2007 NSDI Cooperative Agreement Program

Category 4: Geo-Enabled Federal Businesses Initiative
Applied Cooperative Geo-Enabled Business Case

Cooperative Agreement Program Number: 07HQAG0105

Project Title: *Leveraging Geospatial Resources - Making the Case for Geo-Enabling Decision Processes in the Great Lakes*

Final Report

Report Date: January 15, 2009

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Collaborating Organizations: U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Geological Survey

Narrative

Summary of Project Activities

In 2004-05, over 1,600 stakeholders contributed to development of a comprehensive strategy report to addresses significant environmental problems affecting the Great Lakes – St. Lawrence River ecosystem under the auspices of the Great Lakes Regional Collaboration (GLRC). The GLRC was formed under the auspices of the Great Lakes Interagency Task Force[1] created by a Presidential Executive Order in 2004.[2] The Presidential Order obligated federal agencies to work with an array of stakeholders across the region to define a comprehensive strategy to restore and protect the significant environmental and natural resources of the Great Lakes.

The strategy report listed over 45 key objectives to be implemented within the near future, one of which was to meet a lofty goal of restoring ecological function to over 1.1 million acres of wetlands within the U.S. drainage basin to the Great Lakes. To coordinate federal actions to achieve a fraction of this commitment over the near term, the GLRC Executive Committee established a Wetlands Subcommittee led by a consortium of U.S. federal agencies, with the U.S. Environmental Protection Agency (USEPA), U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (USF&WS) and National Oceanic and Atmospheric Administration (NOAA) taking key leadership roles.

[1] http://www.epa.gov/greatlakes/collaboration/taskforce/index.html
[2] http://epa.gov/greatlakes/collaboration/taskforce/eo.html

To embark on attaining a fraction of the overall wetlands restoration goal, the Wetlands Subcommittee has identified the need for a comprehensive, spatially-based tracking, monitoring, and reporting system to better manage and protect Great Lakes wetland complexes. At present, however, *there exists no comprehensive system to track, monitor, and report on wetlands loss or degradation in the Great Lakes Region.* The unavailability of such a geo-enabled system significantly impairs the region's ability to diagnose areas of need and evaluate restoration progress.

In response to this information gap, the Great Lakes Commission (GLC), through the 2007 National Spatial Data Infrastructure (NSDI) Category 4 Cooperative Agreement Program (CAP) has created a web-based *Spatial Decision Support System* utilizing free and open source software and Open Standards to facilitate comprehensive baseline tracking and analysis of wetlands change over time. Specifically, this system does the following:

1. The system is designed to integrate all available wetlands data for the Great Lakes drainage basin, using national, state, and provincial sources. These data are currently inconsistent in scale, resolution, accuracy, temporality, and classification, which make baseline comparison amongst different wetlands datasets challenging. The aggregation and normalization of this information across time and space will better support trend assessments and restoration progress reporting.

2. The system integrates major land cover datasets collected under NOAA's Coastal Change Assessment Program (C-CAP), wetlands datasets from the USF&WS National Wetlands Inventory (NWI) and classified hydric soils mapped under the U.S. Department of Agriculture Soil Survey Geographic Database (SURGGO), allowing for quick comparisons of major classification factors not readily available in the past for use in assessing changes in wetlands extent over time.

3. The system integrates data from the USACE Great Lakes Habitat Initiative (GLHI) database and feeds similar applications. The GLHI project includes an inventory of site-specific actions to protect and restore wetlands and aquatic habitat across the U.S. portion of the Great Lakes region. By leveraging this database, efforts to identify and account for areas of wetlands change (i.e. restoration gains) can be better understood and managed throughout the region.

4. The system is designed to provide for a suite of user-friendly query and analysis tools to help users discover and analyze aggregated wetlands datasets. These tools, although not fully functional at the time of this report, will facilitate comprehensive, inter-agency tracking, reporting, and analysis within the Great Lakes region.

5. The system is designed to provide downloading capabilities through a variety of file formats and as OGC Web services. Although incomplete at present, this capability is expected to maximize the accessibility and extensibility of otherwise unconnected wetlands data.

To communicate to potential users the availability of these tools in support of wetlands tracking and analysis, the GLC is working to actively engage the support of the Wetlands Subcommittee, the Great Lakes Interagency Task Force, and other federal, state, and local entities throughout the region. Additionally, this project uses the Great Lakes Information Network (GLIN) for hosting and promoting access to the wetlands Spatial Decision Support System (SDSS); visit: http://erie.glin.net/wetlands/. Since 1993, GLIN has been a trusted and reliable source of information for those who live, work or have an interest in the Great Lakes, and has become a necessary resource for informed, spatially-driven decision-making in the region.

Key Collaborators

The work completed under this project was designed, developed and implemented by Pete Giencke, currently with Google Earth, and Guan Wang, a GIS programmer with the GLC. Invaluable input on the design of the SDSS and integration of geospatial datasets to support wetlands restoration/protection activities under the GLRC initiative was provided by Brian Huberty, NWI Coordinator with the USF&WS in Fort Snelling, MN, Dr. Kurt Kowalski with the USGS' Great Lakes Science Center in Ann Arbor, MI, Mike Greer of the USACE in Buffalo, NY and Heather Stirratt, Todd Goeks, Nate Herold of NOAA, in Minneapolis, MN, Chicago, IL and Charleston, SC, respectively.

Wetlands Management

Wetlands, or "land characterized by the presence of water at a frequency and duration sufficient to support...wetland vegetation or aquatic life"[3] play an important role in the Great Lakes region. Wetlands contain diverse habitats that support a wide variety of species and are critical way stations for migratory birds and insects. They serve as sediment and nutrient retention areas, improving overall water quality in adjacent bodies of water. Wetlands reduce erosion by mitigating the impact of wave action on back-lying lands and, in a corollary role, reduce the severity of floods by slowing the rate at which runoff water enters the system. In many areas, wetlands also contribute to the economy by improving fisheries, providing recreation opportunities, and supporting agricultural practices.

Despite these benefits, wetlands in the United States, and especially within the Great Lakes region, have suffered significant and systematic degradation. Some wetland areas have been harvested for crops or timber, or mined for peat. Many have been drained, filled, or flooded to for agricultural and other uses. Prior to European settlement, approximately 221 million acres of wetlands are thought to have covered what is now the coterminous United States. By the mid-1980s, anthropogenic changes to wetlands had reduced the total acreage by over 50%, such that only about 103 million acres of wetlands remained[4] (Figure 1). The Great Lakes region, specifically, has seen a loss of more than half of the original wetlands in the basin.[5] Clearly, humans have transformed the character and appearance of wetlands on a national scale, profoundly altering the nature, extent, and functionality these important ecosystems.[6]

Within the binational Great Lakes basin, federal and non-federal agencies, NGOs, and tribal entities now have a mission-related focus on wetlands management and regulation. Programs devoted to wetlands restoration and protection include the Natural Resource Conservation Service (NRCS) Wetland Reserve Program, the USF&WS Partners for Fish and Wildlife Program, the Farm Services Administration (FSA) Conservation Reserve Enhancement Program, the FSA Continuous Conservation Reserve Program and the USACE regulatory program authorized under Section 404 of the Clean Water Act.[7] These federal programs are helping to restore and protect Great Lakes wetlands. However, efforts to quantify these successes have been hampered by the lack of a comprehensive tracking and reporting system for monitoring changes in wetlands extent and function.

[3] Part 303, Wetlands Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451
[4] Dahl, T.E., and Johnson, C.E., 1991. Wetlands--Status and trends in the conterminous United States, mid-1970's to mid-1980's. Washington, D.C., U.S. Fish and Wildlife Service.
[5] http://www.mnrg.gov/meetings/2006meeting/pdfs/overview-iatf-wetlands-subcommittee.pdf
[6] Prince, Hugh C. Wetlands of the American Midwest: A Historical Geography of Changing Attitudes University of Chicago Geography Research Paper
[7] http://www.michigan.gov/deq/0,1607,7-135-3313_3687-10419--,00.html

Figure 1 – States with notable wetland loss, 1790s to mid-1980s [8]

<u>Great Lakes Wetlands and Related Datasets</u>

For the Great Lakes, there exist many overlapping wetlands datasets, including those at national, state, and provincial levels (Figure 2 below, a critical component in the logic diagram for developing a consistent wetlands monitoring program for the region, detailed in Attachment 2).

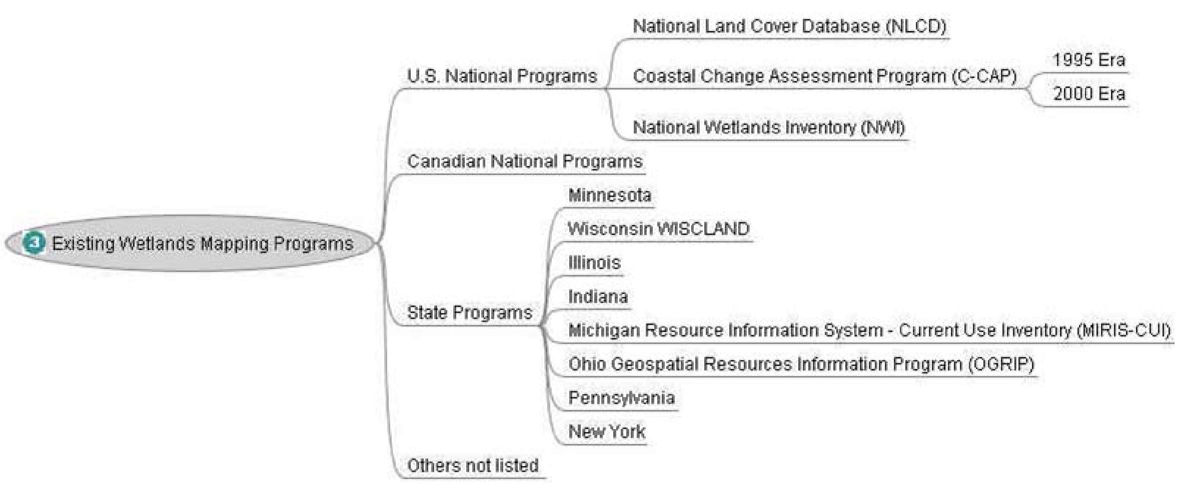

Figure 2 –Wetlands Mapping Programs in the Great Lakes [9]

[8] http://water.usgs.gov/nwsum/WSP2425/history.html
[9] http://wiki.glin.net/display/GLCW/Wetland+Monitoring+Decision+Tree

Unfortunately, these wetland datasets are often incompatible, owing to temporal, spatial, and classification consistencies (Figure 3). The Great Lakes wetlands SDSS is designed to deliver these often disparate representations of complex geographies and classification approaches with the hope that future aggregation and normalization of these data would occur to support periodic change assessments over the entire region.

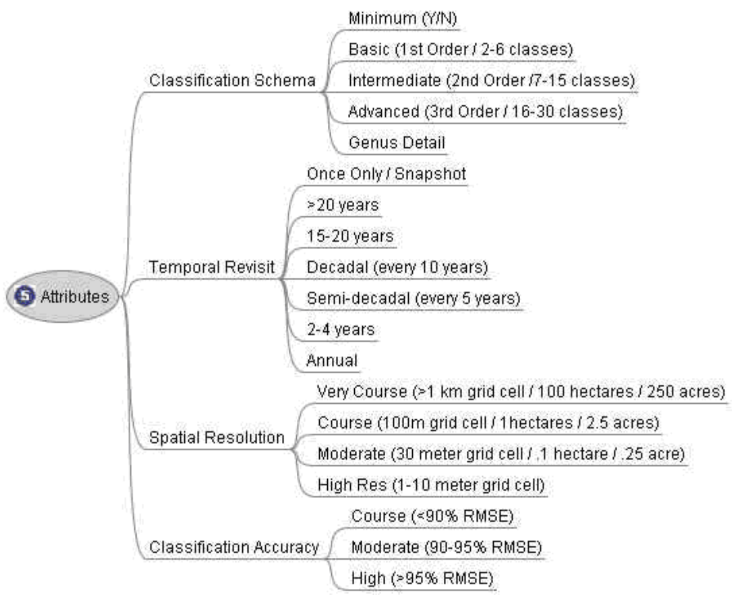

Figure 3 – Wetlands Classification Attributes[10]

Key Accomplishments

<u>Assessment of the Characteristics of the Great Lakes Wetlands SDSS</u>

To meet the need for a system to help manage and analyze wetlands habitat in the Great Lakes region, the GLC has designed and built an initial version of a wetlands-focused SDSS. An SDSS is an interactive, computer-based system designed to support a broad user community in achieving greater decision-making efficacy when solving semi-structured spatial problems.[11] A semi-structured spatial problem is one that requires users to utilize computational processes, including data analysis and visualization (Figure 4). The Great Lakes SDSS is expected to facilitate human-computer interaction, thereby affording resource managers increased ability to manage wetlands restoration within their respective jurisdictions.

[10] http://glos.us/wiki/display/GLCW/Wetland+Monitoring+Decision+Tree

[11] Sprague, R. H., and E. D. Carlson (1982) Building effective Decision Support Systems. Englewood Cliffs, N.J.:Prentice-Hall, Inc.

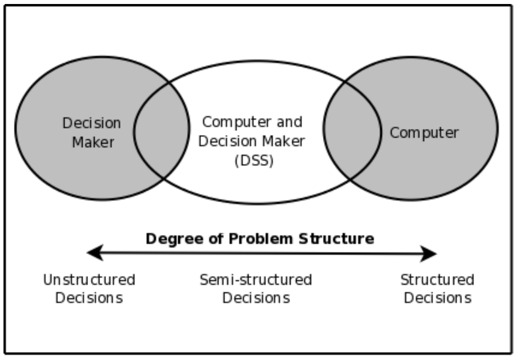

Figure 4 – Degree of Problem Structure[12]

The wetlands restoration and protection decision-making process can be broken into three major phases: *intelligence*, *design*, and *choice*. The *intelligence* phase involves searching or scanning the environment for circumstances calling for the attention of decision-makers. After issue have been identified in the intelligence process, the *design* process outlines decision alternatives to be analyzed and evaluated, and ultimately selected in the *choice* phase of the process (Figure 5 below).

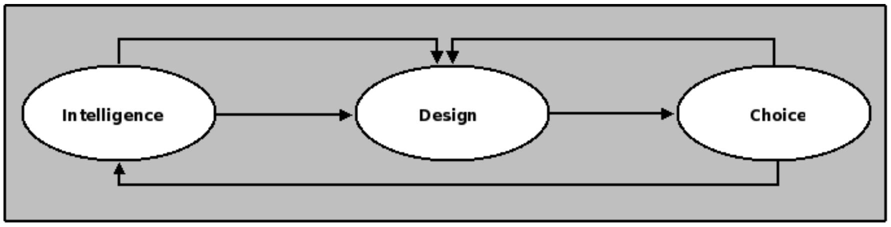

Figure 5 - Phases of decision-making [13]

In the decision support framework, the effectiveness of the intelligence phase is determined by the extent to which it is possible to "integrate and explore data and information from a wide variety of sources."[14]

<u>Weighing SDSS Software Alternatives</u>

A key consideration in the design of the Great Lakes Wetlands SDSS was to consider if a Free and Open Source Software (FOSS) solution was most advantageous for implementing and maintaining a long-term operational support. A series of alternative approaches in terms of cost, geospatial capabilities, license type, and overall advantages and limitations were assessed. The results of this assessment are included under Attachment 3 to this report.

[12] Simon, H. A. (1960) *The new Science of Management Decision.* New York: Harper and Row.
[13] http://www.ncgia.ucsb.edu/giscc/units/u127/figures/figure1.gif
[14] Simon, H. A. (1960) *The new Science of Management Decision.* New York: Harper and Row.

Functional Design for the SDSS

The Great Lakes Wetlands SDSS is structured to integrate a wide variety of regional datasets to:

6. Provide access to aggregated, normalized Great Lakes wetlands datasets using national datasets such as NWI, C-CAP (1996, 2001 integrated, 2006 awaiting download and integration) and the NLCD (not populated yet, with high correspondence to C-CAP) along with state and provincial sources (such as WISCLAND, OGRIP, among others not yet populated);

7. Integrate ancillary "framework" geospatial layers including the National Hydrologic Dataset (NHD), National Elevation Dataset (NED) and other seamless layers (not yet accomplished) to better discriminate wetlands characteristics and normalize baseline conditions;

8. Include a direct linkage with the USACE Great Lakes Habitat Initiative (GLHI) project database. The GLHI project provides an inventory of site-specific, regional-scale wetlands and aquatic habitat restoration/protection projects; this linkage allows resource managers to delineate and upload their complete, in-progress, or proposed site-specific wetlands protection and restoration activities through the GLHI tools, which in turn can define the acreages anticipated for any resulting wetlands gains; it also allows users to view adjacent wetland parcels which can reduce habitat fragmentation , and to view other proposed, completed, and ongoing restoration projects in the region;

9. Provide a "lightweight" web-based visualization interface to explore aggregated geospatial datasets; the visualization mechanism uses a "best-practices" approach to presenting geospatial datasets, combining base raster layers (such as high resolution imagery) to provide context for the overlain vector-based wetland layers (Figure 6);

10. Implement an easy-to-use search mechanism with the web mapping application; this functionality would allow users to perform spatially structured queries against the aggregated geospatial datasets;

11. Make value-added project data widely available through a range of file formats and OGC Web services (not currently functional); these formats are expected to include Keyhole Markup Language (KML), Portable Document Format (PDF), Shapefile (SHP) and Javascript Object Notation (JSON); data will also be available as a Web Mapping Service (WMS) and as a Web Feature Service (WFS).

Development of the SDSS

The Great Lakes Wetlands SDSS is a concept-proven prototype application that completely relies on FOSS. From the system architecture view, it was built on top of a Linux Operating System, PostgreSQL/PostGIS database, Geoserver GIS engine, and other software packages, including GDAL/OGR, proj4. From the application level, the data access tier and business process tier were developed by PHP and the user interface was adopted using a Ext-javascript library. The interactive map on the client side was written by OpenLayers. All software utilized is license-free and allow users to use, change, and improve the software and to redistribute it in modified or unmodified form. This license-free component of the software allows for the SDSS to be freely replicated elsewhere, owing to the zero-dollar cost of the software.

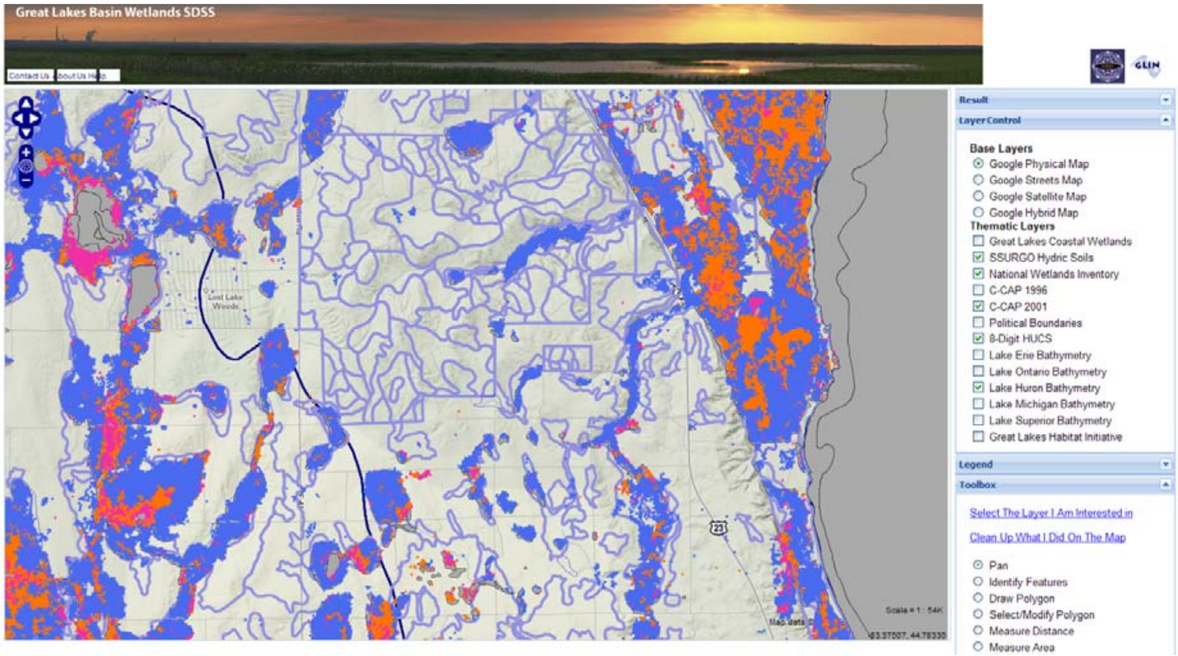

Figure 6 – Great Lakes Wetlands SDSS Map Viewer (http://erie.glin.net/wetlands)

In order to take full advantage of OGC standards and make data discoverable through the Internet, Service-Oriented Architecture (SOA) is used in a broad sense as an approach to system development and integration where functions are grouped according to business process and packaged as services. All wetlands data are published as WMS through the GIS engine, which supports both "GetMap" and "GetFeatureInfo" methods. Requests for other data types are interpreted by a request proxy either before it echoes the GIS engine or after the GIS engine returns its results. In other words, the standard request process inside the GIS engine is not intercepted by customized requests, which helps to keep all services independent. Services talk to each other through pre-defined interfaces and the protocol, such as SOAP. The system workflow engaged in SDSS is graphically represented in Figure 7 below.

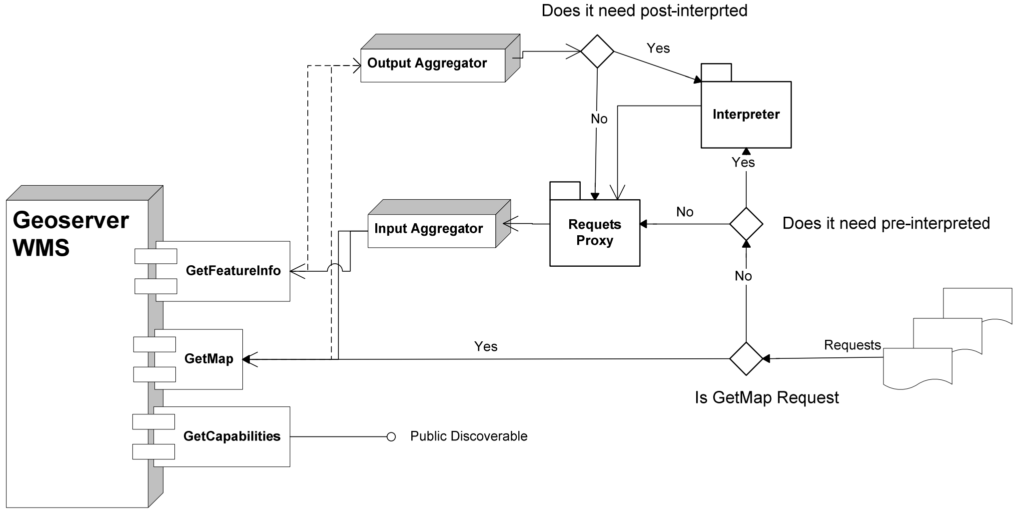

Figure 7 – Great Lakes Wetlands SDSS Workflow

Great Lakes Wetlands SDSS Service Requirements

From a systems-engineering standpoint, there are several non-functional or service requirements that the SDSS must provide to be useful for regional, inter-agency application. The satisfaction of these requirements will determine the overall operation and utility of the system[15] and in this case include:

- The SDSS must be sufficiently extensible to support its potential use as thematic content is expanded;
- The SDSS must be scalable in both the horizontal and vertical dimension to meet the highly specific and wide-ranging needs of the diverse user community;
- The SDSS needs to maximize platform compatibility and ease-of-use to ensure access and usability of the compiled data and associated tools for users and their browsers, operating systems, etc.
- The SDSS needs to be cost-effective and easy to implement, given the project's modest budget and aggressive timeline.

To meet these requirements, the following technical specifications have been realized:

- The Great Lakes Wetlands SDSS leverages open geospatial (OpenGIS) standards; open geospatial standards, or technical specifications detailing standardized interfaces or encodings[16], are vetted through the Open Geospatial Consortium (OGC), which is composed of "344 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications"[17]; the goal of the OGC, through the OpenGIS standards process, is to systematize mechanisms for transferring and accessing geospatial data; utilizing OpenGIS standards within the SDSS maximizes the "interoperability" of data, allowing for greater potential downstream access and use of the data;

- For dissemination and ingestion of value-added project data, the OGC Web Mapping Service (WMS) and Web Feature Service (WFS) standards will be used; users of the Great Lakes SDSS can view project data in a variety of ways using these services, from web browsers, to standalone desktop applications (i.e. ArcGIS), to Web 2.0 mashups;

- Leverage a platform-independent codebase; a cross-platform codebase, or underlying development language, is one that can be run on multiple platforms (e.g. operating systems, web browsers, computer architectures) with same or similar performance; code written in a platform-independent language can be run on a wide range of potential systems, allowing for potential uses of the codebase in other geographic or thematic domains; the SDSS utilizes the Javascript, PHP, and Python languages in creating a system that's usable in many different environments;

- Leverage FOSS for data storage and display; from the backend PostgreSQL/PostGIS spatial database to the frontend OpenLayers map visualization software, the SDSS utilizes public domain software, otherwise known as FOSS, throughout; FOSS is software that is license-free, and allows users to use, change, and improve the software, and to redistribute it in modified or unmodified form; this license-free component of the software allows for the Great Lakes Wetlands SDSS to be freely replicated elsewhere, owing to the zero-dollar cost of the software.

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[15] Andrew Stellman and Jennifer Greene (2005). *Applied Software Project Management*. Cambridge, MA: O'Reilly Media. ISBN 0-596-00948-8.
[16] http://www.opengeospatial.org/standards
[17] Ibid

Wetlands Data Normalization

As can be seen, there exists tremendous variation amongst the multiple wetlands GIS data layers covering the region. In coming up with solution to provide an "apples-to-apples" comparison of wetlands data over time, normalization of wetlands data becomes necessary to the extent possible. Normalization in this case refers to ensuring semantic compatibility of wetland delineations and collapsing wetland classifications such that each dataset contains the same wetland classes. This comes at a cost however, as layers with a higher resolution will become generalized as part of the normalization process.

In coming up with a baseline definition for wetlands classifications sufficient for inter-dataset comparison, it was determined that the NOAA C-CAP dataset would provides the best baseline categorization of the different wetland types. The C-CAP provides six core wetlands classes, three of which generally correspond with those classifications found in other Great Lakes wetlands datasets. The definitions are:

- Palustrine Forested Wetland. This class includes "all tidal and nontidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent."[18]

- Palustrine Scrub/Shrub Wetland. This class includes "all tidal and non tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. The species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions."[19]

- Palustrine Emergent Wetland (Persistent). This class includes "all tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Plants generally remain standing until the next growing season. Total vegetation cover is greater than 80 percent."[20]

Care needs to be exercised in defining a spatial resolution required for a baseline comparison of different wetlands datasets. More investigation is required into this, as the spatial resolution of each dataset varies so greatly. Tentatively, a 30-meter spatial resolution is being considered. This resolution is based upon the Landsat 5 satellite's spatial resolution, from which the C-CAP data is derived.

Improving Federal Business Decision-making

Consolidation of the heretofore separate data themes in a more comprehensive and complete data framework is the first step in developing an effective and sustainable SDSS structure. Dataset consolidation should help regional resource managers to determine the efficacy of using various datasets for their applications based upon their varying characteristics of temporality, spatial resolution, and classification approaches.

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[18] http://www.csc.noaa.gov/crs/lca/tech_cls.html#14
[19] Ibid
[20] Ibid

For instance, permit evaluators working under the 404 permitting program by the USACE and within state governments can now assess the likelihood of wetland occurrences by visualizing previous classifications all within the same georeferenced viewer, and in the near future with additional contextual referencing including landform and stream networking. Likewise these same permit evaluators will be able to inform the process of tracking changes in wetlands extent by providing field verification directly to the Wetlands SDSS in future expansions of the systems.

In its current state of development, the Great Lakes Wetlands SDSS has already benefitted to the habitat restoration process currently being undertaken by the Interagency Task Force supporting the GLRC process. Procedures for integrating federal wetlands datasets under this project have been used to determine anticipated ecological benefits likely to be attained by implementation of over 240 projects identified in the GLHI database. The Wetlands Viewer for the SDSS is also being used to drive map queries from the GLHI database, allowing a wide range of regional stakeholders easy access to critical ecological information about their respective projects.

The region continues to face challenges in tracking restoration process for the biennial data call conducted by the President's Council on Environmental Quality (CEQ). The initial version of the SDSS will allow for quick comparisons of baseline wetlands conditions using the various classification approaches historically employed. However, the five-year repeat cycle characteristics of C-CAP data are the best available information for informing the two-year update requirement of the CEQ reporting program.

Finally, the Great Lakes Wetlands SDSS, acting as the central data repository, will provide significant value to the State of the Lakes Ecosystem Conference (SOLEC) indicator reporting process managed by the USEPA and Environment Canada. SOLEC indicators developed to assess wetlands change over the region have never been adequately reported on, since critical data to support these tasks have never been normalized to allow for defensible change detection analysis.

Conclusions

The web-based nature of the Great Lakes Wetlands SDSS facilitates geo-enabled decision making on a regional, inter-agency, and collaborative basis. Importantly, the SDSS will allow decision makers to explore and analyze areas with present wetlands coverage, as well as past and future wetlands restoration projects. Armed with this knowledge, members of the Wetlands Subcommittee can generate a set of proposed management plans to make informed, geo-enabled decisions related to wetlands restoration activities.

On a technical level, the utilization of free and open source software in the creation of the SDSS is equally significant. The use of a free and open source spatial database in conjunction with an open source mapping frontend, will allow other geographies, and other disciplines the opportunity to leverage the SDSS, in a very cost-effective manner. Its adaptable codebase provides significant extensibility, allowing developers to customize the SDSS to evolving uses. Similarly, the use of OpenGIS standards (i.e. OGC services) as a mechanism to distribute value-added project data ensures that users, regardless of platforms, can access the SDSS and its output. These services cut across business lines, and allow end users to access and acquire project data in a variety of business applications.

In all, the SDSS represents a substantive movement forward in terms of aggregating and accessing wetlands information for the Great Lakes region. Through the SDSS, resource managers can make better, more informed decisions affecting Great Lakes wetlands protection and restoration, especially those in support of near term, federal commitments.

Next Steps

Considerable follow-up work still needs to be completed to realize the full potential of the Great Lakes Wetlands SDSS. These major additional tasks include:

1. Populate the SDSS with NLCD, C-CAP-06, WISCLAND, MIRIS, OMNR and other state wetlands classifications datasets;
2. Complete implementation of code to provide basic query capabilities;
3. Add download capability for various formats that are served directly from the SDSS;
4. Incorporate ancillary datasets including National Hydrologic Database (NHD), National Elevation Database (NED) and NatureServ rare, endangered and threatened habitat/species datasets;
5. Develop and implement a normalization protocol to exploit information from differing available wetlands datasets; and
6. Explore potential linkages with the USACE's 404 permit records database to provide field verification input.

Feedback on Cooperative Agreements Program

Within the Great Lakes region, NSDI-CAP grants have historically proven to be an effective mechanism for bringing organizations, ideas, and technology together. Many of these regional pilot projects have been expanded beyond their initial scope of work, including the following:

- The 2006 Minnesota and Wisconsin Fifty State Initiative, whose output (a long-term strategic vision) has been adopted nationwide.
- The 2005 "Developing a Strategic Plan for GIS in Wisconsin" project has evolved into the Wisconsin Geographic Information Coordination Committee (WIGICC), a sanctioned state-wide entity tasked with coordinating GIS activities in WI.
- The 2004 Great Lakes Information Network Data Access (GLINDA) GIS Portal for aggregating regional metadata into a centralized repository. The GLINDA project has morphed into the GLIN GIS, which is currently aggregating and disseminating regionally-focused data for the Great Lakes, serving over 10,000 visitors a month.

Despite the overall success of these and other regional CAP-funded projects, there are several weaknesses in the CAP Program, the remediation of which would further the accomplishment of these projects.

- Although the CAP program is heavily-promoted through the FGDC website, there appears to be a significant shortfall in marketing of the final products produced under the program and the lay geospatial community. The program should seek to promote other recognized geospatial channels (e.g. Planet Geospatial, Where 2.0, etc) to market project results beyond standard FGDC channels.
- The CAP program should encourage and facilitate partnerships among the different program awardees. Such collaboration has the potential to leverage economies of scale in terms of providing better, cheaper, more extensible products on a yearly basis.
- Finally, funding guidelines should be reviewed and updated to account for the growing need to web-enable GIS data and products. The current stipulation that FGDC funding cannot be used for hardware costs (i.e. bandwidth, servers) is a major constraint. For projects that depend on web-enablement, it is necessary to budget for continuing bandwidth, security, etc. to enhance the sustainability of the product.

Attachments

Attachment 1 – Glossary
Attachment 2 – Characteristics of Wetlands Mapping Programs
Attachment 3 – SDSS Software Alternatives

Attachment 1: Glossary

API: Application programming interface.
ArcGIS: ArcGIS is an integrated collection of GIS software products for building a complete GIS. ArcGIS enables users to deploy GIS functionality wherever it is needed—in desktops, servers, or custom applications; over the Web; or in the field.
Business Case: The business need that a project intends to address. A business case includes the reasons for the project, the expected business benefits, the options and alternatives, and the expected costs.
ESRI: A commercial company responsible for creating GIS application and server software. The two software packages in primary use outside of AOOS are ArcGIS and ArcIMS. http://www.esri.com/.
FGDC: Federal Geographic Data Committee. http://www.fgdc.gov/. The FGDC is an interagency committee that promotes the coordinated, use, and dissemination of geospatial data on a national basis.
Great Lakes Information Network (GLIN): An information service providing "one-stop shopping" for Great Lakes-related resources.
Great Lakes Interagency Task Force: On 18 May 04, President Bush signed Executive Order (EO) 13340. The EO established the Great Lakes Interagency Task Force, composed of Secretaries from the Departments of State, Army, Agriculture, Commerce, HUD, Homeland Security, Interior, Transportation, the Administrator of the EPA and the Chairman of the Council on Environmental Quality.
GLIN GIS: The Maps and GIS section of the GLIN website (http://gis.glin.net) provides a centralized location to discover, publish, and acquire geospatial data for areas within the Great Lakes region.
GIS: Geographic Information System. GIS describes a particular type or format of data that work with geospatial software. Typical categories or formats of GIS data are point, raster or shape files. One unique feature of these datasets is geo-reference metadata is embedded.
KML: Keyhole Markup Language. KML is an XML grammar and file format for modeling and storing geographic features such as points, lines, images and polygons for display in Google Earth™ and Google Maps™.
Mapserver: Software. Mapserver is an Open Source development environment for building spatially enabled internet applications. http://mapserver.gis.umn.edu/.
MySQL: http://www.mysql.com/. An open source and commercial relational database system. This is one of two open source databases in use by AOOS. See also **PostgreSQL**.
NOAA: National Ocean and Atmospheric Administration
OGC: Open Geospatial Consortium; OpenGIS®. http://www.opengeospatial.org/. OGC is a non-profit, international, voluntary consensus standards organization that is leading the development of standards and location based services.
OS: Operating System. The software layer that handles transactions between programs and hardware and devices attached to the computer (e.g. hard drives, USB drives, video card, motherboard, mouse and keyboard).
PostGIS: PostGIS enables support for geographic objects to the PostgreSQL object-relational database. http://postgis.refractions.net/.
PostgreSQL: PostgreSQL is a powerful, open source relational database system. http://www.postgresql.org/. This is one of two open source relational databases in use by AOOS. See also **MySQL**.
WFS: The OpenGIS® Web Feature Service Interface Standard (WFS) is an interface allowing requests for geographical features across the web using platform-independent calls. The XML-based GML is the default payload encoding for transporting the geographic features.
WMS: The OpenGIS® Web Map Service (WMS) Implementation for the creation of spatially referenced portrayal of geographic information as a digital file (e.g. JPEG, PNG).
XML: Extensible Markup Language. http://en.wikipedia.org/wiki/XML.

Attachment 2: Characteristics of Wetlands Mapping Programs

U.S. National Programs

National Wetlands Inventory (NWI)
Source: U.S. Fish and Wildlife Service
Description: Records of wetlands location and classification as defined by the U.S. Fish & Wildlife Service containing ground planimetric coordinates of wetlands point, line, and area features and wetlands attributes. NWI maps are compiled through manual photointerpretation of NHAP or NAPP aerial photography supplemented by soils surveys and field checking of wetland photo signatures. Delineated wetland boundaries are manually transferred from interpreted photos to USGS 7.5 minute topographic quadrangle maps and manually labeled. Digital wetlands data are either manually digitized or scanned from stable-base copies of the 1:24,000 scale wetlands overlays registered to the standard USGS 7.5 minute quadrangles into topologically correct data files.
Limitations: The NWI maps do not show all wetlands since the maps are derived from aerial photointerpretation with varying limitations due to scale, photo quality, inventory techniques, and other factors. Consequently, the maps tend to show wetlands that are readily photointerpreted given consideration of photo and map scale. It is suggested that users also consult other information to aid in wetland detection, such as U.S. Department of Agriculture soil survey reports and other wetland maps that may have been produced by state and local governments, and not rely solely on NWI maps.

National Land Cover Database (NLCD) 2001
Source: Multi-Resolution Land Characteristics (MRLC) Consortium
Description: NLCD 2001 is a land-cover database comprised of three elements: land cover, impervious surface and canopy density. NLCD 2001 provides land cover data necessary to meet the vision of the National Map currently being created by the USGS using Landsat 7 and Landsat 5 multi-temporal data and ancillary data. The MRLC Consortium is a partnership of federal agencies, including USGS, NOAA, USEPA, USDA, USF&WS, and the U.S. Forest Service (USFS), National Park Service (NPS), Bureau of Land Management (BLM) and the USDA Natural Resources Conservation Service (NRCS). One of the primary goals of the project is to generate a current, consistent, seamless, and accurate National Land cover Database (NLCD) circa 2001 for the United States at medium spatial resolution. This landcover map and all documents pertaining to it are considered "provisional" until a formal accuracy assessment can be conducted.

Coastal Change Assessment Program (C-CAP)
Source: National Oceanic and Atmospheric Administration
Description: The C-CAP maps land cover for coastal regions with a focus on wetlands categories, including the entire Great Lakes drainage basin so far on a five-year repeat cycle, using Landsat data. C-CAP coordinates closely with the NLCD effort and incorporates data directly into the National Map.

U.S. State Programs

Wisconsin Wetland Inventory
Source: Wisconsin Department of Natural Resources
Description: Wisconsin Wetland Inventory (WWI) maps show graphic representations of the type, size and location of wetlands in Wisconsin. These maps have been prepared from the analysis of high altitude imagery in conjunction with soil surveys, topographic maps, previous wetland inventories and field work. The data are accurate at a scale of 1:24,000. The initial inventory was completed in 1984. Wetlands of 2 acres and larger are outlined on the maps. Smaller wetlands are identified by point symbols. Detailed information on the WWI mapping standards can be found in the *Classification Guide for the Wisconsin Wetland Inventory*.
Limitations: Budget constraints limit the updates to a 20 year cycle.

Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND)
Source: Wisconsin Department of Natural Resources
Description: The WISCLAND (Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data) Land Cover data set is a raster representation of vegetation/land cover for the state of Wisconsin. The source data were acquired from the nationwide MRLC acquisition of dual-date Landsat Thematic Mapper (TM) data primarily from 1992. The image processing technique followed was published in the UMGAP Image Processing Protocol (1998). The original pixel size of the source TM data is 30 meters, however the classified WISCLAND Land Cover data (excluding URBAN) are generalized or 'smoothed' to an area no smaller than four contiguous pixels (equivalent to approximately one acre). The result of this smoothing is that any feature five acres or larger may be resolved in the data (i.e., Minimum Mapping Unit (MMU) of five acres). The Land Cover data are usable at nominal scales of 1:40,000 to 1:500,000 for a wide variety of resource management and planning applications. The classification scheme was designed to be compatible with existing classification schemes such as UNESCO's and Anderson's.

Michigan Wetland Inventory Maps
Source: Michigan Department of Environmental Quality
Description: Wetland inventories for Michigan were produced on a county-by-county basis, all in the same manner. Inventories were produced by overlaying data from the following sources:

1. The National Wetland Inventory (NWI) circa 1981, conducted by the U.S. Fish and Wildlife Service through interpretation of topographic data and aerial photographs.
2. Land Cover, as mapped by the Michigan Department of Natural Resources' Michigan Resource Inventory System (MIRIS) circa 1978, through interpretation of aerial photographs.
3. Soils, as mapped by the USDA circa 2005, NRCS.

Limitations: The inventories represent existing information that suggests the probability that a wetland may or may not exist in a given area. Areas shown as wetlands, wetland soils, or open water on the map are potential wetlands, and deserve further site investigation to verify if wetlands are actually present. The maps may not identify all potential wetlands in a county. It may show wetlands that are not actually present and it may not show wetlands which are actually present.

Minnesota National Wetlands Inventory
Source: Minnesota Land Management Information Center (LMIC)
Description: LMIC converted the Minnesota NWI files to ARC/INFO coverage format and edge-matched the files. In cooperation with the DNR and USFWS, LMIC revised the legends to correct errors and to add items for individual portions of the NWI code. DNR added translations from the Cowardin wetland classification system to the Circular 39 wetland classification system.
Limitations: The Minnesota NWI inherits the same limitations as the National scale NWI. In addition, data with adjustments made to the classification system by LMIC are available only in 7.5 minute by 7.5 minute blocks.

Illinois
Source: National Wetlands Inventory
Description: *See* ***National Wetlands Inventory***

Pennsylvania
Source: National Wetlands Inventory
Description: *See* ***National Wetlands Inventory***

New York State Regulatory Freshwater Wetlands
Source: New York State Department of Environmental Conservation
Description: Wetland boundaries were delineated as "approximate" on 1 to 24,000 scale maps using a variety of methods, including aerial photographic interpretation, reference to published maps and field investigations. However, due to changes over time in the wetland resource, field verification of wetland boundaries is increasingly important. Digital wetland borders are derived from individual 1 to 24,000 quads, either by digitizing or by scanning followed by semi-automated raster to vector conversion. Quality assurance and quality control procedures included overlay of plot of digital boundaries on original source map with the condition for acceptance being no visible separation allowed between boundaries. Data were complete in 1989 and are updated as amendments occur.
Limitations: Data are available on a county basis for all areas of New York State outside the Adirondack Park

Ohio Wetland Inventory
Source: Ohio Department of Natural Resources
Description: The wetlands inventory for the State of Ohio was produced by the digital image processing of Landsat Thematic Mapper Data. The resolution of the Thematic Mapper data is a 30 meter by 30 meter cell. The satellite data reflect conditions during the specific year and season the data was acquired, therefore all wetlands present in an area may not be indicated. Statistics generated from the inventory are intended solely as an approximation.

Attachment 3: Weighing SDSS Software Alternatives

In gauging the decision whether to realize a wholly Free and Open Source Software (FOSS) solution for the SDSS, especially as it relates to the storage and display of integrated geospatial datasets, it is appropriate to examine the alternatives in terms of cost, geospatial capabilities, license type, and overall advantages and limitations.

PostGIS

Vendor Description: PostGIS is an extension to the PostgreSQL which allows GIS (Geographic Information Systems) objects to be stored in the database. In effect, PostGIS "spatially enables" the PostgreSQL server, "allowing it to be used as a backend spatial database for geographic information systems (GIS), much like ESRI's SDE or Oracle's Spatial extension. PostGIS follows the OpenGIS "Simple Features Specification for SQL" and has been certified as compliant with the "Types and Functions" profile. PostGIS includes support for GiST-based R-Tree spatial indexes, and functions for analysis and processing of GIS objects."[21] [22]
License: GNU General Public License (public)
Geospatial capabilities: PostGIS supports many standards including the Open GIS Consortium (OGC) standards for Well Known Text (WKT) and Well Known Binary (WKB) representations of data. PostGIS fully supports the OGC Simple Features specification, and provides over 400 geospatial functions.
Cost: Free
Advantages: PostGIS is free, highly customizable, provides cross-platform functionality, is supported by most of open source GIS packages, and works with multiple programming languages including Perl, PHP, Python, TCL, C, C++, Java, C#, and more.
Limitations: Owing to its Open Source nature, customer support options are limited to mailing lists, FAQs and listservs. PostGIS is known to perform less efficiently than Oracle and MySQL, and not fully supported by ArcMap 9.2, the world's most popular desktop GIS software.

ArcSDE

Vendor Description: "ArcSDE technology is an integrated part of ArcGIS Desktop and ArcGIS Server and a core element of any enterprise GIS solution. Its primary role is to act as the database access engine to spatial data, its associated attributes, and metadata stored within a relational database management system (RDBMS)".[23]
License: Propriety (commercial)
Cost: From $10,000 for a commercial license + commercial database license (>$5,000)
Geospatial capabilities: Supports OGC's Simple Feature Specification for SQL, support for all ESRI Geometry Types, and provides over 200+ Geospatial operators/functions.
Advantages: ArcSDE provides a wealth of customer support including 24x7x365 solutions available through ESRI and commercial entities. ArcSDE enjoys a very successful track record in the form of various industries and government agency case studies. It is a cross-platform solution, and supports many underlying databases including DB2, Informix, SQL Server, SQL Server Express, and Oracle.
Limitations: ArcSDE is a relatively expensive solution, requiring a costly commercial database to drive its operation (changing after v9.2). It is also tightly integrated with other ESRI products, making it an unattractive option for those on a limited budget. The ArcSDE API is not open source, which prevents any customization of the backend functionality.

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[21] http://postgis.refractions.net/documentation/
[22] http://postgis.refractions.net/
[23] http://www.esri.com/software/arcgis/arcsde/

Oracle Spatial

Vendor Description: "Oracle Spatial is an option for Oracle Enterprise Edition that provides advanced spatial features to support high-end GIS and LBS solutions. Oracle Spatial forms a separately-licensed option component of the Oracle Database. Oracle Spatial aids users in managing geographic and location-data in a native type within an Oracle database, potentially supporting a wide range of applications — from automated mapping/facilities-management and geographic information systems (GIS), to wireless location services and location-enabled e-business."[24]
License: Propriety (commercial)
Cost: $10,000 for single "Processor license" + Oracle License (> $5,000)
Geospatial capabilities: Oracle Spatial upports OGC's Simple Feature Specification for SQL, provides over 400 spatial functions, and supports SDOGeometry, comprised of points, line strings, polygons
Advantages: Oracle Spatial is a robust, highly scalable, and well-document, well-supported spatial database. It is a cross-platform solution, supported by most of GIS services/software vendors.[25] Database performance is said to be excellent, although little published empirical evidence exists.
Limitations: Oracle Spatial requires an underlying Oracle database, which can result in cost-prohibitive solution for those without an existing license. Given the project's functional requirements including modest budget and need for a highly-customizable and highly-capable database, it can be seen PostGIS provides the greatest "bang for the buck" in terms of providing a suitable backend. For the frontend data visualization

OpenLayers and web mapping alternatives

OpenLayers

Vendor Description: "OpenLayers is a pure JavaScript library for displaying map data in most modern web browsers, with no server-side dependencies. Open Layers makes it easy to put a dynamic map in any web page. OpenLayers implements industry-standard methods for geographic data access, such as the OpenGIS Consortium's Web Mapping Service (WMS) and Web Feature Service (WFS) protocols. As a framework, OpenLayers is intended to separate map tools from map data so that all the tools can operate on all the data sources."[26]
License: BSD License (public)
Cost: Free
Advantages: OpenLayers is an free, OGC-compliant, lightweight solution for creating maps online. OpenLlayers can take advantage of WMS and WFS services, and is supported by most server-side GIS engines, including GeoServer and MapServer.
Limitations: OpenLayers requires server-side GIS support, or public mapping services available. There are limited support options available, limited to mailing lists, FAQs and wiki entries. A robust library of pre-built tools doesn't exist, and requires an experience Javascript developer to implement more advanced web mapping solutions.

ArcGIS Server

Description: "ArcGIS Server is a complete and integrated server-based enterprise GIS. It comes with out-of-the-box, end user applications and services for spatial data management, visualization, and spatial analysis. ArcGIS Server supports software development on the .NET Framework and the Java (programming language). ArcGIS Server services can be consumed by web browsers, mobile devices and

[24] http://www.oracle.com/technology/products/spatial/index.html
[25] http://www.oracle.com/technology/products/spatial/pdf/10gr2_collateral/spatial_twp_10gr2.pdf
[26] http://www.openlayers.org

desktop systems. ArcGIS Server supports interoperability standards such as OGC and W3C. Several service like mapping services, geocoding services, geodata management services, geoprocessing services, virtual globe services and network analysis services are available via a SOAP API."[27] [28]

License: proprietary (commercial)

Cost: From $10,000 for a commercial license

Advantages: ArcGIS Server provides an OGC-compliant framework for web mapping, is highly-customizable through .NET or Java. ArcGIS Server provides ready-made templates for web mapping, and includes extensions for added geospatial visualization capabilities. It is also a very well-supported product, taking advantage of ESRI's exhaustive support network.

Limitations: ArcGIS Server is a "heavy" application, and can yield a more complex and computationally costly solution than necessary. As ArcGIS Server is tightly integrated with other ESRI products, it requires a sizable investment in ESRI software to really perform "as advertised." Given the project's functional requirements, including the need to have a scalable and lightweight frontend viewer, OpenLayers was chosen for the mapping frontend. By leveraging in-house Javascript expertise, it's projected that the project will have a faster and just-as-functional mapping frontend, at a fraction of the cost, by realizing an Open Source solution.

[27] http://en.wikipedia.org/wiki/ArcGIS_Server

[28] http://www.esri.com/software/arcgis/arcgisserver/about/who-uses.html