programs. Identify and correct deficiencies and ensure that programs are achieving the requirements of the Clean Water Act.
- Standardize, test, and implement a risk-based approach to manage beaches and recreational waters. The approach should build upon existing water quality monitoring programs, employ the latest technology for microbial assessment and standardized sanitary survey criteria based on a holistic watershed assessment, rely on real-time testing methodologies and improve forecasting. This requires the use of sanitary inspections to come up with a beach classification system in addition to microbial assessment under the BEACH Act.

Habitat and Species

- Develop and improve observation systems and monitoring programs for aquatic invasive species, native lake trout, lake sturgeon, *Diporeia*, native lake herring, deep water cisco, yellow perch, walleye, lake whitefish, and lake run trout (coaster brook trout).
- Develop and improve observation systems and monitoring programs to address: non-point source pollution; habitat loss or increased habitat acreage for priority habitat types; shoreline invasive species; coastal wetland management; inland wetlands; biodiversity loss from nutrient enrichment; changes to inland wetlands and lakes as caused by invasive species; and coupling of physical and biological characteristics of habitats in the open lakes.

Non-point Source Pollution

- Establish a contaminant observing system for persistent/bioaccumulative or and emerging toxic pollutants on a significant percentage of Great Lakes tributaries within the next decade.
- Coordinate control efforts and associated monitoring networks for nutrients, contaminants, pathogens, and sediment among Great Lakes jurisdictions. Coordinated elements may include consistent standards, anti-degradation benchmarks, coordinated monitoring networks, and enforcement activities.
- Develop a long-term sediment sampling and assessment plan.
- Improve measuring, monitoring, data evaluation, and reporting of remedial treatments for sediments.
- Within the long-term sediment monitoring program, provide full federal funding for NPS load monitoring for selected sensitive watersheds.

Sustainable Development

- Ensure staffing and maintenance of observation systems and monitoring programs to support sustainability indicators.
- Improve monitoring programs to support improved regional fish advisories (more monitoring of more fish species in more places more often).

Toxic Pollutants

- Adequately monitor--including spatial and temporal continuity--for chemicals of concern for each of the SOLEC toxic pollutant indicators, including contaminants in air, water, sediments, fish, and other biota.
- Track information from state and national programs that monitor toxic pollutants in food.
- Develop standardized analytical methods for selected chemicals of emerging concern.
- Analyze fish contaminant monitoring program archives for chemicals of emerging concern.
- Increase support for state and tribal fish monitoring programs on emerging contaminants and dioxins.
- Develop an integrated multimedia monitoring program for at least two representative waterbodies with different mercury methylation capacities (e.g., upstate NY and Upper Peninsula of MI) to assess their response to mercury emission reductions.
- Develop a surveillance program in collaboration with wastewater treatment plants to assess the presence and significance of pharmaceuticals, endocrine-disrupting chemicals and personal care products in final effluent, sewage sludge, and affected tributaries.
- Institute a Great Lakes human biomonitoring program including analysis of chemicals of emerging concern in human tissue, with enhanced monitoring of sensitive populations.
- Improve AOC-specific data collection and better utilize existing AOC monitoring data.
- To maximize the use of available funds, assess current monitoring programs to identify opportunities to save costs by decreasing monitoring frequency, decreasing monitoring locations, and/or switch to cheaper monitoring methods (e.g., passive air samplers) for chemicals for which sources have declined substantially, concentrations are below identified risk levels and currently show little unpredictable spatial or temporal variation.
- Assess and ensure in-use analytical guidelines for toxic pollutants are current and accurate.

Indicators

Restoration and protection of the Great Lakes ecosystem requires a clear view of the current state and underlying patterns of the system and its many interrelated components. Collection, interpretation and reporting of information are needed to assess progress toward achieving goals and specific objectives. Indicators are the gauges that provide information on the state of the Great Lakes to citizens, resource managers and stakeholders. Indicators detail the conditions at a particular point in time, allow us to monitor changes over time, provide a basis for management decisions, and allow us to track the success of actions intended to restore the ecosystem. When appropriately formulated and implemented, indicators should be an integral part of the decision-making process regarding the Great Lakes system. Indicators build significantly on observing and monitoring programs by integrating the information produced by these programs with our understanding of the ecosystem to provide information regarding the past, current and future response of the system to stressors. When built upon a firm scientific basis, a comprehensive suite of indicators can help explain observed changes in the ecosystem and may lend some predictive ability regarding future changes.

Essential to the development and use of actionable indicators is the underlying data and information used to evaluate them. Standardized and coordinated observations, summarized over space and time and managed in suitable information architecture, provide the basis for successful indicator programs. Improvements to each of these components are needed to adapt to changing resource management needs of the Great Lakes.

Background

The 1987 protocol to the GLWQA called for the development of indicators of ecosystem health (IJC 2000). SOLEC was created by the USEPA and EC to meet some of the reporting obligations required by the GLWQA (USEPA and EC 2002). Through biennial conferences hosted by the U.S. and Canada, a suite of indicators has been developed to report on the state of various components of the ecosystem and its chemical, physical, and biological parameters. Since 1998, reports for over 50 indicators have been prepared and presented at the biennial SOLEC meetings. While SOLEC relies heavily on the voluntary cooperation of many agencies and organizations that collect environmental data, it has no authority or funding to direct that specific monitoring programs be maintained to update the indicator suite. Figure 2 shows how SOLEC is structured to relate the integrity of the ecosystem to the underlying stressors, sources and human factors.

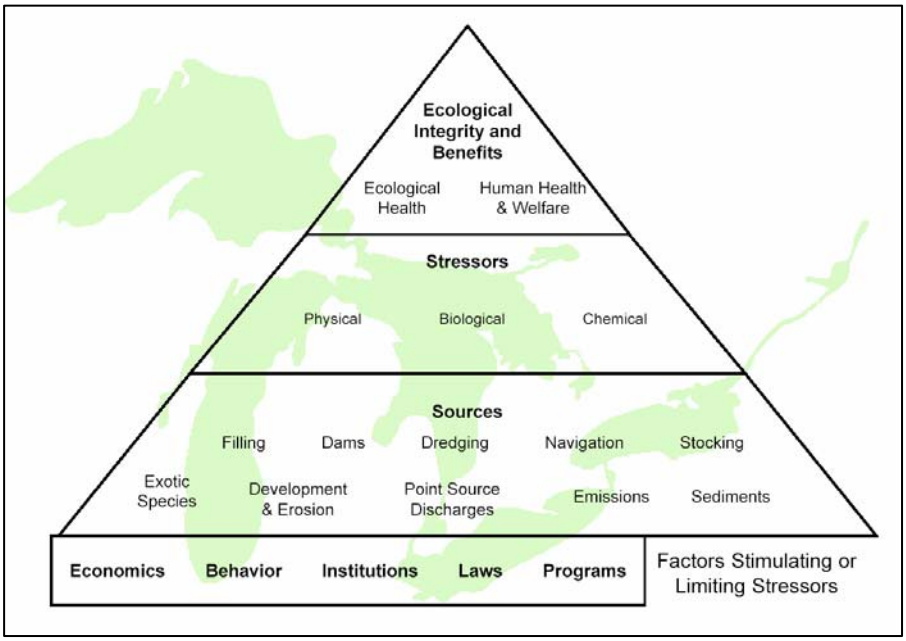


Figure 2: Great Lakes Ecological Integrity Factors

A number of similar or related indicator-development projects have been conducted in the Great Lakes basin, and several are still underway. The Great Lakes Coastal Wetlands Consortium (GLCWC), funded by the USEPA, has developed a suite of indicators for coastal wetlands and is currently testing and revising related monitoring protocols (GLCWC 2005). Indicators of coastal conditions are being developed and tested under the Great Lakes Environmental Indicators (GLEI) project by a consortium of researchers coordinated through the University of Minnesota – Duluth (GLEI 2003). Other indicators have been developed for the Lakewide Management Plans (LaMPs) or Remedial Action Plans (RAPs) for AOCs and for reporting of environmental conditions by state and local agencies and organizations.

Problem Statement

Although a suite of Great Lakes indicators has been developed through the SOLEC process, few monitoring programs are currently funded to provide necessary data for the indicators to be fully utilized. Lack of consistent data collection activities and differing information management approaches across the region also present a continuing problem. The comprehensiveness, organization and reporting of the indicator suite—although continually improving—require additional coordination and institutional support across regional organizations. A report by the General Accounting Office (GAO) in April 2003 (GAO 2003, 2004) concluded that there are currently several organizational impediments to successful implementation of a Great Lakes indicator suite. There is a diversity of monitoring and reporting efforts occurring in the Great Lakes basin by a multitude of organizations and although this diversification of effort could be a great benefit if well coordinated, comprehensive planning and coordination of these activities across the basin is lacking.

The GAO report found that funding to support broad participation by state and local groups in well-coordinated indicator and monitoring activities is inadequate. As a result, the volume of information collected, its organization and management, and the variety of methods used for interpretation and reporting do not meet the region's needs. Although the USEPA Great Lakes National Program Office (GLNPO) is assigned the coordination responsibility by the 1987 Clean Water Act Amendments, the GAO report states that partnerships must be thoroughly encouraged across all regional agencies to support concerted reporting of Great Lakes indicators. A regional coordination body is needed to ensure communication, cooperation and planning for these activities within the region. Although the SOLEC offers much of this coordinating function, adequate funding is needed to ensure participation of all stakeholders in this process.

In addition, many of the existing SOLEC indicators are qualitative in nature, limited by current observation and monitoring capabilities. Indicators based upon qualitative assessments can be unreliable when employed to determine the severity of risk or the degree of restoration/protection attained.

Desired State

A comprehensive set of indicators must be in place to assess progress in achieving each of the ecosystem goals for restoring and protecting the Great Lakes. These indicators must answer both simple and complex questions regarding the health of the ecosystem and its components. In order to inform environmental managers, decision makers, the public and other stakeholders about the trends and the current state of the ecosystem, the suite of Great Lakes indicators must:

- be organized into a flexible framework that accommodates various temporal and spatial scales (e.g., local, lake wide, watershed, basin-wide), environmental issues, ecosystem components and/or human-related issues to accommodate needs of multiple stakeholders and decision-makers;
- include a full range of indicator types, building on current and past efforts;

- be selected through a formal process designed to include careful consideration by subject experts, stakeholders and decision-makers (i.e., the user groups);
- be supported and accepted by stakeholders;
- be relevant to the assessment questions and management concerns at all levels of governance (i.e., federal, state, local and tribal); and
- be supported by observing and monitoring data and information technologies that are operationally maintained to provide ready-access.

Each of these characteristics is described in greater detail below.

Flexible framework: The current suite of SOLEC indicators can be organized into a variety of different classes or categories depending on user needs. Table 2 shows how each SOLEC indicator has been assessed for its relevancy to the issue areas of the Great Lakes Collaboration. Most of the SOLEC indicators have been assessed for relevancy to the GLWQA Beneficial Uses, IJC Desired Outcomes, Great Lakes Fish Community Goals and Objectives, Great Lakes Issues, and other potential groupings. Additional indicators that may need to be developed for specific applications are described in Table 3. A relational database would be needed to allow indicators to be sorted among such groupings to facilitate reporting to meet the needs of various user groups. The framework should also include indicator descriptions, assessments, and other supporting information that can be obtained by users through an interactive web-interface.

Full range of indicator types*:* The current suite of Great Lakes indicators recognizes the PSR model (Pressure, State, and human Response). It has been suggested that "Driver" indicators should also be added to this model. Interconnections between indicators must be better defined to illustrate how the state of the environment and the pressures and the human activities are related. The current suite of SOLEC indicators has been developed and refined from a larger group of candidate indicators. Over the years, the list of indicators has expanded and the descriptions revised or clarified. Current indicators should be used as the basis for an expanded suite that covers all appropriate aspects of the Great Lakes ecosystem. A thorough discussion of ecological indicators is provided by Niemi and McDonald (2004) and applications to coastal areas, including for the Great Lakes are discussed by Niemi *et al.* (2004).

Spatial and temporal scales: The current suite of indicators is focused on the whole Great Lakes basin or on individual lakes or sub-basins. There is an unmet need to inform local decision-makers and identify indicators and/or measures relevant to local areas. Local areas would include municipalities, regional planning commissions, and AOCs, among others. Most "nearshore" and/or coastal areas should be assessed at smaller scales than sub-basins. The suite of Great Lakes indicators must be able to assess conditions and trends from both the basin-wide and individual watershed level, depending on user needs.

Formal process, including criteria: A formal process for identifying, developing and selecting Great Lakes indicators has been established and used by SOLEC organizers. This process has involved panels of experts for geographic areas and issues and should be maintained in the future. Criteria for indicator selection are well established and expansions of the suite must build on the SOLEC process, using the same or similar criteria.

Agency commitments and support by stakeholders: Agency commitments to monitoring, assessing and reporting on the Great Lakes indicator suite must be all inclusive. Currently the USEPA and EC fund and operate monitoring programs for some of the Great Lakes indicators, while the USFWS supports six indicators. Other agencies have not formally declared responsibility for data collection, evaluation and reporting. To foster acceptance of the indicator suite, stakeholders at all levels of government as well as non-governmental organizations would be encouraged to participate in the process for indicator selection

and in monitoring, data collection and reporting. Financial resources would be available to cover the costs for data collection, evaluation and reporting for all indicators, involving stakeholders from federal, state and local organizations.

Evaluation of Alternative Approaches

Five levels of implementation of the Great Lakes indicator suite are considered below, including likely consequences for resource management decision-making. The scenarios provided are explored relative to current funding and resources for Great Lakes monitoring, indicator development and reporting. Because of the substantial dependence of indicators on observing/monitoring programs and data management, altered approaches to these activities are also considered.

Status Quo, no change in resources available

Currently, monitoring programs are in place for a number of physical, chemical and biological components of the Great Lakes basin, some of which are directly aligned with designated indicators. Indicators are grouped in the categories of Contamination, Biotic Communities, Invasive Species, Aquatic Habitats, Human Health, Land Use/Land Cover, Resource Utilization, and Climate Change. Of the 81 designated indicators identified through the SOLEC process, reports have been prepared for 56. The non-reported indicators are either still in development or data are not available or readily accessible. Few monitoring programs have been modified to better support the indicators. Further indicator development progresses slowly on a group-by-group basis (e.g., coastal wetlands, forest lands, groundwater, islands) as personnel and funding resources are made available. Indicator reporting relies heavily on data collected for other purposes, often indirectly related to information needs.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- inconsistent availability of data;
- inconsistent timeliness of data;
- limitation on application of existing indicators to identify emerging contaminant problems ;
- conditions at AOCs will continue to be largely unaddressed;
- reporting through the SOLEC process will continue to be incomplete; and
- the Great Lakes ecosystem will be continue to be vulnerable to current and future threats.

Reduced Resources from present levels

With reduced resources (personnel and/or funding) observations and monitoring would be reduced to basic elements (e.g., to support state regulatory or compliance activities only) or eliminated altogether (e.g., large research vessel operations for open water data collection). Further indicator development and refinement would be greatly curtailed or stopped. There would be heavier reliance on data collected for other purposes and more assumptions would need to be made to exploit available information. Priorities for data collection would likely shift from Great Lakes basin-wide assessments to more local areas (i.e., AOCs).

The consequences affecting resource management for the Great Lakes system under this scenario include:

- data would be even less accessible;
- management decisions would be based on even less complete information;
- management decisions would increasingly be based on faulty assumptions;
- there would be minimum efforts expended to evaluate the magnitude of continuing threats; and
- the Great Lakes ecosystem would be increasingly vulnerable to new threats.

Same Resources Available, with revisions to monitoring and reporting

Some efficiency may be achieved with better coordination of data collection activities and monitoring programs and integration with indicators. Better federal-state-local collaboration would strengthen availability of data. Information management, data sharing and data availability would need to be an important priority. Diversion of resources might result in fewer indicators being implemented, however. Those that are implemented would be based on better observational data and more robust monitoring programs.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- data would be more readily available;
- most ecosystem components would continue to be inadequately assessed;
- management decisions would continue to be based on incomplete information for most indicators;
- management decisions for some indicators would continue to be based on faulty assumptions;
- there would be no improvement in the ability to evaluate the magnitude of continuing threats; and
- the Great Lakes ecosystem would be as vulnerable to new threats in the future as in the present.

Enhanced Implementation, additional resources provided

A priority would be placed on improving applications of information technology, data sharing, and data availability. Federal, state and tribal monitoring programs would be better aligned to the needs for reporting the status of more indicators. Additional data collection would be established at currently unobserved or under-observed areas, including nearshore areas, tributaries and other watershed ecosystem components. Observation stations and networks in proximity to the AOCs would be densified and instrumented to provide more information content to improve monitoring programs for these locales.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- greater information integration would occur between federal, state and tribal stakeholders;
- information would be more readily available through a well designed information management strategy and decision support framework;
- management decisions would be more scientifically defensible due to more complete information;
- management decisions dealing with most indicators would be based on better assumptions; and
- there would be enhanced ability for prevention of new threats to the Great Lakes ecosystem.

Fully Funded and Implemented Indicator Suite

Implementation of a complete suite of Great Lakes indicators would provide the information that has been identified as necessary and sufficient to assess the status and trends of the Great Lakes ecosystem components. Particular attention would be focused on priority threats: contaminants (including nutrients, legacy and “emerging” chemicals), invasive species and habitat degradation. Indicator development would proceed in a focused and timely manner so all ecosystem components can be assessed.

Data collection activities would be fully coordinated across federal, state, local and tribal agencies, non-governmental organizations and other stakeholders. Monitoring program protocols would be fully coordinated and adhered to, and full quality assurance/quality control would be exercised for all observations and monitoring program. Metadata records, denoting the legacy, accuracy and appropriateness of use for all data would be in-place along with procedures to update these records as new information became available. Laboratory capacity would be increased to accommodate increased need for sample analysis. An integrated information management system would be developed to promote timely data discovery and access for a variety of stakeholders.

The consequences affecting resource management for the Great Lakes system under this scenario include:

- more agencies would be committed to be responsible for indicator monitoring, assessment and reporting;
- integrated information management would be substantially realized promoting enhanced data discovery and sharing;
- management interventions could be applied to mitigate existing threats to the Great Lakes ecosystem;
- new threats could be identified earlier and averted or mitigated; and
- there would be better assessments of ecological conditions on human health and well being.

Recommended Actions

Overarching Recommended Action

To meet the information and management needs of Great Lakes restoration activities, the Great Lakes Interagency Task Force should promote the continued development and implementation of science-based indicators, including implementation of indicators developed through the SOLEC process.

Rationale: Restoration of the Great Lakes ecosystem must begin by setting clear and quantifiable goals and desired endpoints for critical Great Lakes attributes. A set of measurable and meaningful indicators is essential for determining progress in meeting these goals and in helping decision-makers adapt their management actions in accordance with the ecosystems response. High-priority, management-relevant indicators must be identified, scientifically developed and tested for each critical restoration issue. Current indicators should be extended to include watershed issues and enhanced to draw in more stakeholder and scientific involvement. As an established and successful binational effort, the SOLEC process needs to receive increased financial support and stakeholder participation to accomplish the goals of comprehensive regional assessments.

The initial focus would be to validate selected SOLEC indicators and add additional indicators specific to the priorities of the GLRC strategy teams. A searchable online system would be developed to provide access to indicator descriptions, data, interpreted information, reports and summaries, maps and charts and related metrics of protection/restoration progress. The coordinating function of the SOLEC would be maintained but expanded to engage more stakeholder involvement. The focus of the SOLEC process would also need to be further broadened beyond water quality to include all priority issues affecting Great Lakes ecological protection and restoration.

Cost: $4 million for five years

Specific recommended actions imbedded in the overarching recommendation are described below.

Detailed Action 4: The SOLEC process should be adapted to meet the needs of an expanded set of indicators for the Great Lakes. Subgroups of experts, organized by topic area, should work together under the SOLEC framework to review existing indicators and develop, refine and test other indicators identified as priority issues.

Indicator subgroups would be composed of subject matter experts who represent all stakeholders across the region and would engage or include Canadian representation. They, in turn, could create individual

expert teams to define indicator needs for specific priority issues. The groups shall undertake, but not be limited to, the tasks of:

- screening potential indicators through an established set of criteria;
- identifying and clarifying the interconnections between and among the indicators, to provide a better "thread" linking environmental conditions, pressures on the environment, and human activities to mitigate the pressures;
- developing a detailed description of each indicator, including its purpose, metrics, features, limitations, etc.;
- testing the indicator; and
- developing protocols for monitoring and additional data collection.

Priority issues for individual indicators teams might include:

- invasive species;
- habitat;
- persistent toxic substances;
- species and wildlife health;
- AOCs;
- pathogens;
- sediments;
- nutrients / eutrophication;
- water resources;
- sustainability measures (including a *Genuine Progress Index* for the Great Lakes);
- human health; and
- commercial fisheries.

This recommendation would cost $8 million over five years, which is included in the cost for the overarching or strategic recommended action. The lead U.S. agency for this effort would be the USEPA-GLNPO and would involve a host of stakeholders, including U.S., Canadian and tribal interests.

Detailed Action 5: A relational database should be developed and maintained that contains information on: a) the attributes of each indicator, b) historic and new data resources and c) interpreted information provided by the indicator.

The database should allow the indicators to be sorted and filtered by a variety of criteria and/or key words, and various combinations of indicators could then be retrieved an analyzed as appropriate for the end user. This online system for indicator descriptions, data, and interpreted information must be developed and maintained. The system should be searchable and include indicator descriptions, indicator reports, indicator underlying data, indicator summaries and interpretations, flexible groupings of indicators for retrieval, and geo-referenced custom displays (e.g., maps, charts).

The cost to implement this recommendation would be $2 million over five years which is included in the cost for the overarching or strategic recommended action. The lead U.S. agency for this effort would be the USEPA-GLNPO. The development of this indicator relational database would involve key experts from the Great Lakes Data Infrastructure Working Group discussed elsewhere in this Appendix.

Detailed Action 6: A Great Lakes Indicators Grants Program should be created to provide funding support to partner agencies and organizations to implement the Great Lakes Indicator suite.

The grant program would provide funding to eligible recipients to:

- assume responsibility for the data collection, assessment and reporting of specific Great Lakes indicators;
- develop and adopt common protocols for monitoring programs to meet implementation requirements for the Great Lakes suite of indicators; and
- adopt the use of indicators in better decision-making and Great Lakes environmental management.

The cost to implement this recommendation would be $18 million over five years, which is included in the cost for the overarching or strategic recommended action. The lead U.S. agency for this effort would be the USEPA-GLNPO and would involve a host of stakeholders, including U.S. federal, state, local and tribal interests and NGOs.

Table 2: Crosswalk of Current SOLEC Indicators with GLRC Priority Issues.

SOLEC I.D. #	SOLEC Indicator Title	Toxic Substances	Sustainable Development	Coastal Health	Nonpoint Source	Habitat and Species	Areas of Concern	Aquatic Invasive Species
6	*Fish Habitat*					X	X	
8	Salmon and Trout		X			X		
9	Walleye		X			X		
17	Preyfish Populations		X			X	X	X
18	Sea Lamprey		X			X		
68	Native Freshwater Mussels					X		X
93	Lake Trout		X			X		
104	Benthos Diversity and Abundance				O	X	X	X
109	Phytoplankton Populations				X	X	X	X
111	Phosphorus Concentrations and Loadings		O		X	X	X	
114	Contaminants in Young-of-the-Year Spottail Shiners	X			X	X	X	
115	Contaminants in Colonial Nesting Waterbirds	X			X	X		
116	Zooplankon Populations				O	X	X	X
117	Atmospheric Deposition of Toxic Chemicals	X				X		
118	Toxic Chemical Concentrations in Offshore Waters	X			X	X		
119	Concentrations of Contaminants in Sediment Cores	X			X	X	X	
121	Contaminants in Whole Fish	X			X	X		
122	Hexagenia		O		X	X		
123	Abundances of the Benthic Amphipod *Diporeia*		O			X		
124	External Anomaly Prevalence Index for Nearshore Fish	X			O		X	
125	Status of Lake Sturgeon in the Great Lakes		O			X		
3514	Commercial/Industrial Eco-Efficiency		X					
3516	*Household Stormwater Recycling*							
4175	Drinking Water Quality		X	X				
4177	Biologic Markers of Human Exposure to Persistent Chemicals	X			X			
4179	*Geographic Patterns and Trends in Disease Incidence*			O	X			
4200	Beach Advisories, Postings and Closures		X	X	X		X	
4201	Contaminants in Sport Fish	X	X		X	X		
4202	Air Quality	O						
4501	Coastal Wetland Invertebrate Community Health				X	X		X
4502	Coastal Wetland Fish Community Health				X	X		X
4504	Coastal Wetland Amphibian Diversity and Abundance				X	X		
4506	Contaminants in Snapping Turtle Eggs	X			X	X		
4507	Wetland-Dependent Bird Diversity and Abundance				O	X		
4510	Coastal Wetland Area by Type		X			X		
4511	*Coastal Wetland Restored Area by Type*		X			X		
4516	*Sediment Flowing into Coastal Wetlands*		X		X	X		
4858	Climate Change: Ice Duration on the Great Lakes							
4860	*Phosphorus and Nitrogen Levels (Coastal Wetlands)*		X		X	X		
4861	Effects of Water Levels Fluctuations		X		X	X		
4862	Coastal Wetland Plant Community Health		O		X	X		

SOLEC I.D. #	SOLEC Indicator Title	Toxic Substances	Sustainable Development	Coastal Health	Nonpoint Source	Habitat and Species	Areas of Concern	Aquatic Invasive Species
4863	*Land Use Adjacent to Wetlands (Coastal Wetlands)*		X		X	X		
4864	*Human Impact Measures (Coastal Wetlands)*		X			X		
7000	Urban Density		X			X		
7002	Land Cover - Land Conversion		X		X	x		
7006	Brownfield Redevelopment	O	X					
7028	Sustainable Agriculture Practices		X		X	X		
7043	Economic Prosperity		X					
7054	*Ground Surface Hardening*		X		X	X		
7056	Water Withdrawal		X		X			
7057	Energy Consumption	O	X					
7060	Solid Waste Generation	O						
7061	Nutrient Management Plans		X	O	X	X		
7062	Integrated Pest Management	O	X		X	X		
7064	*Vehicle Use*	O	X					
7100	Natural Groundwater Quality and Human-Induced Changes		X		X	X		
7101	Groundwater and Land: Use and Intensity		X		X	X		
7102	Base Flow Due to Groundwater Discharge		X		X	X		
7103	Groundwater Dependant Plant and Animal Communities		O			X		
8114	*Habitat Fragmentation*		X			X		
8129	Area, Quality, and Protection of Special Lakeshore Communities - Alvars		O			X		
8129	Area, Quality, and Protection of Special Lakeshore Communities - Cobble Beaches		X			X		
8129	*Area, Quality, and Protection of Special Lakeshore Communities - Islands*		X			X		
8129	*Area, Quality, and Protection of Special Lakeshore Communities - Sand dunes*		X	O		X		
8131	Extent of Hardened Shoreline		X		X	X		
8132	*Nearshore Land Use*		X		X	X		
8135	Contaminants Affecting Productivity of Bald Eagles	X	X		X	X		
8136	*Extent and Quality of Nearshore Natural Land Cover*		X		X	X		
8137	*Nearshore Species Diversity and Stability*		O			X		
8142	*Sediment Available for Coastal Nourishment*	O	X		X	X		
8146	*Artificial Coastal Structures*		X		X	X		
8147	Contaminants Affecting the American Otter	X			X			
8149	*Protected Nearshore Areas*		X			X		
8150	*Breeding Bird Diversity and Abundance*	O	X			X		
8161	*Threatened Species*					X		X
8162	*Health of Terrestrial Plant Communities*					X		
8163	*Status and Protection of Special Places and Species*		X			X		
8500	Forest Lands - Conservation of Biological Diversity		X		X	X		
8501	*Maintenance and Productive Capacity of Forest Ecosystems*		X			X		
8502	*Maintenance of Forest Ecosystem Health and Vitality*		X			X		
8503	*Forest Lands-Conservation & Maintenance of Soil &*		X		X	X		

SOLEC I.D. #	SOLEC Indicator Title	Toxic Substances	Sustainable Development	Coastal Health	Nonpoint Source	Habitat and Species	Areas of Concern	Aquatic Invasive Species
	Water Resources							
9000	Acid Rain		X			X		
9002	Non-Native Species (Aquatic)		X			X		X
9002	*Non-Native Species (Terrestrial)*		X			X		
9003	*Climate Change: Effect on Crop Heat Units*							
Proposed New Indicators for "Well Being"								
	Value of the Great Lakes to Basin Residents		X					
	Sense of Place: Indian Tribes Around the Great Lakes Basin		X			X		
	National Park Visitation					X		
	Capacity of Federal Program for Great Lakes Priorities							
	Public Recreational Access to the Great Lakes					X		
	Access to Information about the Great Lakes			O		X		
	Research/Educational Opportunities			O		X		
	Population and Income Distribution		X					

Italics denote no indicator report available; 'X' denotes a direct relationship, 'O' denotes indirect relationship
Table reflects the current SOLEC suite as of September, 2005.

Table 3: Indicator Needs and Recommended Actions for GLRC Priority Issues

Aquatic Invasive Species

- To support indicators, USGS, USFWS, NOAA and the Smithsonian Environmental Research Center should cooperatively lead the creation and maintenance of an accessible, integrated, and centralized database that allows for the reporting and tracking of AIS infestations. These databases should include: a catalog of non-native, non-naturalized organisms currently or potentially in trade; a list of species proposed for importation and/or interstate commerce; a list of species which are being screened; a documentation of trends and practices in commerce, trade and cultural activities; and information on criminal activity. Where appropriate (except for criminal activity) information in the database should be made available to the public.

Areas of Concern

- Develop scientifically justified, measurable delisting targets for all beneficial use impairments (BUIs) in all U.S. AOCs that address AOC-specific conditions and are consistent with federal, state, local and tribal regulations and policies. (Note: It is not clear the extent to which existing state and local indicators are sufficient for setting delisting targets or whether improvements to existing indicators or new indicators are needed. The extent of this problem will vary from AOC to AOC. The most difficult targets to identify are those related to habitat and wildlife BUIs).

- Federal, state, local and tribal partners should collaboratively develop local or statewide (as applicable) delisting targets for all U.S. AOCs by the end of 2008 in accordance with the *Delisting Principles and Guidelines* adopted by the US Policy Committee in December 2001. Congress should provide funds to Great Lakes States, community-based coordinating councils, and EPA's Great Lakes National Program Office to enable more rapid development of delisting targets and related activities.

- Develop AOC indicators, including the number of AOCs delisted/restored) and the number/proportion of known contaminated sediment sites in the Great Lakes that have been remediated.

Coastal Health

- Establish and continually assess indicators (particularly *real-time* indicators) for pollutants entering and/or in near-shore waters, including: bacterial and chemical contamination; biological oxygen demand (BOD); algal and bacterial indicator organisms; phosphorus, nitrogen, and other nutrients; viral contaminants; and inadequately treated sewage
- Establish indicators for beach contamination, e.g., bacterial, algal, and chemical contamination (see indicators above) (e.g., whether beaches have "good" water quality, the number of contamination events per bathing season, etc.).
- Establish indicators for risk/safety of Great Lakes fish consumption.
- Establish indicators for drinking water quality (e.g., chronic and episodic threats of biological and chemical contamination; ambient water quality criteria for parasites, pathogens, and disinfectant by-product precursors, etc.).
- Establish indicators for drinking water and wastewater treatment infrastructure (e.g., indicators for aging system deficiencies and success of security measures for vulnerable resources/facilities, etc.).
- Establish indicators for health communications (e.g., whether information crucial to Great Lakes coastal health is "consistently visible" in media, brochures, signs, education curricula; changes in the knowledge level of coastal decision-makers and the general public, etc.).
- Establish indicators for coastal health response actions and implementation measures (e.g., whether the Safe Drinking Water Act amendments are adopted, storm water control plans are in place, wastewater discharge permits are updated, etc.).
- Develop alternative indicators for human health risk at beaches, as identified by epidemiological studies (Current bacterial indicators, such as *E. coli*, may not provide the most accurate indication of risk).

Habitat and Species

- Develop indicators to address: amount of habitat protected/restored (Open water, nearshore, wetland, riparian and coastal); species numbers and/or population diversity in response to habitat changes; increase in acreage of priority areas; population levels and trends; reproductive success, harvest and productivity; and miles of stream restored.
- To address indicator needs for open water and near-shore habitats:
  - Evaluate lake trout restoration efforts by tracking increase in the number of lake trout stocked
  - Evaluate efforts to re-establish native lake sturgeon and corgonines in those areas of the Great Lakes from which they have been extirpated
  - Assess fish stocking and management results for important Great Lakes fishes such as yellow perch, lake whitefish, lake trout, and walleye stocks
  - Assess recruitment of lake trout and other important native species.
- To address indicator needs for wetland habitats:
  - Measure acquisition and protection of wetlands and uplands as nesting habitats to implement portions of the North American Waterfowl Plan
  - Determine number and trends of breeding pairs of waterfowl
  - Assess self-sustaining non-endangered population levels for all currently listed wetland wildlife species, as determined by the state Departments of Natural Resources
- To address indicator needs for riparian habitats:
  - Assess restoration of tributaries in each Great Lakes state
  - Assess restoration efforts for coaster brook trout and lake sturgeon in Great Lakes tributaries
- To address indicator needs for coastal shore and upland habitats:
  - Assess protection and restoration of coastal and upland habitats across the basin
  - Inventory and assess Great Lakes coastal habitats and prioritize them for protection and restoration
  - Assess and monitor Areas of Concern in coastal shore areas

Non-point Source Pollution

- Establish, evaluate and report on indicators regarding:
  - Acres of wetlands added (number and percent increase)
  - Acres of buffer areas added (number and percent increase)
  - Decreased soil erosion or loss (amount and percent decrease)
  - Animal feed operation owners and operators who complete comprehensive nutrient management plans (number and percent)
  - Priority watersheds in regime that monitor flow delivery, sediment reduction, and habitat protection at sustainable levels (number of watersheds which monitor the measures and develop sustainable levels)
  - Beaches with complete Total Maximum Daily Loads (TMDLs) for priority pollutants (percent and number)
  - Animal feed operation owners using nutrient and phosphorous management plans (percent)
  - Distribution and presence of hormones, antibiotics, pesticides, PBTs, soil erosion, etc.
  - Contaminant levels and other measures required by the BEACH Act (for beaches only)
  - Mercury emissions from power plants within specified region (e.g., percent reduction within 150 miles)
  - Closures per year of bathing beaches in the Great Lakes system (number and percent change)

Sustainable Development

- Establish a common metric to assess the value of ecosystem services
- Develop indicators and metrics for sustainability and a corresponding database to track and evaluate sustainability trends and progress toward goals
- Topics for sustainability indicators could include:
  - land use and development (e.g., density of development, brownfields redevelopment)
  - agriculture (e.g., farmland loss, use of conservation tillage practices)
  - forestry (e.g., size & fragmentation of forests)
  - transportation (e.g., vehicle miles traveled, urban congestion, air pollutant emissions)
  - industrial activities (e.g., adoption of pollution prevention programs and environmental management systems, recycling rates)
  - water infrastructure (capacity to meet demand)
  - recreation and tourism (e.g., economic benefits, trail and greenway development)
  - fisheries (e.g., economic benefit, fish stocks)
  - a "genuine progress index" for the Great Lakes

Toxic Pollutants

- Continue and expand usage of the SOLEC process as a regional forum for developing additional toxic pollutant indicators, assessing indicators and reporting.
- Develop toxic pollutant indicators for emissions/releases and additional environmental compartments.
- Expand current indicators to include additional chemicals of concern.

Research

Problem Statement

Research on the Great Lakes provides the understanding necessary to:

- make well informed, scientifically-supportable decisions and actions;
- assess the associated risks, expectations and timelines of management actions;
- plan for effective observation and monitoring programs; and
- identify sensitive and meaningful indicators of ecosystem status.

Research is the fundamental underpinning of all other components of a sound decision-support strategy. However, the current level of funding for Great Lakes research does not sufficiently support the amount of research and development needed to address the host of issues affecting the system (U.S. Commission on Ocean Policy 2004). In fact, the federal government has actually *decreased* the relative amount of spending for research on oceans, coasts and the Great Lakes by half over the last 20 years (U.S. Commission on Ocean Policy 2004); a period of time that has seen an increasing number of threats to these systems and greater need for effective, scientifically-based management actions. Past investments in research have had 'national security payoffs. . . [and] made significant contributions to the nation's overall well-being and have been a major force in the education and preparation of an internationally superior, multi-disciplinary workforce' (U.S. Commission on Ocean Policy 2004). Investments made during the 20th century made the United States the world leader in oceanographic sciences, a position that can not be maintained if funding levels remain stagnant or decrease further. The effects of decreases in research funding are particularly acute in the Great Lakes where most agencies have seen level funding (at best) for the last ten years, despite a consistent increase in the number of Congressional mandates and the number of threats to the long-term health of the Lakes and the communities that surround them (Great Lakes Commission 2005). The current funding situation is such that federal agencies are not able to accomplish all of research activities they are currently tasked with carrying out, much less all of the research that actually needs to be conducted.

In addition to lack of adequate funding, research on the Great Lakes is not fully coordinated throughout the Basin as a whole. Research in the Great Lakes is typically focused on specific locations, lakes, or issues (Lake Erie Millennium Network 2001; Johnson 2003; Council of Great Lakes Research Managers 2004; Eadie et al. 2004; SeaGrant 2004; U.S. Commission on Ocean Policy 2004; GLASS 2005; Great Lakes Fishery Commission 2005; Great Lakes Research Consortium 2005). Although research in these localized areas can be well-coordinated, no Great Lakes Basin-wide strategy has been formally adopted to coordinate all research efforts throughout the entire Basin. Currently, research is conducted by a variety of organizations representing federal, tribal, state, and local governments, colleges and universities, and the private and non-governmental sectors all of which are forced to compete for limited funding. The lack of an accepted, coordinated, region-wide strategy with adequate funding limits research efforts from achieving their maximum societal, ecological and resource management benefits.

The Governor's priority issues described in this strategy document are complex, interrelated phenomena that link the physical, chemical and biological aspects of the lakes directly with human society. The Great Lakes community can no longer be satisfied with single issue research. These complexities need to be acknowledged and an ecosystem approach needs to be adopted to management of the Great Lakes. Therefore, Great Lakes research must also refocus to an ecosystem approach with greater emphasis on predictive forecasting and adaptive management. Improvements in predictive capabilities are needed, particularly regarding the impacts of chemical, biological and physical changes on ecosystem structure and function. In doing so, the community will face the challenges of ecological complexity, data

management and definition of the useful scales of forecasts and forcing functions. However, improved observations within the system, enhanced monitoring programs, and new multidisciplinary approaches to research will spur advances in adaptive management (U.S. Commission on Ocean Policy 2004).

To develop forecasting capabilities research will also need to be re-focused at prediction rather than explanation. A variety of predictive models is currently available and many more continue to be developed. Some types of ecosystem predictions may be made with statistical analyses. Other predictions will require research-enhanced quantitative ecosystem understanding, particularly relative to biological-physical-chemical interactions on a lake-wide basis and over a range of time and space scales. Process-level ecological models and novel forecasting methodologies will need to be developed using focused research, published data, and data from integrated observing systems. In order to develop ecosystem predictions for the Great Lakes, research scientists, coastal users, and management decision-makers must work together to identify and focus the types of predictions required, as well as, the time and space scales of interest. Ecosystem forecasts could help to improve decision-making for coastal stewardship, mitigate the impacts of natural events and human activities, reduce impacts of natural hazards, enhance communication between scientists and mangers, and provide more effective science direction and cross-disciplinary integration (NOAA 2005b). In the Great Lakes, predictions of wind, waves, ice cover, water levels, surface temperatures, currents, and marine meteorology are already made. Predictions of the impacts of extreme natural events, societal pressures, and climate variability on ecosystem processes need to be part of the next generation of lake management tools (NOAA 2005b). Building the ability to predict the cumulative effects of multiple stressors is, however, one of ecology's most significant challenges.

The Great Lakes community is well poised to take leadership in developing ecosystem predictions for coastal environments. Existing data, methods, models, and understanding are sufficient for "first generation" predictions for a limited number of important ecological issues but perhaps only with relatively wide confidence limits. These efforts would be significantly enhanced with the implementation of a generally-accepted, coordinated, region-wide research strategy accompanied by adequate funding to carry out its vision.

Desired State

We share the vision and desired state of the U.S. Ocean Policy Committee regarding the state of research for the 21st century and beyond. We too:

> "envision a time when the importance of reliable data and sound science is widely recognized and strong support is provided for physical, biological, social, and economic research, as well as ocean [and Great Lake] exploration. The nation invests in the needed scientific tools and technologies, including ample, well-equipped surface and underwater research vessels, reliable, sustained satellites, state-of-the-art computing facilities, and innovative sensors that can withstand harsh [underwater] conditions. A widespread network of observing and monitoring stations provides a steady stream of data, and scientific findings are translated into practical information and products for decision makers, vessel operators, educators, and the public. In this hoped-for future, better education is a cornerstone of national ocean policy, with the United States once again joining the top ranks in math, science, and technology achievement" (U.S. Commission on Ocean Policy 2004).

The Great Lakes research and resource management community requires a better understanding of the mechanisms underlying ecosystem changes. This will increase the ability of resource managers to make timely, well-informed decisions affecting not only human health but the ecosystem at large. Great Lakes research programs must, therefore, be fully funded, comprehensive and strategically coordinated to meet

user needs. To ensure that research is targeted at ecosystem level predictions, an effective research coordination strategy must also be developed and implemented. This research strategy will pro-actively guide research while remaining flexible enough to accommodate new needs and emerging issues. A Great Lakes research strategy would:

- provide a central forum for research funding priorities and opportunities including:
    - promote technical workshops on issues of concern for identifying research needs throughout the research and management communities;
    - establish Science Advisory Groups to address management and research issues;
    - promote effective collaboration of researchers to address questions at relevant scales;
- deploy scientific expertise, facilities, and funding in collaborations that optimize the use of resources and lead to highest quality products and science-based outcomes that are forward-looking and ecosystem-focused;
- promote holistic ecosystem approaches to solving Great Lakes issues;
- promote mechanisms to identify ecosystem changes, indicate trends, prioritize gaps in scientific information and research needs and report annually to the Great Lakes management and research funding community;
- address the nine priorities identified by the Great Lakes governors for the region (CGLG 2003);
- maintain an inventory of research programs and projects;
- allow for all categories of research to be addressed in an efficient, effective, and flexible manner; and
- recognize the significance of monitoring and observations in identifying ecosystem concerns and the role applied and basic research plays in solving immediate problems.

An additional component to an effective research strategy is communication among researchers. Research needs and information gaps must be synthesized from the knowledge and experience of the Great Lakes management and research community, in venues where people know they can bring an idea to the entire Great Lakes community. Research coordination forums might be events held at the International Association of Great Lakes Research (IAGLR) annual conference, technical meetings by organizations such as the GLFC, special workshops or cyber seminars.

Existing Federal Research Efforts[1]

The challenges facing the Great Lakes community are complex and interrelated. Addressing all of the multiple challenges discussed in this Strategy requires a strong, well-focused research program. Scientifically supported management decisions based on fundamental ecosystem understanding and reliable facts about human health and the environment are the key to success. New research technologies must be developed to identify and assess environmental stressors. New remedial technologies must be developed to help restore and sustain the natural resources of the Ecosystem. The Great Lakes community is fortunate to have numerous federal, Tribal, state, provincial, and university research organizations that are poised to fulfill these scientific needs.

The International Joint Commission's Council of Great Lakes Research Managers (CGLRM) has a responsibility to identify binational research priorities and emerging issues relative to the Great Lakes Water Quality Agreement. In addition, the Council produces an annual Great Lakes Research Inventory. The information produced by the Council can be used to identify the scientific knowledge gaps that limit

[1] Text from this section was taken directly from the U.S. Policy Committee for the Great Lakes. 2002. Great Lakes Strategy 2002 a Plan for the New Millenium: A Strategic Plan for the Great Lakes Ecosystem, 44 pp., U.S. Policy Committee for the Great Lakes.

the ability of Great Lakes managers to meet specific goals of the GLWQA. The research priorities and Research Inventory can assist federal, Tribal, state, provincial, academic institutions, and funding organizations in developing research objectives for the Great Lakes.

Most agencies conduct or fund research that addresses their mission-specific priorities. Through communication and collaboration, information is developed that provides the science-based decision-making framework for the management goals and key objectives throughout this strategic plan. Examples of several agency research programs follow:

A broad research foundation is necessary for understanding the ecosystems that support the Great Lakes. NOAA has a very broad and multidisciplinary scientific mission in the Great Lakes. NOAA, through the Great Lakes Environmental Research Laboratory and through the Sea Grant Research and Extension Program conducts research and monitoring that provides the fundamental understanding necessary to model and predict the structure and function of aquatic environments and to identify and integrate information to improve the scientific basis for decision-making. GLERL houses a unique combination of scientific expertise in ecosystem modeling and food webs, biogeochemistry, invasive species, physical limnology, fish ecology, climate, contaminant cycling, and water resources. New tools, approaches, and models use the new knowledge and the growth of understanding obtained to advance assessment and prediction. Improved models are able to better predict ecosystem behavior, and hence offer better guidance to resource managers and decision makers. NOAA research partnerships with academia, with other federal agencies, and with the private sector are critical components in an overall strategy to provide our Nation's leaders with the knowledge and application-oriented findings and recommendations they need to make informed decisions.

The U.S. Geological Survey (USGS) is a science and information agency that plays an important role in providing sound information on the environmental and natural resources to management and regulatory agencies. In the Great Lakes region, the USGS Great Lakes Science Center in Ann Arbor, MI (and its eight field stations and fisheries research vessels on each lake) and the USGS water resources offices in each of the eight Great Lakes States are the most well known units of the USGS. The Great Lakes Science Center conducts annual fish stock assessments, fishery research, coastal and wetlands ecology, terrestrial ecology with emphasis on Federal public lands, and non-indigenous species research. The water resources offices conduct tributary monitoring programs and a wide spectrum of surface and groundwater research. Recently, the USGS embarked upon a strategic change initiative and is promoting integrated scientific investigations that take advantage of its expertise in biology, geology, mapping, and water disciplines and to enhance its partnerships with other organizations in order to better address the resource issues nationwide and specifically in the Great Lakes region.

The USEPA Office of Research and Development, in partnership with Program and Regional Offices, has established research strategies that address national needs to advance monitoring designs for assessing the ecological condition of aquatic resources, develop techniques to identify causes of impairments, establish nutrient, habitat and toxics criteria, model and forecast future conditions to support risk-based remediation and restoration options, and develop knowledge and understanding of toxic pathways in aquatic life for predicting effects of chemicals. Consistent with development and implementation of these strategies, USEPA's research effort in the Great Lakes Basin parallels the national effort. The USEPA Mid-Continent Ecology Division in Duluth, MN and Grosse Ile, MI, is responsible for coordinating and undertaking ORD's assessment and effects-based research in the Great Lakes Basin. This Division is leading efforts in predictive toxicology and in developing assessment approaches, including efficient monitoring designs and diagnostic indicators for large ecosystems, such as the Great Lakes and Great Rivers. The US EPA’s Great Lakes National Program Office supports strategic research needs through partnerships with organizations within the Great Lakes Basin. The Great Lakes Program Office supports

significant water quality monitoring programs of Great Lakes open waters and supports strategic remediation of areas of concern through the Legacy Act.

Assessment of Ongoing Coordination Efforts

A variety of means currently exist within the Great Lakes to coordinate research but they typically under-funded and focused on a particular theme, resource, or issue concerning a specific region or lake and not the basin or ecosystem as a whole. A brief description and assessment of several collaboration/coordination efforts are provided below.

Thematic Research

- The IAGLR holds a conference every year with specific symposia and technical sessions and publishes the peer-reviewed journal, *Journal of Great Lakes Research*. IAGLR is an excellent forum for the exchange of ideas and information concerning the Great Lakes and other large bodies of freshwater around the world. Conferences and workshops also provide opportunities to build personal relationships between researchers.

- The (SOLEC) is another biennial forum for reporting on the status of each lake and various elements of ecosystem indicators. Research presented focuses on the development of indicators to measure the health of the lake ecosystem. More information on SOLEC, its strengths and weaknesses is provided in the *Indicators* portion of this Appendix.

- The National Oceanographic Partnership Program (NOPP) is made up of 15 Federal agencies that have 'oceans' in their Charter or have some sort of ocean-related mission. It helps to organize and direct research through cooperative funding between agencies and other non-federal organizations (National Oceanographic Partnership Program 2005). The new draft NOPP strategic plan contains five goals: implement the integrated observing system; increase student and public awareness, knowledge and understanding of the oceans; modernize the oceanographic infrastructure; collaborate to strengthen interagency initiatives in research and their connections to operations; and remove obstacles to partnering. The Great Lakes are not currently well represented in the NOPP, even though the Great Lakes research community has much in common with the larger oceanographic research community (Council of Great Lakes Research Managers 2004). Funds are available and could be pursued for research on the Great Lakes but the NOPP itself does not provide a mechanism through which Great Lakes specific issues can be addressed in total.

- In 2002, the NSF funded a workshop to define the current research needs and develop an implementation plan that was realistic in scope and would insure the establishment of a healthy, productive and sustained research program on large lakes of the world. The Science of Freshwater Inland Seas (SOFIS) workshop brought together a broad spectrum of researchers to share their knowledge and accomplishments in areas of circulation dynamics, the chemistry and biology of large lakes systems, and geological limnology (Johnson 2003). Similar to the NOPP program, the NSF may be petitioned as a source of funding to carry out research projects, however, the SOFIS network deals with a much larger topic than just the Great Lakes. Although it provides an excellent means for researchers to learn from one another, it does not provide a mechanism to strategically coordinate research within the Great Lakes.

Resource Specific Research

- The Great Lakes Fishery Commission (GLFC) encourages and financially supports research on the Great Lakes fishery and the sea lamprey (Great Lakes Fishery Commission 2005). The GLFC brings together researchers from universities, private consulting firms, federal, provincial, and state agencies, as well as commission staff to conduct research and communicate findings for the commission. It holds technical workshops on the state of fisheries science for each Great Lake. The GLFC fishery program is organized around three themes: exotic invertebrates and food-web disruption, reintroduction of native fishes to the Great Lakes, and human dimensions. The theme areas for the sea lamprey program are: assessment, pheromones, trapping, barriers, sterile males, and lampricides' mode of toxic action. Important research areas all, but focused very narrowly on specific issues.

Region or Lake Specific Research

- The Lake Erie Millennium Network is a series of events that focus on the environmental issues of Lake Erie (Lake Erie Millennium Network 2001). The objectives of the Network are:
    - to summarize the current status of Lake Erie;
    - to collectively document the research and management needs of users and agencies; and
    - to develop a framework for a binational research network to ensure coordinated collection and dissemination of data that will address research and management needs.

  To these ends, the Network has been successful in bringing federal, provincial, state, university and other organizations together to prioritize and execute research for Lake Erie. The Network could be used as an example of how to coordinate research for the other Great Lakes as well.

- The USEPA LaMP program is a plan of action to assess, restore, protect and monitor the ecosystem health of each Great Lake. Each LaMP has a technical committee that coordinates monitoring efforts and identifies data needs of all the government, tribal, and non-government partners working to improve the Lake ecosystem. A public consultation process is also used to ensure that the LaMP is addressing the public's concerns (U.S. EPA 2005). Each LaMP also has a RAP to deal with specific Areas of Concern within the lake. However, since each LaMP is written to address the needs of a specific lake, the ecosystem (or basin) as a whole is not addressed.

- The New York Great Lakes Research Consortium (GLRC) coordinates resources and research facilities within the state of New York. Its focus, however, is strictly on lakes Ontario and Erie and the inland lakes within New York State (Great Lakes Research Consortium 2005).

Basin-wide Research Coordination

- The Council of Great Lakes Research Managers (CGLRM) was created by the IJC in 1984 to serve as the principal advisor on research programs and needs (Council of Great Lakes Research Managers 2004). The CGLRM is charged with:
    - promoting effective communication and collaboration between researchers and agencies in Canada and the United States;
    - encouraging researchers to share their findings;
    - compiling a summary of current and planned research programs related to the GLWQA (Annex 17 – Research and Development);
    - identifying and prioritizing research needs to identify gaps;
    - encouraging the U. S. and Canadian governments, Parties to the Agreement, to shift funding toward studies relevant to the GLWQA's purpose;

- creating an inventory of research programs (http://ri.ijc.org/); and
- drafting recommendations to better coordinate research on the Great Lakes.

The CGLRM, as the research coordination arm of the IJC, provides the venue where research needs and information gaps can be communicated to all research entities within the Great Lakes basin, including agencies and organizations that fund research. Research issues before the CGLRM focus on themes that are necessary to support managers and policy makers in fulfilling the various statutes and agreements that protect and restore the Great Lakes.

The CGLRM and its members can promote research networks and cooperation and synergy among the research institutions addressing Great Lakes issues. The CGLRM can bring the most pressing research needs before funding organizations to seek basin-wide support in solving problems. The CGLRM and its members work with established forums, such as the BEC, LaMPs, RAPs, SOLEC, IAGLR, GLFC, Great Lakes Indian Fish and Wildlife Commission (GLIFWC), to encourage collaboration on holistic ecosystem approaches to problems and encourage collection of quality data at relevant scales. The CGLRM can sponsor basin-wide forums to address emerging issues, such as impacts of new invasive species or specific families of chemicals.

Although the IJC and the CGLRM are well positioned and staffed to perform research coordination for the Great Lakes, recent reductions in funding levels to many U.S. federal agencies have weakened their abilities to participate as fully as necessary to insure long-term success. In addition, some of the priority issues being addressed within the GLRC go beyond the realm of the GLWQA.

- The Great Lakes Research Office (GLRO) was established by Title 33 United States Code 1268. The GLRO was placed within the NOAA and to be housed within a Great Lakes state. NOAA placed the GLRO with GLERL. The GLRO is tasked with the following responsibilities:

  - Identification of Issues – The GLRO shall identify issues relating to the Great Lakes resources on which research is needed. The GLRO shall submit a report to Congress on such issues before the end of each fiscal year which shall identify any changes in the Great Lakes System with respect to such issues.
  - Inventory – The GLRO shall identify and inventory Federal, State, university, and tribal environmental research programs (and, to the extent feasible, those of private organizations and other nations) relating to the Great Lakes system, and shall update that inventory every four years.
  - Research Exchange – The GLRO shall establish a Great Lakes research exchange for the purpose of facilitating the rapid identification, acquisition, retrieval, dissemination, and use of information concerning research projects which are ongoing or completed and which affect the Great Lakes System.
  - Research Program – The GLRO shall develop, in cooperation with the Coordination Office (USEPA GLNPO), a comprehensive environmental research program and data base for the Great Lakes system. The data base shall include, but not be limited to, data relating to water quality, fisheries, and biota.
  - Monitoring – The GLRO shall conduct, through the NOAA-GLERL, the National Sea Grant College program, other Federal laboratories, and the private sector, appropriate research and monitoring activities which address priority issues and current needs relating to the Great Lakes.

  Although the formation and operation of the GLRO has been authorized by Congress, no funds have been appropriated so far to implement this activity.

Research Needs: Ecosystem Approach[2]

Research is the cornerstone on which to build and improve environmental forecasts that enable ecosystem-based management and provide critical information for decision makers and the public. Continuous research is required to improve information products obtained with observation and monitoring systems, to design new products, and to develop the technology for better observation and monitoring systems in the future. Research is needed to explore integration opportunities across observing systems and data sets to provide better products for the operational community (for example, new forecast models using both satellite and ground-based GPS data) and for researchers (for example, long-time series data sets for climate change research).

Ecosystem-based management involves environmental conservation, protection, and management approaches that are used in the decision making process. The principal aim is to have a balanced cycle of harvest and renewal of natural resources by reducing the current potential conflicts between the natural resources and the users of these resources through improved ecosystem understanding. An ecosystem approach to management requires that the formulation and implementation of management measures recognize the existence of significant social-economic, chemical, biological, geological, and ecological relationships both within and among species, habitats, and the physical environment. An enhanced understanding of ecosystems by establishing the necessary knowledge, tools, and capabilities is needed to accelerate the nation's transition to ecosystem approaches to planning and management. As such, ecosystem-level research needs to overall:

- promote technological development and knowledge used to advance research and observing system capability, solve conservation problems, explore undiscovered habitats and systems, and create new opportunities for economic growth without compromising sustainability;
- investigate sources, fates, and effects of anthropogenic influences, including contaminants (e.g., inorganic and organic chemicals) and thermal changes;
- conduct interdisciplinary research to better understand marine biological, chemical, and physical processes and their implications for human health;
- forecast and assess temporal scales of ecosystem variability, including impacts of physical processes that affect biodiversity, trophic, multi-species interactions, distribution, and ecosystem production dynamics;
- create biophysical coupled models of water mass movements and their effects on biological productivity including fisheries recruitment and population distribution;
- study aquatic biodiversity and how anthropogenic stresses, extreme environmental events, and climate influence population dynamics of coastal and marine ecosystems;
- understand the dynamics of social and economic systems and their relation to ecosystem management. Develop methodologies and "tools" for estimating non-monetary ecosystem value that can be translated into decision support tools for stewardship of coastal and marine ecosystems;
- define the time and space scales needed to capture the fundamental physical and biological drivers that are required for ecosystem forecasts and natural resource assessments;
- measure the natural scales of variability regarding physical-biological coupling, food web dynamics and ecosystem production in selected ecosystems;
- define observational needs to assess the impact of management decisions on fisheries and coastal and Great Lakes resources and habitat quality;

[2] Information in this and the follow section was largely taken from NOAA. 2005a. Research in NOAA: Toward Understanding and Predicting Earth's Environment A Five-Year Plan: Fiscal Years 2005 - 2009, 60 pp. Final Report Pre-publication Copy, National Oceanic and Atmospheric Administration, Silver Spring, MD.

- develop and test new chemical and biological sensors for coastal and Great Lakes observing systems; and
- develop parameters and indices of eutrophication, water quality, HABs, and contaminants (including pharmaceuticals and steroids) in coastal and marine ecosystems; provide trends in contaminant concentrations; and identify new anthropogenic contaminants.

Research Needs: Ecological Forecasting

Forecasting is a standard tool in meteorology but is comparatively new to the aquatic sciences. Ecosystem forecasting predicts the effects that biological, chemical, physical, and human-induced changes—extreme natural events, climate change, land and resource use, pollution, invasive species, fisheries impacts, coral bleaching, and interactive effects—have on ecosystems and their components. An understanding of physical-biological-chemical coupling and the various space and time scales is needed to predict such factors as fish recruitment and productivity, HABs, beach closings, and water quality.

Forecasts and interpretative tools that use a scientific basis to assess the results of management and science policy actions are also needed. These types of forecasts and assessments act as a feedback loop to monitor the effectiveness of the decision-making process. Forecasting capacity will be extended to include the potential impacts of management intervention on social and economic systems associated with ecosystems, and the potential implications for altering the way people interact with the ecosystem. These activities will lead to better understanding of the impacts of potential environmental threats and understanding the implications of the decision making process. Therefore, researchers and resource managers interested in using ecological forecasting need to:

- develop forecasts for the ecological effects of varying weather patterns and extreme physical events;
- define the primary forcing factors and time and space scales that cause HABs and anoxia for Great Lakes regions;
- define the primary forcing factors and time and space scales that affect water quality and quantity for Great Lakes regions;
- define the primary forcing factors and time and space scales that affect fish recruitment and fisheries production for Great Lakes regions;
- develop methodologies and tools for estimating non-monetary ecosystem value that can be translated into decision support tools for stewardship of ecosystems;
- study aquatic biodiversity and how anthropogenic stresses, extreme environmental events, and climate influence population dynamics of ecosystems;
- advance data assimilation techniques; satellite, radar, ocean, hydrologic, and land surface assimilation;
- describe the water resource allocation and socio-economic impact; and
- describe the effect of the climate phenomena on the hydrologic cycle.

Overall Assessment

Although a variety of research coordinating bodies exist at regional scales or on specific themes, no single agency or entity in the Great Lakes Basin has the ability and/or authority to fully fund, direct, guide, and coordinate research on the Great Lakes in a comprehensive manner. Most current research programs are focused on specific issues or lakes and do not provide models that are readily applicable to the Basin as a whole. None of the current programs are able to set Basin-wide research priorities or manage resources in an effort to meet the research needs of adopting an ecosystem approach or guiding research toward ecological forecasting. In addition, existing programs are often forced to compete for limited research

dollars. The CGLRM can facilitate communication between the various stakeholders (particularly binational efforts) but it has no authority to set goals and enforce that they are carried out. The GLRO within NOAA currently has the Congressional mandate to identify research needs and coordinate efforts with other US entities but the funding authorized to carry out this task has not been appropriated.

Recommended Actions

Overarching Recommended Action

To support Great Lakes restoration activities with appropriate scientific foresight, planning and assurance of results, the overall federal research budget to the Great Lakes should be doubled over the next 5 years. In addition, adequate funds should be made available to support a Great Lakes Research Office as authorized in the 1987 Clean Water Act Amendments (33 U.S.C. 1268) to coordinate these research efforts. Finally, for all new appropriations in support of Great Lake's restoration activities, at least 10% of these funds should be dedicated toward research to aid planning and assessment.

Rationale: Great Lakes research provides the understanding necessary to make informed, scientifically supportable decisions and actions, to assess the associated risks, expectations and timelines of management actions, to plan effective monitoring and observation systems and to identify sensitive and meaningful indicators of ecosystem status. Current research programs do not offer sufficient support to address all research needs. In addition to explaining the current state of the lakes, research is needed to improve predictive capabilities regarding the lakes, particularly regarding the impacts of chemical, biological and physical changes on ecosystem structure and function. Research should be a fundamental and integral part of any restoration or management decision.

Additional research is required to: a) set management goals and expectations: b) assess risks in management alternatives; c) identify the most cost-effective restoration strategies; d) evaluate connectedness to other components of the ecosystem; and e) evaluate progress in achieving management goals and expectations. Research needs to be focused on improving predictive capabilities regarding the lakes, particularly regarding the impacts of chemical, biological and physical changes on ecosystem structure and function. Per the U.S. Commission on Ocean Policy, overall research funding should be doubled over the next five years to fix the observation that "chronic under-investment has also left much of [the region's] infrastructure in woefully poor condition." The Great Lakes Research Office (GLRO) would work in conjunction with existing institutional entities to coordinate a comprehensive research strategy with an emphasis on predictive ecosystem-based research organized to address existing and emerging ecological issues. Great Lakes research programs need to be funded in accordance with an established research strategy, emphasizing research integration in the decision making process. The GLRO would closely coordinate all activities with the IJC's Council of Great Lakes Research Managers. Research should also be a fundamental and integral part of a comprehensive Great Lakes restoration program. At least ten percent of the restoration funding should be devoted to the effort. To support independent and localized investigations, increased support of university-based Great Lakes science is needed through increased competitive grants for Great Lakes research through the National Science Foundation and other federal and state programs.

Cost: Overall doubling of current research funding (an annual increase of approximately $35 million within 5 years), plus 10% of any additional restoration efforts and $600,000 annually (or $3 million over 5 years) would be used to support the research office.

Detailed Action 7: The Council of Great Lakes Research Managers (CGLRM) should be adopted as the central hub for bi-national coordination of research and observations.

With members representing every research organization from Canada and the U.S. in the Great Lakes basin, the CGLRM can be an effective coordinating body to support managers and decision-makers in fulfilling the goals of the GLWQA and the GLRC. The CGLRM has the capacity to work with other organizations, such as the GLFC, LaMP and RAP committees, the BEC, and various federal, provincial, tribal, state, and local governments to collectively promote international research of highest priority for informing solutions to Great Lakes ecosystem problems. The GLRO would support staff positions and some of the coordination and prioritization work of the Council. Research should also be a fundamental and integral part of a comprehensive Great Lakes restoration program. The cost for this activity is included within the prior recommended actions.

Table 4: Research Needs and Recommended Actions for GLRC Priority Issues

Aquatic Invasive Species

- Expand the ship Ballast Water Technology Demonstration Program, and EPA's Environmental Technology Verification program to hasten development of effective shipboard treatment systems and develop alternatives to on-board treatment, such as (but not limited to) cargo transfer, shore-based treatment and use of Clean Water Act discharge permits.
- Investigate options for permanent hydrological separation of the Great Lakes and Mississippi River systems.
- Conduct research to develop, test and evaluate alternative barrier types and prevention approaches, including demonstration projects. Conduct economic analyses to compare cost-effectiveness of various alternative approaches.
- Initiate a federally funded granting process for dispersal barrier effectiveness monitoring, research and development (needs Congressional authorization and appropriation).
- Investigate means to convey storm and wastewater discharges via canals without spreading AIS.
- Investigate alternative means for cargo transportation between the Great Lakes and adjacent watersheds in the U.S. (needs Congressional authorization and appropriation).
- Develop and implement new control methods for species of concern. Develop and administer a grant program to fund research, development, demonstration, and verification of environmentally sound and cost-effective approaches to control and eradicate AIS.

Areas of Concern

- Develop environmentally friendly sediment treatment and destruction technologies, beneficial uses, and alternate disposal options. Examine innovative approaches and alternatives to the disposal of contaminated sediments in Confined Disposal Facilities (CDFs) or landfills.
- Fully fund the research and development program per Section 306 of the Great Lakes Legacy Act. This research should test and promote treatment technologies that allow for the separation, immobilization or destruction of contaminants in sediments, in-stream or upon removal, focusing on the development of technologies that neither produce new contaminants nor release contaminants to the environment.
- Conduct research to support development of delisting targets and/or to evaluation of progress toward delisting/restoring AOCs, particularly for fish tumors and wildlife-habitat issues.

Coastal Health

- Determine the annual discharges from the 147 Great Lakes combined sewer overflow (CSO) communities.
- Determine the number of sanitary sewer overflow (SSO) communities in the Great Lakes basin.
- Determine the number of plants that discharge partially treated sewage into the Great Lakes or tributaries in the most recent year.
- Determine the number of sewage-related water intake temporary closures and/or boil water alerts.
- Determine the number/volumes of industrial dischargers to sewage treatment plants.
- Research (and compile existing information on) heavy metals, industrial chemicals, and pharmaceuticals entering the Great Lakes from sewage treatment plants.
- Demonstrate cost savings from including soft path approaches in comprehensive plans to reduce wastewater overflows.
- Develop habitat modification techniques that reduce nuisance resident wildlife, such as gulls, which have an adverse impact on beach and other coastal areas.
- Research sources and transport of biological toxins (e.g., botulism) through the food web.
- Research the sources and relative input of chemical contaminants to the coastal environment.
- Develop, test and implement process-based and statistical forecasts for beach closures, drinking water intakes, rainfall, spatially explicit watershed hydrology models, hydrodynamics, toxic pollutants, harmful algal blooms, and water quality for recreations use of the Great Lakes.
- Determine the trigger mechanisms for beach closures and the factors that affect toxin production in algal blooms.
- Assess abilities of wastewater treatment to remove substances known (or suspected) to be of concern in wastewater treatment plant effluent and sewage sludge and develop new treatment technologies.
- Determine the frequency and type of fish consumed to improve consumption advisories for Great Lakes fish.
- Identify environmental sources capable of adversely impacting Great Lakes coastal health during dry weather (e.g., foreshore beach sands, avian/animal deposition, algal blooms, and submerged sediments) and the relative contributions of these sources.
- Develop alternative indicators for human health risk at beaches, as identified by epidemiological studies (Current bacterial indicators, such as *E. coli*, may not provide the most accurate indication of risk).

Habitat and Species

- Develop research programs and projects for sustaining native lake trout, lake sturgeon, *Diporeia*, native lake herring, deep water cisco, yellow perch, walleye, and lake whitefish, lake-run brook trout (coaster brook trout).
- Conduct research to identify and quantify the natural, physical and biological factors that affect fish recruitment and production in the Great Lakes and develop coupled Bio-physical models to forecast fish recruitment for all important Great Lakes fish species.
- Research the physical and chemical factors that affect fish recruitment and production.
- Research the impacts of large scale-inter-annual variations in climate, lake temperatures on anoxia on fish growth and production.
- Research the variations of the lower food webs and impact on fish growth and production.

Non-point Source Pollution

- Conduct research needed to develop standards and regulations for emerging and problematic chemicals.
- Conduct research needed to update standards and expand regulations (including land application of sewage and manure) to include emerging chemical, hormones, antibiotics, and pesticides.

Sustainable Development

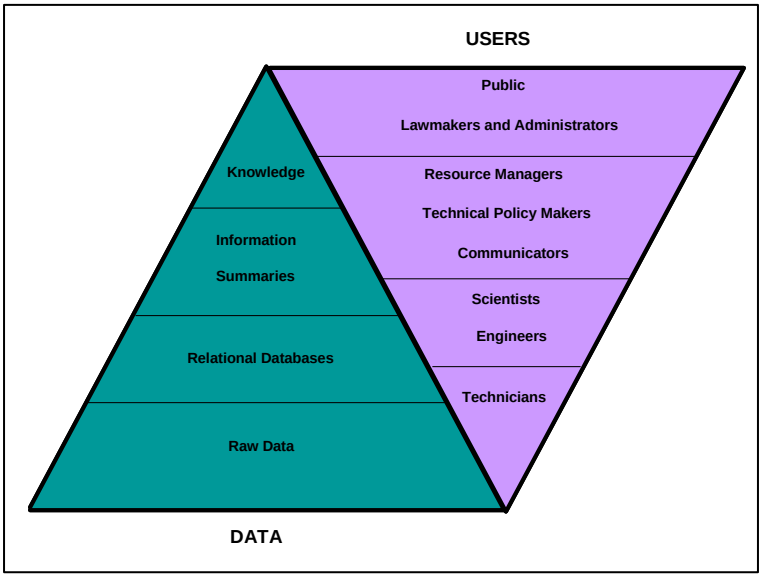
- Research the economic, ecological, and social costs and benefits of proposed restoration actions to guide the analysis of their sustainability and prioritization for funding.
- Study inter-jurisdictional, sprawl-related governance to identify how institutions and policies can individually and/or collectively promote sustainable development.
- Support research and evaluation of sustainable land use and development.
- Study the potential value-added forest products and products that can be made from later-success ional, higher-cost wood. Develop market niches for these products.
- Conduct applied research on renewable and alternative energy systems, and sustainable manufacturing practices.
- Research and evaluate the economies of scale, regulatory barriers, incentives, and transportation efficiencies needed for co-generation (bio-energy).

Toxic Pollutants

- Develop improved chemical Quantitative Structure Activity Relationships (QSARs) to determine fate, transport and effects of contaminants.
- Develop risk assessments for emerging contaminants of concern and grandfathered contaminants.
- Develop a Great Lakes basin-wide, multi-media exposure model (transport, fate, and bioaccumulation) framework and apply to both current priority chemicals and chemicals of emerging concern as identified with screening tools and/or monitoring programs.
- Apply lake-wide mass balance models (and collect required data) to assess progress and program effectiveness in reduction of Binational Toxics Strategy and LaMP priority chemicals.
- Study effects of food web changes on contaminant transfer and investigate the accuracy of older models.
- Utilize predictive chemical screening programs such as the PBT Profiler and QSARs to inform Great Lakes pollution prevention and monitoring programs regarding potential chemicals of concern.
- Determine sources contributions of mercury deposition to the Great Lakes and to concentrations of mercury in fish in the Great Lakes region.
- Identify continuing sources of PCBs to the Great Lakes, particularly diffuse urban sources.
- Develop a surveillance program in collaboration with wastewater treatment plants to assess the presence and significance of pharmaceuticals/EDCs/PCPs in final effluent, sewage sludge, and affected tributaries.
- Determining the human or environmental threats posed by discharges of endocrine disrupting chemicals, pharmaceuticals and personal care products in wastewater effluent, sewage sludge, or affected tributaries. Develop appropriate tools (e.g. treatment requirements/effluent limit regulations, pre-discharge reduction programs) to reduce the discharges of these chemicals in effluent and sewage sludge.
- Collaboratively develop approaches to reduce toxics through re-design of industrial processes and along the supply chain, particularly through the efforts of sectors/industry associations.
- Research cost-effective mercury emissions controls for use by the taconite industry.
- Improve understanding of the speciation of Hg emissions from sources.
- For selected priority chemicals of emerging concern, develop water quality standards and criteria and fish tissue criteria for protection of human health, aquatic life, and wildlife.
- Develop a complete toxicological database for emerging contaminants of concern and grandfathered contaminants.
- Assess human and wildlife toxicity for mixtures of chemicals and through multiple exposure routes.
- With a broad-based, community or population level approach, reliably determine the risks associated with low-level exposure to Great Lakes contaminants (e.g., Health Canada report about morbidity and mortality in AOCs vs. other areas).
- Determine effects of toxic pollutant and other stressors on human health (e.g., are effects of contaminant exposure greater on children who already have a disease?) and wildlife populations (e.g., are observed contaminant exposure effects greater in organisms experiencing habitat loss?).
- Expand and improve federal, state, and local emissions inventory programs to: provide greater information accuracy and consistency; improve and expand the speciation of emissions; increase standardization and transparency of collection methods; and evaluate and address additional source categories and chemicals.
- Develop standardized analytical methods for selected chemicals of emerging concern.
- Analyze fish contaminant monitoring program archives for chemicals of emerging concern.

Data and Information Management

Successful implementation of the actions envisioned by the GLRC will rely heavily on data and information management tools and systems that must be integrated across partnering jurisdictions and organizations. In the current age of technology, integrated information implies that a coordinated and distributed enterprise-level system exists. This "Great Lakes enterprise information system" would need to involve all level of governments and all other stakeholders that produce, manage or need access to information to support the ecological protection and restoration.



Effective information management strategies recognize the complexity of information formats and the needs to deliver various products to targeted audiences. Figure 3 showcases that as data are transformed from their raw formats (e.g., as observations), they are frequently managed in a relational database structure, which in turn are used to generate information (e.g., input to monitoring programs and indicator reports). This information is transformed into public knowledge as this distillation process proceeds.

Figure 3: Data and User Pyramids

Meanwhile the user community has widely divergent needs for data and information. Few users need ready access to the raw observational data and relational database structure, while other professionals need access to basic data as well as information summaries. Communicators, policy developers and most resource managers need access to these same information resources but also have needs to access general knowledge about a particular subject matter. The wider public audience (and the lawmakers and administrators that serve them) generally require access to factual information alone, but may also need access to all information resources that support these facts.

Problem Statement

Currently creation of a truly integrated Great Lakes enterprise information system is prevented by an array of significant technological, procedural and policy constraints. Overcoming these constraints requires commitment and effort from all levels of government and from all partnering organizations. The most prominent constraints are described in detail below:

Where are the data? Perhaps the simplest of the identified constraints is the need for data "discovery," which could include any of the following questions. Where are the data? What format is the data in? Does the data have metadata (information about the data)? Who owns or maintains them? What computer system and software supports them? How can they be accessed (if they can)? Most of these questions are straightforward and can be answered by employing existing data standards at all levels of management (federal, state, local, and private). However, resources have never been adequately allocated to meet the needs for data documentation, archival and development of data discovery tools.

Documentation of the quality, accuracy, source and format of data assets is often impaired by insufficient recognition and support for such activities at senior management levels. Consequently, organizations collect data for their own purposes without appropriate metadata production to enable "discovery" by others. Cataloguing and communicating data holdings are essential to the development of collaborative efforts, but are not conducted by many organizations within the region. These activities would greatly reduce the potential for duplication of effort in data collection activities. Many organizations have not allocated the resources to ensure that metadata production occurs, impairing the ability of others to discover, access and use their information resources.

Multiple formats: Variability in data standards, formats and management systems present an additional constraint on effective regional information management. These factors are often complicated by institutional resistance to changes required for collaborative endeavors. Information management is often conducted primarily to meet specific project needs, state or local geographic needs, proprietary software requirements, and convenience. Regional compatibility is infrequently a primary concern. Many of the local, state and regional information systems rely upon unique information structures (i.e., classification systems, units of measurement, projections, scales, acceptable precision, etc.), complicating conversion of similar information across wider Great Lakes watersheds.

Storage and access*:* The logistics of accessing data also pose an obstacle for moving data across dynamic enterprise systems. Each dataset has unique technical specifications (e.g., projection, naming conventions, field properties, etc.) which must be accounted for. These attributes need to be considered in designing appropriate database architecture and connectivity protocols to link datasets. In some cases, databases will need reformatting. In others, conversion of datasets will be required. Furthermore, most institutions have inadequate technological capabilities to support implementation of a distributed enterprise system for the region. Solutions must be reached that draw on the capabilities and address the needs of the diverse partners within the community.

Large file sizes: The size of individual datasets can create access and distribution problems. Spatial data, especially those that use imagery, are often extremely large (i.e., hundreds of megabytes). Storing and/or accessing these large datasets pose unique problems. Large bandwidths and high speed connectivity are significant considerations in designing the enterprise information architecture for the region. Currently, many organizations do not have high speed Internet capabilities with adequate bandwidth.

Quality and accuracy*:* Considerable emphasis has been placed across the region over the last decade on development of complex applications, tools and systems to store, manage and display geospatial data used in Geographic Information Systems (GIS). These GIS investments present extraordinary value but are often founded upon comparatively poor data or lack the necessary metadata that includes assessments of its quality and accuracy. Utilizing poor quality data in sophisticated applications can produce deceiving results. Convenient access and attractive user interfaces often belie significant data uncertainties and shortcomings. Data quality should be clearly communicated and confidence parameters (even if qualitative) provided whenever these data are used to support critical decision-making. The scale of many data collection activities across organizations are of little use at local or regional levels. Federal data, although it is generally comprehensive and sophisticated, is often collected at a national scale and cannot be used for local planning or remediation. This results in local projects that duplicate the collection of federal data to satisfy local needs. Ideally, data should be collected to standards that are developed at the local scale but can also be generalized and "rolled-up" for regional, state and federal levels.

Data sharing agreements*:* There are numerous institutional and legal constraints to sharing data across the Great Lakes region. Some organizations treat data as proprietary and do not allow access. Others have implemented security infrastructures to protect the integrity of their holdings which preclude access by outsiders. There are excellent enterprise information systems currently in place within individual federal

agencies and within state, provincial and local governments, but few multijurisdictional data sharing agreements currently exist to provide ready exchange among these agencies. The Environmental Information Exchange Network in the U.S. could be an operating model for multijurisdictional information exchange (Exchange Steering Board 2005). Many of these issues are discussed in the proceedings of the 2004 Great Lakes Regional Data Exchange Conference (GLC 2005).

Desired State

The long term vision for the Great Lakes enterprise information system includes:

- coordinated and collaborative maintenance of high quality data;
- implementation of common data standards;
- implementation of agreements between users for data use and maintenance;
- utilization of web services that facilitate data discovery, evaluation, access and decision support;
- wide access to data across all institutional boundaries; and
- an infrastructure that will ensure the system's growth and sustainability.

Each of these tasks will require substantial stakeholder engagement over time to define expectations, to identify their implications and to seek consensus on collaborative solutions. The development of strong working relationships between multiple levels of government, academia and other organizations must have senior management support. These partnerships must be championed by individuals who have the technological expertise and the ability to clearly communicate goals and objectives and dedicate the time and effort required.

Figure 4 below depicts the importance of ensuring that information resources are adequately self documented to support their discovery, evaluation and access. The Great Lakes enterprise information system needs to provide linkages to the general public, agency users, state and federal Internet portals and to global information infrastructure, particularly for binational resource management with Canadian agencies. Although data interoperability and access are the ultimate goal, not all organizations will have the ability to provide all data in the short term. As a result, promotion of established metadata standards should be an immediate emphasis for all organizations within the region and existing Internet "clearinghouses" should be enhanced to provide access to these documented information resources.

Assessment of Ongoing Efforts

The Great Lakes region has benefited significantly with the advent of the Internet and the subsequent development of the Great Lakes Information Network (GLIN www.great-lakes.net). GLIN provides a centralized clearinghouse for information about the binational Great Lakes-St. Lawrence region. GLIN is a partnership of federal, state, provincial and other agencies and organizations that has been managed by the GLC. Since its inception in 1991, GLIN's usage has grown exponentially from 68 thousand hits in February 1995 to 5.1 million hits in April 2005. The continued development of GLIN has focused on utilizing new technologies as they become operational to advance the communication backbone for the region. Unfortunately, GLIN's development over time has been stymied by piecemeal funding, causing incremental improvements but not substantial and structural changes. In August 2003, an array of regional information technology experts met to discuss future enhancements to GLIN and prospective means for sustaining the network. A key objective of this brainstorming session was to define strategic directions for GLIN for the next decade (GLC 2004).

In 2004, the first Regional Data Exchange (RDX) conference was conducted to bring together information technology experts and related managers to discuss opportunities for development of interoperable computer systems and information exchange programs within the region (GLC 2005). These types of conferences and similar thematic workshops, with a specific regional focus, are critically needed for the development of a Great Lakes enterprise information system.

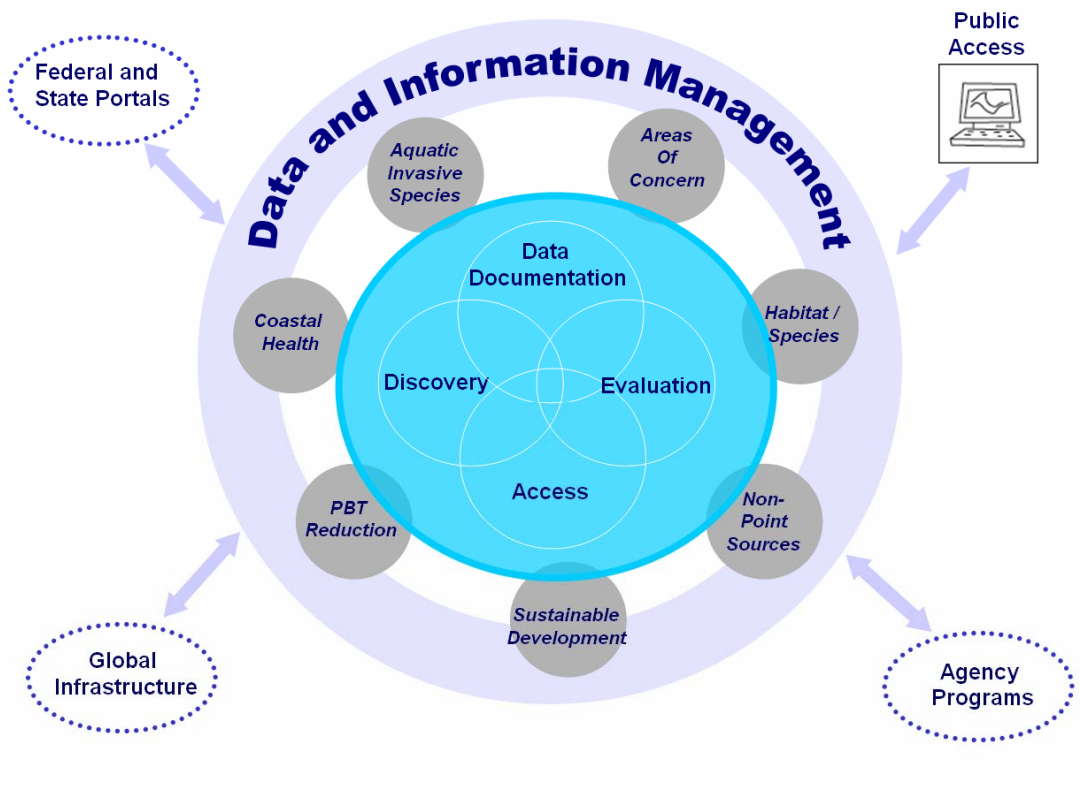


Figure 4: Data and Information Management Schematic

Recent developments and advancements of geospatial information technologies, such as Web Mapping and Web Feature Services (WMS/WFS), offer substantial benefit to the environmental and resource managers within the region to access and use data and information from a distributed network. Prototype applications of WMS/WFS technologies have been implemented within the region, including using GLIN as the backbone for these queries.

Each of the federal, state, provincial, regional, and municipal agencies within the region has invested heavily in developing its own operational information systems to meet its specific needs. Numerous success stories exist on how these investments provide substantial benefits within an organization or jurisdiction. However, interagency and multijurisdictional information exchange is rare across the region, particularly those featuring integrated operations on a real-time basis.

A good example of cross-governmental information exchange exists within the Land Information Ontario (LIO) and Ontario Geospatial Data Exchange (OGDE) programs maintained by the Ontario Ministry of Natural Resources (OMNR). The programs can be good models for the GLRC on how to deal with issue resolution, process coordination, and unanticipated challenges (OMNR, 2002). The LIO operates a warehouse where critical provincial (including all OMNR) geospatial data resources are catalogued, documented, stored, retrieved and distributed. The OGDE is a partnership initiative designed to allow organizations to share geospatial information resources, based upon one common legal agreement. Partners in the OGDE include all levels of governments within Ontario (federal, provincial, municipal), First Nations and aboriginal communities and other public sector entities such as conservation authorities, school boards, and academic institutions.

Although there have been substantial achievements within the region on information integration and management, significant challenges still exist. In general, current data and information management activities within the Great Lakes basin can be described as:

- isolated and non-collaborative;
- little adherence to data standards and lack of metadata production;
- lack of communication on information management between and within organizations;
- lack of funding to sustain data and information activities;
- significant duplication across organizations for data collection, management and maintenance of common data;
- project focus to data resources, which limits documentation and sharing beyond the original use;
- restrictive data sharing policies; and
- reactive management which limits strategic planning and sustainability of partnerships.

Each of these factors needs to be addressed to develop a functional Great Lakes enterprise information system to meet the needs of ecosystem protection, restoration and management.

In addition to these factors, many individuals and institutions are not comfortable with web-based data access and sharing, primarily due to lack of experience or knowledge. Focused training and web-based tutorials need to be made available on a continual basis to mediate these impediments.

Evaluation of Alternative Approaches

Data and information requirements underlie each of the Priority Issues identified under the GLRC strategy development. Achieving the goals of the strategy could be achieved through numerous alternative approaches to Great Lakes data and information management. However, all alternatives will need to include similar concepts of consistency and would only differ based upon the amount of financial resources provided to them. Specific components of a successful approach to implementing a Great Lakes enterprise information system include:

Data standards and metadata production: At a minimum, critical Great Lakes data must meet established data standards that are universally accepted and implemented between organizations. Those data should be discoverable and accessible throughout the community in order to ensure consistent content and accuracy. Metadata production is needed for all critical data so that users can understand the lineage and quality of data that are distributed between systems. The development of comprehensive data standards that bridge organizational requirements is essential.

Data quality: Data and information management are often associated with the hardware, software and infrastructure components that enable the access, display and modeling of data. However, these technologies alone do not address the requirements for the establishment of high-quality, well-managed data holdings. System designs evolve rapidly and technology will continue to improve the abilities of organizations to access data across the Great Lakes basin. Emphasis should be placed on the development and improvement of quality data in order to ensure that decisions are being made using the best available information base. Often the best quality data is collected at local levels for specific purposes. Those data are generally not widely discoverable but contain high quality information that could be used by state and regional managers for decision making. A coordinated, collaborative approach to data collection needs to be implemented using stakeholder based data standards so that all organizations are able to benefit from data collection activities that are taking place across the basin. This would reduce the duplication of data collection efforts while providing high quality information that could be used at all levels of government.

Data access policies: Alternate strategies and policies related to data access should facilitate data sharing and allow organizations to use and incorporate data that is being collected and managed within the Great Lakes community. This requires senior management and political support to reduce and/or eliminate the legal, policy and legislative constraints that currently restrict or hinder access to organizational data holdings.

Pursuing one or two of these approaches will achieve only limited progress toward fulfilling the overall Great Lakes information system needs. Only through a deliberate and focused effort to develop a Great Lakes enterprise information system will current stakeholder and political expectations be met. Programs to create forums for discussion and collaboration could greatly assist in moving all these agendas forward.

Recommended Actions

Overarching Recommended Action

To facilitate easy and accessible information exchange among all regional partners, stakeholders and decision makers and to create a consistent and comprehensive repository of Great Lakes data, the Great Lakes Interagency Task Force and all regional partners should augment the regional information management infrastructure (i.e. establish a network of networks), adopt standardized data management protocols and commit to open data availability.

Rationale: The U.S. Commission on Ocean Policy recognized that: "The data generated from increased research, enhanced monitoring networks, and new observing systems will be essential in improving our management of ocean and coastal resources. However, two major challenges face today's data managers: the sheer volume of incoming data, which strains storage and assimilation capabilities, and the demand for timely access to the data in a variety of formats by user communities. Meeting these challenges will require a concerted effort to modernize the current data management system and will require greatly improved interagency planning and coordination." In the Great Lakes, infrastructure is required to help turn data into useful information. Integrated and coordinated scientific and technical information is needed to adequately share results of ecosystem investigations with stakeholders. Long-term funding of an information management infrastructure to acquire and exchange timely, objective and accurate information is needed. The infrastructure will facilitate two-way communication between scientists and stakeholders, also allowing stakeholder needs to inform the investigations. The information management infrastructure should mesh with and augment existing infrastructure, such as the Great Lakes Information Network (GLIN) and provide for sustainability of such a network as an independent regional asset. A workgroup of information management professionals is needed to implement the distributed network of servers and databases to support this infrastructure. The workgroup should include representatives from key stakeholders with recognized data stewardship expertise and would coordinate interagency and inter-jurisdictional partnerships and mitigate institutional and legal barriers. The workgroup would promulgate data standards, quality assurance protocols, metadata production and region-wide multi-server search and access capabilities. The Federal Geographic Data Committee (FGDC), under the direction of the USGS, should be the lead entity for these activities. Each of the Great Lakes states should be represented along with key regional governmental councils, federal agencies and other stakeholders.

Cost: $2 million per year for five years

The strategic or overarching recommended action above will be heavily reliant upon positive developments on each of the detailed recommended actions presented hereafter.

Detailed Action 8: A work group of information management professionals should be established to coordinate the implementation of a distributed network of servers, databases and related infrastructure to meet the needs for Great Lakes ecological protection and restoration.

The workgroup should be composed of information management professionals from key regional organizations with recognized information technology and data stewardship expertise. The system architecture should be built around GLIN or a suitable alternative and provide for funding for its long-term sustainability as an independent regional asset. The distributed or decentralized network of servers should be designed to exploit the advent of the Internet2 backbone.

Policy issues that the workgroup would address include:

a) articulation of the importance of collaborative information management across the region to critical partner organizations;
b) development of an implementation plan that identifies issues and solutions, including the identification of existing management tools and opportunities;
c) documentation of current organizational policies and impediments that inhibit or restrict access to critical data and prospective solutions/actions for an open information sharing environment;
d) inventorying of all existing and pertinent datasets across all organizations, including resolution of questions dealing with access or viewing constraints (e.g., sensitive or protected data);
e) identification of data that is collected by multiple organizations in order to develop a more coordinated strategy to reduce the duplication of public sector efforts; and
f) development of partnership agreements between stakeholders, including resolution of legal and security concerns.

Technical issues that the workgroup would address include:

a) defining the system's operational goals and objectives;
b) establishing a coordinated approach for basin-wide implementation of web services to discover, report on and access data and projects;
c) identifying tools and applications, both existing and needed, that provide organizations with the capability to utilize data held by others;
d) inventorying and documenting current data management systems affecting the region that are used for storing and distributing data and developing and implementing recommendations for establishing interoperability requirements between these systems;
e) ensuring that partnering organizations keep pace with technology and application development through a technical center of excellence and/or periodic technical conferences, symposia, workshops or focused training events;
f) functioning as a data exchange clearinghouse, whose purpose is to advise organizations of existing data and data collection efforts (either past, underway or planned) to minimize redundancies in data collection;
g) Identifying and cataloguing critical/key data sets that are common to multiple organizations across the basin where accepted data standards (collection, database design and maintenance) currently do not exist; and
h) Developing and implementing a coordinated and collaborative approach to data standards (collection, database design and maintenance) for key data across the GL basin in order to improve data collection activities and reduce duplication of efforts.

The total anticipated cost for supporting the workgroup would be $3 million over the next five years. The FGFC, under the direction of the USGS, should be the lead entity for these activities. Each of the Great Lakes states should be represented on this working group along with key regional governmental councils, federal agencies and other stakeholders.

Detailed Action 9: A Great Lakes Information Infrastructure Grants Program should be created to provide funding support to partner agencies and organizations to implement common standards for information exchange and system interoperability.

The information management workgroup should oversee management of a grants program to provide necessary funding to partnering agencies to cover a portion of systems costs for servers, networks and database infrastructure that is critical to implementation of a Great Lakes enterprise information system. This grant program would include opportunities for technical training for staff of collaborating organizations to meet the overall goals for Great Lakes information integration. This would include funding to convert existing data holdings from their current state into a standard – this could include everything from hard copy mapping and data collection to registering GIS databases to a common georeferencing standard..

The total anticipated cost for supporting this grant program would be $5 million over the next five years. The USGS should be the lead federal agency for these activities.

Detailed Action 10: Partnering Great Lakes organizations should establish formal data custodians who are given roles and responsibilities for critical data related to Great Lakes environmental and resource management activities.

The role of Data Custodian is critical to key data sets across the basin. The establishment of a Data Custodian for those data ensures that a coordinated and collaborative approach can be realized for data that is determined to be important for multiple organizations. As well, it should reduce any duplication of efforts related to data collection activities since one organization would be responsible for development of data standards, coordinating data collection activities and making those data accessible to others.

It should be emphasized that one Data Custodian needs to be identified for each of the critical data – that would mean that the USGS would not be responsible for many of those data, but there would be a logical Data Custodian in place who can champion the standards from an organizational perspective. As an example, data that is currently collected by the USEPA would be the USEPA "custodial responsibility, not the USGS. Likewise, the same would hold true for data that is collected and managed by the US Fish and Wildlife Service.

Those data do not necessarily have to be collected by those individual organizations but they would be responsible for establishing the standards to which information needs to be collected at. Those standards should recognize the highest quality of information that can be collected and managed through partnerships at all levels.

The roles and responsibilities of the Data Custodians should include all of the following:

a) long term care of data for standards, collection, maintenance;
b) ensuring data are current, accurate and complete across the basin;
c) establishing and developing a coordinated, partnership approach to those data; and
d) coordinating funding opportunities to ensure that data is maintained.

Each of the partnering Great Lakes organizations would need to be responsible for designation of its respective Data Custodian based upon unique mission expertise as determined by the GLDIWG. The FGDC, led by the USGS, would be the logical federal entity to coordinate implementation of this recommended action. The costs for maintaining this function have not been determined, but should be borne by the respective organization.

Detailed Action 11: Partnering Great Lakes organizations should consolidate inventories of information holdings through population and maintenance of metadata listings on national and regional metadata clearinghouses.

Each of the partnering Great Lakes organizations would need to be responsible for their own level of participation in this endeavor. The FGDC, led by the USGS, would be the logical federal entity to coordinate implementation of this recommended action. The costs for maintaining this function have not been determined, but should be borne by the respective organization.

Detailed Action 12: Partnering Great Lakes organizations (federal, state, tribal, provincial, municipal, NGOs and academia) need to develop data sharing agreements between themselves that are legally acceptable and organizationally supported. The goal should be to develop a single agreement (or as few as possible) that all organizations can enter into to facilitate the exchange of data.

Currently, individual entities enter into data sharing agreements in an ad hoc fashion requiring multimple agreements between multiple agencies. If each organization has to enter into separate agreements with all organizations hundreds of agreements will be required to fully implement a true exchange of data amongst resource managers across the basin. This arrangement is neither efficient not desired. A single, or a small number of, data sharing agreements that individual entities could join would greatly increase the efficiency of data sharing throughout the Basin. Each of the partnering Great Lakes organizations would need to be responsible for their own level of participation in this endeavor. The FGDC, led by the USGS, would be the logical federal entity to coordinate implementation of this recommended action. However, the FGDC and the USGS cannot speak for, or act on behalf of, any organization but themselves. Legally binding data sharing agreements require organizational review, legal acceptance and sign-off in order to be valid. The development of a single agreement would require all organizations to participate. The costs for maintaining this function have not been determined, but should be borne by the respective organization.

Communication

Problem Statement

The region has a wealth of environmental monitoring programs, scientific research and environmental planning initiatives underway. Likewise, a wide array of communications tools is currently employed in the region. The quantity of Great Lakes information is growing rapidly along with the tools through which information can be shared. However, there is little integration or coordination of communication efforts to adequately share collected information with the many audiences in the Great Lakes.

Desired State

To fulfill the overall goals of the Great Lakes Regional Collaboration Strategy, coordinated communication activities are needed regarding scientific and technical information within the Great Lakes region to benefit a wide variety of audiences. These audiences—including both decisionmakers and stakeholders—include Congress and policymakers; existing federal, state/provincial, municipal agencies; non-governmental Great Lakes organizations; tribal communities; and the general public, among others. The goal of the communications activities under this strategy is to produce and disseminate clear, credible, scientifically-backed information that can be integrated as a basis for Great Lakes decision-making. A well-planned and executed Communications Strategy guided by a regional Communications Working Group will be integral to the long-term success of the GLRC.

Assessment of Ongoing Efforts

The following is a summary of existing Great Lakes communications tools for non-technical audiences. This inventory includes significant regional efforts underway in five areas of communication: mainstream media (newspapers, TV, radio), Internet/web, email/discussion forums, print publications, and meetings/conferences. These five channels were identified as the primary routes by which the public currently obtains information about Great Lakes issues.

Mainstream Media / Newspapers, TV, Radio

Primary

- Great Lakes Radio Consortium (broadcast on Public Radio stations regionally)
- Illinois: Chicago Tribune, Chicago Sun-Times
- Indiana: South Bend Tribune, The Northwest Indiana Times
- Michigan: Detroit Free Press, The Detroit News
- Minnesota: Duluth News Tribune, Minneapolis Star Tribune, St. Paul Pioneer Press
- New York: Rochester Democrat and Chronicle, The Buffalo News
- Ohio: The Toledo Blade, Cleveland Plain Dealer
- Ontario: The Globe and Mail, The Windsor Star, Toronto Sun
- Pennsylvania: Erie Times-News, Pittsburgh Post-Gazette
- Quebec: Montreal Gazette, La Presse, Le Devoir
- Wisconsin: Milwaukee Journal Sentinel, Green Bay Press-Gazette, Green Bay News-Chronicle

A comprehensive list of other media sources is available at http://www.great-lakes.net/links/media/.

These outlets primarily get their Great Lakes information from news releases or contacts with government agencies and Great Lakes organizations. Some reporters from these outlets cover environmental information. Information provided through these outlets should be clear, concise and scientifically accurate. Each of these outlets uses its own sources of information. A coordinated communication source would make it easier for these outlets to report on Great Lakes topics and minimize the effort for Great Lakes sources to provide the information.

Local TV and radio stations
These sources need local and immediate information. A centralized source to contact would increase the accuracy of their reporting. They are currently contacted in a similar method as newspapers.

Tribal newspapers and radio
Extra efforts are often necessary to reach a tribal audience because Internet access is not universal and there are so many affected tribes within the Great Lakes basin with their own governments, programs, interests and communication conduits (e.g., tribal newspapers, tribal radio stations, and tribal radio programming). Information access, outreach/raising awareness and decisionmaking all involve different communication strategies and would need to be customized to reach various tribal audiences, including tribal governments, tribal members, among others.

Support for training organizations – Support by way of speakers and information for the training of reporters in the Great Lakes region through such efforts as the Knight Center for Environmental Journalism at Michigan State University, and the Institute for Journalism and Natural Resources.

Internet/Web

Great Lakes Information Network (GLIN**) –** www.great-lakes.net or www.glin.net

Since its inception in 1993, GLIN has provided timely and comprehensive data and information on the environment and economy to the region's scientists, managers, policymakers and residents. GLIN is maintained by the Great Lakes Commission, with development led by a regional advisory board. As subsections of GLIN, several related web sites are notable:

- BeachCast –http://www.glin.net/beachcast
- Great Lakes Daily News – http://www.glin.net/news
- Great Lakes Hydrology / Current Conditions – http://www.glin.net/conditions
- Water levels forecasts from U.S. Army Corps of Engineers – Detroit District very popular with boaters/fishers and shoreline property owners.
- The Education And Curriculum Homesite (T.E.A.C.H.) – http://www.teachgreatlakes.net or http://www.glin.net/teach**)**

Great Lakes Environmental Directory - http://www.greatlakesdirectory.org/
A project of the Environmental Association for Great Lakes Education and the Great Lakes Aquatic Habitat Network & Fund to foster and support a vital, effective grassroots sector working locally to protect the natural resources of the Great Lakes basin.

Great Lakes Forever - http://www.greatlakesforever.org/
Great Lakes Forever – an initiative led by the Biodiversity Project based in Madison, Wis. – is designed to raise awareness of the ecological value of the Great Lakes and concern about the threats to the ecosystem's health, and to encourage citizen involvement in Great Lakes protection.

Others**:** Great Lakes Restoration (http://www. restorethelakes.org), Healing Our Waters (http://www.healingourwaters.org), Protect the Great Lakes (http://www.protectthegreatlakes.org), U.S. EPA and EC programs (http://www.binational.net), and numerous web sites of federal/state agencies and Great Lakes-related programs.

Email/Discussion Forums

glin-announce listserv - http://www.great-lakes.net/lists/glin-announce/
Postings include general Great Lakes announcements, new reports, resource management policy issues, requests for proposals, federal budget updates, and announcements of regional conferences or special Great Lakes events. Subscribers: 1,500.

Other GLIN-hosted lists (100+), various issues/Working Groups – http://www.glin.net/lists/
Total subscribers ~10,000.

alt.great-lakes newsgroup - http://news-reader.org/alt.great-lakes/
Open discussions of the Great Lakes and adjacent places, primarily tourism and fishing-related discussions. Approximately 400 messages per month.

Numerous statewide email lists from natural resource agencies, environmental advocacy groups.

Print Publications

Great Lakes Atlas - http://www.epa.gov/glnpo/atlas
Published jointly by USEPA and EC. Third Edition, published 1995.

Publications from Great Lakes Sea Grant Network **–** www.greatlakesseagrant.org
Seven programs serving the Great Lakes region: IL/IN, MI, MN, NY, OH, PA, WI

Numerous publications from federal/state/local natural resource agencies.

Meetings/Conferences

Great Lakes Conference / Biennial Meeting of International Joint Commission - http://www.ijc.org/2005biennial/about_en.php

State of the Lakes Ecosystem Conference (SOLEC) - http://cfpub.binational.net/solec/intro_e.cfm

Lakewide Management Plan (LaMP) forums - http://www.epa.gov/greatlakes/gl2000/lamps/

Others**:** IAGLR Annual Conference, numerous state-specific Great Lakes hearings/workshops on Annex implementation, invasive species, etc.

Communications Plan

A comprehensive communications plan has never been developed for the region which identifies requisite steps for delivering appropriate messages to the disparate user groups within the Great Lakes region. The communications plan needs to be properly researched and developed to assure that the right messages get to the right audiences in the most efficient, effective manner possible. The focus of the communication plan should be on decision-making support in the region, including specific audiences from lawmakers to residents. The communication plan needs to include the following components:

- development of a detailed current situational analysis including:
  - identification of key audiences (not just "the public" but specific groups) and messages/strategies/techniques to communicate with each with communication objectives being specified for each audience;
  - detailed listing of current scientific and technical data generated in the Great Lakes region and how that data can be shared including determination of any gaps;
  - detailed listing of current communication tools available in the region (building on information contained in this appendix);
  - benchmarks of successful programs that effectively communicate scientific and technical information in the region; and
  - determination of current hindrances to communicating Great Lake issues;
- determination of the relevant information that needs to be communicated, including "key messages" for each of the GLRC strategy teams;
- determination of specific messages for each target audience;
- determination of the communication tools appropriate to deliver these messages (i.e., a prioritized list of which communication tools are most effective in reaching specific audiences);
- development of guidelines for the most effective methods to translate scientific materials for a lay audience;
- development of a timeline for implementation of a comprehensive communication plan; and
- development of an annual evaluation schedule for the communication plan to determine its effectiveness in reaching target audiences, as well as identify information gaps and new communication tools; and

Additional considerations to be included in a comprehensive Great Lakes communication plan include:

- expected communication tools would include media, web sites, fact sheets, toll-free Great Lakes hotline, web conferencing, brochures, interviews, special events, meetings, and public service announcements;

- the GLIN would be promoted as the definitive source for both acquiring and exchanging timely, objective and accurate information for the region;

- there would be an effort to create and promote opportunities for audiences to communicate through new and emerging technologies, including web conferencing and Internet message boards, with communications being continually adapted to new media, such as mobile communications devices; and;

- there would be increased support for efforts such as the Knight Center for Environmental Journalism at Michigan State University, which prepares journalists to report on environmental issues through speaker bureaus and training opportunities.

Recommended Actions

Overarching Recommended Action

To coordinate and manage communication of scientific and technical information, the Great Lakes Interagency Task Force should establish a communications workgroup composed of public affairs specialists from Federal, State, and regional entities and key industries.

Communications professionals would make up the workgroup and provide the oversight for the development, and implementation of a comprehensive regional communications plan with assistance from staff or consultants. The communication plan would include periodic reviews of audience needs and assess optimal methods of information delivery to decision-makers and the public. By sharing experience, tools and workloads, the workgroup would facilitate efficient and consistent delivery of Great Lakes information to disparate audiences and oversee small grants to regional and local organizations to enhance communications efforts. The workgroup should rely upon the expertise of established networks, such as the Great Lakes Sea Grant Network and the Great Lakes Information Network. Additional funding would provide for a regional web portal to facilitate critical elements of the communication plan, and to broaden the distribution of Great Lakes information.

The communications workgroup should be made up of communications professionals from key government agencies dealing with the Great Lakes; environmental groups; regional organizations (e.g., CGLG, GLC, Great Lakes Cities Initiative); Native American interests; and relevant industry associations. A starting point for this group is the Federal Interagency Task Force Communications Group made up of top communications people from 11 federal government agencies. This team functions as a rapid response team on critical communication issues. The communications workgroup would need the full-time support of 1-2 FTE, public relations agency support or both. The workgroup would provide oversight for implementation of a comprehensive Great Lakes Communications Plan.

The total anticipated cost for full implementation is $1 million per year for the next five years. The USEPA would be the logical lead U.S. agency to manage funding for the communications workgroup.

Below are detailed recommended actions that would support the overarching recommendation above.

Detailed Action 13: A comprehensive Communications Plan should be developed to identify requisite steps for delivering information on Great Lakes priority issues to the disparate user groups within the region

The development of a comprehensive Communications Plan should be the first task of the communications workgroup and should be completed within six months of its initiation. The USEPA should be the lead U.S. federal agency and engage all stakeholders in the development of this Plan through the deliberations of the workgroup. The costs for this activity are included under the overarching recommended action.

Detailed Action 14: Catalog published research and data on the region's natural resources, environment, flora and fauna, people and culture and economic activities.

This action would be conducted in consort with the data management workgroup discussed above under Data and Information Management. This information should be provided in searchable format over the Internet. The U.S. federal lead for this activity should be the USEPA and engage all affected stakeholders.

Detailed Action 15: Enhance the content and marketing of a regional web portal (e.g., GLIN) to provide user friendly access to high quality data and information.

Broaden the distribution and marketing of Great Lakes communications tools, chiefly those listed above, at national, state/provincial, regional and local levels using the functionality of the Internet. The communications workgroup should determine the lead U.S. federal agency to oversee this activity. The costs to create these improvements are embedded in the overarching recommended action.

Table 5: Communications Needs and Recommend Actions for GLRC Priority Issues

Aquatic Invasive Species

- Implement angler, cultural and stakeholder education programs to prevent release of non-native organisms in rivers, canals and waterways.
- Support cost effective AIS outreach and education programs conducted by federal, state, tribal, agencies, academic programs and organizations.
- Collaboratively develop, coordinate, and implement cost effective AIS prevention programs and campaigns based on social science strategies and integrating existing products or campaigns.
- Develop and implement watercraft inspector training/education programs in each state and design and distribute materials including windshield fliers, winch post decals, and bait bucket stickers to encourage recreational users to adopt preventive behaviors.
- Develop public service announcements and purchase advertising in recreation-oriented media. Develop and distribute tip sheets for boaters and anglers. Feature AIS prevention messages and ways to minimize AIS impacts on boats and other recreational equipment at Great Lakes basin water access sites. Provide information on AIS at visitor centers along key transportation corridors and boating and angling events.
- Include AIS information and list infested waters in recreation safety and regulation publications.
- Assess and evaluate AIS boater and angler outreach and education programs; use assessment results to better understand, target, and manage recreational activities and to use the most effective methods.
- Develop marketing strategies to enhance distribution of new and existing AIS educational materials to schools and learning centers and provide training for teachers.
- Implement a program that educates all facets of the maritime commerce industry about the urgency and cost-effectiveness of preventing/containing AIS, the status of prevention, needs for advancing prevention.
- Support a new AIS Organisms-in-Trade educational campaign modeled on the Sea Grant AIS-HACCP and Pet Industry Joint Advisory Council/Sea Grant/USFWS Habitat campaigns; the Great Lakes Panel on ANS should approve the highest priority draft educational materials and programs, based on listed species of highest concern and considering all pathways (not just live food).

Areas of Concern

- The USEPA and each Great Lakes state should establish cooperative agreements for administering the AOC restoration program, including communications and outreach roles and responsibilities and procedures for documenting and reporting progress.
- Conduct early, broad public outreach regarding siting decisions for disposal or treatment of sediments.
- AOC data sharing should be promoted under a “Federal-State AOC Coordinating Committee.”

Coastal Health

- Develop effective public communication regarding water quality, including the risks of transmissible disease.
- Develop effective communication regarding the importance of stakeholder involvement.
- Educate the public about anthropogenic sources of contamination (from boaters, bathers, pets, household products, private septic systems, etc.) and how individuals can reduce their impact.
- Provide coordinated and consistent information about fish consumption advisories.

Habitat and Species

- Educate the public and private landowners about best watershed management practices.
- Generate an annual report on coastal wetland loss. Track and jointly report on the success of all federally funded coastal wetland protection, restoration and enhancement programs.
- Develop public education and communication programs on native species and priority habitat types.

Non-point Source Pollution

- Evaluate the results of surveys on the effectiveness of fish consumption advisories, and make course corrections, particularly to improve communication with high-risk communities and populations
- Develop outreach program on suburban lawn nutrients and investigate value of existing State or local limitations on phosphorus in fertilizer.

  Develop sediment control outreach and information for non-urban areas.
- Encourage local drainage districts or other authorities to develop drainage codes that reflect sediment reduction packages, beginning with the development of model codes and outreach.
- Promote the enforcement of sediment regulations through web-based guidance, case studies, FAQs.
- Through existing outreach and educational programs, promote awareness of alternatives to respond to altered flow regimes (e.g., storm-water detention, retrofitting detention basins, rain gardens, permeable pavements). Provide technical assistance (model ordinances, legal drafting, GIS and decision support) to local governments to prevent flow regime alterations from new development.
- Through existing programs, support local governments and NGOs for real-time pollutant monitoring.
- Through existing programs support local governments and NGOs for public education and immediate implementation of BMP's in beach areas.
- Develop decision support and self-evaluation tools to assist and educate operators of concentrated animal feeding operations.
- Develop nutrient management techniques for homeowners and developers. Provide information about reducing the use of nutrients and pesticides. Develop and implement a unified education and outreach strategy for rural and urban land users on the need for sediment and nutrient reduction.
- Promote awareness of responses to altered flow regimes such as storm water detention, permeable pavement, and other methods.

Sustainable Development

- Develop outreach materials to brand the Great Lakes as a competitive place to live, work, invest, and play.
- A regional database of sustainability data should be established, building on the process initiated by SOLEC; this database would be used to track and evaluate sustainability trends (using sustainability indicators and metrics) and progress toward goals.
- Report on ecosystem services at the watershed level to better track and prioritize funding decisions.
- Draw on existing programs and governance models across the region to better disseminate information.
- Develop a brand identity and system-wide marketing strategy for the Great Lakes. Integrate marketing to promote growth of businesses and jobs in the Great Lakes region with outreach that educates and promotes sustainable behavior.
- Provide outreach through the Great Lakes Dredging Team for environmentally responsible dredging and dredged material management.

Toxic Pollutants

- Create and maintain a central body or clearinghouse for chemical screening information from various screening programs in the Integrated Risk Information System (IRIS) or another appropriate database.
- Expand existing national burn barrel outreach effort via the USEPA's PBT Program or other program.
- Develop and provide fish consumption advice that is consistent across the basin. Communicate fish advice effectively to citizens, health care workers and sensitive populations, including multi-lingual formats.
- Identify gaps in education and outreach information; determine where the message is unsuccessful and why by creating benchmarks to determine behavior change.
- Expand successful toxic pollutant outreach programs.
- Develop a consistent and easily accessible basin-wide message regarding the presence and possible health effects of toxic pollutants and ways to reduce their release. Topics would include fish consumption mercury thermometers, energy conservation, household hazardous waste, burn barrels, and others.
- Continue and expand usage of the SOLEC process as a regional forum for developing any additional PBT indicators that are needed and assessing and reporting on indicators.
- Distribute the "Blueprint for Mercury Elimination", a mercury-reduction guidance for wastewater treatment plants, to all Great Lakes wastewater treatment plants.
- Quantify and report the emissions of toxic substances from poorly understood sources (including diffuse urban sources, open burning, in-use PCB transformers, sewage sludge treatment, and natural sources.
- Develop a Great Lakes Pollution Prevention and Education Outreach Fund, to support critical State toxic pollutant programs, including: pollution prevention/energy efficiency (P2/E2) technical assistance providers; education and outreach to schools; fish consumption advisories; household hazardous waste, electronic collection and recycling; and pesticide clean sweeps.

Glossary of Terms

Adaptive Management: A rigorous combination of management, research, monitoring, and means of changing practices so that credible information is gained and management activities are modified by experience.

Anthropogenic changes: Human-induced alteration of the landscape, the environment or environmental processes.

Drivers: Large scale events or human-related sectors broadly influence many of the pressures on the ecosystem. Examples include energy generation, transport, industry, agriculture and tourism.

Eutrophication: A natural process, that can be accelerated by human activities, whereby the concentration of nutrients in rivers, estuaries, and other bodies of water increases; over time this can result in anaerobic (lack of oxygen) conditions in the water column; the increase of nutrients stimulates algae "blooms" as the algae decays and dies, the availability of dissolved oxygen is reduced; as a result, creatures living in the water accustomed to aerobic conditions perish.

Geodetic control networks: A reference system, or datum, is the set of numerical quantities that serves as a common basis for the sharing of geo-spatial data. Networks of individual entities work together to establish these reference systems.

Geo-referenced: Align geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data. Geo-referencing may involve shifting, rotating, scaling, skewing, and in some cases warping or rubber sheeting the data.

Goal: A condition or state desired to be brought about through a course of action or program. Goals are usually qualitative statements that provide direction for plans and projects. Goals are not specific numerical limitations, but conditions or states which can be obtained through careful planning and implementation.

Hydrodymanic models: Used in complex aquatic systems to represent detailed transport patterns. Hydrodynamic models are also used to predict sediment transport which includes chemicals or metals that are sorbed to the sediments.

Indicator suite for the Great Lakes: A compilation of indicators necessary and sufficient to characterize the state of the Great Lakes ecosystem, pressures impacting components of the ecosystem, and management actions to alleviate the pressures.

Indicator: In the context of SOLEC, it is a measurable feature (or features) that provides outcome-oriented, managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality.

Internet2: A non-profit consortium which develops and deploys advanced network applications and technologies, mostly for high-speed data transfer. It is led by 207 US universities and partners from the networking and technology industries (such as AT&T, Intel, Sun Microsystems, and Cisco Systems). Some of the technologies it has developed include IPv6, IP multicasting and quality of service.

Lakewide Management Plans (LaMPs): A comprehensive strategy developed jointly by the United States and Canada to restore and protect beneficial uses in the open waters of each Great Lake.

LIDAR: (Light Detection and Ranging; or Laser Imaging Detection and Ranging) is a technology that determines distance to an object or surface using laser pulses. Like the similar radar techology, which uses radio waves instead of light, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

Littoral system: The shallow–water zone (less than 2 meters deep) at the edge of a lake or pond; a subsystem in the Lacustrine System of the U.S. Fish and Wildlife Service wetland classification system.

Metadata: Data that describes or provides background information on other data.

Monitoring: The systematic tracking of changes in conditions and progress toward meeting a management objective.

Multispectral imagery: Images of the same object (Earth or planetary surface), taken in different bands of visible or infrared region of electromagnetic continuum. This is the main type of images acquired by Remote sensing (RS) radiometers. Usually satellites have 3 to 7 or more radiometers (France's SPOT has 3, Landsat has 7). Each one acquires one digital image, in RS called scene, in a small band of visible spectra, ranging 0.7 µm to 0.4 µm, called red-green-blue (RGB) region, and going to infra-red wavelengths of 0.7 µm to 10 or more µm, classified as NIR-Near InfraRed, MIR-Midle InfraRed and FIR-Far InfraRed or Thermal. In the Landsat case we have 7 scenes comprising a 7 band multi spectral image.

Objective: Specific descriptions of the state of condition that must be met in order to achieve goals and vision.

Observations: The act of measuring or recording of an event, state, condition or phenomenon, with instruments and the notation of these facts.

Operational forecasting: Prediction of future events for management purposes, the results of predictions are often disseminated to the public.

Pressure Indicators: Indicators that provide information about the pressures that modify or influence components of the environment or of human health and well-being. Examples include the amount of pollutants discharged to the environment, the rate of urbanization, the presence of exotic species such as zebra mussels, and the amount of wetlands filled in.

Radar: An acronym for RAdio Detection And Ranging or Radio Angle Detection And Ranging. It is a system used to detect, range (determine the distance of), and map objects such as aircraft and rain.

Remedial Action Plans (RAPs): Plans that embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in Areas of Concern throughout the Great Lakes ecosystem basin.

Response or Human Activities Indicators: Indicators that address societal responses give us valuable information about what we are doing to prevent, reduce or eliminate the stresses, and whether we are achieving what we set out to do.

State Indicators: Indicators directly measure environmental conditions, as in "state of the environment" by providing information to help answer questions that concern us such as: Can we eat the fish? Can we swim at the beaches? Can we drink the water? Is the ecosystem healthy and functioning as we would expect?

SOLEC (State of the Lakes Ecosystem Conference): The SOLEC conferences are hosted by the U. S. Environmental Protection Agency and Environment Canada on behalf of the two Countries every two years in response to the binational Great Lakes Water Quality Agreement. The conferences are intended to provide a forum for exchange of information on the ecological condition of the Great Lakes and surrounding lands.

Target (or Endpoint): Specific, attainable, quantitative end points for indicators that determine achievement of objectives.

Vision: A general description of the desired state of a lake, geographical area, or bioregion that is expressed by a group of stakeholders. A vision statement provides a description of a desired state – it provides direction and establishes a horizon to be sought.

Water balance: An accounting of the inflow to, outflow from, and storage changes of water in a hydrologic unit.

List of Acronyms

ADCP – Acoustic Doppler Current Profiler
AIS – Aquatic Invasive Species
AOC – Area of Concern
AVM – Acoustic Velocity Meter
BEC – Binational Executive Committee
BOD – Biological Oxygen Demand
BTS – Binational Toxics Strategy
BUI – Beneficial Use Impairment
CDFs – Confined Disposal Facilities
CGLG – Council of Great Lakes Governors
CGLRM – Council of Great Lakes Research Managers (IJC)
COSEE – Center for Ocean Sciences Educational Excellence
CSO – Combined Sewer Outfalls
DFO – Department of Fisheries and Oceans (Canada)
EC – Environment Canada
EDCs – Endocrine Disruption Chemical
EMS – Early Monitoring Syndrome
FGDC – Federal Geographic Data Committee
GAO – Government Accounting Office
GEOSS – Global Earth Observing System of Systems
GIS – Geographic Information System
GLACEO – Great Lakes and Central US Ecological Observatory
GLASS – Great Lakes Association of Scientific Ships
GLBA – Great Lakes Beach Association
GLC – Great Lakes Commission
GLCWC – Great Lake Coastal Wetlands Consortium
GLEI – Great Lakes Environmental Indicators
GLERL – Great Lakes Environmental Research Laboratory (NOAA)
GLFC – Great Lakes Fishery Commission
GLIFWC – Great Lakes Indian Fish and Wildlife Commission
GLIN – Great Lakes Information Network
IATF – Great Lakes Interagency Task Force
GLNPO – Great Lakes National Program Office (USEPA)
GLOS – Great Lakes Observing System
GLRC – Great Lakes Regional Collaboration
GLRO – Great Lakes Research Office (NOAA)
GLSGN – Great Lakes Sea Grant Network
GLWQA – Great Lakes Water Quality Agreement
GSC – Geological Survey of Canada
IADN – Integrated Atmospheric Deposition Network
IAGLR – International Association for Great Lakes Research
I&IST – Information and Indicators Strategy Team
IJC – International Joint Commission
IOOS – Integrated Oceans Observing System
IEOS – Integrated Earth Observing System
IRIS – Integrated Risk Information System
LaMP – Lake-wide Management Plan
LIO – Land Information Office (OMNR)

NEON – National Ecological Observatory Network
NGO – Non-governmental organizations
NGS – National Geodetic Survey (NOAA)
NOAA – National Oceanic and Atmospheric Administration
NOPP – National Oceans Partnership Program
NPS – Non-Point Source
NSF – National Science Foundation
NWS – National Weather Service (NOAA)
OGDE – Ontario Geospatial Data Exchange
OMNR – Ontario Ministry of Natural Resources
PBTs – Persistent Bioaccumulative Toxics
PCBs – Polychlorinated Biphenyls
PCPs – Personal Care Products
QSARs – Quantitative Structure Activity Relationships
RAPs – Remedial Action Plans
RDX – Regional Data Exchange (Conferences)
SMOC –Sound Management of Chemicals
SoFIS – Science of Freshwater Inland Seas
SOLEC – State of the Lakes Ecosystem Conference
SSO – Separated Sewer Outfalls
ST – Strategy Team of the Great Lakes Regional Collaboration
T.E.A.C.H. – The Education and Curriculum Homesite
USACE – U.S. Army Corps of Engineers
USCG – U.S. Coast Guard
USEPA – U.S. Environmental Protection Agency
USFS – U.S. Forest Service
USFWS – U.S. Fish and Wildlife Service
USGS – U.S. Geological Survey
WFS – Web Feature Service
WMS – Web Mapping Service

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