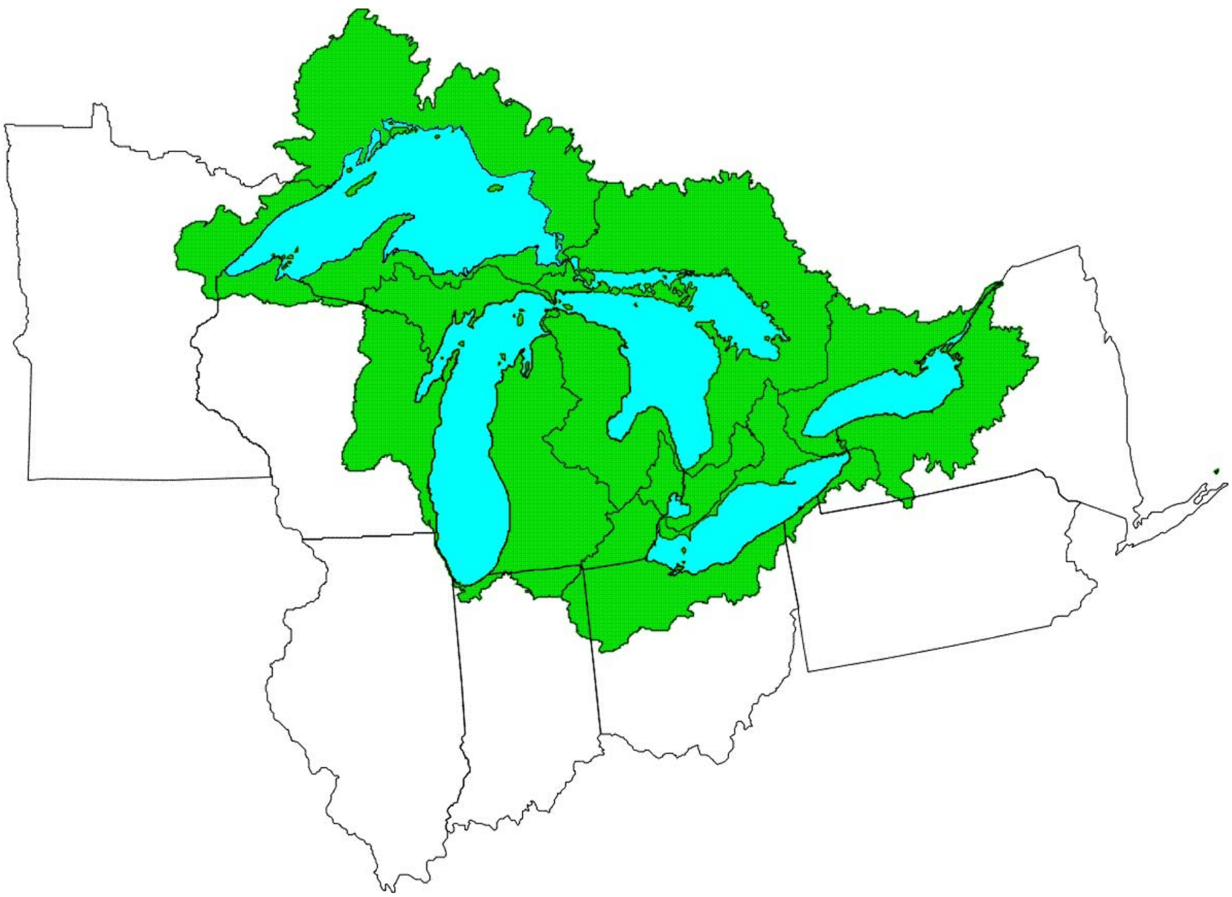
Improvements to the Great Lakes – St. Lawrence River Biohydrological Information Base

In response to Public Law 106-53, Water Resources Development Act of 1999, Section 455(b), John Glenn Great Lakes Basin Program, Great Lakes Biohydrological Information

Appendix I: Land Use and Land Cover



April 2005

US Army Corps of Engineers®

Measurement Converter Table

U.S. to Metric

Length
feet x 0.305 = meters
miles x 1.6 = kilometers

Volume
cubic feet x 0.03 = cubic meters
gallons x 3.8 = liters

Area
square miles x 2.6 = square kilometers

Mass
pounds x 0.45 = kilograms

Metric to U.S.

Length
meter x 3.28 = feet
kilometers x 0.6 = miles

Volume
cubic meters x 35.3 = cubic feet
liters x 0.26 = gallons

Area
square kilometers x 0.4 = square miles

Mass
kilograms x 2.2 = pounds

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Appendix I:

Land Use and Land Cover

Introduction

Water resources are heavily impacted by human activity on the lands that surround them. Historical patterns for that activity in the Great Lakes-St. Lawrence River region can be divided into four or five general categories. Prior to European settlement and through the fur trade era, the human population was small and the land throughout the region was covered by forests, prairies, small settlements and small agricultural plots. During the logging era, forests were cleared and extensive damage was done to riparian vegetation and stream banks as logs were transported by river to growing cities and mill sites. During the agricultural era that followed, cleared forests and other wooded areas and prairies were turned into cropland, and large cities began to develop. The industrial era brought still larger cities and the introduction of an expanding paved road network. The modern era is marked by extensive imperviousness, urban sprawl and commercial and institutional features that accompany it, and limited regrowth of wooded areas and forests as agriculture uses decline.

Two approaches are commonly taken to mapping areas and impacts of human activity on the land. The term “land use” describes activities taking place on or affecting the land’s surface, e.g., residential housing, retail commerce, crop farming or recreational uses. Land use is typically characterized at the parcel scale, especially in urban, suburban and developing areas. It can readily be gathered from property (cadastral) maps and zoning maps. “Land cover”, on the other hand, refers to the physical properties of the land surface and the materials that overlay it, e.g., grass, wetland, mixed deciduous forest or asphalt. Several different types of land cover are possible within any land use category, so land cover mapping usually requires ancillary data from sources like parcel or zoning maps.. For small areas, land cover can be determined by ground surveys or from site plans, but normally it is mapped from aerial or satellite imagery.

Land cover data gathered from images of any kind is subject to the amount of detail available from the image, referred to as its resolution. It is usually possible to gather more detailed information from low-altitude aerial photography than from photographs taken at high altitudes. In the same manner, satellite sensors capable of viewing the Earth’s surface as a collection of 1-meter pixels will provide more information than those that discern pixels of 30 meters wide by 30 meters long. However, the notion that higher resolution is better does not always hold true as the geographic extent expands. The process of classifying satellite data or aerial photographs into land cover categories is labor intensive at any scale. As the area of interest increases, data quantities and processing needs grow exponentially and large investments need to be made in computer resources. For large geographic areas, slightly lower resolution data often provides adequate information at substantially lower costs.

Land use and land cover mapping efforts take place at many levels across the Great Lakes-St. Lawrence River basin. The spectrum ranges from local work focused on individual political jurisdictions or drainage areas to national programs housed at multiple federal agencies. Data for these efforts come from a variety of sources, including ground surveys, property and zoning records, aerial photography and satellite imagery. Results, in turn, may exist in a number of formats and projections, and they may not be accessible by other units of government.

Land Use and Land Cover — Consequences and Impacts to Water Resources

Both surface waters – lakes, streams and rivers – and groundwater are affected by land use/land cover characteristics. Land cover impacts the rate at which surface precipitation flows into lakes, rivers and streams, and helps determine what materials are carried from the land surface into those water bodies. Land cover also affects whether waters falling on the ground can be absorbed and transported into groundwater aquifers.

Trees, shrubs and grasses on natural, vegetated land surfaces act as shelters and a retaining system for the underlying soil. In the Great Lakes region, approximately 70 percent of the precipitation that falls on these surfaces is absorbed at that location, then returns to the atmosphere, either as transpiration from plants or as simple evaporation (Bowles, 2002). The remainder moves either laterally through surface vegetation and topsoil layers into wetlands and surface waters, or infiltrates into deeper layers and recharges groundwater.

In comparison, bare soil, without a covering layer of vegetation, does a relatively poor job of absorbing moisture. Instead, water from precipitation can flow overland as sheet runoff, picking up unanchored particles in the process and carrying them into lower-lying areas or depositing them in surface waters as sediment. Early examples of this come from the logging era, when tree cover was removed for commercial purposes and riparian vegetation that stabilized stream banks was destroyed as logs were transported downriver. The process continued during the agricultural era because exposed soil between crop rows and in areas of overgrazing exhibits similar characteristics. Topsoil is lost, sediment loads in streams are increased, groundwater recharge is reduced, and the risk of flooding rises.

Compacted soils and any land covered by a building or by materials such as concrete or asphalt take this a step further by being impenetrable to water. Such areas, commonly categorized as impervious surfaces, are receiving considerable attention from many sectors as impacts, corrective measures and plans for the future are evaluated.

The Issue of Impervious Surfaces

Impervious surfaces in general impact groundwater recharge and streamflow. At the purely physical level, none of the precipitation that falls on an impervious surface can be absorbed where it fell, and very little of it will remain at that location long enough to evaporate. Both the amount and velocity of surface runoff increases in and around these areas, which means:

- Water levels in receiving tributaries fluctuate more rapidly and across a greater range
- Erosion increases
- Flooding increases
- More sediment is carried to surface waters
- Surface water temperatures increase
- Groundwater recharge is reduced

In addition, there is a potent chemical dimension to runoff from many impervious surfaces because:

- Many of these surfaces collect significant quantities of pollutants (leaked vehicle fluids, transported chemicals, road deicing compounds, fertilizers, etc.) which wash into surrounding soils and surface waters
- Natural processes linked with infiltration (physical filtration and the breakdown of some compounds by biological processes) are prevented or reduced

Studies indicate that surface waters are affected by low total percentages of impervious surface in the watershed. In one study, 5.3 percent impervious surfaces was sufficient to cause measurable declines in stream biotic integrity (Milton et al, 2003). The same study cited declines in a rapidly urbanizing area with impervious surface totals as low as 4 percent, but speculated that poorly regulated construction practices may have been the source of much of that damage. Common figures from a number of sources show habitat and biological diversity decline sharply when impervious surface percentages exceed 8 – 10 percent of the watershed. Beyond 25 – 30 percent, habitat ratings become "poor" and biological indicators decline below Clean Water Act goals.

Urban land uses bring with them the largest percentages of impervious surface to total land cover. A USDA report estimates that land cover on a 1/10th-acre residential lot, with the house, driveway, outbuildings and sidewalks factored in, will include 65 percent impervious surface. As lot size increases, this percentage goes down, but even on a one-acre lot, 20 percent of the land will be covered by impervious surfaces (Urban Hydrology for Small Watersheds, 1986). Thus, almost any residential neighborhood lies beyond the threshold where impervious surfaces impact water resources.

Table I.1 below lists values for estimating land cover by land use type for some urban land uses. In another, more general categorizing scheme, offices, stores, houses, etc., where people live and work account for approximately 35 percent of the total. The other 65 percent is made up of parking lots, roads, driveways, sidewalks and other transportation infrastructure, much of it designed to accommodate the automobile.

Table I.1 Impervious Surface Estimates for Selected Urban Land Use Types (adapted from "Do It Yourself!", NEMO Technical Paper No. 4)

Minimum Lot Size (Acres)	Minimum Lot Size (Hectares)	Land Use Description	Percent Impervious Surface (USDA-NRCS Study Values)
0.12	0.05	Individual Residential Lot	65
0.25	0.10	Individual Residential Lot	38
0.32	0.13	Individual Residential Lot	30
0.50	0.20	Individual Residential Lot	25
1.0	0.40	Individual Residential Lot	20
		Townhouse/Garden Apt.	44
		Commercial/Business	85
		Industrial	72

Land Use / Land Cover Information Resources

Information on land use is commonly drawn from jurisdiction-based maps. At the state and regional level, community boundaries and areas of special jurisdiction like national parks and state game preserves allow depictions of land use by general category, such as urban, rural, agricultural or open land. Within individual jurisdictions, cadastral (property) maps, zoning maps and community master plans present a more detailed depiction of land use, both in terms of physical location and often by providing detailed descriptions of property requirements and particular activities allowed.

Current land cover information is available through several federal programs, programs in most states and through planning agencies in many counties and cities:

Two federal datasets exist for the Great Lakes region, the National Land Cover Dataset (NLCD), housed at the US Geological Survey, and the datasets developed for the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (C-CAP). Both were developed from Landsat Thematic Mapper satellite images. They are limited to the 30m by 30m resolution of the satellite's sensor, meaning grid cell of data represents approximately one- quarter acre of landscape, so the information becomes difficult to use if applied to too small an area. On the other hand, these images represent the entire Great Lakes-St. Lawrence River basin and can function as a reasonable overview of the entire area or any of its component watersheds at the time the imagery was acquired.

Satellite imagery is now the norm for statewide land cover mapping as well, and the NLCD is commonly used as a baseline from which update efforts are carried out state by state. State land cover mapping programs may include older data extracted from aerial photography, and several states have acquired and processed satellite imagery above and beyond the NLCD in the interest of having shorter or more consistent update cycles.

Local land use/land cover data development efforts vary with the community's perceived needs. Often, land use information has been developed based on property boundaries, zoning maps and community master plans. Meanwhile, recent aerial photography or high-resolution satellite imagery may exist, but primarily as reference material for projects undertaken in a number of departments. There is little emphasis on categorized land cover information from such sources, so land cover data layers are seldom created from them.

Implementation Options

Tasks for improving the information base related to the land use and cover across the Great Lakes-St. Lawrence River basin are presented in this section. These tasks are defined within the framework of identifying the potential U.S. federal role in creating and maintaining an information base to support science-based decisions on water withdrawals and diversions from the Great Lakes-St. Lawrence River basin. Each task is defined at different options of implementation under the U.S. Army Corp of Engineers' plan formulation approach. This approach, in a broad sense, is being used to develop systematic strategic plans that Congress could consider for supporting the states' Great Lakes Charter Annex decisionmaking process.

Five implementation strategies are presented, each as a separate integrated approach. This, however, is not an exclusive list and does not represent an "all or nothing" approach. Individual elements from one strategy could be pulled out and funded separately, making an important contribution to Great Lakes - St. Lawrence River basin information base. Even modest increases in funding over the "Without Plan" strategy can enhance decisionmaking. Water resources managers should examine each particular integrated strategy as well as individual tasks to discern where important progress can be made.

Described below are five implementation strategies considered:

- **Without Plan Strategy** – Describes the status of the activity as it currently exists. Without change, this current status may actually decline, representing negative impacts. If negative impacts are expected, they are highlighted wherever possible.

- **Minimum Investment Strategy** – Describes the least costly measures needed to insure minimum functionality of the decision support system. Not all system components of an implementation plan are included in this strategy.

- **Selective Implementation Strategy** – Describes an integrated system comprised of prioritized components. Few components are fully funded, but no essential components are excluded.

- **Enhanced Implementation Strategy** – Describes an integrated system that includes all essential components at funding levels, which enhance information accuracies and decision support system functionalities.

- **Full Implementation Strategy** – Describes an integrated system that fully implements the described activity. Technical staff and financial resources are not restricted. Information accuracies and completeness approaches state-of-the science.

Due to the interdependent nature of many issues described in the appendices, some information may be repeated in total or in part elsewhere in another appendix. The interdependence of the information is noted explicitly in the appendices wherever appropriate.

A dollar value has been estimated for the four potential strategies that require additional investment over a 10-year implementation schedule. Monetary value is based on the best available information through extensive research and review by project collaborators and is presented in 2004 U.S. dollars. Further information is provided in Appendix K – Cost Evaluations and Risk Assessments, including an analysis of the uncertainty associated with these estimates.

Comparisons of costs at various implementation levels provide a useful measure of investment versus return. It is important to remember that the primary objective of all investments is to reduce uncertainties associated with decisionmaking. Since the hydrogeology and meteorology of the Great Lakes – St. Lawrence River system is highly complex, reductions in uncertainty are sought for each task outlined for the integrated information system.

The definition of the individual tasks outlined in this report has sought to eliminate "double-counting" as much as possible. Costs for the various tasks also explicitly address any interdependencies that occur under a particular implementation strategy. Cost estimates for each task under each implementation strategy also reflect anticipated economies of scale.

Risk and Uncertainty

Risk and uncertainty are inherent aspects of all facets of an integrated information system for water management of the Great Lakes – St. Lawrence River system. Risk can be viewed relative to human and aquatic health, to real property, to the ability to attain profit from a commercial venture, or to relative benefits that can be attained at given investment levels.

The integrated information system described within this report, once improved above current conditions, has a very low likelihood of adverse risk to human health, life or personal property. It is simply a monitoring, modeling and predictive system that does not include significant physical structures or construction. The converse does apply however; continued financial stressors on the monitoring system can cause atrophy of monitoring abilities which could, in turn, mask physical, chemical and biologic change to natural streamflow throughout the system.

Risk is also factored in throughout this report related to the prospective reward or benefit attained at increasing levels of investment. Each task in the integrated information system is evaluated in terms of cost effectiveness, whenever practical. This discussion is addressed in detail in the Main Report, although each appendix includes detailed information on the risk/return for each task under each implementation strategy.

Uncertainty is pervasive throughout the design, implementation and operation of any integrated water management system. At the current level of investment in groundwater, surface water and open lake monitoring and modeling, cumulative withdrawals from headwater systems cannot be detected, measured or adequately estimated. Hence, the uncertainty of cumulative hydrologic effects is extremely large under the Without Plan and Minimum Investment Strategies. Even under the Full Implementation Strategy, uncertainty will continue to exist, albeit at a much lower level. This uncertainty would be accompanied, however, with an accurate error budget including almost all hydrologic and biologic factors, which currently does not exist.

The analytical functions of the integrated information system will generally have reduced uncertainties as funding increases from one implementation strategy to the next. In addition, these uncertainties can be computed with greater confidence as more investment is made in the monitoring frame and computer modeling. The legal defensibility of permitting water withdrawal improves as uncertainty is reduced, in part or in total.

Integrated Information System Tasks

Tasks 52-54 described in this appendix present an integrated approach towards collecting and managing information on the groundwater and geology of the Great Lakes – St. Lawrence River system. It is important to see these tasks as "building blocks" for the integrated information system. Improvements under any specific task will provide incremental benefit, but the sum of the parts provides the greatest opportunity for reducing uncertainties under each implementation strategy. These tasks are repeated below.

Task 52: The USGS, in conjunction with the NOAA and the USACE and in cooperation with state agencies, need to produce comprehensive and consistent land cover datasets for the entire Great Lakes - St. Lawrence River basin on a five-year repeat cycle.

Task 53**:** The USGS, in conjunction with the USACE and in cooperation with state agencies, need to produce high-resolution land cover data within the Great Lakes - St. Lawrence River basin to support detailed assessments of specific water withdrawal proposals.

Task 54: The USGS, in conjunction with the USACE and in cooperation with state agencies, need to produce land cover change evaluations from available data and 30-year land use projections for the entire the Great Lakes – St. Lawrence River basin to refine ecological impact assessments and anticipated future demands on water resources.

Implementation Mechanisms and Costs

The proposed approaches/mechanisms for implementing the tasks and associated costs are provided below for each of the five implementation strategies considered. The U.S. federal agency which has the assigned mission responsibility for implementing these activities is identified, whenever clear. If potential overlap occurs between U.S. federal agencies in mission responsibilities, one is proposed over the other based on perceived technical or administrative competencies to complete the necessary work within budget and schedule.

Task 52: The USGS, in conjunction with the NOAA and the USACE and in cooperation with state agencies, needs to produce comprehensive and consistent land cover datasets for the entire Great Lakes - St. Lawrence River basin on a five-year repeat cycle.

Without Plan (52) – Various agencies will continue to work together within the Multi-Resolution Land Characteristics consortium which produced the 1992 National Land Cover Dataset (NLCD) and has begun work on a version based on 2000-era data. Completion time will depend on funding from partners and may range from three to seven or more years. No formal repetition cycle is planned. The utility of data that is more than 10-years old is suspect. Current programmatic investments indicate that there will be few predictions of land cover characteristics to support critical water resource management decisionmaking.

Minimum Investment (52) – Provide additional funding to NOAA to acquire and process 2005 satellite imagery for the Great Lakes-St. Lawrence River region as part of a change analysis cycle under the Coastal Change Analysis Program (C-CAP) at a cost of $300 K over two years.

Selective Implementation (52) – Provide additional funding to NOAA to acquire and process 2005 satellite imagery for the Great Lakes-St. Lawrence River region as part of a change analysis cycle under the Coastal Change Analysis Program (C-CAP) at a cost of $300 K over two years.

Enhanced Implementation (52) – Provide additional funding to NOAA to acquire and process 2005 satellite imagery for the Great Lakes-St. Lawrence River region as part of a change analysis cycle under the Coastal Change Analysis Program (C-CAP). In addition, cross-reference classification categories from NOAA C-CAP and USGS NLCD 1992 to allow change analysis for the period over which a national land cover dataset exists and processing has been carried out. The estimated cost for this activity is $500 K over 2 years. Estimated cost is based on similar programs.

Full Implementation (52) – Coordinate NOAA's C-CAP efforts and the efforts of the Multi-Resolution Land Characteristics Consortium to institutionalize and streamline the efforts of all agencies involved in those processes. Establish a program to acquire and process new imagery every 3- years, releasing new land cover datasets within 6-months of data acquisition. The estimated cost for this activity is $1.5 M over 10 years, with commensurate funding annual funding thereafter to insure that the 5-year repeat cycle is maintained. Estimated cost is based on similar programs.

Task 53: The USGS, in conjunction with the USACE and in cooperation with state agencies, needs to produce high-resolution land cover data within the Great Lakes - St. Lawrence River basin to support detailed assessments of specific water withdrawal proposals.

Without Plan (53) – Local communities, especially urban areas, will gradually acquire high-resolution data products for use in land use planning and other efforts. There will be poor spatial completeness and little or no temporal match between adjacent political units. The data may or may not be processed for classification into land cover categories.

Minimum Investment (53) – Provide funding to the USGS to acquire high-resolution satellite imagery and create a high-resolution land cover dataset for priority rapidly changing areas within the Great Lakes - St. Lawrence River basin. Existing lower resolution data sets and census information would be used to determine these priority areas. The estimated cost of this activity would be $500 K over 3 years.

Selective Implementation (53) – Provide funding to the USGS to acquire high-resolution satellite imagery and create a high-resolution land cover dataset for rapidly changing areas within the Great Lakes - St. Lawrence River basin. Existing lower resolution data sets and census information would be used to determine priority areas. The estimated cost of this activity would be $3 M over 10 years.

Enhanced Implementation (53) – Provide funding to the USGS to acquire high-resolution satellite imagery and create a high-resolution land cover dataset for all urban areas and major transportation arteries across the Great Lakes - St. Lawrence River region and update this mapping every 5-years. Existing land cover datasets can be used to determine priority areas. The cost for this activity is estimated at $4.5 M over 10-years with commensurate annual funding thereafter.

Full Implementation (53)
Provide funding to the USGS to acquire high-resolution satellite imagery and create a high-resolution land cover dataset for all areas within the Great Lakes - St. Lawrence River region and update this mapping every 3-years. The cost for this activity is estimated at $6.0 M over 10-years with commensurate annual funding thereafter.

Task 54: The USGS, in conjunction with the USACE and in cooperation with state agencies, needs to produce land cover change evaluations from available data and 30-year land use projections for the entire the Great Lakes – St. Lawrence River basin to refine ecological impact assessments and anticipated future demands on water resources.

Without Plan (54) – Various agencies will likely develop land cover change mapping products. These products, however, will not be complete, be inconsistent over varying analysis periods, with varying classification strategies and varying spatial scales. Comprehensive and comparable products for the region will be lacking. Emphasis on future land cover projections will also not likely be addressed, and if so, will likely be incomplete in geographic scope, inconsistent in spatial scale, and temporal detail and based upon differing classification methods.

Minimum Investment (54) – Provide funding to the USGS to develop data standards and consistent analysis procedures for land cover change and future projections specific to the needs of water resource decisionmaking for the Great Lakes – St. Lawrence River system. At a minimum, the National Land Cover Dataset would be used to assess changes over the last 10-12 years. The cost for this activity is estimated at $200 K over 2 years.

Selective Implementation (54) – Provide funding to the USGS to develop data standards and consistent analysis procedures for land cover change and future projections specific to the needs of water resource decisionmaking for the Great Lakes – St. Lawrence River system At a minimum, the National Land Cover Dataset would be used to assess changes over the last 10-12 years. The cost for this activity is estimated at $200 K over 2 years.

Enhanced Implementation (54) – Provide funding to the USGS to develop data standards and consistent analysis procedures for land cover change and future projections specific to the needs of water resource decisionmaking for the Great Lakes – St. Lawrence River system. Information from the National Land Cover Dataset would be used to assess changes over the last 10-12 years and other ancillary and higher-resolution data sources. The cost for this activity is estimated at $300 K over 2 years.

Full Implementation (54) – Provide funding to the USGS to develop data standards and consistent analysis procedures for land cover change and future projections specific to the needs of water resource decisionmaking for the Great Lakes – St. Lawrence River system. Information from the National Land Cover Dataset would be used to assess changes over the last 10-12 years and other ancillary and higher-resolution data sources. The cost for this activity is estimated at $1.5 M over 10 years and commensurate annual funding thereafter.

Total Costs Over 10 Years

Without Plan (TOTAL) – $0.0 M

Minimum Investment (TOTAL) – $1.0 M

Selective Implementation (TOTAL) – $3.5 M

Enhanced Implementation (TOTAL) – $5.3 M

Full Implementation (TOTAL) – $9.0 M

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