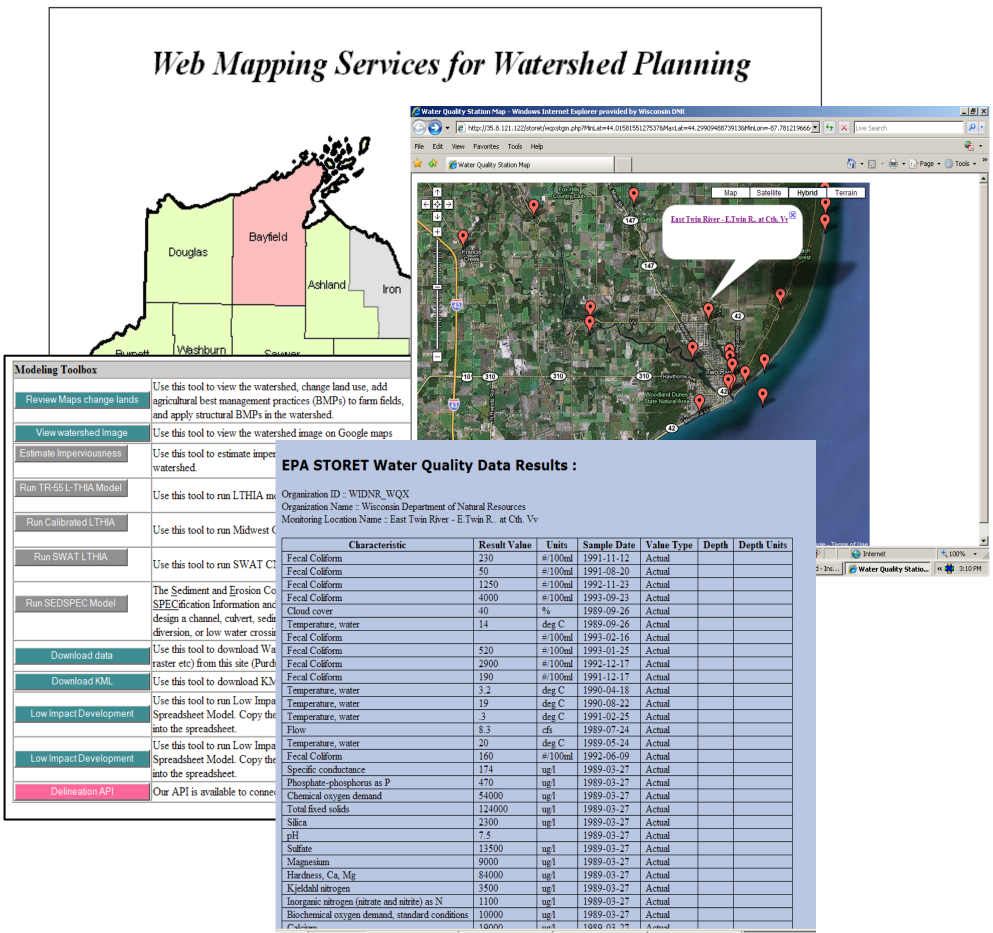
A Web-based Decision-support System for Watershed Management:

Progress towards Data Exchange, Data Analysis, and Model Calibration



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Summary: This report describes grant-funded work undertaken by the Wisconsin Department of Natural Resources and the Midwest Spatial Decision-support Systems Partnership between September 2006 and March 2010 to demonstrate how a web-based, decision support system for watershed management could be developed in conjunction with the National Environmental Information Exchange Network. Our work has been part of a broader effort to use Internet and geographic information system (GIS) technologies to help identify and solve environmental problems. This report describes the work we undertook with the Midwest Partnership to implement an Exchange Network challenge grant, documents the deliverables produced, presents lessons learned, and makes recommendations to improve future data sharing and decision-support tool efforts. This document also fulfills final reporting requirements for our Federal Assistance Agreement

The U.S. Environmental Protection Agency supported our work, in part, with Federal Assistance Agreement No. OS-83320901. Points of view expressed in this report do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency. Mention of trade names and commercial products does not constitute endorsement of their use.

Cover Illustrations: Status map of Internet mapping sites in Wisconsin (developed by Jerry G. Sullivan, Wisconsin DNR) and screen captures of tools developed by the Midwest Spatial Decision-support Systems Partnership as a part of the grant-funded work.

A Web-based Decision-support System For Watershed Management:

Progress towards Data Exchange, Data Analysis, and Model Calibration

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1. Introduction

The U.S. Environmental Protection Agency (U.S. EPA) awarded a multi-year "challenge" grant to the Wisconsin Department of Natural Resources (Wisconsin DNR) to demonstrate how a web-based, decision support system for watershed management could be developed. Our work has been part of a broader effort to use Internet and geographic information system (GIS) computer technologies to help identify and solve environmental problems (see, for example, Watermolen 2009; Mednick and Watermolen 2009; Mednick 2009a, b; Welch 2005; Lucero et al. 2004). This report describes the work we undertook with our partners to implement this grant-funded project, documents the deliverables produced, presents lessons learned, and makes recommendations to improve future data sharing and decision-support tool efforts. This document also fulfills final reporting requirements for the U.S. EPA Federal Assistance Agreement (OS-83320901).

1.1. Environmental Issue and Need for the Project

Local watershed management forms the basis for continued economic development and environmental improvement throughout the United States. Successful implementation depends on an integrated approach that brings together scientific, socio-political, and educational advances made across many disciplines and modified to fit the needs of the individuals and groups who write, implement, evaluate, and adjust their watershed management plans and projects.

Disciplines such as water resource management, land use planning, and biodiversity preservation—where numerous conflicting objectives and a variety of stakeholders are involved—have become increasingly complex. Yet, the public expects objectives and planning methods to become ever more interwoven and to "strike the right balance." As a result, environmental decision problems are essentially conflict analyses (Lahdelma et al. 2000) characterized by socio-political, environmental, and economic value judgments, and tend to involve multiple decision makers and stakeholders from various disciplines more regularly than other kinds of decision problems (Gray et al. 1996). In such situations, reliable and up-to-date environmental data and information are requisite for supporting the formulation, implementation, and evaluation of policy decisions and management actions.

Many communities, however, cannot afford even the most basic approaches to, or initial screening of, their environmental problems. Yet, a wide variety of modern information and analytical tools are now available to assist with these tasks. When properly presented, these freely accessible tools can help meet this challenge by allowing informed screening and preliminary selection of alternatives, eliminating large amounts of initial "leg work" for watershed stakeholders.

The National Research Council conducted a comprehensive review of U.S. EPA's watershed management approach (National Research Council 1999). The Council recommended that a watershed, decision-support system encompass "*…a suite of computer programs with components consisting of databases, simulation models, decision models, and user interfaces that assist a decision maker in evaluating the economic and environmental impacts of competing watershed management alternatives"*. In times of increasingly limited local resources, access to free, coherently organized, scientifically based information becomes all the more important. Our exploratory work via the challenge grant helps implement the National Research Council's vision through work in the following areas: data exchanges, data analysis, decision support tools, and technology transfer.

1.2. The National Environmental Information Exchange Network

The National Environmental Information Exchange Network (Exchange Network) is a partnership among states, Native American Indian tribes, and the U.S. EPA focused on the exchange and increased access of environmental information via the Internet. This standards-based approach provides real-time access to higher quality data while saving time, resources, and money for Exchange Network partners. The

Network's website (www.exchangenetwork.net) provides additional information about the effort and includes links to its "Getting Started Guides".

Network partners have successfully built and tested network nodes and have begun implementing network data exchanges. A "data exchange," or "data flow," is the Exchange Network term for any routine transfer of information between two or more network partners. Exchanges are typically of information about particular environmental interests, such as surface water quality or air quality. As network partners develop the resources to implement data flows, they are made available via the Exchange Network website. This sharing allows future trading partners to take advantage of existing tools. Users can access these exchange resources and learn more about on-going Exchange Network projects by clicking on program-specific communities of interest on the Exchange Network website.

The Exchange Network provides an overall national infrastructure for strategic and tactical decision making at both the national and sub-national levels. Work on the Exchange Network is driven by the individual and collective business needs of the partners. That is, partners exchange data not simply for the sake of exchanging data, but rather to increase the efficiency and effectiveness of their respective natural resources management and environmental protection efforts (Ackerman 2005, Watermolen 2007). The biggest payoffs from these investments are likely to accrue at the state and local levels where most environmental decisions are actually made.

The Exchange network uses modern technology to facilitate the exchange and increased access of information to address these business needs. Since 2002, the U.S. EPA has supported implementation of the Exchange Network through its National Environmental Information Exchange Network Grant Program. The grant program has provided funding for states, territories, and federally recognized Native American Indian tribes and has played an enormous role in the current successes of the Exchange Network. The Wisconsin DNR has been an active Exchange Network participant for several years. In fiscal year 2006, Wisconsin DNR, on behalf of the Midwest Spatial Decision Support Systems Partnership (Midwest Partnership), received a "challenge" grant to demonstrate how a Web-based, decision support system for watershed management could be developed. The vision was to integrate automated tabular and spatial data discovery, exchange, and analysis tools within a watershed management framework.

1.3. The Midwest Spatial Decision Support Systems Partnership

The goal of the Midwest Partnership is to develop, promote, and disseminate web-based, spatial, decision-support systems to help manage watersheds in the Midwest. In particular, the Midwest Partnership aims to make these systems freely available via the Internet to local officials, natural resource managers, and the general public, a goal that aligns well with the Exchange Network.

Primary members of the Midwest Partnership include:

- U.S. EPA
- Michigan State University
- Purdue University
- University of Wisconsin-Extension
- Wisconsin Department of Natural Resources
- Great Lakes Commission
- U.S. Geological Survey
- Local and regional planning agencies

The Midwest Partnership aims to provide maximum information and analytic tools to those levels of government and citizens closest to actual watershed management challenges (i.e. state and local decision makers and practitioners). The partnership offers both direct access to its own free web-based, decision-support tools and road maps to other websites where additional tools can be found. Two tools developed by the Midwest Partnership, Digital Watershed and L-THIA, provide the foundation for our work undertaken as part of the Exchange Network challenge grant.

1.3.1. Digital Watershed

Michigan State University's Institute of Water Research developed Digital Watershed as a centralized information repository and on-line computing center for watersheds in the United States (Shi et al. 2004). This tool is based on the comprehensive database of 8-digit watersheds included in U.S. EPA's BASINS system (U.S. EPA 2001a). The database contains regulated facilities, river network, digital elevation model (DEM), state soil, and other data layers. Digital Watershed is interconnected with local level watershed information by a scaling function, and provides a portal to various modeling tools. Users can access Digital Watershed online at http://35.8.121.101/water/index.htm.

1.3.2. L-THIA: Long-term Hydrologic Impact Assessment Tool

Purdue University's Department of Agricultural and Biological Engineering developed the Long-term Hydrologic Impact Assessment (L-THIA) tool to provide local planners, decision-makers, and the interested public with a tool for predicting the impact of potential land use changes on stormwater runoff and various nonpoint source pollutants (Choi et al. 2003, Engel et al. 2003). L-THIA estimates long-term average annual runoff for land use and soil combinations, based on actual long-term climate data for a user specified area. The underlying model is a spatially distributed automation of the widely accepted curve number method (SCS 1986), relating direct runoff to 24-hour precipitation under various conditions, coupled with a polluted runoff model that estimates the event mean concentration of various pollutants based on empirically-derived coefficients for different land uses and agricultural practices. L-THIA can be accessed and run via the World Wide Web or as a free extension to desktop ArcGIS software. Users can access L-THIA online at https://engineering.purdue.edu/mapserve/LTHIA7/.

1.4. Report Organization

Chapter 2, "Project Overview and Accomplishments," restates the project goals as outlined in Wisconsin DNR's original grant application and summarizes the principle activities and accomplishments associated with each area of focus. Chapter 3, "Lesson Learned, Recommendations, and Future Work," documents key findings from our development efforts, suggests further enhancements to data sharing and decision-support systems, and outlines possible next steps. A chapter dealing with overall "Project Administration" follows. Chapter 5, "Acknowledgments," and Chapter 6, "Literature Cited, Further Reading, and Background Material," help place our work in the context of other efforts and list resources that we found helpful in defining, developing, and evaluating our demonstration project. Finally, an appendix lists presentations resulting from the Midwest Partnership's challenge grant work.

2. Project Overview and Accomplishments

During the course of the project, Wisconsin DNR and the Midwest Partnership met objectives outlined in the grant application for each of 11 goals. These efforts included producing several deliverables that were not part of the initial scope of the project, but which were needed in order to accomplish our stated objectives or to lay the groundwork for a more widespread transfer of technology/methods in the future. This chapter outlines these accomplishments. Our most significant findings and recommendations are discussed in Chapter 3, “Lessons Learned, Recommendations, and Future Work.” In addition, the following chapters and appendix provide supporting materials and list presentations resulting from the Midwest Partnership’s work and related to our project accomplishments.

Our work on Goals 1-3 focused on new Exchange Network data flows and enhanced data access. Goals 4-6 focused on data analysis and reporting, while work on goals 7-9 related to enhancing models and creating a scientifically sound decision-support environment. Goals 10-11 focused on outreach and technology transfer. Progress and accomplishments in each of these areas is described below.

2.1. Data Exchanges/Flows

A “data exchange,” or “data flow,” is the Exchange Network term for any routine transfer of information between two or more network partners. Flows are typically of information about particular environmental interests, such as surface water quality or air quality. As network partners develop the resources to implement data exchanges, they make those resources available via the Exchange Network website. This allows future trading partners to take advantage of existing tools without duplicating efforts.

Prior to our challenge grant project, the Exchange Network focused almost exclusively on U.S. EPA, state environmental and public health agencies, and Native American Indian tribal government data exchanges. Data flows occurred primarily between state and U.S. EPA to support compliance with federal, regulatory reporting requirements (O’Neill 2005, Rakouskas 2006), for example, U.S. EPA's Cross-Media Electronic Reporting Regulation (CROMERR)[1]. Wisconsin DNR was an early participant in the Exchange Network and had developed a number of water related data exchanges prior to the challenge grant. We wanted to further develop data flows consistent with these earlier efforts.

The Wisconsin DNR and Midwest Partnership also continued to be interested in data exchanges as a means of increasing the efficiency and effectiveness of natural resources management and environmental protection efforts, rather than simply for the sake of exchanging data. We recognized that information systems that allow local users to access and use data aggregated through the Exchange Network would have potentially large payoffs if they could inform decision making at levels where most environmental decisions are actually made (i.e. the local and state levels). We believed that advent of web services created opportunities to flow data to users. In addition, we also believed that information collected by local and regional governmental agencies and local watershed groups could be exchanged with states and U.S. EPA to enhance analyses, planning, and decision making.

As a result, the data exchange efforts undertaken as part of our challenge grant work focused on three areas: implementation of a new data exchange between Wisconsin DNR and U.S. EPA (Section 2.1.1), development of a new tool to allow any Internet user to access STORET data (Section 2.1.2), and exploration of data flows involving local and regional data custodians (Section 2.1.3).

[1] The Cross-Media Electronic Reporting Regulation provides the legal framework for electronic reporting under all of the U.S. EPA’s regulations. CROMERR applies to: regulated entities that submit reports and other documents to U.S. EPA under Title 40 of the Code of Federal Regulations, and states, tribes, and local governments that are authorized to administer U.S. EPA programs under Title 40. The rule establishes standards for information systems that receive reports and other documents electronically to satisfy requirements of Title 40 programs.

2.1.1. Goal 1: Exchange Water Quality Assessment Data

Background: Each data exchange has its own requirements described in its Flow Configuration Document. To participate in an exchange, the following are core requirements:

- Exchange Network Node **-** A Network node enables data sharing among different information systems via the Internet. It is a partner's point of presence on the Exchange Network.
- Partner Database/IT System **-** This system contains the data you want to share and includes an application that interacts with the Node.
- Network Authentication and Authorization Service (NAAS) Permissions - Sharing data via the Exchange Network requires that users have NAAS security privileges.
- Process for Generating XML **-** Information transmitted over the Exchange Network is expressed in eXtensible Markup Language (XML), and you must have a machine or process capable of generating XML files. The Exchange Network provides a dedicated XML schema for each flow to transmit data in XML.

Each data element a partner wants to share from its database needs to be matched to the XML Schema provided by the Exchange Network flow. Some exchanges may also require a node to perform flow-specific functions and interact with the Network Authentication and Authorization Service to authenticate and authorize specific users.

In 2005, Wisconsin became the first state to submit watershed assessment data to U.S. EPA using XML schema. U.S. EPA, however, was unable to process the data in the proposed format. Our challenge grant project sought to address this problem.

> **Grant Goal:** Develop XML schema and data flow protocols to exchange Wisconsin's water quality assessment data.

Activities and Progress: The Wisconsin DNR team worked with the U.S. EPA to compare the Assessment Database (ADB) and Wisconsin DNR's Water Assessment, Tracking, and Report System (WATERS)[2] table structures and XML protocols for the 2006 data submittal. Wisconsin DNR modified database queries based on information learned from that experience.

This process involved mapping the Wisconsin DNR's WATERS and Surface Water Integrated Monitoring System (SWIMS)[3] database to the ADB table structure provided by U.S. EPA. Wisconsin DNR compiled XML reports for each of the following reporting periods, as well as corresponding GIS shapefiles, and both were submitted to U.S. EPA for incorporation into its ATTAINS database (see below): 2005, 2006, 2008, and 2010. The 2008 Wisconsin electronic submittal served as a pilot for integrated reporting using an XML format. Wisconsin had submitted its 305(b) data using this XML format since 2004; in 2008, Wisconsin DNR began providing integrated submittals using a blend of 11 XML files and GIS data layers of assessment units (lines and polygons).

The year 2010 database submittal was considered the state's first formal integrated data submittal, although the Wisconsin DNR began work on rectifying and providing truly integrated 305(b) and 303(d) data submittals in 2008, as described above. Also during this time, Wisconsin fully developed its Exchange Network node, upgrading to version 2.0. Several automation tools and related data flow procedures were developed and documented under different grants. However, this work was fundamental to preparing the data for full implementation of U.S. EPA's ATTAINS XML schema (see below).

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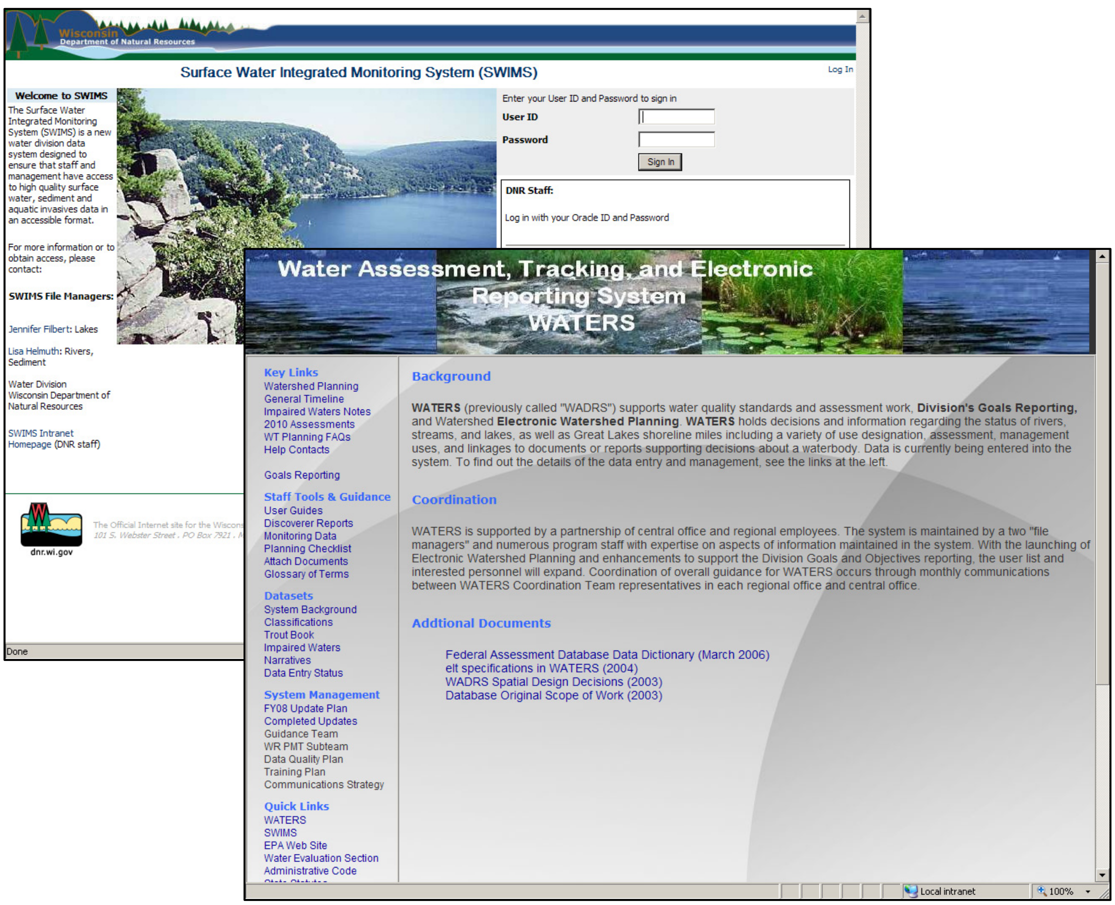
[2] WATERS supports the Wisconsin DNR's water quality standards and assessment work, goals reporting for the agency's Water Division, and electronic watershed planning efforts. WATERS holds decisions and information regarding the status of rivers, streams, and lakes, as well as Great Lakes shoreline miles including a variety of use designation, assessment, management uses, and links to documents or reports supporting decisions about a waterbody.
[3] SWIMS is the Wisconsin DNR's statewide database for storing and accessing water quality data. Monitoring stations are identified in the database against a 1:24,000 scale hydrography GIS layer, which makes them available in maps to view, verify, and use in presentations, reports, and analyses. SWIMS monitoring stations also are cross-referenced with the Wisconsin DNR Fisheries Management Database.

During our challenge grant period, U.S. EPA moved forward with development of the Assessment, TMDL Tracking and Implementation System (ATTAINS) database. The ATTAINS database contains information reported by the states to U.S. EPA about the conditions in their surface waters. The database is comprised of information on the attainment of water quality standards (i.e. the 305(b) information), as well as the list of impaired waters that need a total maximum daily load (TMDL) (i.e. the 303(d) list). ATTAINS combines what formerly was referred to as the National Assessment Database (NAD) and the National TMDL Tracking System (NTTS). Wisconsin DNR program staff followed these developments and reformulated our data mapping strategy based on federal plans for data reporting.

Accomplishment: Wisconsin DNR began providing integrated 303(d) and 305(b) data submittals using a blend of XML files and GIS data layers.

The final schema, which is now available, is fundamental to implementing the data flows. In future years, the Wisconsin DNR will follow up on the XML files created through this grant, and the higher quality datasets that were subjected to quality assurance/quality control practices through this grant, to create database views from the XML schema, map the data to the ATTAINS database, and flow draft files via the accepted WQX process.

In addition, the Wisconsin DNR team took part in a 2007 survey of TMDL tracking databases conducted by a U.S. EPA consultant and offered to provide assistance to other states as requested.



2.1.2. Goal 2: Provide Access to STORET Data

Background: The U.S. EPA's STORET (STOrage and RETrieval) data warehouse provides a centralized repository for water quality monitoring data collected by states, tribes, watershed groups, federal agencies, volunteers, and universities (U.S. EPA 2004a). These entities submit data to STORET in order to make their data publically accessible and so the data can be re-used for additional analyses. Data in STORET are of a documented, known quality. Each sampling result is accompanied by information on where the sample was taken (latitude, longitude, state, county, hydrologic unit code [HUC], and a brief site identification), when the sample was gathered, the environmental medium sampled (water, sediment, fish tissue, etc.), and the name of the organization that sponsored the monitoring. In addition, the STORET Warehouse contains information on why the data were gathered, sampling and analytical methods used, the laboratory that analyzed the samples, quality control checks used in sample collection, handling, and data analysis, and the personnel responsible for the data (U.S. EPA 2005).

STORET is one of the most sought after and, until recently, seldom used national databases for watershed management decisions (e.g., see Carleton et al. 2005, Russo et al. 2008). This has been due mostly to STORET's large size and virtual inaccessibility to people outside of U.S. EPA; STORET dates back to U.S. EPA's reliance on mainframe computers and a complex data model. The initial versions were quite cumbersome and a challenge for users and failed to gain popular acceptance (Burnette 2009).

Grant Goal: Integrate STORET into Digital Watershed and make STORET data available.

Activities and Progress: Wisconsin DNR contracted with Michigan State University's Institute of Water Research to link U.S. EPA's STORET web services to Digital Watershed (see Section 1.3.1). The MSU team was the logical group to develop the new functionality as that team had previously developed Digital Watershed and maintains the intellectual property rights associated with this publically available system. In addition, a separately funded project undertaken by the MSU team and the National Park Service provided a starting point for development of the new application that integrates STORET data with the watershed delineation capabilities of Digital Watershed.

U.S. EPA's Water Quality Exchange (WQX) represents the more recent evolution of STORET. During the course of our grant work, U.S. EPA made considerable progress on the development of the WQX and transitioned away from a distributed database model and towards the Exchange Network model for the sharing of data (U.S. EPA n.d., U.S. EPA 2006). This new framework makes it easier to submit and share water quality monitoring data. The WQX defines a standard set of data elements that must be captured in a data submission file in order for the data to come into STORET (U.S. EPA 2006). A standard set of Internet protocols defines how a data submission is made to U.S. EPA.

U.S. EPA also began providing a suite of SOAP[4] based web services which provide direct access to data in STORET. The new web services provide improved accessibility to the data, and allow users to incorporate data from STORET into their own specialized applications that include water quality modeling, data analysis, priority setting, decision making, and public information (U.S. EPA 2007).

The Midwest Partnership wanted to make use of these new services as a means to allow the public and local users to access the STORET data in meaningful ways. The MSU Team developed this new capability using several of U.S. EPA's web services:

- http://www.epa.gov/storet/web_services.html
- http://iaspub.epa.gov/webservices/StationService/
- http://iaspub.epa.gov/webservices/StoretResultService/

[4] SOAP (Simple Object Access Protocol) is a protocol specification for exchanging structured information in the implementation of web services. It relies on extensible markup language (XML) for its message format, and usually relies on other application layer protocols (e.g., HTTP) for message negotiation and transmission.

Specifically, when a user selects an "Access EPA STORET Water Quality Data" button on the interface, Digital Watershed passes latitude-longitude bounding box parameters to the "getStationsForMap" operation of the STORET Station Web Service. The returned station results in XML format are then parsed out and drawn on a Google Maps interface with point symbols using the latitude and longitude information from the web service. Every station "pin" on the map contains a link that when clicked presents a dialog box to users. As a result of these efforts, Digital Watershed's water quality data access function now allows users to view all water quality stations within the current map extent, as well as see all water quality parameters for specific water quality stations in tabular format.

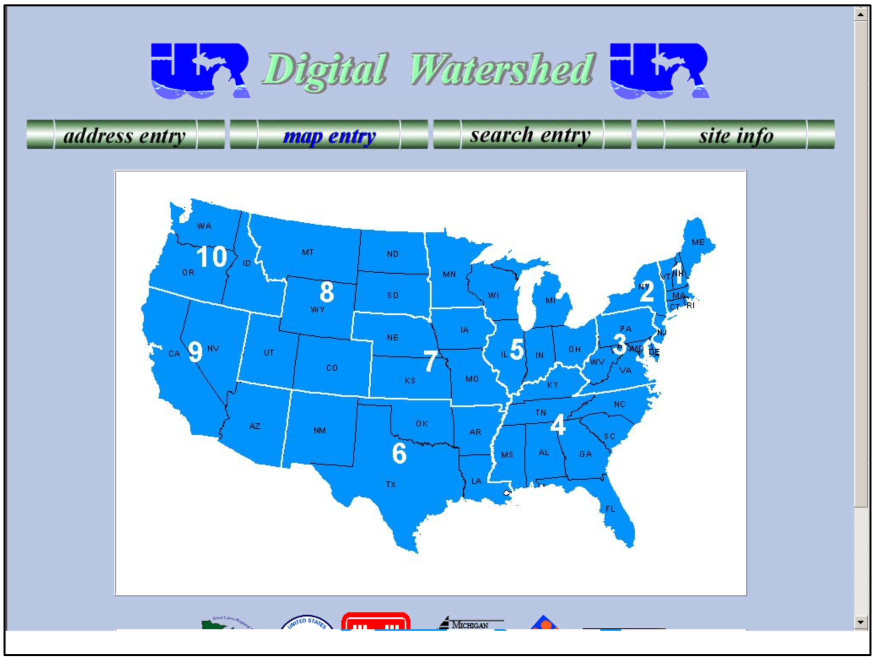
To our knowledge, the new Digital Watershed interface developed as part of the challenge grant represents the *first* and *only* nation-wide application that allows users to access STORET data, using nothing more than their Internet browser software. The interface allows users to see the data in relation to other watershed and land use features.

Accomplishment: Digital Watershed represents the first and only computer application that allows users to access STORET data nation-wide using nothing more than an Internet browser.

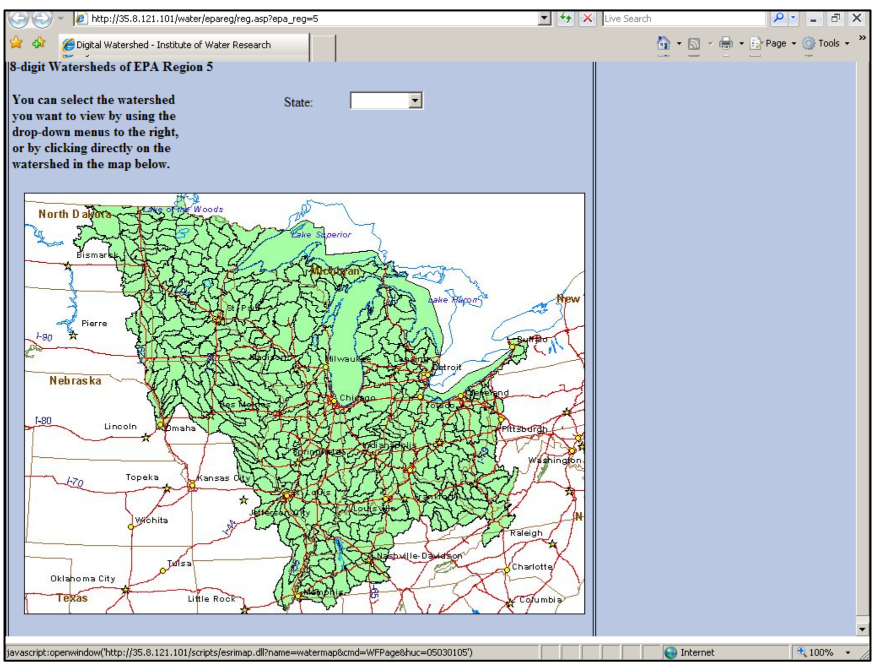
The following descriptions/instructions and screen captures illustrate this new functionality as the end-user experiences it.

To access STORET data on a watershed basis, users first go to the main Digital Watershed interface on the MSU Institute of Water Research's website (http://35.8.121.101/water/index.htm). Users can also locate the interface through a Google search for "Digital Watershed."

Clicking on the “map entry” button returns a map of the United States with U.S. EPA regions highlighted.

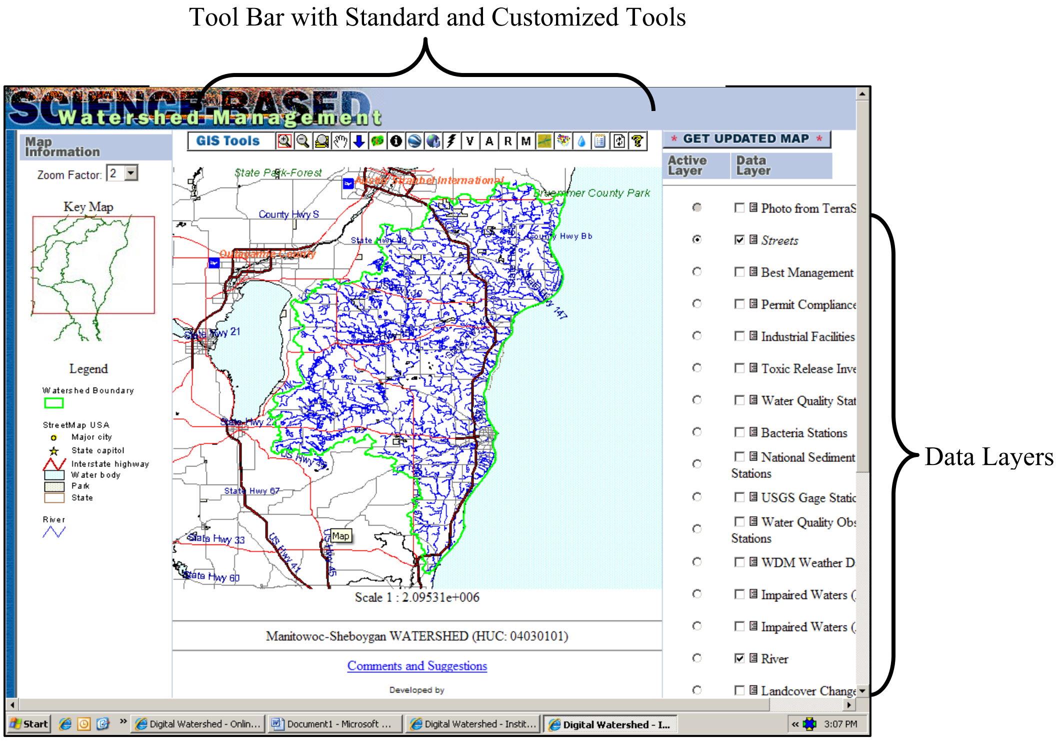


Clicking on the Region 5 section of the U.S. map opens a new window with a map of the 8-digit watersheds for that area. Clicking on other regions yields similar results.

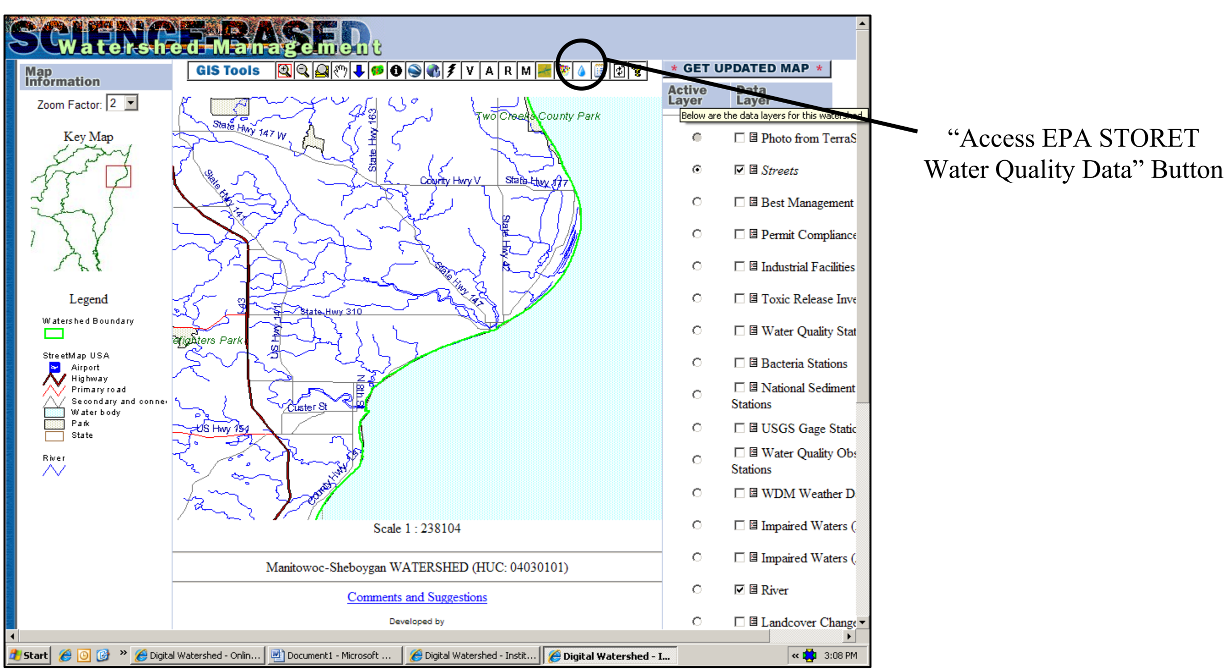


Clicking directly on any location on the 8-digit watershed map opens a new interactive map window that allows the user to “zoom in” to specific rivers and their surrounding watersheds. Users also can select the watershed they want to view by using the drop-down menus to the right.

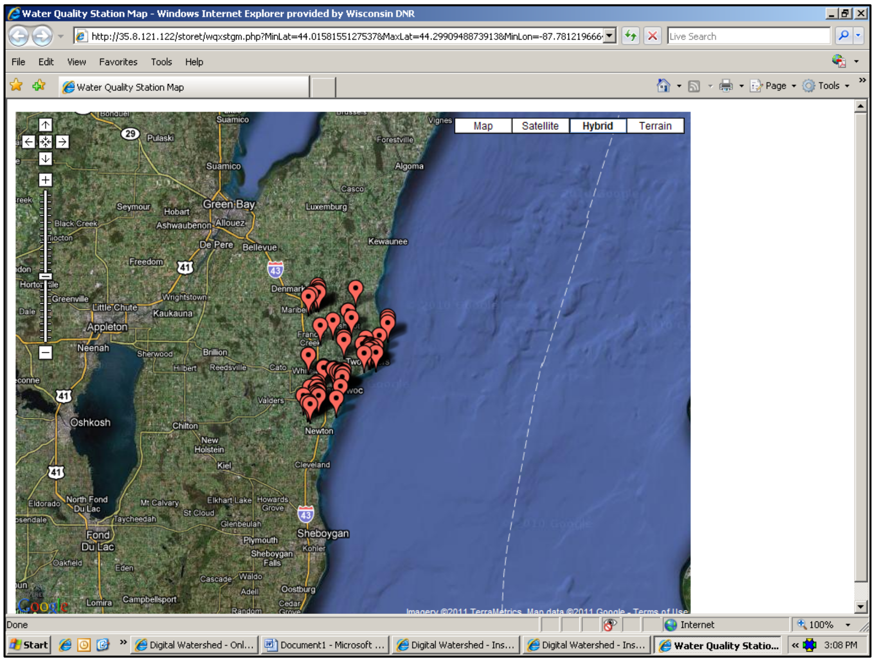
The standard web mapping interface that opens allows users to turn various data and image layers on and off. A tool bar across the top of the mapping interface provides access to a suite of standard and customized tools, including those used to access STORET data. Users can "zoom in" further to pinpoint specific locations or waterbodies of interest. A scale bar appears at the bottom of each map to provide spatial perspective.



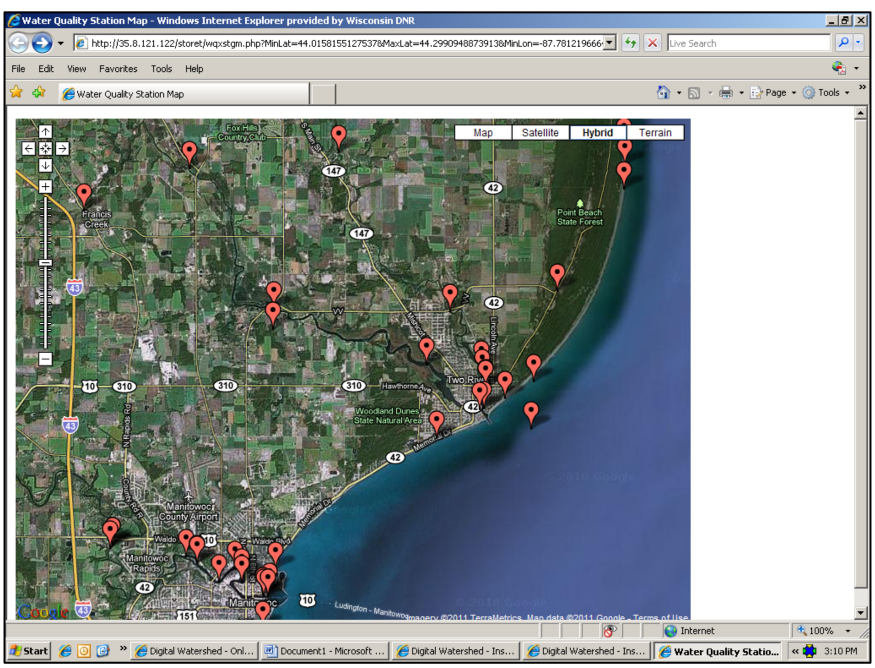
The tool bar along the top includes an "Access EPA STORET Water Quality Data" button.



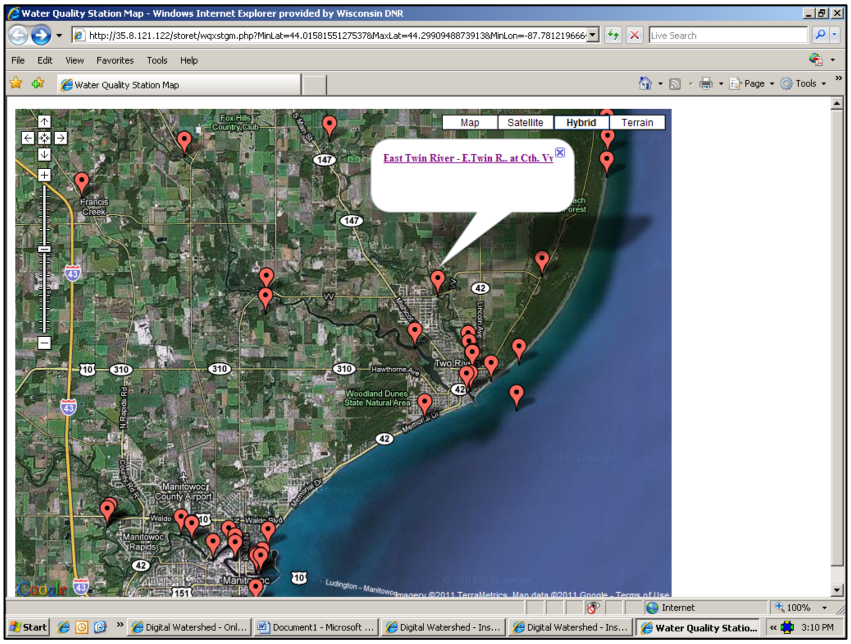
Clicking the "Access EPA STORET Water Quality Data" button on the tool bar directs Digital Watershed to open a new window and produce a "Water Quality Station Map." This Google map interface includes standard "pins" that locate STORET data stations in the area, allowing users to quickly see where water quality monitoring has been conducted.



By using the standard sliding scale bar and compass navigation tools on the left side of the map and the "click and drag" pan function, users can navigate the map and zoom to their specific STORET station(s) of interest. Users can also select the underlying image (map, satellite image, or combination) that they would like to have visible to aid navigation/orientation.



Clicking on an individual station "pin" opens a dialog box that depicts the name of the water quality monitoring station and provides a link to the tabular data.



Clicking on the link in the dialog box directs Digital Watershed to retrieve all STORET water quality parameter data for that specific station and present them in tabular format.

EPA STORET Water Quality Data Results :

Organization ID :: WIDNR_WQX
Organization Name :: Wisconsin Department of Natural Resources
Monitoring Location Name :: East Twin River - E.Twin R.. at Cth. Vv

Characteristic	Result Value	Units	Sample Date	Value Type	Depth	Depth Units
Fecal Coliform	230	#/100ml	1991-11-12	Actual		
Fecal Coliform	50	#/100ml	1991-08-20	Actual		
Fecal Coliform	1250	#/100ml	1992-11-23	Actual		
Fecal Coliform	4000	#/100ml	1993-09-23	Actual		
Cloud cover	40	%	1989-09-26	Actual		
Temperature, water	14	deg C	1989-09-26	Actual		
Fecal Coliform		#/100ml	1993-02-16	Actual		
Fecal Coliform	520	#/100ml	1993-01-25	Actual		
Fecal Coliform	2900	#/100ml	1992-12-17	Actual		
Fecal Coliform	190	#/100ml	1991-12-17	Actual		
Temperature, water	3.2	deg C	1990-04-18	Actual		
Temperature, water	19	deg C	1990-08-22	Actual		
Temperature, water	.3	deg C	1991-02-25	Actual		
Flow	8.3	cfs	1989-07-24	Actual		
Temperature, water	20	deg C	1989-05-24	Actual		
Fecal Coliform	160	#/100ml	1992-06-09	Actual		
Specific conductance	174	ug/l	1989-03-27	Actual		
Phosphate-phosphorus as P	470	ug/l	1989-03-27	Actual		
Chemical oxygen demand	54000	ug/l	1989-03-27	Actual		
Total fixed solids	124000	ug/l	1989-03-27	Actual		
Silica	2300	ug/l	1989-03-27	Actual		
pH	7.5		1989-03-27	Actual		
Sulfate	13500	ug/l	1989-03-27	Actual		
Magnesium	9000	ug/l	1989-03-27	Actual		
Hardness, Ca, Mg	84000	ug/l	1989-03-27	Actual		
Kjeldahl nitrogen	3500	ug/l	1989-03-27	Actual		
Inorganic nitrogen (nitrate and nitrite) as N	1100	ug/l	1989-03-27	Actual		
Biochemical oxygen demand, standard conditions	10000	ug/l	1989-03-27	Actual		
Calcium	19000	ug/l	1989-03-27	Actual		

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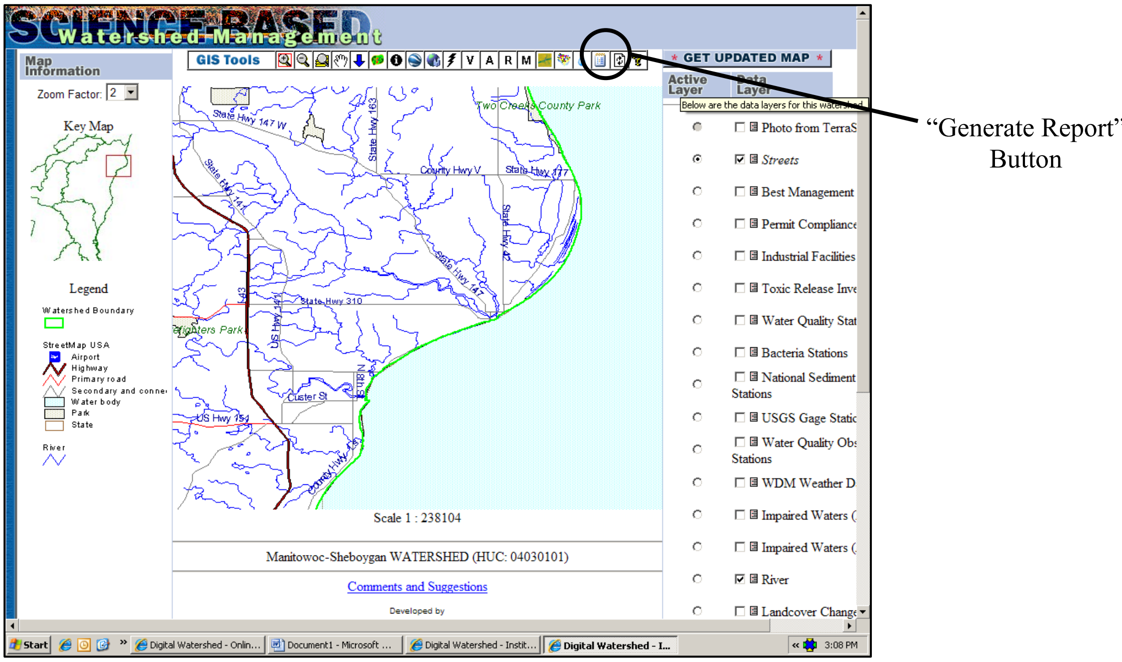
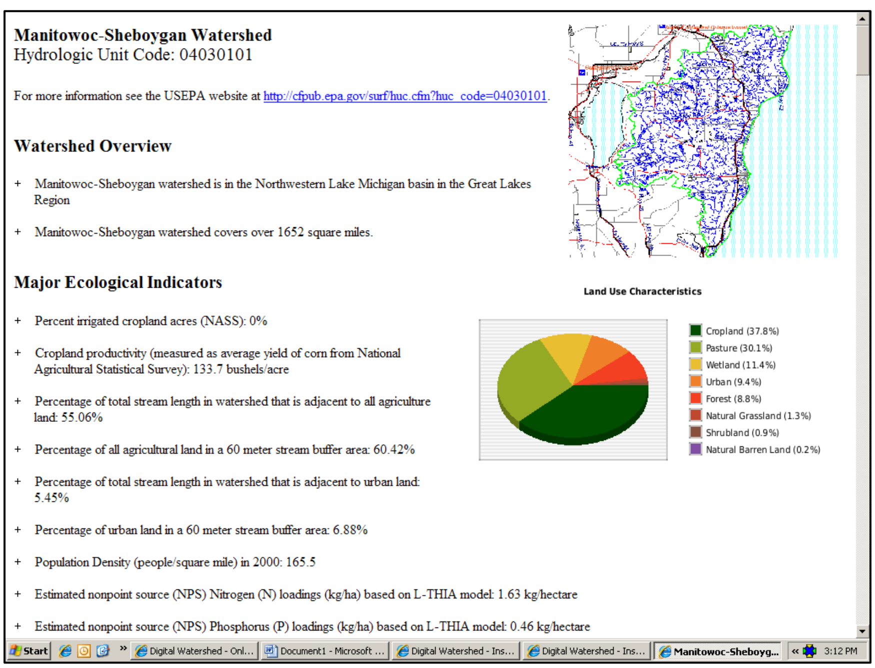
The table indicates who collected the data, the specific parameters ("characteristics") sampled, the units measured, sample dates, and value type (actual vs. predicted), as well as the actual data collected.

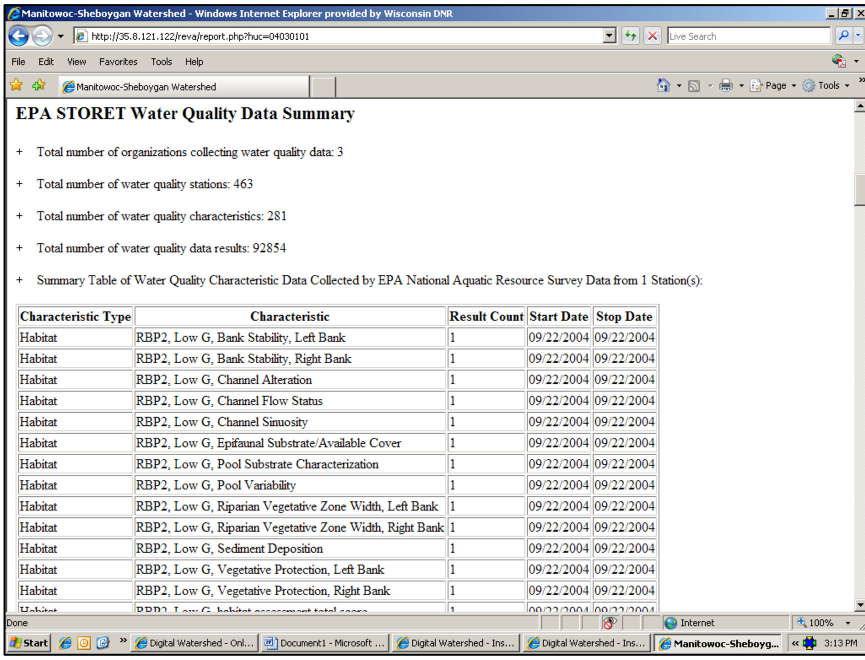
Digital Watershed also allows users who are interested in looking at the watershed as a whole to view a summary of STORET data for the entire 8-digit HUC watershed. Clicking on the “Generate Report” button next to the “Access EPA STORET Water Quality Data” button on the tool bar retrieves the summary report.



The watershed summary reports that are generated by Digital Watershed include a variety of information related to the watershed (see project accomplishments for Goals 4 and 5 below), including summary statistics, ecological indicators, and the STORET water quality summary.



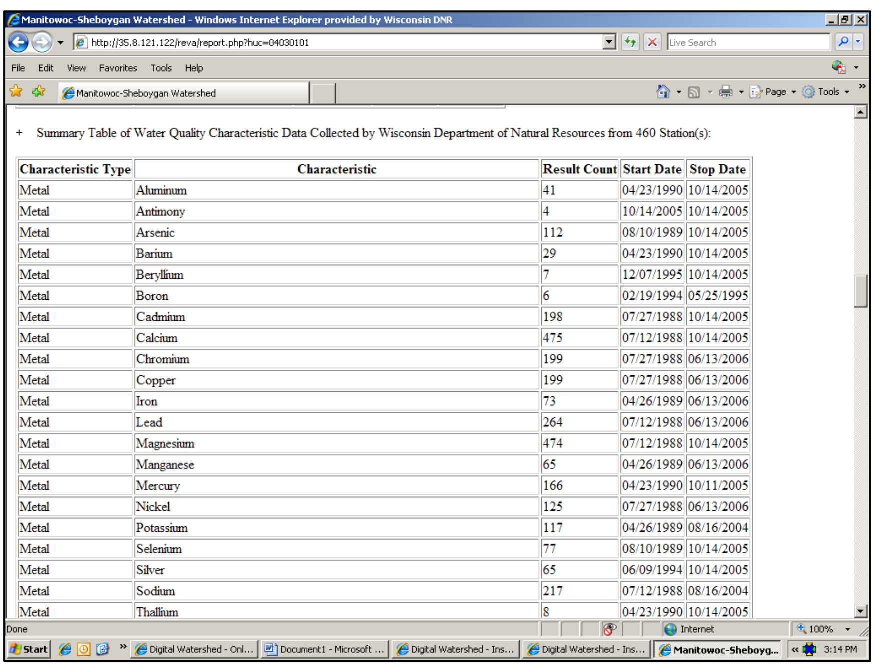
By scrolling down on the watershed summary report, users find an "EPA STORET Water Quality Data Summary." This summary indicates the number of organizations (e.g., U.S. EPA, state environmental agencies, local watershed groups) collecting water quality data, the total number of water quality stations, the total number of water quality characteristics (parameters) monitored, and the total number of water quality data results in the watershed. Separate summary tables present the specific water quality characteristics, number of results, and the dates of monitoring for each of the organizations that have conducted monitoring in the watershed.



EPA STORET Water Quality Data Summary

+ Total number of organizations collecting water quality data: 3
+ Total number of water quality stations: 463
+ Total number of water quality characteristics: 281
+ Total number of water quality data results: 92854
+ Summary Table of Water Quality Characteristic Data Collected by EPA National Aquatic Resource Survey Data from 1 Station(s):

Characteristic Type	Characteristic	Result Count	Start Date	Stop Date
Habitat	RBP2, Low G, Bank Stability, Left Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Bank Stability, Right Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Channel Alteration	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Channel Flow Status	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Channel Sinuosity	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Epifaunal Substrate/Available Cover	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Pool Substrate Characterization	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Pool Variability	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Riparian Vegetative Zone Width, Left Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Riparian Vegetative Zone Width, Right Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Sediment Deposition	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Vegetative Protection, Left Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Vegetative Protection, Right Bank	1	09/22/2004	09/22/2004



+ Summary Table of Water Quality Characteristic Data Collected by Wisconsin Department of Natural Resources from 460 Station(s):

Characteristic Type	Characteristic	Result Count	Start Date	Stop Date
Metal	Aluminum	41	04/23/1990	10/14/2005
Metal	Antimony	4	10/14/2005	10/14/2005
Metal	Arsenic	112	08/10/1989	10/14/2005
Metal	Barium	29	04/23/1990	10/14/2005
Metal	Beryllium	7	12/07/1995	10/14/2005
Metal	Boron	6	02/19/1994	05/25/1995
Metal	Cadmium	198	07/27/1988	10/14/2005
Metal	Calcium	475	07/12/1988	10/14/2005
Metal	Chromium	199	07/27/1988	06/13/2006
Metal	Copper	199	07/27/1988	06/13/2006
Metal	Iron	73	04/26/1989	06/13/2006
Metal	Lead	264	07/12/1988	06/13/2006
Metal	Magnesium	474	07/12/1988	10/14/2005
Metal	Manganese	65	04/26/1989	06/13/2006
Metal	Mercury	166	04/23/1990	10/11/2005
Metal	Nickel	125	07/27/1988	06/13/2006
Metal	Potassium	117	04/26/1989	08/16/2004
Metal	Selenium	77	08/10/1989	10/14/2005
Metal	Silver	65	06/09/1994	10/14/2005
Metal	Sodium	217	07/12/1988	08/16/2004
Metal	Thallium	8	04/23/1990	10/14/2005

2.1.3. Goal 3: Integrate Local Data

Background: Effective watershed management approaches require recognition of local and regional conditions. As such, many local government agencies (e.g., municipal sewerage districts, water management/drainage districts, inland lake protection and rehabilitation districts, public health agencies, etc.), working alone or in partnership with state and federal agencies, undertake various water quality monitoring projects, often to understand and address recognized problems in their jurisdictions. Numerous local watershed groups, volunteer monitors, private companies, and academic institutions also collect water quality data for a variety of projects/purposes (GAO 2004, Wisconsin DNR 2009, U.S. EPA 2010). Many data collectors store their water quality data on a project-specific basis, such as in a database for a single research project. While these data are generally available by request, only those who know about the agency's projects may know about or access these data (GAO 2004). Nonetheless, these data can be aggregated with data from other sources to develop a more complete picture of watershed conditions, stressors, and management opportunities. The Wisconsin DNR and Midwest Partnership have been interested in facilitating the sharing of these types of local data for broader management consideration.

Several recently developed Internet mapping technologies now make the broader sharing and integration of local data possible. These include:

> **Web map service (WMS)** – a standard protocol for serving geographically referenced map images over the Internet that are generated by a map server using data from a GIS database. WMS specifications were first developed and published by the Open Geospatial Consortium (OGC)[5] in 1999. While useful for visualization and navigation purposes, WMS interfaces, and similar online mapping portals (e.g., Google Maps), return only images, which end-users cannot edit or spatially analyze with their GIS tools.
>
> **Web feature service (WFS)** – an interface that allows requests for geographical features across the web using platform-independent calls. The XML-based GML furnishes the default payload-encoding for transporting the geographic features (i.e. the source codes), but other formats like shapefiles can also serve for transport.
>
> **Catalog service for the web (CSW)** – a standard protocol that defines common interfaces for discovering, browsing, and querying metadata associated with data, services, and other potential resources.
>
> **ArcIMS Map Service** – a web-hosted application that accepts requests for maps and data and returns corresponding results. The language used for all ArcIMS Map Service requests and results is ArcXML[6]. An ArcIMS service is similar to a WMS but is accessed through the web by submitting requests to and receiving products from an ArcIMS application server. ArcIMS services do not support SOAP, but may be constructed as image services or feature services and can also be made OGC compliant as WMS or WFS. The U.S. EPA web services provide all four types of ArcIMS Map Services for STORET.

The Wisconsin DNR and Midwest Partnership wanted to explore the possibility of using these technologies to exchange locally collected data that could be used in watershed planning and management. Our grant application noted that we would partner with various regional efforts to pilot this type of data sharing. The Northeastern Illinois Planning Commission (NIPC), through its partnership with Chicago Wilderness, was already gathering data throughout the Chicago region (10 counties in Illinois, as well as parts of Wisconsin and Indiana), with a special focus on watershed health. The Bay-Lake Regional Planning Commission

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[5] The Open Geospatial Consortium is an international industry consortium of 436 private companies, government agencies, and universities that participate in a unique consensus process to develop publicly available interface standards. OGC standards support interoperable solutions that "geo-enable" the web, wireless, and location-based services and mainstream information technology. The standards enable technology developers to make interoperable spatial information and services (i.e. enable technologies to be accessible and useful with all kinds of applications).

[6] ArcXML = Arc Extensible Markup Language, a specific implementation of XML.

(RPC) undertakes similar efforts in an 8-county region in northeastern Wisconsin. The Midwest Partnership proposed working with these two partners to link local data with Digital Watershed to allow locally generated data to be placed into a broader context and enable more informed decision making.

> **Grant Goal:** Integrate locally available watershed data into Digital Watershed and make those data available for viewing.

Activities and Progress: Up until 2007, the Northeastern Illinois Planning Commission (NIPC) served as the official comprehensive planning agency for the six-county Chicago metropolitan area. The Commission carried out three broad responsibilities: 1) conducting research required for planning for the region, 2) preparing comprehensive plans and policies to guide the development of the region, and 3) advising and assisting local governments. Legislation passed by the Illinois General Assembly while our challenge grant application was under review combined the staffs of NIPC and the Chicago Area Transportation Study (CATS) to create the new Chicago Metropolitan Agency for Planning (CMAP). The aim was to better serve the region by better integrating transportation and land use planning.

CMAP's first year of existence required extensive work to consolidate the two organizations. Its first *Strategic Report on Visioning, Governance, and Funding* described a regional vision for addressing the significant challenges that face Metropolitan Chicago. This 2006 report also defined the new agency's mission and strategic direction and provided goals for each of seven focus areas. Implementation of the state's Regional Planning Act provided a major focus for the report, which primarily addressed issues of governance, staff transition, and organizational structure (CMAP 2007). Equally important were preliminary strategies for securing stable, adequate funding. Finally, near-term priorities of the CMAP Board were described.

Over the next year, CMAP instituted sweeping changes to the way its predecessor agencies managed projects internally, with new policies to establish consistent, efficient procedures for planning, executing, and monitoring projects (CMAP 2007). CMAP also instituted new grants and contracts procedures to govern how staff apply for and administer grants from external funding sources. Finally, CMAP transitioned to a new "matrix" organizational structure that realigned various functions (CMAP 2007).

U.S. EPA awarded the challenge grant to Wisconsin DNR during this transitional period. Although CMAP staff initially signed on as partners in the grant application, the ensuing organizational changes and the uncertainties associated with new priorities and directions led to a CMAP decision to withdraw from full participation in the grant-funded work. In order to make progress on our local data sharing goals, we worked with U.S. EPA Region 5 staff to slightly modify the scope of our work plan for this goal.

As noted earlier, numerous local agencies and institutions collect water quality data. An essential first step in tapping into these data is being able to discover sources of current, local data that can be accessed as web services and integrated with on-line analytical modeling tools for watershed planning. To address this need, Wisconsin DNR staff conducted an inventory of Internet mapping sites/services that could support watershed planning in Wisconsin and the Great Lakes Basin. The study reviewed the state of Arc IMS, ArcGIS Server, WMS, and WFS services in the region. The reviewed websites included local, county, regional, state, federal, university, and private sources, for which staff documented and summarized:

- their ability to be streamed into other clients.
- their publishing of coordinate system data.
- their content for a range of 13 themes relevant to watershed characterization.

Accomplishment: Wisconsin DNR completed the first comprehensive inventory and assessment of Internet mapping sites, in Wisconsin and throughout the Midwest/Great Lakes Region, which could be used for watershed management and planning.

An analysis was made of which map themes needed for watershed planning were accessible via the Internet mapping sites, and whether these themes were selectable, queryable, or extractable. Important themes included: watershed boundaries (at any scale), soils, wetlands, land cover, land use, environmental corridors, zoning, elevation, slope, hillshade, water quality data, monitoring stations, and gauging stations. A report summarizing the findings (Sullivan 2009) was shared with the Midwest Partnership and U.S. EPA and posted to the U.S. EPA Environmental Science Connector. We summarized key findings below.

Locating Internet Mapping Sites: Like most states, Wisconsin lacks a definitive, synoptic, up-to-date registry of Internet mapping sites. Our study relied on several principle sources. WISCLINC, a clearing house maintained by the Wisconsin State Cartographer's Office, lists Internet mapping sites, but is neither complete nor updated. The Wisconsin State Cartographer's Office also manages a State GIS Inventory (RAMONA). All counties are required to annually update their profile in this inventory, including providing URLs of their land records/GIS/Internet mapping sites. State agencies and RPCs, however, are not required to contribute such information. The University of Wisconsin Sea Grant Institute maintains a site that lists county and municipal web mapping sites in Wisconsin:

- http://coastal.lic.wisc.edu/wisconsin-ims/wisconsin-ims.htm

In 2009, most (63 of 72) Wisconsin counties and at least two RPCs maintained Internet mapping sites, using a variety of software (Fig. 2-1). Three counties collaborated on a shared site. Nine counties did not have any public facing Internet mapping sites and five were under development.

Status of WMS and WFS Sites: The development of WMS sites in Wisconsin was found to be in its infancy. The Wisconsin State Cartographer's Office, University of Wisconsin Sea Grant Institute, and UW's Environmental Remote Sensing Center had worked on deploying WMS sites, but no county WMS sites were known. The newest sites were deployed by the Bay-Lake RPC as part of our challenge grant work (see below). The Bay-Lake RPC had deployed both ArcIMS image sites and parallel WMS sites.

WFS sites were even scarcer. The Wisconsin State Cartographer's Office had produced two WFS sites. At the time of the survey, the Bay-Lake RPC expressed intentions of offering WFS versions of each of its county land use sites. The Bay-Lake RPC made the first experimental sites for part of the Town of Manitowoc available, one each with ArcIMS and MapServer.

Internet Mapping Software Used: ArcIMS was found to be the most frequent software choice being used by 54 counties. Of these, 41 county ArcIMS sites were found to be streamable; 13 were not or behaved too slowly to be practical in a streaming mode (they simply caused ArcMap to bomb). We found four county ArcGIS Server sites. None of these counties, however, had chosen to allow the public to stream their sites to a client such as ArcMap. Two counties developed sites with the open source MapServer software, but neither was a WMS site and therefore could not be streamed. Three county sites were developed with Autodesk's MapGuide. Access to these sites required download of a plug-in (which can be problematic in organizations that tightly restrict users' ability to download and install software). None of the MapGuide sites had been designed as a WMS and were therefore not streamable. The two RPC ArcIMS sites were streamable. The Bay-Lake RPC offered six distinct county-based web services, all as WMS. The South Eastern Wisconsin Regional Planning Commission (SEWRPC) covered its seven-county area in a single ArcIMS service.

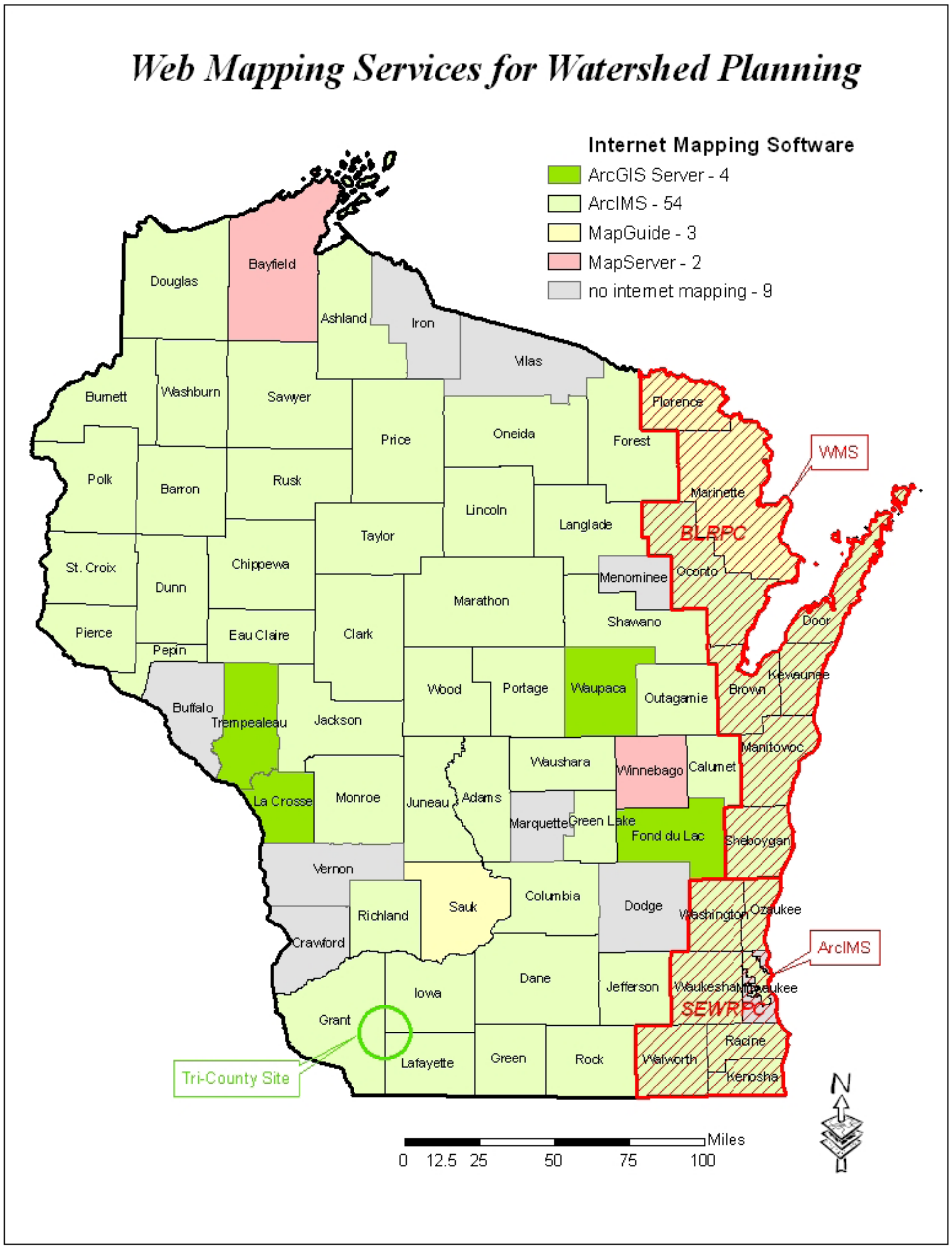


Figure 2-1. *Internet Mapping Software Used in Wisconsin, 2009.*

<u>Coordinate Systems:</u> The data available on Wisconsin's Internet mapping sites were referenced to a variety of coordinate systems (Figure 2-2). Unlike any other state, Wisconsin developed individual county coordinate systems (WCCS) based on custom spheroids. These were reengineered as the Wisconsin Coordinate Reference System (WISCRS; Danielsen and Koch 2009), which is now the sole local system for Wisconsin defined in ESRI's product suite. Of the 41 streamable Internet mapping sites, 11 were based on WCCS, eight were based on WISCRS, and 16 were based on WISCRS but did not publish their coordinate system information. Four streamable county sites used State Plane Coordinates (SPC; Stem 1989) based on the Wisconsin South Zone and NAD 27. One streamable site used SPC Wisconsin South Zone based on NAD 83 (Schwartz 1989). One site used SPC27S, based on NAD 27, but did not publish its coordinate system information although the features were extractable.

No streamable county sites were based on Universal Transverse Mercator (UTM). (Note: Purdue University's watershed tools, such as OWL, were based on UTM 16, NAD 83, but did not download projection files with the extracted data sets.) The newer Bay-Lake RPC WMS sites (see below) were all based on World Geodetic System 1984 (WGS 84), which is fairly common for integrating diverse WMS sites. Several other custom systems were encountered in the survey. Fully one third, or 22 sites, were not streamable; no attempt was made to determine the coordinate systems used by these sites.

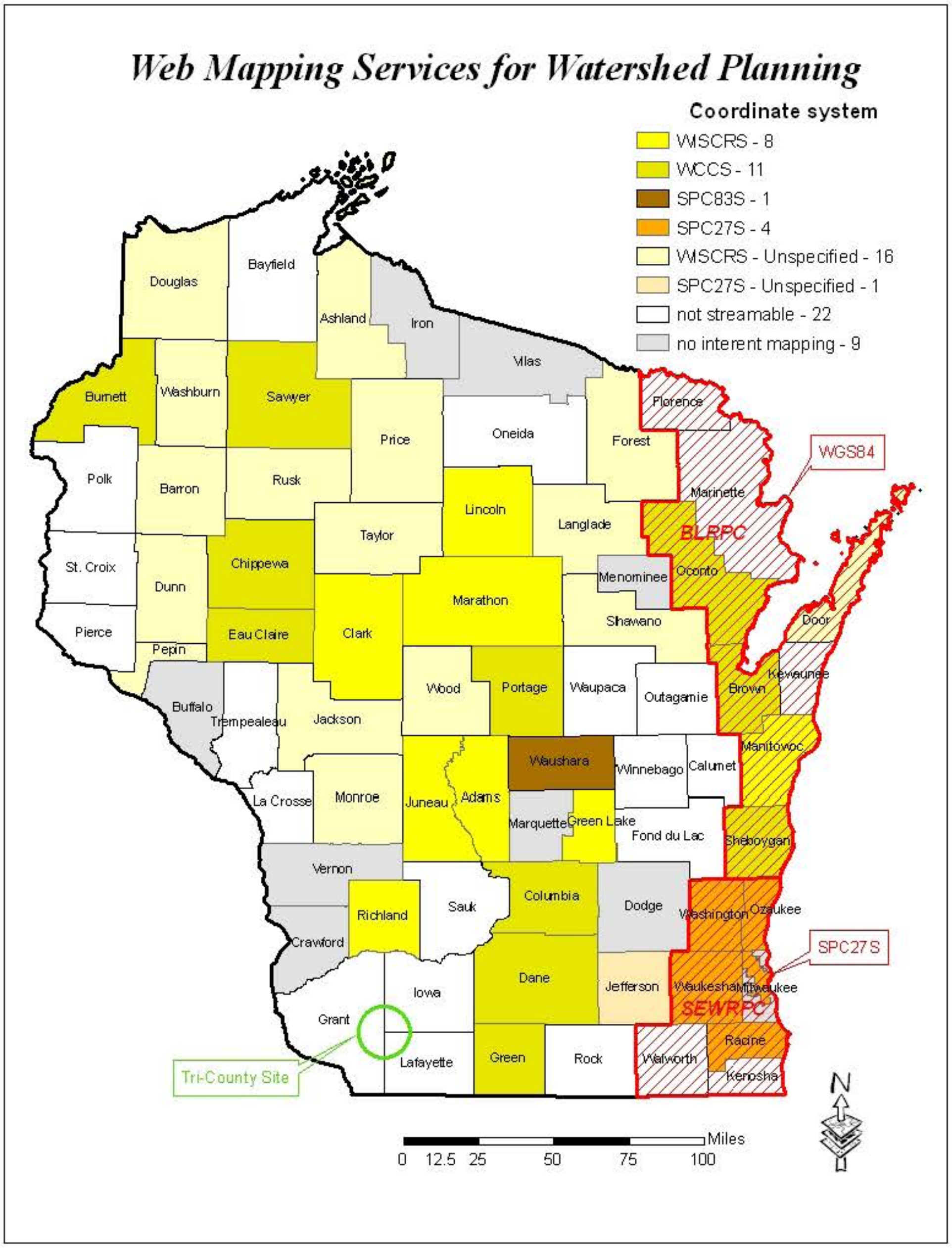


Figure 2-2. *Coordinate Systems Used by Internet Mapping Sites, 2009.*

<u>Extractable Data:</u> The ability to set a layer as selectable, select a subset of features, and extract these first to a layer file and then to a shapefile stored locally is relatively uncommon (Figure 2-3). Only seven streamable sites with published coordinate system information, and two without, continued to offer this functionality. In earlier versions of ArcIMS (prior to version 9.2), this was the default setting for a theme.

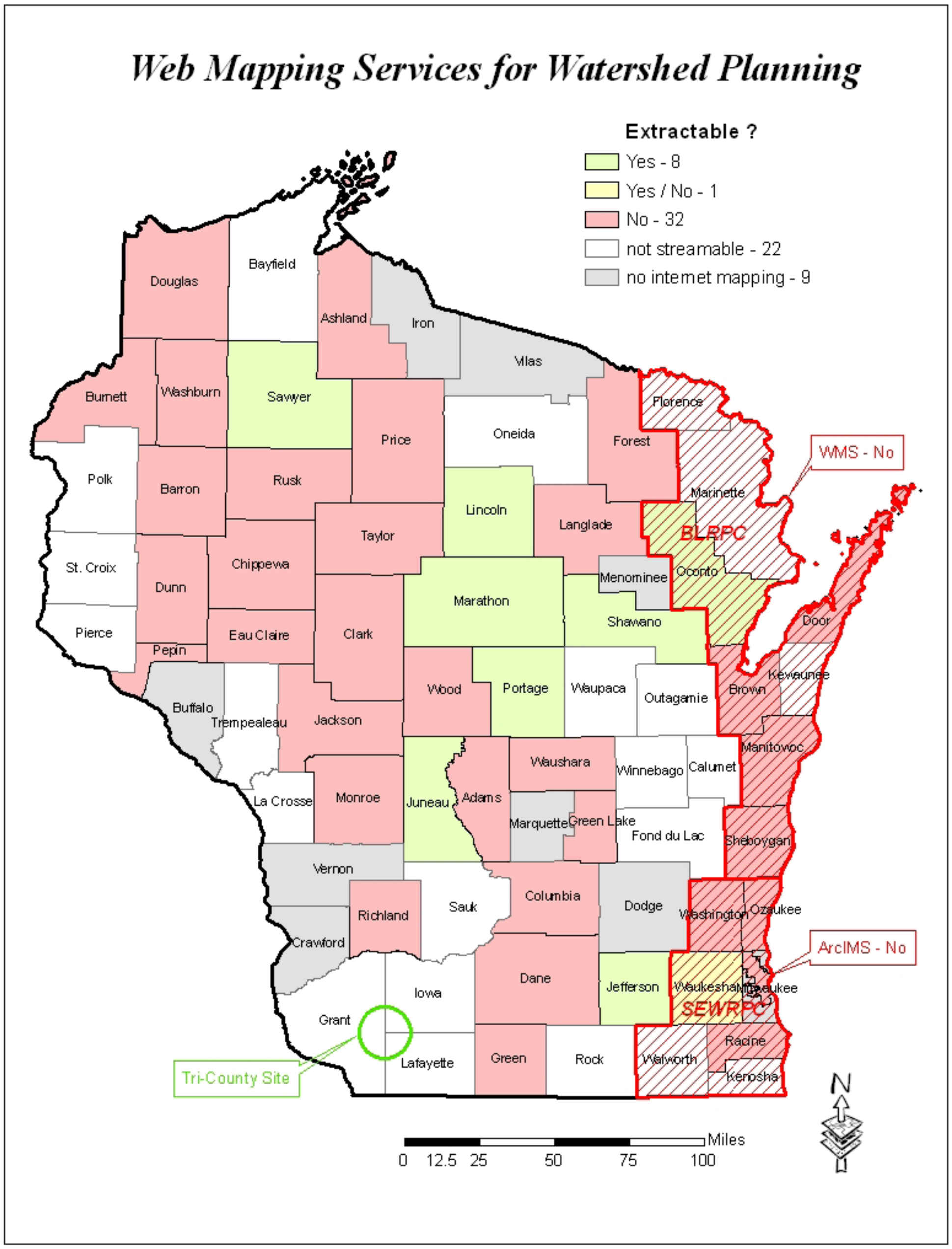


Figure 2-3. *Internet Mapping Services with Extractable Data, 2009.*

> ***Accomplishment: Watershed boundaries for 12-digit HUCs were added to the Wisconsin DNR's Surface Water Data Viewer, providing the only complete coverage of these watersheds in the state.***

<u>Watershed Boundaries:</u> The Wisconsin DNR's Surface Water Data Viewer was the only site that included a complete 12-digit HUC coverage. These watershed boundaries were added to the site in late summer 2008 as part of our challenge grant work. Of the 41 streamable county sites, 11 support representations of watersheds, including six with coordinate system information. Another nine non-streamable sites include watershed boundaries, primarily Wisconsin DNR's 1:24,000 watersheds clipped to the county line. Barron County is an exception in having sub-24,000 watersheds delineated.

Dane County's Internet mapping site was anomalous among the county sites. The site's 1:24,000 watersheds extended beyond the county boundary to show entire watersheds. Also, the site included 928 fine grained watersheds (~ 1.33 sq. miles) derived from processing high resolution hydrography against a high resolution DEM (~11m). These were finer grained than 12-digit HUCs, which in Wisconsin average ~31 sq. miles.

<u>Hydrography:</u> We found some depiction of hydrography included on all 63 county Internet mapping sites. These layers were generally Wisconsin DNR's 1:24,000 Hydro layer, a locally generated hydrography layer, or a combination of the two. In some cases, the source of the layer was not indicated. Occasionally, drainage paths from DEM processing were also shown. The hydrography layers, however, had scarcely any attributes other than waterbody name associated with them. Those with the Wisconsin DNR 1:24,000 layer generally preserved the basic attribute structure of the distributed shapefile, including the Water Body ID Code, which links to the Wisconsin DNR's rich attribute databases.

<u>Hydrologic Soils:</u> Fifty county Internet mapping sites served SSURGO soils data (U.S. Department of Agriculture 1995), with or without attributes or symbology. Given Wisconsin's strategic initiative to leverage 80% matching federal funds and the completion of SSURGO soils mapping and digitizing, counties had been eager to include soils data in their sites. Most of these sites, however, were designed only for localized queries when zoomed into a neighborhood view of parcels; very few sites were designed to afford landscape scale rendered views for planning purposes, such as across entire watersheds, basins , or counties. Often, soils were shown as outlines only; either outlines with soil mapping unit labels always on or outlines with selectable labels. It was quite common to find soil mapping units as randomly filled polygon colors, a feature that was not particularly useful for examining landscape patterns. Often the soils data had no attributes; or sometimes only a handful of key attributes. Very rarely, the Internet mapping sites were linked to the NRCS Web Soil Survey[7] (e.g., the Bayfield and Florence county sites). Only a few county sites included Hydrologic Soil Group as a rendered view or attribute (Door, Polk, and Waukesha counties). SEWRPC included soils as polygons with labels and attributes for its seven-county area.

<u>Land Cover and Land Use:</u> Surprisingly, only eight county Internet mapping sites offered any view of land cover. These included two streamable sites with coordinate system information, three without, and three unstreamable sites. (While all counties could use the Wisconsin DNR's WISCLAND data, they provide coarser resolution [30 meters] and are becoming dated [LANDSAT imagery from 1992-1993 was interpreted].) Digital land use data were accessible for 19 counties, either via the county's own Internet mapping site or an RPC site. Of the county sites, four were streamable with coordinate system information, four were streamable without coordinate system information, and one was not streamable.

<u>Monitoring and Gauging Stations:</u> No county Internet mapping sites showed these themes. Wisconsin's sole source for these data was the Wisconsin DNR's Surface Water Data Viewer.

We used these findings to identify possible local data sources, as well as to highlight enhancements that would more readily enable data sharing or make Internet mapping sites more useful.

<u>Development of New Internet Mapping Sites:</u> The Bay-Lake RPC completed land use inventories in Door, Manitowoc, and Marinette counties during the grant period. The Wisconsin DNR contracted with the Bay-Lake RPC to develop a WMS in ArcIMS for these and other land use inventories available in its 8-county region. Coding upgrades were done to Apache and Tomcat to make sure these worked correctly with ArcIMS, which was upgraded from 9.1 to 9.2. UW-Sea Grant assisted the Bay-Lake RPC with these upgrades and the associated information technology issues.

Accomplishment: Bay-Lake RPC made land use inventories for 8 northeastern Wisconsin counties available on an ArcIMS mapping site as WMS and WFS services.

The data from these surveys were integrated into the RPC's web services in 2008 and 2009. These inventories were posted to the RPC's ArcIMS Internet mapping site using WMS and WFS services.

[7] http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

The Bay-Lake RPC found that the server running ArcIMS was not able to handle ArcGIS Server. So, the RPC looked at employing a virtual server, owned and operated by a local information technology company. This option allowed the Bay-Lake RPC to use ArcGIS Server technologies and was believed to be an option for the future provision of data via WMS and WFS. Unfortunately, the downturn in the state and local economy prevented the Bay-Lake RPC from fully implementing this option and, ultimately, resulted in the dismantling of the services.

In the meantime, the Bay-Lake RPC provided shapefiles, layer files, and documentation to the Midwest Partnership (via Wisconsin DNR) to be used in developing prototype interfaces using local geospatial data (see Section 2.3.2).

2.2. Data Analyses

Many watershed management activities benefit from analysis tools that organize, summarize, and report data in meaningful ways (Watermolen 2007, 2009; Welch 2005). When standardized reports are coupled with watershed delineation tools, they allow decision makers to focus queries by geographic area of interest (e.g., hydrologic unit, county, etc.) and analyze key data on a meaningful watershed basis (Lucero et al. 2004, Watermolen 2008a, b). More advanced tools, with only a few rules that facilitate the creation of readable reports and maps, can enable watershed managers to select variables germane to their specific situation and then create customized outputs for use in their decisions.

2.2.1. Goal 4: Generate Watershed Reports

Background: A first step in watershed planning is gathering and organizing data and information. Planners rely on information regarding physical and natural features (watershed boundaries, topography, soils, hydrology, climate, habitat, wildlife, etc.), land use and socioeconomic characteristics (land cover, land use, demographics, management practices, etc.), watershed conditions (water quality standards, 305(b) and 303(d) designations, source water assessments, etc.) , and pollutant sources (point sources, nonpoint sources, etc.). Understanding this information requires effort to summarize, analyze, and interpret the data. From work elsewhere, we know that carefully constructed spatial models can be particularly useful for integrating ecological information and communicating assumptions, potential uncertainties, and the complexity of feedbacks to various local stakeholders and can enhance public participation in local processes (Convis 2001, Dale 2003, Conroy and Gordon 2004, Aggett and McColl 2006a, 2006b). U.S. EPA has invested in the development of a number of modeling tools to aid planners in understanding their watersheds, but these tools have not been widely used by local governments (Watermolen 2009).

The Wisconsin DNR and Midwest Partnership believe that linking these tools and their outputs can create efficiencies for watershed planners and decision makers. Specifically, we have worked to integrate two tools developed by U.S. EPA's Office of Research and Development in to our toolkit:

> U.S. EPA's Analytical Tools Interface for Landscape Assessments (ATtILA) tool is an ArcView extension that calculates commonly used landscape metrics (U.S. EPA 2004b). ATtILA accepts data from a broad range of sources and is equally suitable across landscapes, from deserts to rain forests to urban areas, and may be used at local, regional, and national scales.
>
> U.S. EPA's Regional Vulnerability Assessment (ReVA) program conducts research on the evaluation and integration of large and complex datasets and models to assess current conditions and likely outcomes of environmental decisions, including alternative futures. The ReVA team works with select client groups to develop research demonstrations that combine and apply current data and appropriate models across a geographic region with the goals of interpreting current conditions, anticipating future issues, setting management and ecosystem protection priorities, and proactively assessing decisions that may impact multiple outcomes or involve tradeoffs (Smith et al. 2001).

One of the biggest challenges that planners face is determining how much data is enough. Planners must balance resources, their ability to reasonably characterize their planning area, and the need to keep planning processes moving forward. Knowing who collected data, where and when they collected it, and what the results of their efforts were can help planners determine if additional data collection is needed. The STORET web services now include features that allow this type of information to be summarized. We sought to capitalize on this new possibility.

Grant Goal: Create and implement a standardized watershed report tool for Digital Watershed.

Activities and Progress: Wisconsin DNR contracted with Michigan State University's Institute of Water Research to develop a standardized watershed report tool for Digital Watershed. The MSU team was the logical group to develop the new functionality as that team had previously developed Digital Watershed. In addition, a separately funded project undertaken by the MSU team and the National Park Service provided a starting point for development of the new watershed reporting capability.

The MSU team consulted with internal and external domain experts to select information/indicators to include in the standard report. Staff from U.S. EPA's Great Lakes National Program Office provided input as to what information/ indicators would be useful for Lakewide Management Plans (LaMPs). Wisconsin DNR provided a state agency perspective and shared lessons learned from its work with local governments and regional planning commissions. Based on this input and the availability of ATtILA and ReVA outputs, the MSU team developed a standardized 8-digit HUC watershed report.

Accomplishment: Digital Watershed provides a STORET data summary, derived dynamically online from U.S. EPA's STORET web services, for each 8-digit HUC nationwide.

The watershed report generated by this function contains general watershed information, including a watershed map and land cover characteristics pie chart, as well as various ecological indicators derived from U.S. EPA modeling efforts and water quality information extracted from STORET.

Table 2-1 lists parameters derived from ATtILA that are contained in the standardized report. Selected major ecological indicators derived from ReVA and included in the standardized reports are listed in Table 2-2. The "U.S. EPA STORET Water Quality Data Summary" section of the report contains all information derived dynamically online from the U.S. EPA STORET Watershed Summary Web Services:

- http://www.epa.gov/storet/web_services.html
- http://iaspub.epa.gov/webservices/ WatershedSummaryService/

This summary indicates the number of organizations collecting water quality data, the total number of water quality stations, the total number of water quality characteristics (parameters) monitored, and the total number of water quality data results in the watershed. Summary tables present the specific water quality characteristics, number of results, and the dates of monitoring for each of the organizations that have conducted monitoring in the watershed. Planners can use this information to determine if additional data collection is needed.

The descriptions and screen captures that follow (beginning on page 28) illustrate this new functionality as the end-user experiences it.

Table 2-1. *Watershed Report Parameters Derived from ATtILA.*

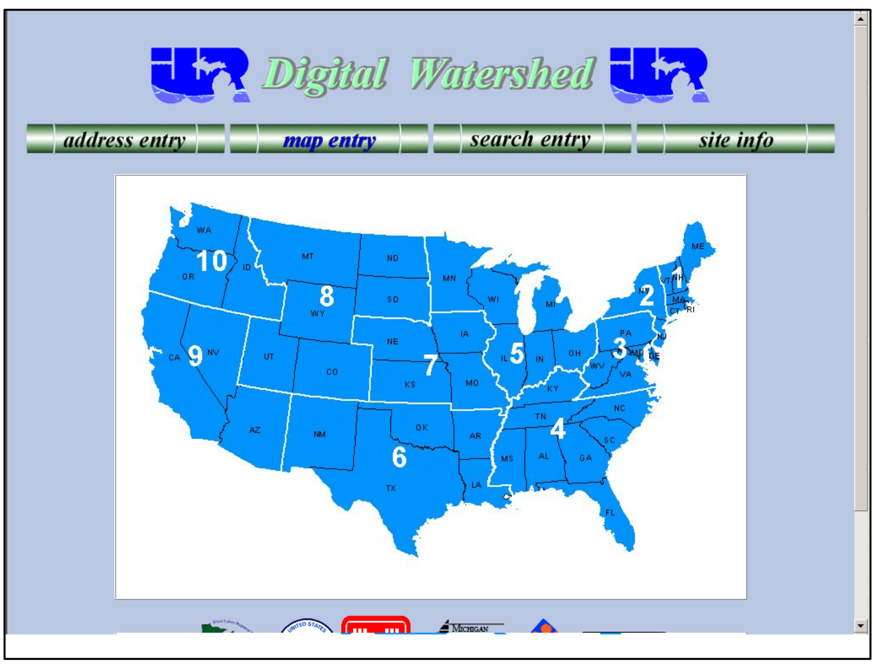
- % Natural land use
- % Forested
- % Wetlands
- % Shrub
- % Natural grassland
- % Natural barren
- % Human land use
- % Urban
- % Man-made barren
- % Agriculture
- % Pasture
- % Crops
- Phosphorus loading
- Nitrogen loading
- % Impervious Surface

Table 2-2. *Ecological Indicators Derived from ReVA and Included in Watershed Reports.*

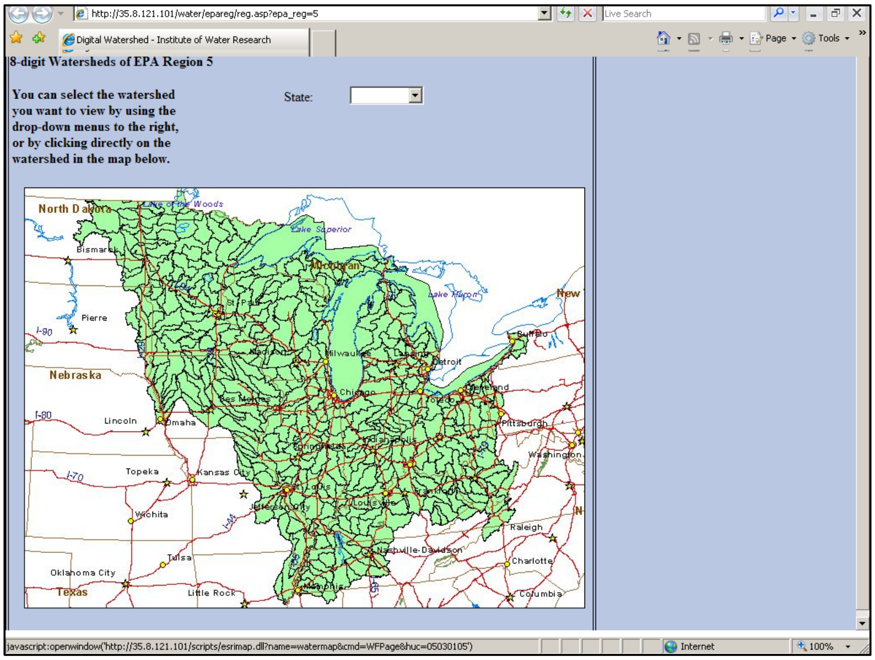
- Percent irrigated cropland acres (National Agricultural Statistical Service).
- Cropland productivity (measured as average yield of corn from NASS).
- Percentage of total stream length in the watershed that is adjacent to all (classes of) agriculture land.
- Percentage of all classes of agricultural land in a 60 meter stream buffer area.
- Percentage of total stream length in watershed that is adjacent to urban land (all classes).
- Percentage of urban land in a 60 meter stream buffer area.
- Population Density (people/square mile) in 2000.
- Estimated nonpoint source (NPS) Nitrogen (N) loadings (kg/ha) based on L-THIA model.
- Estimated nonpoint source (NPS) Phosphorus (P) loadings (kg/ha) based on L-THIA model.
- Estimated nonpoint source (NPS) Suspended Solids (SS) loadings (kg/ha) based on L-THIA model.
- Road density (km/square kilometer) in 2000.
- Stream density (km/square kilometer) in 2000.
- Percent of total surface water withdrawals used for irrigation.
- Percent of total groundwater withdrawals used for irrigation.
- Average surface water use per person (residential use).
- Average groundwater use per person (residential use).
- Percentage of watershed with all (classes of) agriculture land on slopes that is greater than three percent.
- Soil erodbility factor that represents both susceptibility of soil to erosion and the rate of water runoff.

To access the standardized watershed reports, users first go to the main Digital Watershed website (http://35.8.121.101/water/index.htm).

Clicking on the “map entry” button returns a map of the United States with U.S. EPA regions highlighted.

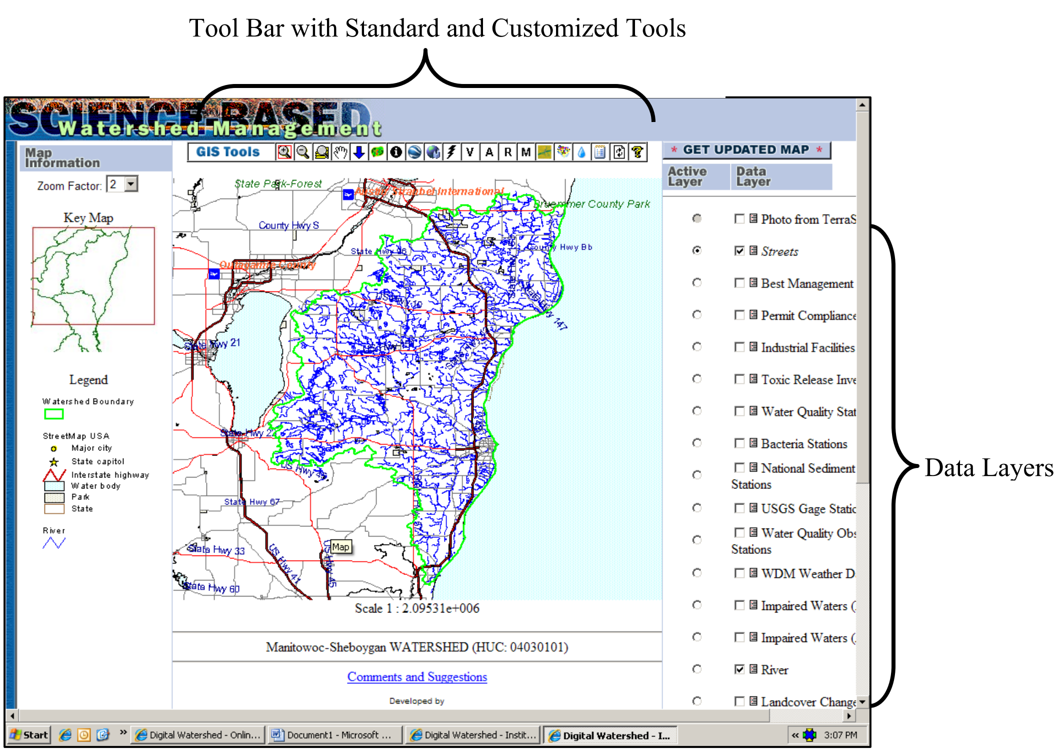


Clicking on the Region 5 section of the U.S. map opens a new window with a map of the 8-digit watersheds for the area.

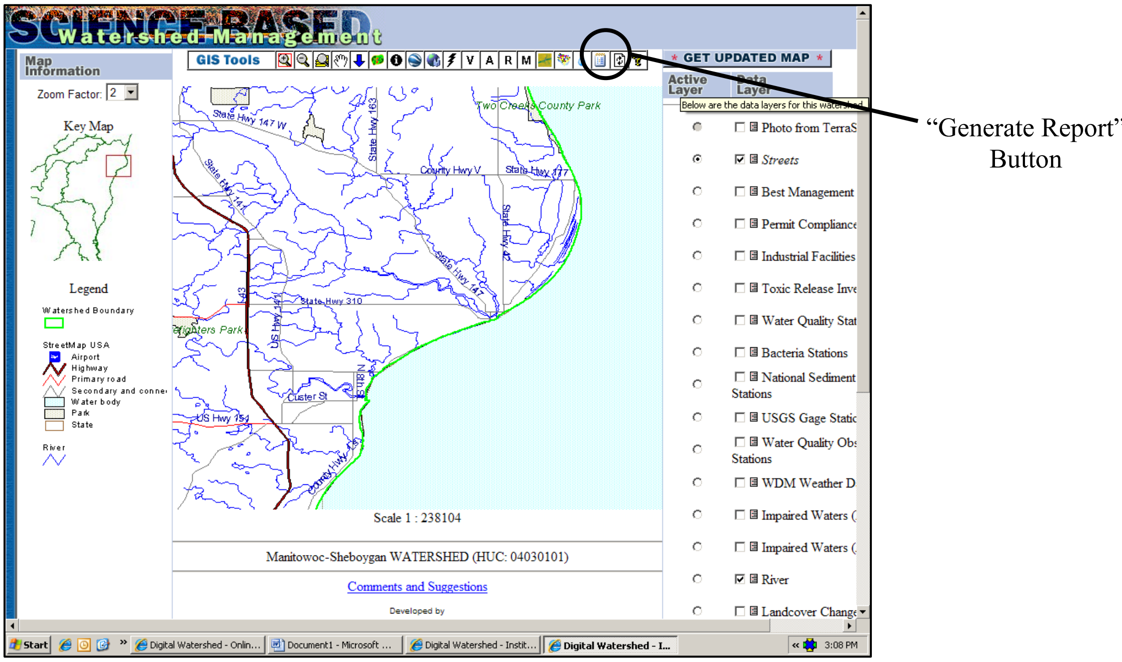


Clicking directly on any location on the 8-digit watershed map opens a new interactive map window that allows the user to “zoom in” to specific rivers and their surrounding watersheds. Users also can select the watershed they want to view by using the drop-down menus to the right.

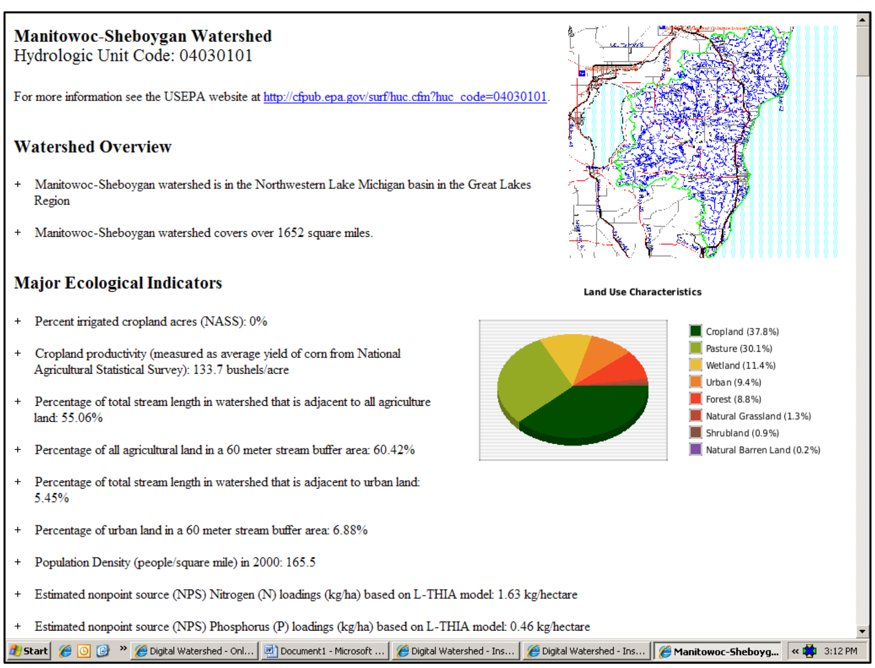
The standard web mapping interface that opens allows users to turn various data and image layers on and off. A tool bar across the top of the mapping interface provides access to a suite of standard and customized tools, including those used to access watershed summary reports.



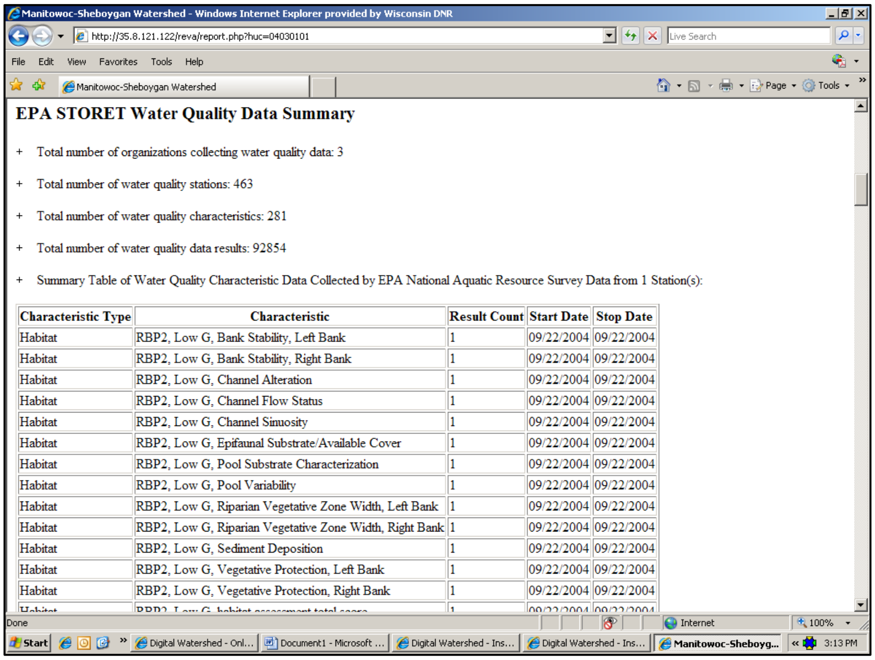
Users can “zoom in” further to pinpoint specific locations or waterbodies of interest. A scale bar appears at the bottom of each map to provide spatial perspective. The tool bar along the top includes a “Generate Report” button that retrieves the watershed summary report.



As indicated above and depicted below, the watershed summary reports generated by Digital Watershed include a variety of information related to the watershed including summary statistics, various ecological indicators, and the U.S. EPA STORET water quality summary (see Project Accomplishments for goals 2 and 3, Sections 2.1.2 and 2.1.3).



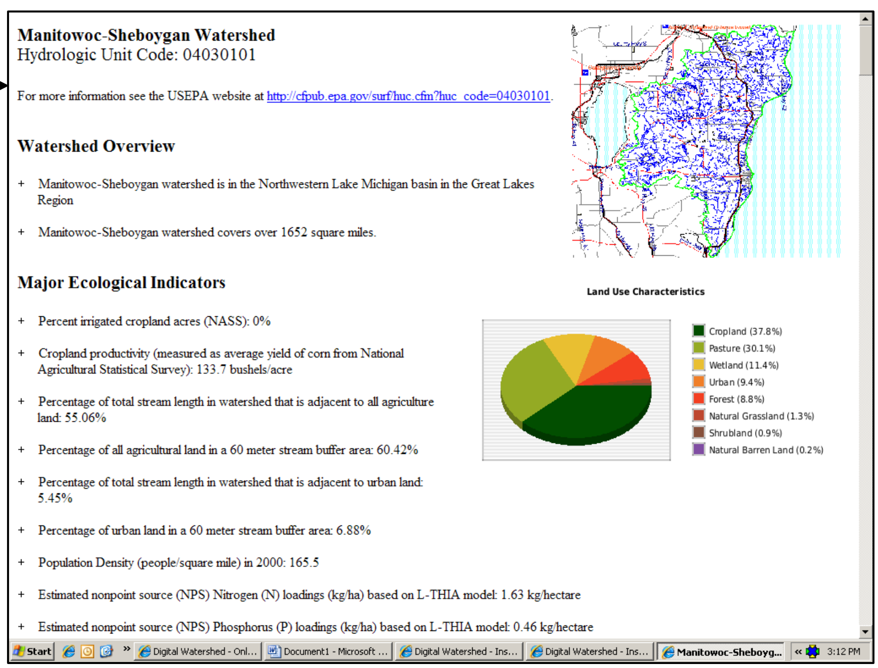
By scrolling down the watershed summary report, users find the “EPA STORET Water Quality Data Summary.” This summary indicates the number of organizations (e.g., U.S. EPA, state environmental agencies, local watershed groups) collecting water quality data, the total number of water quality stations, the total number of water quality characteristics (parameters) monitored, and the total number of water quality data results in the watershed. Summary tables present the specific water quality characteristics, number of results and the dates of monitoring for each of the organizations that have conducted monitoring in the watershed.



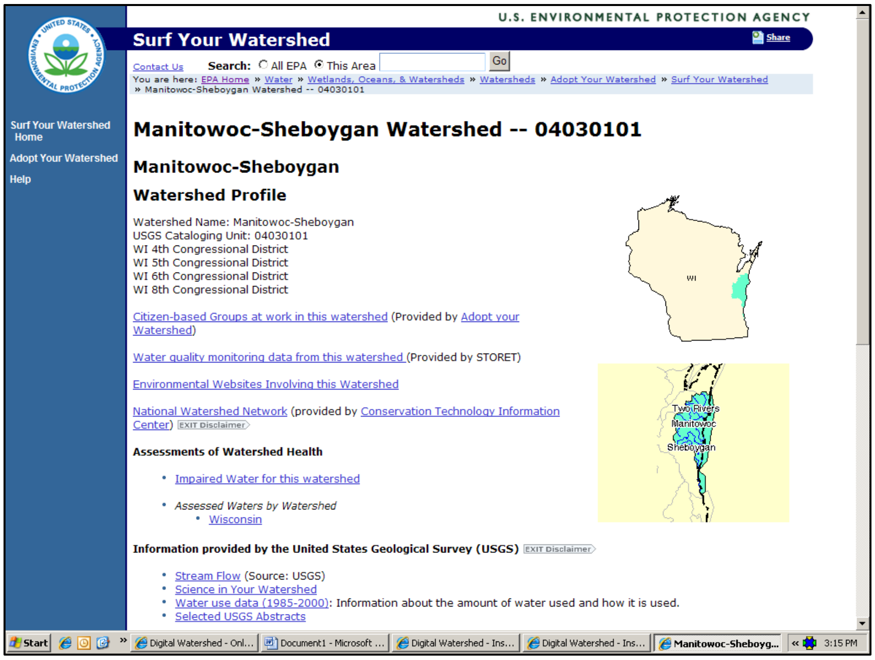
Characteristic Type	Characteristic	Result Count	Start Date	Stop Date
Habitat	RBP2, Low G, Bank Stability, Left Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Bank Stability, Right Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Channel Alteration	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Channel Flow Status	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Channel Sinuosity	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Epifaunal Substrate/Available Cover	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Pool Substrate Characterization	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Pool Variability	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Riparian Vegetative Zone Width, Left Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Riparian Vegetative Zone Width, Right Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Sediment Deposition	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Vegetative Protection, Left Bank	1	09/22/2004	09/22/2004
Habitat	RBP2, Low G, Vegetative Protection, Right Bank	1	09/22/2004	09/22/2004

In addition, the watershed summary report page provides a link to the basin’s watershed profile page on U.S. EPA’s website.

Link to U.S. EPA’s watershed profile page



The 8-digit HUC watershed profile pages on U.S. EPA's website provide tabular access to STORET data, but the sample points are not geographically referenced.



Program staff participated in a November 2007 meeting at the U.S. EPA Region 5 headquarters to discuss the use of the ReVA tool in local and state planning. During that meeting, project staff pointed out that the units of analysis and reporting applied by ReVA are inappropriate for addressing most local and state needs. For example, based on a critical analysis of several dozen past watershed monitoring, modeling, and management efforts, as well as the experience of a number of practitioners, Schueler (1996) found scale to be *the critical* factor in preparing effective *local* watershed plans. Although useful for multi-state regional and national planning, the 8-digit HUCs do not provide sufficient detail to uniquely identify subsequent larger-scale watersheds and their associated management issues (Brown et al. 2000, p.4; Simcox and Whittemore 2004). Locally, managers may prefer the subwatershed (12-HUC) as a planning unit because it is small enough to perform monitoring, mapping, and other watershed assessment tasks in a rapid time frame. A local focus for watershed management is also driven by various socio-political factors. According to Schueler (1996), when watershed plans were conducted on too large a scale (50 or more square miles):

- the focus of the plan became too fuzzy.
- too many different subwatersheds had to be considered, and important differences in stream quality and development patterns could not be isolated.
- land use changes were too complex to forecast, breaking the critical link between individual land use decisions or restoration projects and the watershed plan.
- the number of stakeholders involved in planning proliferated, but actual responsibility for plan implementation diminished.
- costs for both monitoring and watershed analysis skyrocketed.
- a bewildering number of water quality sources, issues, and problems complicated the picture.

In addition, we noted that local and sub-state regional governments that engage in land use and comprehensive planning generally work at municipal and county (or, in a few cases, multi-county) scales. Due to their size, many subwatersheds are entirely contained within the same political jurisdiction which helps to establish clear and direct management authorities and responsibilities. Consequently, it makes sense to focus on subwatersheds when undertaking watershed planning (Center for Watershed Protection 1998). Analyses conducted at the sub-basin (8-digit HUC) level are simply too coarse for answering most of the watershed management questions that state and local governments have.

While we recognize that watersheds transcend these political boundaries, we also recognize the importance of conducting analyses and reporting their results at scales that are meaningful for decision makers. Eight-digit HUCs typically do not do this for the decision makers we most frequently work with. A more preferred unit of analysis and reporting would be the sub-watershed (12- or 14-digit HUC). Wisconsin DNR personnel also noted that analyses conducted at the ecological landscape and ecoregion scales might be more meaningful for many state and local conservation planning efforts.

During the November meeting, the ReVA project manager indicated that her team was exploring the use of 12-digit HUCs and requested Wisconsin DNR's review of ReVA's Midwest Environmental Decision Toolkit. Program staff agreed to introduce other Wisconsin DNR staff and local stakeholders to the ReVA tools and provide feedback to the ReVA team early in 2008. Following the meeting, we introduced Wisconsin DNR staff to ReVA. The staff group had a good overview discussion and developed a plan for getting the ReVA team and contractors meaningful feedback within the specified timeframe. We communicated that plan to the ReVA program manager in early December, with a commitment to provide a consolidated response by the end of January. The ReVA program manager indicated that the contractors would be working on ReVA in the coming weeks and suggested that Wisconsin DNR wait until around mid-January before actually conducting a review.

Given the importance of conducting analyses and reporting their results at scales that are meaningful for decision makers, we had hoped the ReVA team would be able to provide analysis and reporting at the sub-watershed (12- or 14-digit HUC) scale. Wisconsin DNR staff members spent considerable time reviewing the ReVA tools during January and February. We submitted comments to the project director in March 2008 (Watermolen 2008b). Our comments were offered from the perspective of collaborators looking to make investments in ReVA meaningful to a broader range of users (i.e. the state and local people we regularly work with). Although the use cases included in the draft design documents suggest this was the direction the ReVA team was pursuing, the program manager's response to our review and comments suggested this apparently was not the ReVA team's interest/intent and information at the 12-HUC scale was not provided**.** We therefore discontinued our involvement with the ReVA effort.

2.2.2. Goal 5: Define Options for Customizing Reports

Background: Through our previous work (Lucero 2003, 2004; Watermolen 2009, 2010), we have found that even the most basic users of databases and decision-support tools seek a level of functionality and flexibility that allows them to make and interpret their own assumptions when generating reports and modeling outcomes. The ability to customize reports helps save them time. Rather than generating standard reports that may lack the most important information or contain information they do not really need for their purposes, they prefer to create reports that contain the exact information that they or one of their stakeholders needs. Major information technology providers have recognized this type of concern in their quest to address business needs. For example, Google recently moved its Google Analytics product away from "puking out standard reports" to letting users create their own suit of custom reports. Unlike many federal agency analysts and planners who are looking for trends in the "big picture," local watershed practitioners focus on outcomes and therefore seek the information/metrics necessary to address their specific concerns. In addition, when the Wisconsin DNR team worked with others to evaluate the U.S. EPA's ReVA toolkit, we found that users prefer direct access to the data underlying various models and metrics, as well as the ability to generate or modify metrics using their own assumptions. They want to be able to look at the source data and evaluate its quality and integrity through their own review and analytical processes. These users are closest to the environmental problems and often have very nuanced understandings of local conditions and processes. They often want to assess their "gut feelings" about the factors affecting their watersheds. As a result, we sought to work with the ReVA team to allow users to generate metrics "on the fly" similar to how L-THIA allows users to alter land use scenarios and then predict subsequent changes in polluted runoff. We had hoped to use the results of such analyses to populate the content of user-defined reports.

Grant Goal: Define options for a customized watershed report tool for Digital Watershed.

Activities and Progress: We had hoped to integrate functionality and outputs from U.S. EPA's Regional Vulnerability Assessment (ReVA) project with Digital Watershed's reporting capabilities. To this end, the Midwest Partnership, through the work of the MSU team, prepared an extensive list of parameters that could be drawn from the Midwest environmental decision toolkit (EDT) being developed by the ReVA team with the intention of including these model outputs in the standard and customized reports.

Program staff participated in a November 2007 meeting at the U.S. EPA Region 5 headquarters to discuss the use of the ReVA tool in local and state planning. During that meeting, project staff pointed out that with respect to the data and metrics used in ReVA, the users we work with would prefer direct access to the data underlying the metrics, as well as the ability to generate or modify metrics using their own assumptions. For example, when considering endangered and threatened species in our watershed work, we find it important to know just what species occur within a watershed (e.g., when developing a TMDL, we might be more concerned about listed mussel species than we would be about Kirtland's warblers or Karner blue butterflies). Yet, this is not possible given the way ReVA accesses and uses these data in generating the metric associated with listed species. It would be more helpful if we could generate this metric "on the fly" after eliminating the terrestrial species from the analysis.

Accomplishment: Wisconsin DNR reviewed the ReVA Midwest Environmental Tool Kit and suggested ways of making it more meaningful to a broader range of users (i.e. state and local practitioners).

During the November meeting, the ReVA project manager requested Wisconsin DNR's review of ReVA's Midwest Environmental Decision Toolkit. Program staff agreed to introduce other Wisconsin DNR staff and local stakeholders to the ReVA tools and provide feedback to the ReVA team early in 2008. Following the meeting, we introduced Wisconsin DNR staff to ReVA. The staff group had a good overview discussion and developed a plan for getting the ReVA team and contractors meaningful feedback within the specified timeframe. We communicated that plan to the ReVA program manager in early December, with a commitment to provide a consolidated response by the end of January. The ReVA program manager indicated that the contractors would be working on ReVA in the coming weeks and suggested that Wisconsin DNR wait until around mid-January before actually conducting a review.

Given the importance of conducting analyses and reporting their results at scales that are meaningful for decision makers, we had hoped the ReVA team would be able to provide analysis and reporting at the sub-watershed (12- or 14-digit HUC) scale. Wisconsin DNR staff members spent considerable time reviewing the ReVA tools during January and February. We submitted comments to the project director in March 2008 (Watermolen 2008b). Our comments were offered from the perspective of collaborators looking to make investments in ReVA meaningful to a broader range of users (i.e. the state and local people we regularly work with). Although the use cases included in the draft design documents suggest this was the direction the ReVA team was pursuing, the program manager's response to our review and comments suggested this apparently was not the ReVA team's interest/intent and the ability to generate metrics on the fly was not provided. We therefore discontinued our involvement with the ReVA effort.

2.2.3. Goal 6: Create Thematic Map Capability

Background: A thematic map is designed to show a particular theme or themes (e.g., physical, biological, social, political, cultural, economic, etc. attributes) connected with a specific geographic area. These maps use base data such as coastlines, political boundaries, and places only as point of reference for the phenomenon being mapped (Thrower 2007). As a result, thematic maps provide specific information about particular locations (e.g., neighborhood, town, state, region, nation, or continent), provide general information about spatial patterns of the theme (e.g., statistically aggregated data, densities, incidences, rates, etc.), and can be used to compare patterns on multiple maps in order to explore possible correlations between potentially related phenomena.

The end user of a thematic map and the purpose for which it is developed help define how a thematic map should be designed (Thrower 2007). For example, local elected officials might prefer having information mapped within clearly delineated county or voting district boundaries. Watershed practitioners on the other hand would certainly benefit from county boundaries being on a map, but hydrology seldom follows man-made delineations. Maps that display the desired watershed information in the context of watersheds (e.g., 8-HUCs, 10-HUCs, 12-HUCs, catchments, etc.) underneath a transparent county boundary map are often more useful.

Typical geo-spatial data layers include underlying attribute tables that contain important, yet generally inaccessible supporting information. Often this supporting information is needed for hydrologic modeling or economic analyses. Thematic maps can display the geographic distribution of a particular attribute or relationships among several selected attributes. Thematic map tools provide access to these underlying data and allow watershed decision makers to create and add new map layers, thus improving their analyses and decision making.

Goal: Add thematic mapping capabilities to Digital Watershed.

Activities and Progress: Wisconsin DNR contracted with the Michigan State University Institute of Water Research team to add a thematic mapping function into the Digital Watershed system. The MSU team was the logical group to develop the new functionality as that team had previously developed Digital Watershed and maintains the intellectual property rights associated with this publically available system.

The MSU team developed a new map function that allows users to generate a thematic map of their current selection of layers and map extent. The map is generated as a temporary browser display, which the user can print immediately, or cut and paste to another software package to save for later use.

Accomplishment: Digital Watershed allows users to generate a thematic map of their current selection of layers and map extent and print it or cut and paste it into another software package.

Image and data layers included in the thematic map are listed in Table 2-3.

Descriptions and screen captures (beginning on page 37) illustrate this new functionality as the end user experiences it.

Table 2-3. *Image and Data Layers Included in the Digital Watershed Thematic Map.* (**Bold text** indicates those for which metadata was downloaded from U.S. EPA's BASINS.)

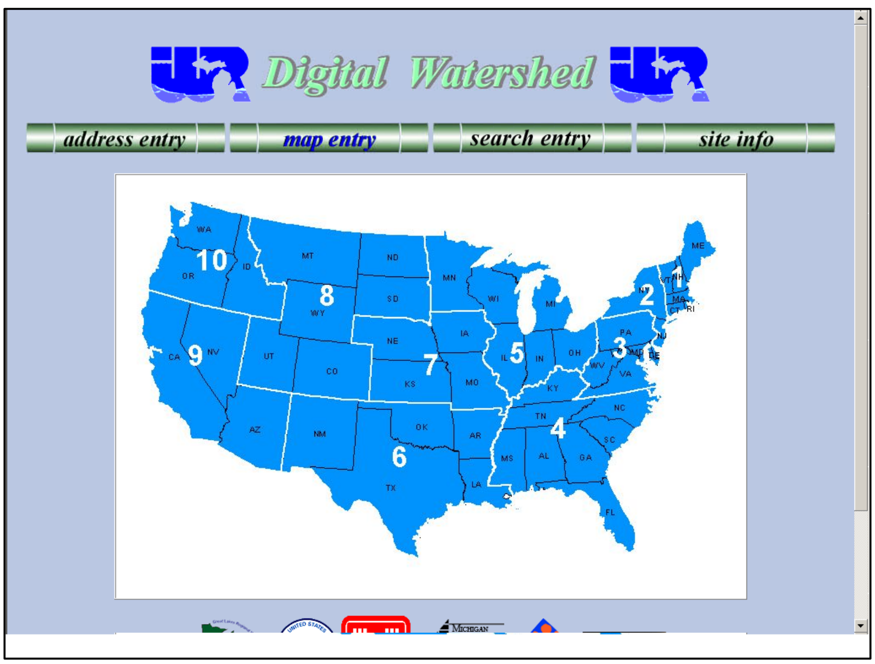
- Aerial photographs from Terra Server
- Streets
- Best Management Practices
- **Permit Compliance System**
- **Industrial Facilities Discharge**
- **Toxic Release Inventory**
- **Water Quality Stations**
- **Bacteria Stations**
- National Sediment Inventory Stations
- **U.S. Geological Survey Gauging Stations**
- **Water Quality Observation Stations**
- **WDM Weather Data Stations**
- Impaired Water (Event)
- Impaired Water (Reach)
- Impaired Water (Area)
- River
- **Land Cover Change (1992-2001) from NLCD**
- Land use 2001
- **State Soils**
- **County Boundaries**
- **State Boundaries**
- **EPA Region Boundaries**
- **Elevation**
- **Cataloging Unit Boundaries**

In addition, the interface for the state of Michigan also includes:

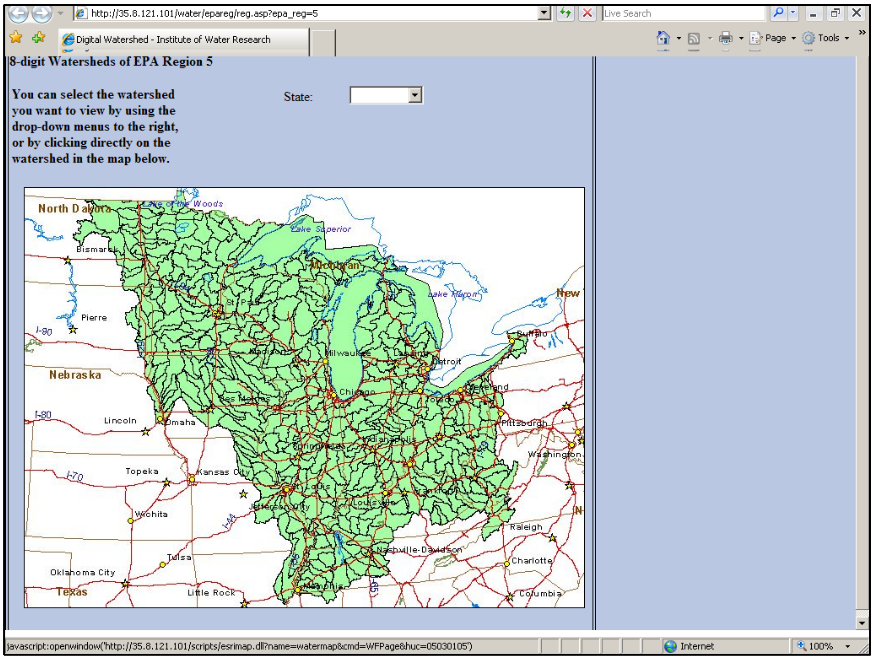
- Flow lines
- Contours
- **Agricultural erosion**

To access the thematic map function, users first go to the main Digital Watershed website (http://35.8.121.101/water/index.htm).

Clicking on the “map entry” button returns a map of the United States with U.S. EPA regions highlighted.



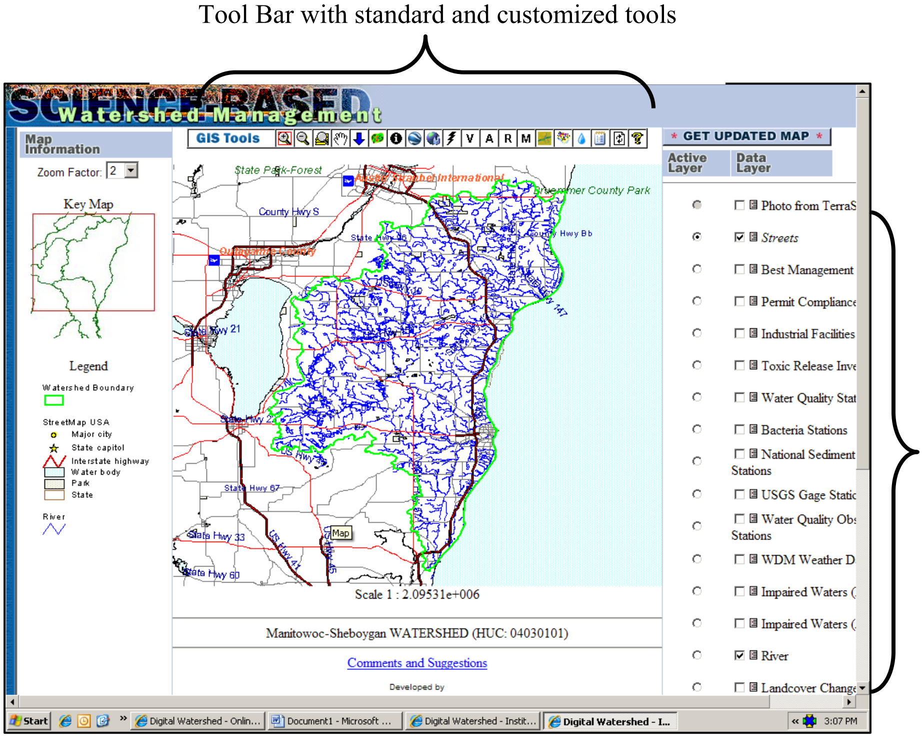
Clicking on the Region 5 section of the U.S. map opens a new window with a map of the 8-digit watersheds for the area.



Clicking directly on any location on the 8-digit watershed map opens a new interactive map window that allows the user to "zoom in" to specific rivers and their surrounding watersheds. Users also can select the watershed they want to view by using the drop-down menus to the right.

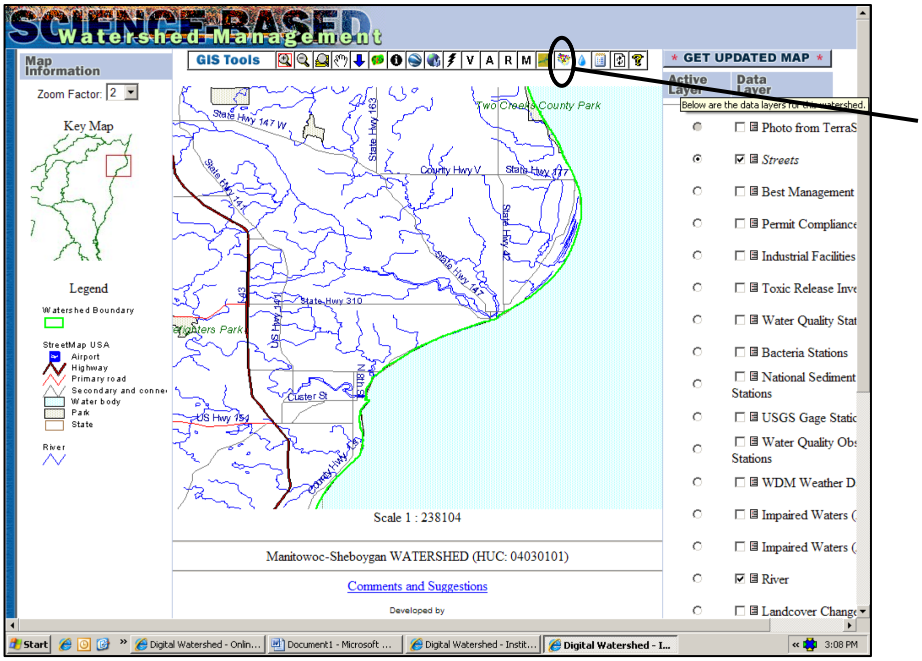
The standard web mapping interface that opens allows users to turn various data and image layers on and off. A tool bar across the top of the mapping interface provides access to a suite of standard and customized tools, including those used to access watershed summary reports.

Tool Bar with standard and customized tools



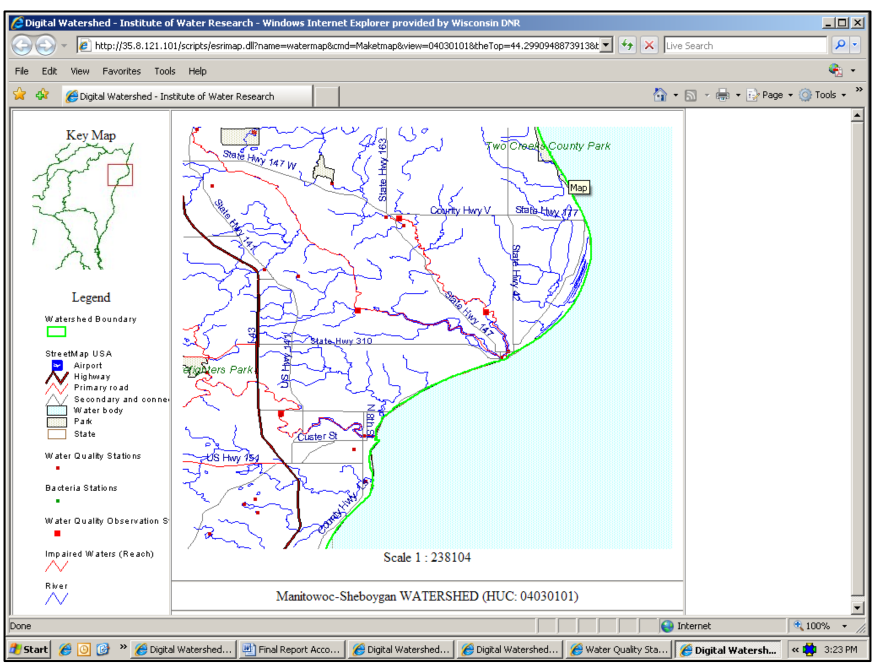
Data Layers

User can "zoom in" further to pinpoint specific locations or waterbodies of interest. A scale bar appears at the bottom of each map to provide spatial perspective. The tool bar along the top includes a "Make Thematic Map" button.



"Make Thematic Map" Button

Clicking the "Make Thematic Map" button opens a new mapping interface window. This window allows users to generate a thematic map of their current selection of layers and map extent. The map is generated as a temporary browser display, which the user can print immediately, or cut and paste to another software package to save.



2.3. Decision Support Tools

One missing link in watershed management remains the availability of robust, "easy-to-use-and-interpret" representation, simulation, and decision models that fit within a comprehensive decision-support system (National Research Council 1999, Watermolen 2007). As part of this project, we worked to enhance tools developed by members of the Midwest Partnership and integrate them with various U.S. EPA tools to create a comprehensive decision-support system that uses the Exchange Network infrastructure.

2.3.1. Goal 7: Enhance Watershed Delineation Capabilities

Background: Effective watershed management approaches require recognition of local and regional conditions. Significantly different natural conditions, ecosystem stressors, and management approaches affect watersheds in differing ways (Center for Watershed Protection 1998). Moreover, even where watersheds are affected by similar stressors, the underlying causes of their problems, and consequently the steps needed to deal with them, can be quite different.

From an ecological perspective, understanding the emergent properties of larger watersheds stems from an in-depth knowledge of local characteristics and processes at the subwatershed (12-digit HUC or smaller) scale. For example, what happens in the local landscape directly impacts headwater streams, which in turn affects major receiving waters. While generally short and narrow, headwater streams collectively represent the majority of the drainage network in many watersheds, and the watersheds and subwatersheds that drain to these streams are "readily identifiable landscape units that integrate terrestrial, aquatic, geologic, and atmospheric processes" (Clements et al. 1996). These streams and subwatersheds function on the same scale as many land development activities, and, in many cases, the influences of development on hydrology, water quality, and biological diversity are most strongly felt at this subwatershed scale. Consequently, it makes sense to focus on headwater streams and subwatersheds when undertaking watershed planning and management efforts (Center for Watershed Protection 1998).

Purdue University's Online Watershed Delineation (OWL) tool delineates watersheds down to less than 100 acres and offers a complete regional database. Purdue's Long-term Hydrologic Impact Assessment (L-THIA) model provides an online tool to assess water quality impacts of land use changes. The OWL and L-THIA tools did not, however, have scaling capability or address entry functions. Integrating Digital Watershed with the OWL and L-THIA tools could make its scaling capability more generally available. This integration also provides OWL and L-THIA with a user-friendly interface and a nation-wide search engine for watershed delineation and modeling via both street address and map-based entries. An earlier U.S. EPA-funded pilot project allowed users to access and use L-THIA through Digital Watershed. We sought to improve these connections and build necessary linkages to other decision models and the National Hydrography Dataset.

> **Grant Goal:** Modify and enhance the watershed delineation capabilities of Digital Watershed by linking the enhanced OWL to Digital Watershed.

Activities and Progress: The Wisconsin DNR contracted with Purdue University's Agricultural and Biological Engineering team to enhance the watershed delineation capabilities of OWL and link the OWL tool to L-THIA and Digital Watershed. The Purdue University team was the logical group to develop the new functionality as that team had previously developed L-THIA and OWL and maintains the intellectual property rights associated with these publically available tools.

The ability to delineate based on a pre-defined 12 digit HUC was demonstrated first for Indiana using a previous version of the 12-digit HUC map layer. During the course of the grant period, certified water boundary data for 12-digit HUCs became available from the NRCS Gateway for the lower 48 states. Wisconsin DNR requested a copy of the nationwide theme. Initially, using the NRCS Gateway, the datasets were too big to be compressed, and the FTP failed. A further request resulted in a zipped, nationwide geodatabase, which was successfully processed into 8-, 10-, and 12-digit HUC themes. An errata Excel file of proposed 8-diigt HUC name changes was also made available. U.S. EPA Region 5, Michigan State

University, and Purdue were also able to avail themselves of this nationwide dataset. *(From this request for a nationwide accessible file, the USDA Geospatial Gateway added FAQ 37: "How do I create one national map of all Watershed Boundary Data (WBD)?")*

Implementing this new 12-digit HUC layer as the base structure for L-THIA meant discarding previously built collections of watershed data, since significant changes in the 12-digit HUC layer outlines occurred throughout the Midwest region. The L-THIA model was built on 8- or 10-digit (clipped) watershed units that include DEM, slope, flow accumulation, direction, land use, and soils all clipped to the watershed. The new watershed outlines meant redoing this data manipulation, a fairly significant task. In this process the upgraded Wisconsin L-THIA was implemented with the U.S. Geological Survey's 10-meter DEM, with high-resolution National Hydrography Data (NHD) water features burned-in, as well as previously mentioned NLCD 2001 land cover and SSURGO soils as base layers.

Purdue developed a new Google Maps interface for L-THIA that includes a WMS layer of the NHD flowlines, the high-resolution version. This has a checkbox so the user can toggle the service on and off. The point of the display of this streaming data service is to locate channels and streams in the urban areas where Google does not depict it in their images. The new L-tHIA tool uses NLCD 2001 land use, U.S. Geological Survey seamless DEMs, NHD stream features, and SSURGO soils (U.S. Department of Agriculture 1995) as input layers, all downloaded and processed into 8-digit HUCs.

The Michigan State Digital Watershed interface can connect with the Google Maps L-THIA interface, meaning Digital Watershed can send a point to delineate and get a KML[8] watershed outline in return.

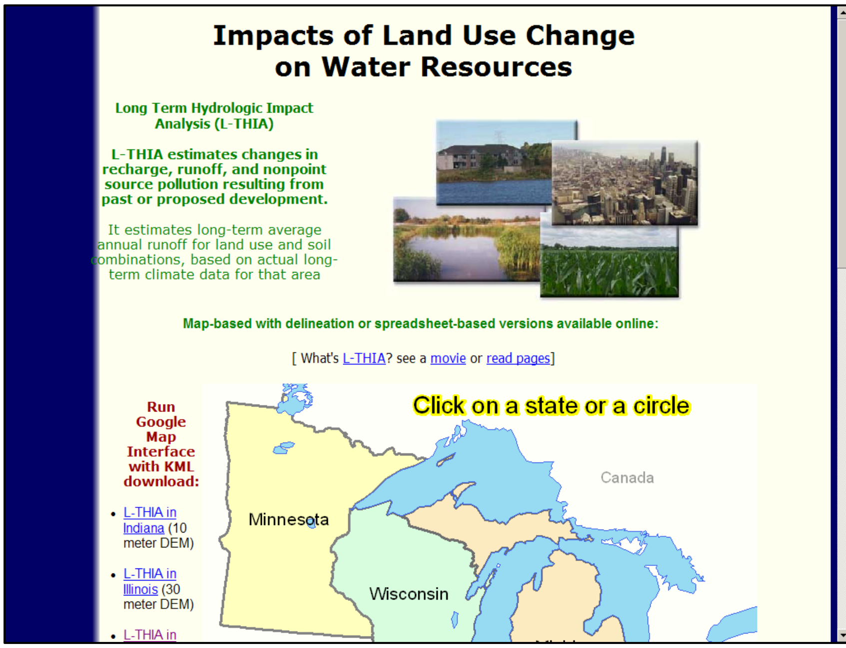
The new OWL tool supports three ways to delineate watersheds, by click, by location coordinate, and by 12-digit HUC watershed.

Accomplishment: The Online Watershed deLineation (OWL) tool delineates the area that drains to a specified pour point and allows users to send the resulting outline and associated land use and soils data to other modeling tools for analysis.

The OWL tool will delineate the area that flows to a pour point and allow users to send that outline, and the associated soil and land use data, to the Midwest Partnership's other online modeling tools. The following descriptions/instructions and screen captures illustrate this new functionality as the end-user experiences it.

[8] KML = Keyhole Markup Language. KML is the primary data format used by Google Earth and several other virtual globe programs. The OGC announced KML as an open standard in April 2008.

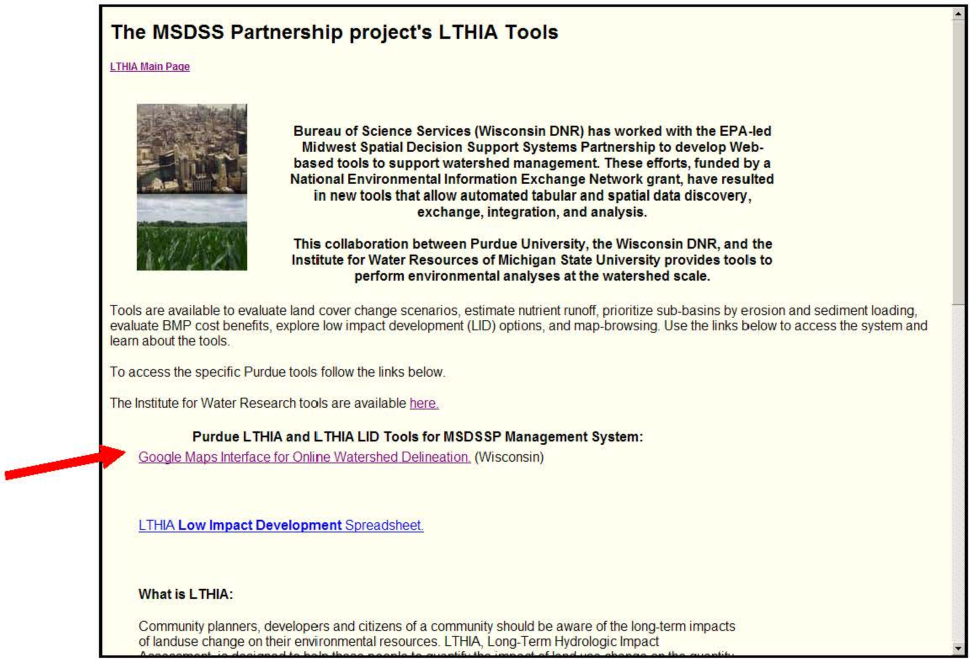
To access the interface, users first go to the main L-THIA website (https://engineering.purdue.edu/~lthia/) and scroll down to the map interface.

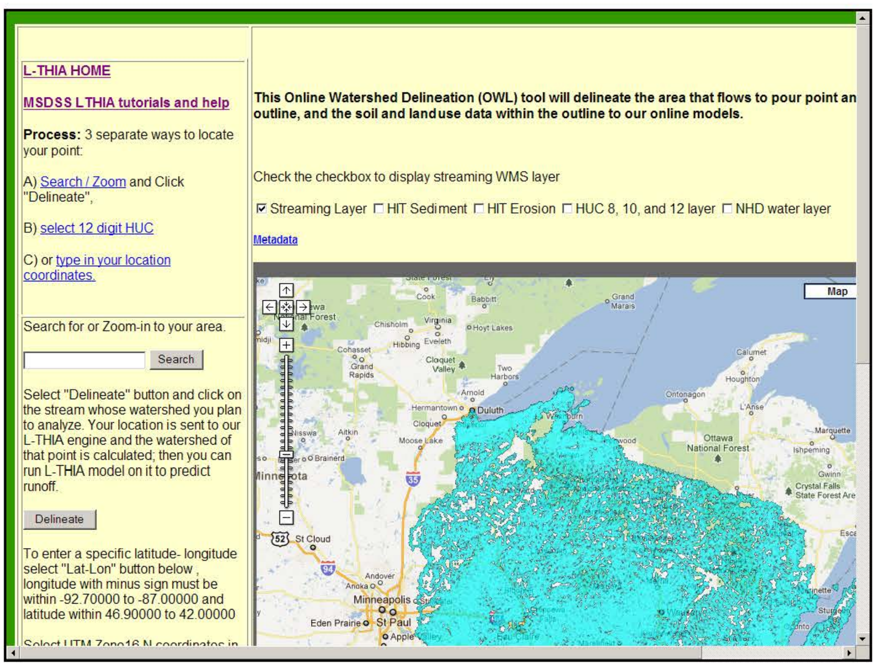


Scroll Down

Clicking within the Wisconsin state outline or the on the "L-THIA in Wisconsin" link in the left column takes the user to the challenge grant project page.

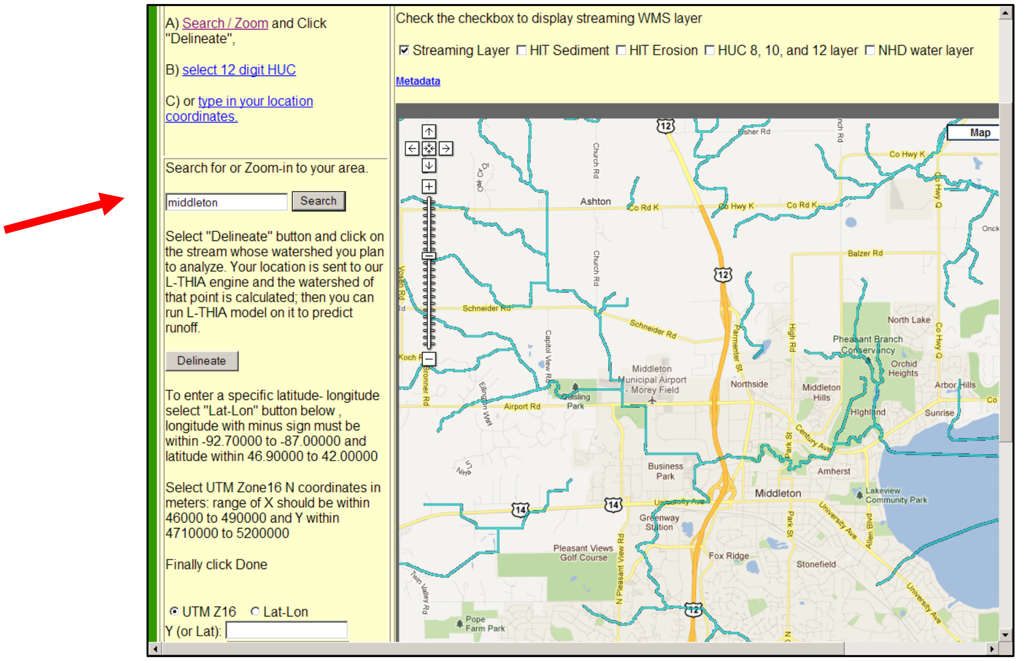
The challenge grant project page includes a link to the Google Maps interface for online delineation



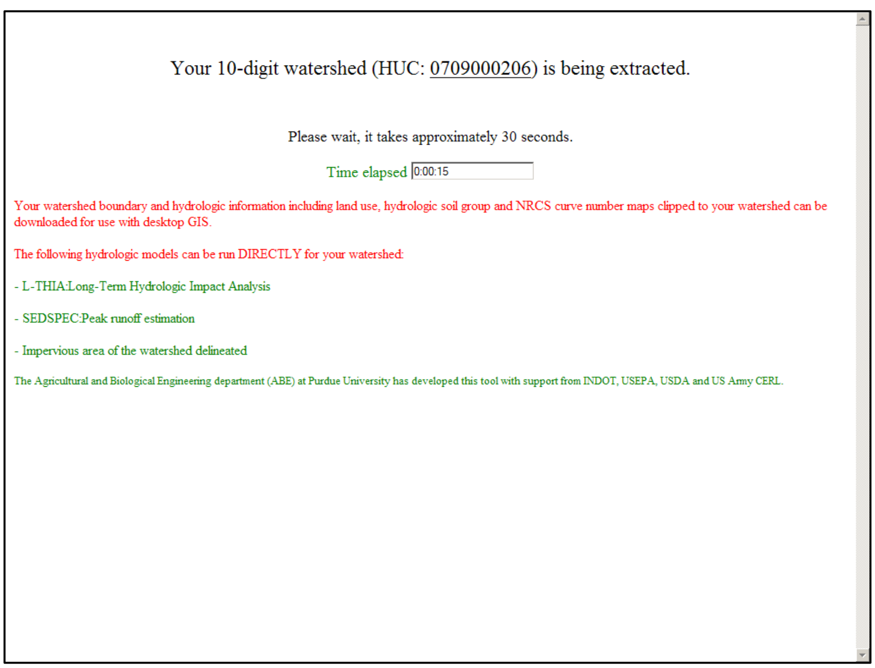


The left hand navigation column of the Google Maps interface provides three ways to locate a point: A) users can search/zoom and click “Delineate”, B) users can select a specific 12-digit HUC, or C) users can type in location coordinates. Each of these options is presented below.

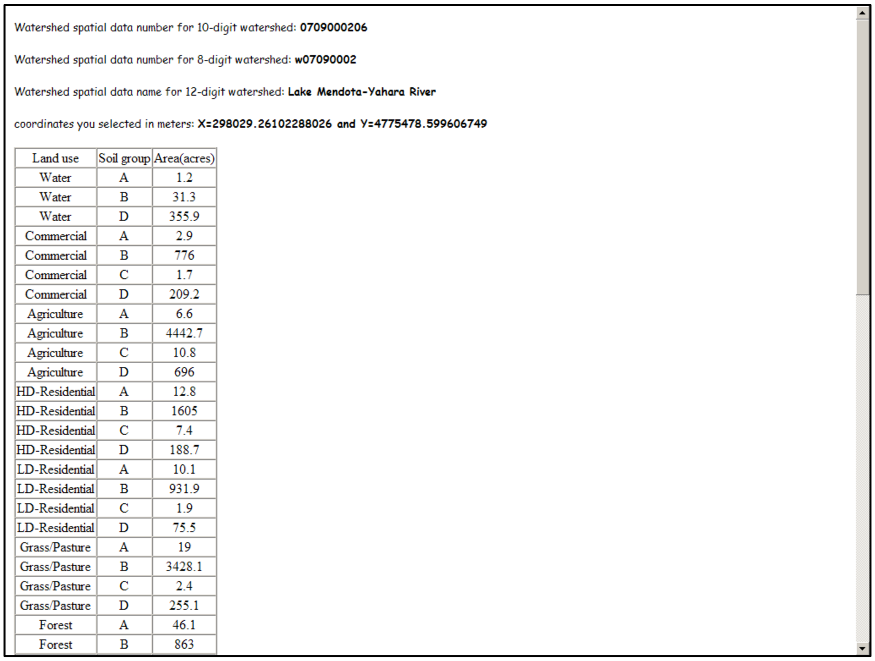
A) If users choose the search/zoom and click "Delineate" method, they simply type in the name of a location in the input box and click on the "Search" button.



Once the user has zoomed in to their location, they can click on the "Delineate" button and then click on the mouth of the stream whose watershed they want to analyze. The location is sent to the L-THIA engine and the watershed of that point is calculated. A temporary screen informs the user of the status of the delineation process.



Once the delineation process is complete, the system presents a report page with summary information related to the watershed. The report includes the coordinates of the pour point selected, the watershed spatial data number for 8-digit and 10-digit HUCs, and the watershed name for 12-digit watershed. Also included is a summary of acreage by land use and soil types. Further down on the page is a “Modeling Toolbox” that provides links to various Midwest Partnership tools, as well as several options for downloading the data.



Watershed spatial data number for 10-digit watershed: **0709000206**

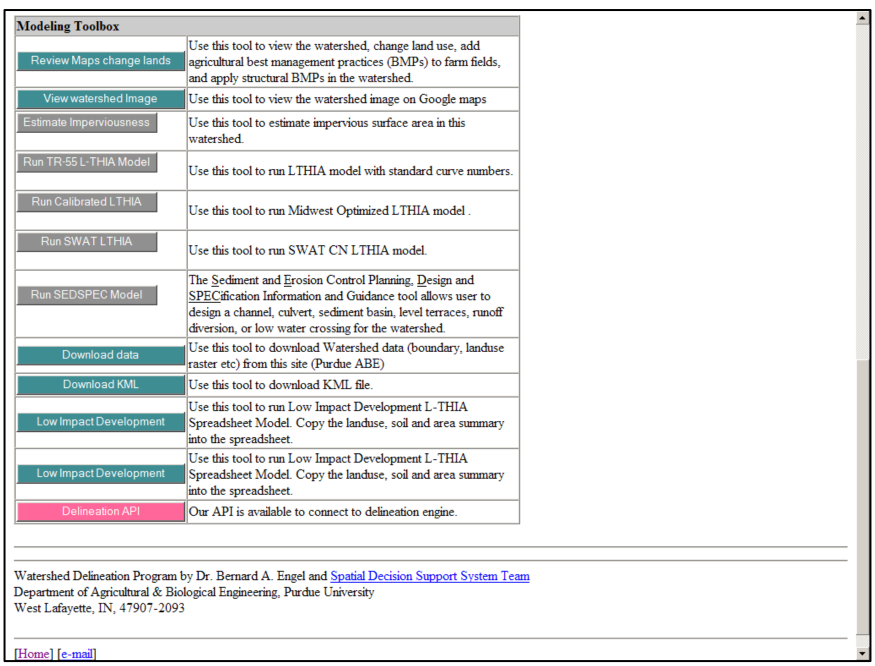
Watershed spatial data number for 8-digit watershed: **w07090002**

Watershed spatial data name for 12-digit watershed: **Lake Mendota-Yahara River**

coordinates you selected in meters: **X=298029.26102288026 and Y=4775478.599606749**

Land use	Soil group	Area(acres)
Water	A	1.2
Water	B	31.3
Water	D	355.9
Commercial	A	2.9
Commercial	B	776
Commercial	C	1.7
Commercial	D	209.2
Agriculture	A	6.6
Agriculture	B	4442.7
Agriculture	C	10.8
Agriculture	D	696
HD-Residential	A	12.8
HD-Residential	B	1605
HD-Residential	C	7.4
HD-Residential	D	188.7
LD-Residential	A	10.1
LD-Residential	B	931.9
LD-Residential	C	1.9
LD-Residential	D	75.5
Grass/Pasture	A	19
Grass/Pasture	B	3428.1
Grass/Pasture	C	2.4
Grass/Pasture	D	255.1
Forest	A	46.1
Forest	B	863

Scroll Down

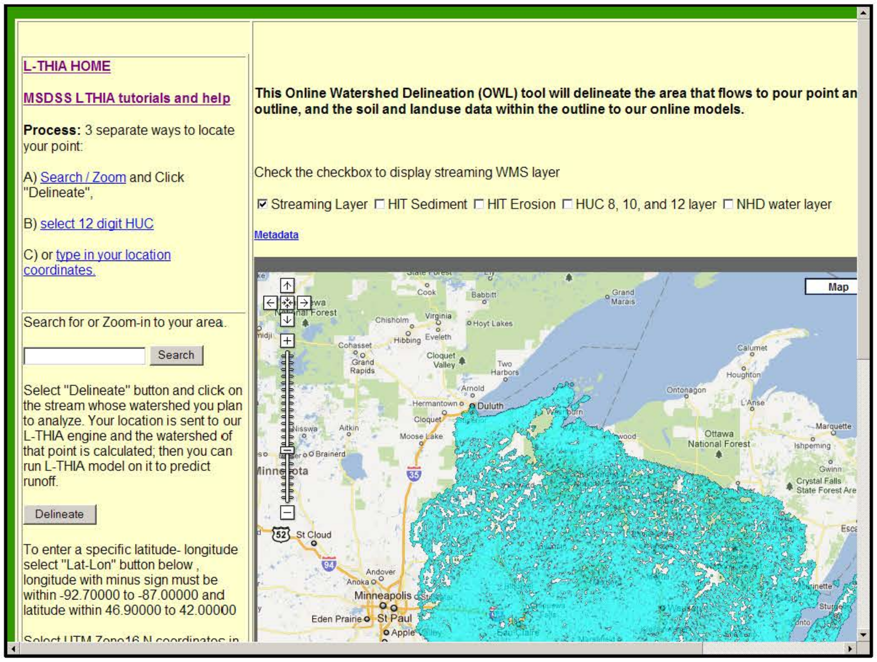


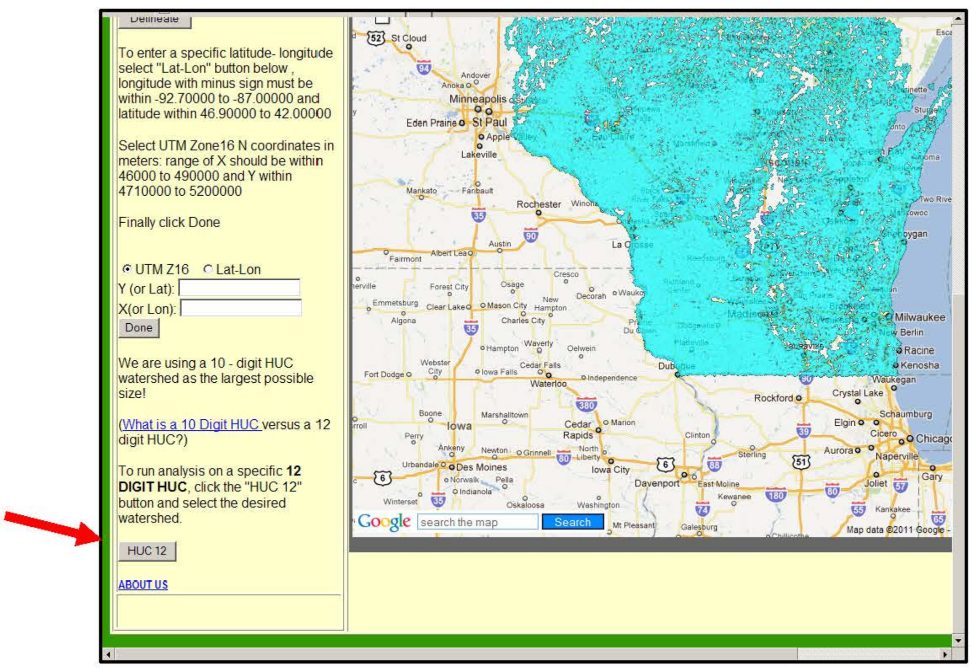
Modeling Toolbox	
Review Maps change lands	Use this tool to view the watershed, change land use, add agricultural best management practices (BMPs) to farm fields, and apply structural BMPs in the watershed.
View watershed Image	Use this tool to view the watershed image on Google maps
Estimate Imperviousness	Use this tool to estimate impervious surface area in this watershed.
Run TR-55 L-THIA Model	Use this tool to run LTHIA model with standard curve numbers.
Run Calibrated LTHIA	Use this tool to run Midwest Optimized LTHIA model .
Run SWAT LTHIA	Use this tool to run SWAT CN LTHIA model.
Run SEDSPEC Model	The Sediment and Erosion Control Planning, Design and SPECification Information and Guidance tool allows user to design a channel, culvert, sediment basin, level terraces, runoff diversion, or low water crossing for the watershed.
Download data	Use this tool to download Watershed data (boundary, landuse raster etc) from this site (Purdue ABE)
Download KML	Use this tool to download KML file.
Low Impact Development	Use this tool to run Low Impact Development L-THIA Spreadsheet Model. Copy the landuse, soil and area summary into the spreadsheet.
Low Impact Development	Use this tool to run Low Impact Development L-THIA Spreadsheet Model. Copy the landuse, soil and area summary into the spreadsheet.
Delineation API	Our API is available to connect to delineation engine.

Watershed Delineation Program by Dr. Bernard A. Engel and Spatial Decision Support System Team
Department of Agricultural & Biological Engineering, Purdue University
West Lafayette, IN, 47907-2093

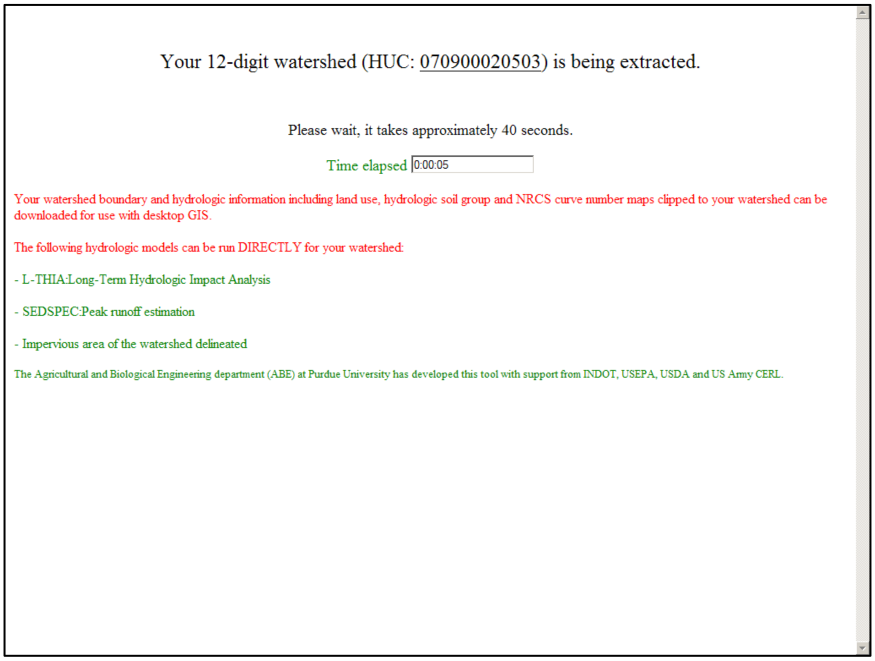
[Home] [e-mail]

B) If users choose the “select a specific 12-digit HUC” option, the browser drops them down the page where the user can click the "HUC 12" button and select the desired watershed by clicking on the map.

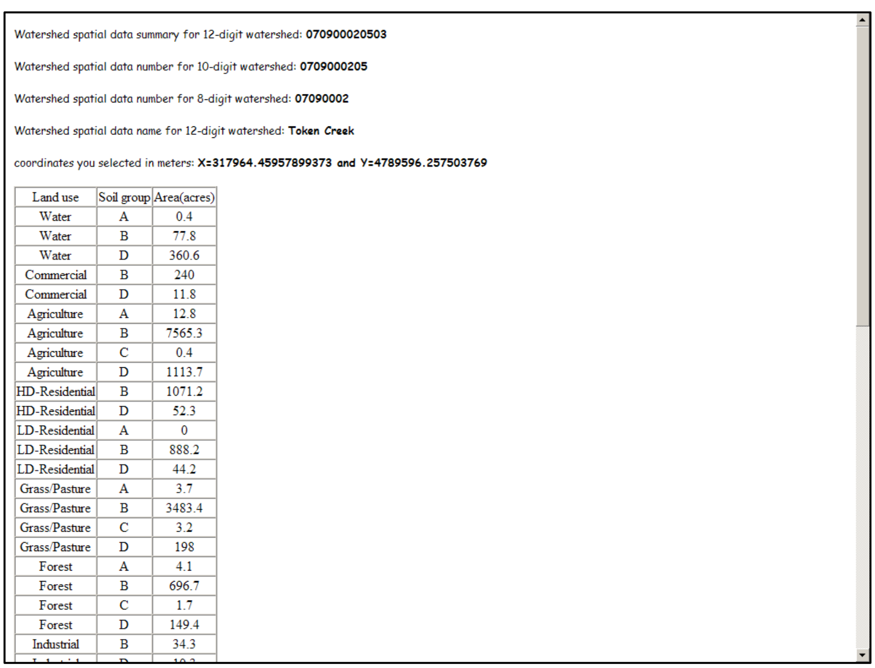




After the user clicks the "HUC 12" button and selects the desired watershed, the location is sent to the L-THIA engine and the watershed of that point is calculated. A temporary screen informs the user of the status of the delineation process.



Once the delineation process is complete, the system presents a report page with summary information related to the watershed. The report includes the coordinates of the pour point selected, the watershed spatial data number for 8-digit and 10-digit HUCs, and the watershed name for 12-digit watershed. Also included is a summary of acreage by land use and soil types. Further down on the page is a “Modeling Toolbox” that provides links to various Midwest Partnership tools, as well as several options for downloading the data.



Watershed spatial data summary for 12-digit watershed: **070900020503**

Watershed spatial data number for 10-digit watershed: **0709000205**

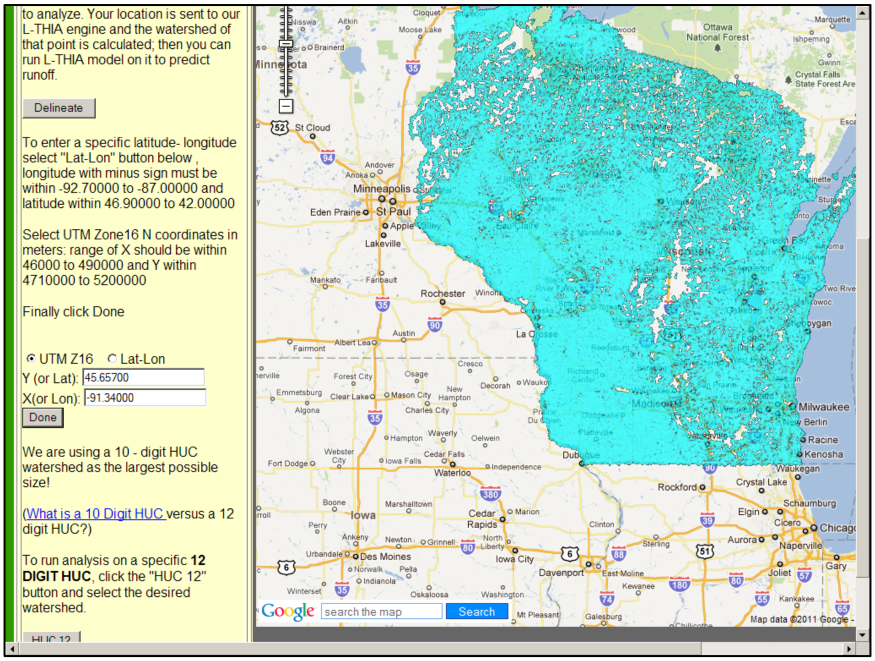
Watershed spatial data number for 8-digit watershed: **07090002**

Watershed spatial data name for 12-digit watershed: **Token Creek**

coordinates you selected in meters: **X=317964.45957899373 and Y=4789596.257503769**

Land use	Soil group	Area(acres)
Water	A	0.4
Water	B	77.8
Water	D	360.6
Commercial	B	240
Commercial	D	11.8
Agriculture	A	12.8
Agriculture	B	7565.3
Agriculture	C	0.4
Agriculture	D	1113.7
HD-Residential	B	1071.2
HD-Residential	D	52.3
LD-Residential	A	0
LD-Residential	B	888.2
LD-Residential	D	44.2
Grass/Pasture	A	3.7
Grass/Pasture	B	3483.4
Grass/Pasture	C	3.2
Grass/Pasture	D	198
Forest	A	4.1
Forest	B	696.7
Forest	C	1.7
Forest	D	149.4
Industrial	B	34.3

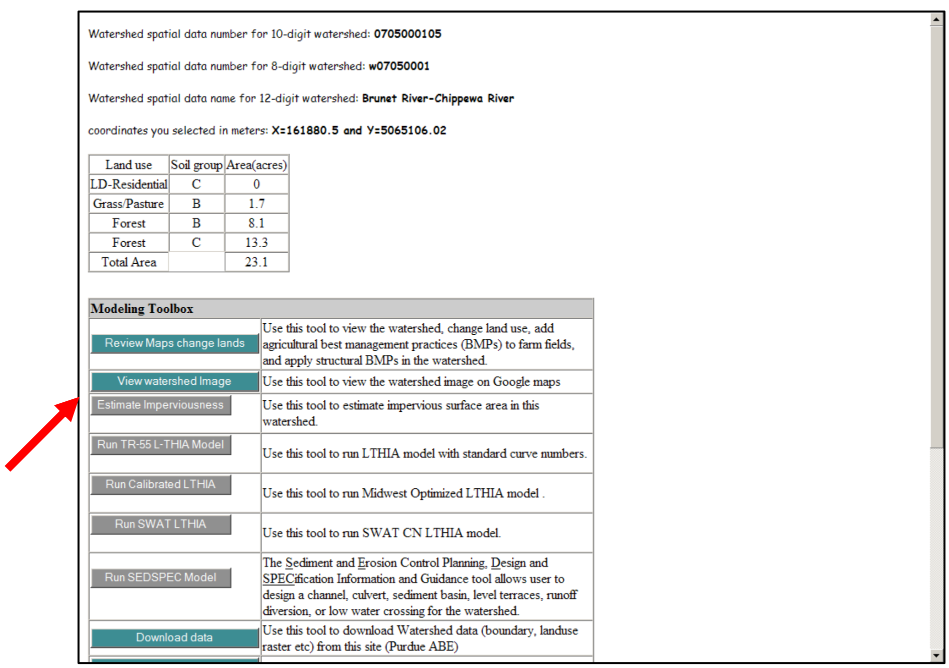
C) If a user knows the specific coordinates of a particular point of interest, he/she can choose the “type in your location coordinates” option.



To enter a specific latitude-longitude, the user selects the “Lat-Lon” button. Longitude with minus sign must be within -92.70000 to -87.00000 and latitude must be within 46.90000 to 42.00000.

To enter a specific UTM coordinate, the user selects “UTM Z16”. Coordinates are entered in meters: range of X must be within 46000 to 490000 and range of Y must be within 4710000 to 5200000.

Once the user enters the coordinates, they click the “Done” button. The delineation process completes and the system presents a report page with summary information related to the watershed.


Watershed spatial data number for 10-digit watershed: **0705000105**

Watershed spatial data number for 8-digit watershed: **w07050001**

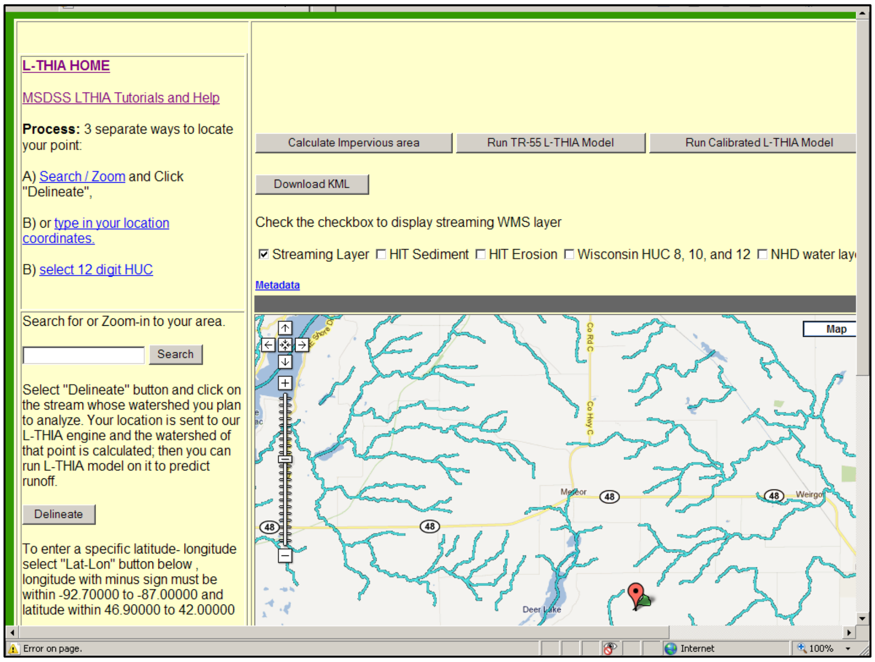
Watershed spatial data name for 12-digit watershed: **Brunet River-Chippewa River**

coordinates you selected in meters: **X=161880.5 and Y=5065106.02**

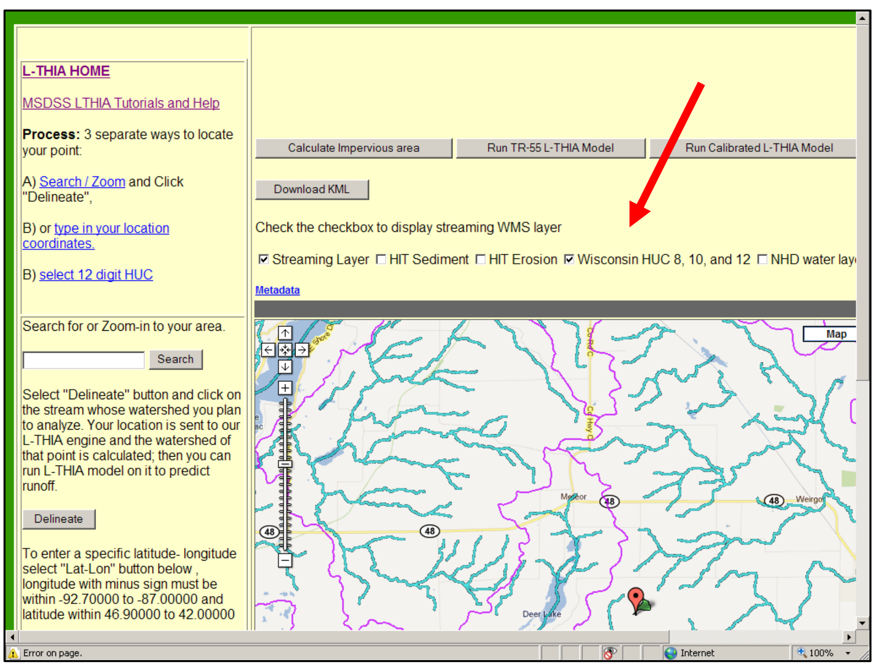
Land use	Soil group	Area(acres)
LD-Residential	C	0
Grass/Pasture	B	1.7
Forest	B	8.1
Forest	C	13.3
Total Area		23.1

Modeling Toolbox	
Review Maps change lands	Use this tool to view the watershed, change land use, add agricultural best management practices (BMPs) to farm fields, and apply structural BMPs in the watershed.
View watershed Image	Use this tool to view the watershed image on Google maps
Estimate Imperviousness	Use this tool to estimate impervious surface area in this watershed.
Run TR-55 L-THIA Model	Use this tool to run LTHIA model with standard curve numbers.
Run Calibrated LTHIA	Use this tool to run Midwest Optimized LTHIA model .
Run SWAT LTHIA	Use this tool to run SWAT CN LTHIA model.
Run SEDSPEC Model	The Sediment and Erosion Control Planning, Design and SPECification Information and Guidance tool allows user to design a channel, culvert, sediment basin, level terraces, runoff diversion, or low water crossing for the watershed.
Download data	Use this tool to download Watershed data (boundary, landuse raster etc) from this site (Purdue ABE)

No matter which navigation option the user chooses, once the summary information page appears, the user can select various options from the "Modeling Toolbox". Clicking on the "View Watershed Image" button in the "Modeling Toolbox" opens a new window with the watershed located on a Google Maps interface.



If the user wants to display watershed boundaries, they can click the box next to "Wisconsin HUC 8, 10, and 12" and the boundaries will appear on the map.



The Google Maps interface allows the user to run several different models, including the "Calibrated L-THIA Model" (see Section 2.3.3). It also allows the user to download the data as a KML file.

2.3.2. Goal 8: Enhance Impervious Surface Calculations

Background: Long-term land use changes can have significant impacts on hydrologic processes (Defries and Eshleman 2004). In natural settings, relatively little annual rainfall is converted to runoff and about half is infiltrated into the underlying soils and water table. This water is filtered by the soils, supplies deep water aquifers, and recharges adjacent surface waters with clean water, especially during dry periods. The replacement of natural or semi-natural land cover with less pervious surfaces reduces the amount of precipitation that infiltrates soils and increases the amount of overland and shallow sub-surface flow. Depending on the degree of impervious cover, the annual volume of storm water runoff in a watershed can increase by two to 16 times from its predevelopment rate, with proportional reductions in groundwater recharge (Schueler 1994). Not only is this runoff volume greater, it also occurs more frequently and at higher magnitudes. Over time, increases in the proportion of a watershed covered by impervious surfaces can lead to declines in the physical, chemical, and biological health of receiving waters, including increased loadings of nonpoint source pollution and reductions in biological diversity (Schueler 1994, Arnold and Gibbons 1996, May et al. 1997, Wydzga 1997, Brabec et al. 2002, Wheeler et al. 2005, Wenger at al. 2008). As a result, streams in urban watersheds possess a fundamentally different character than streams in forested, rural, or even agricultural watersheds (Wang et al. 1997). Impervious cover on as little as 3-5% of a watershed has been linked to stream degradation, with the degradation becoming more severe as impervious cover increases (Schueler 1994, Brabec et al. 2002). As such, the amount of impervious cover in the watershed can be used as an indicator to predict how severe these differences can be and we wanted to integrate impervious surface calculations into the L-THIA modeling framework that links to Digital Watershed.

Grant Goal: Modify and link impervious surface calculation capabilities to Digital Watershed.

Activities and Progress: Wisconsin DNR contracted with Purdue University's Agricultural and Biological Engineering program to integrate impervious surface calculations into the L-THIA modeling framework that links to Digital Watershed. The Purdue team was the logical group to develop the new functionality as that team had previously developed L-THIA.

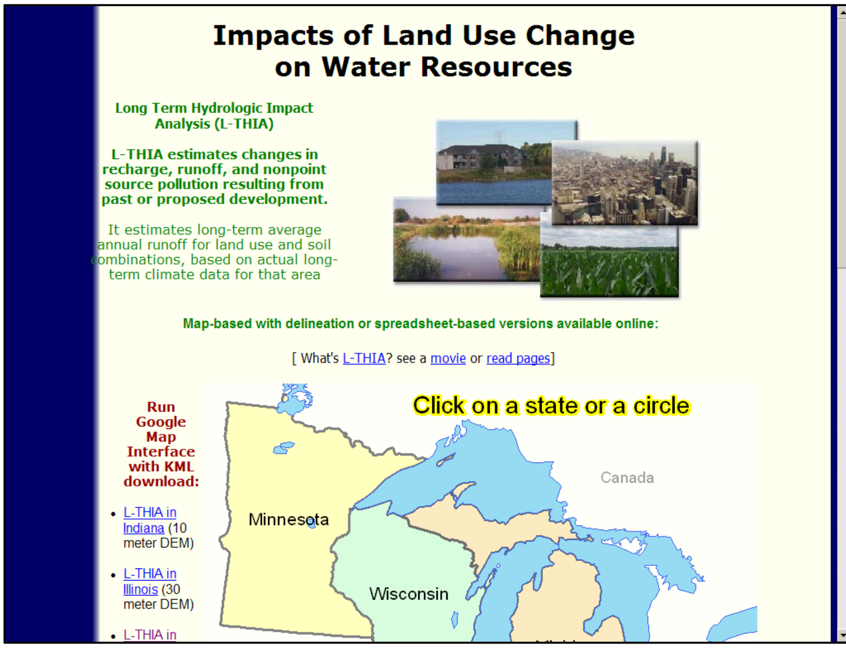
Purdue developed a new Google-based interface that includes the tool to "Calculate Impervious Area" based on the NLCD 2001 land cover data (Homer et al. 2004). This calculation is made from land cover and not from the impervious surface product developed by the U.S. Geological Survey. The new tool summarizes percent impervious surface in the same fashion as L-THIA summarizes land use.

> ***Accomplishment: Purdue University developed a Google-based interface that allows users to calculate the impervious area of a delineated watershed.***

In addition, Purdue provided a demonstration of the ability to include local land cover data using land use shapefiles from Bay-Lake RPC, in lieu of connecting to WFS at this time. As the ability to serve WCS is developed (beyond this project), these could be integrated in the display and analysis functions as well.

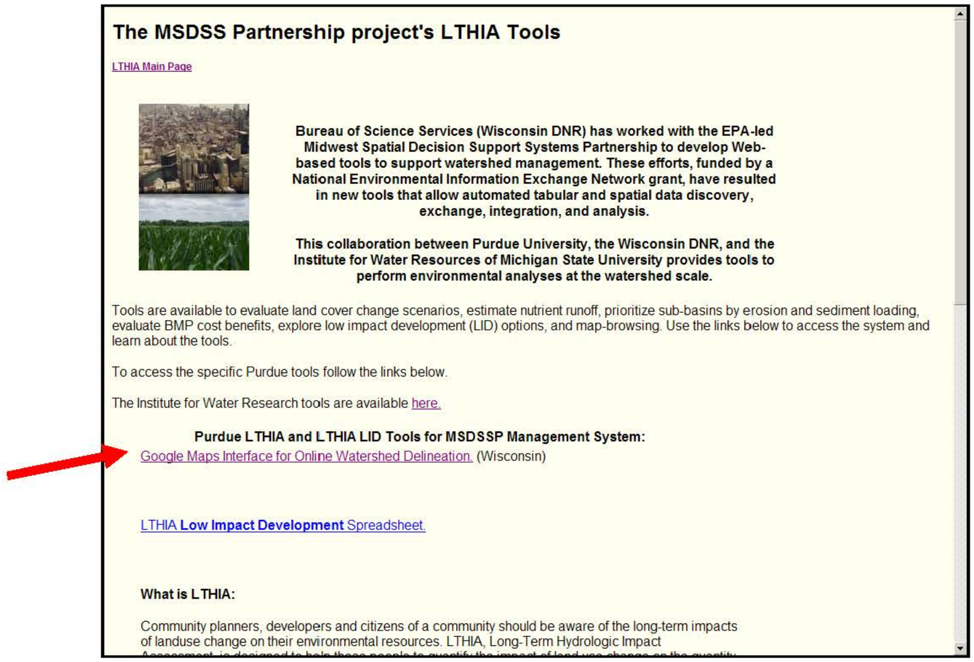
The following descriptions/instructions and screen captures illustrate this new functionality as the end-user experiences it.

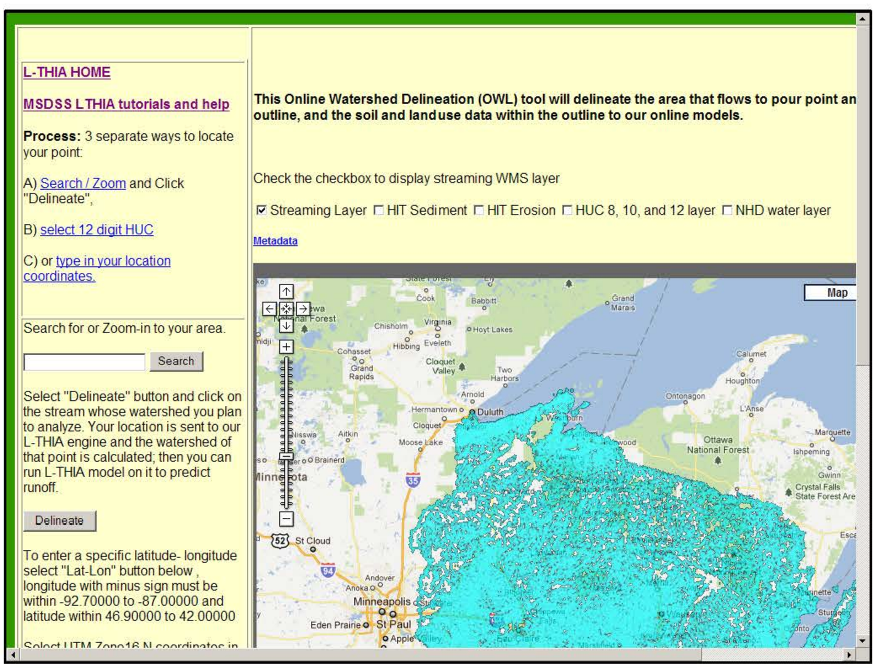
To access the impervious surface calculations, users first go to the main L-THIA website (https://engineering.purdue.edu/~lthia/) and scroll down to the map interface.



Scroll Down

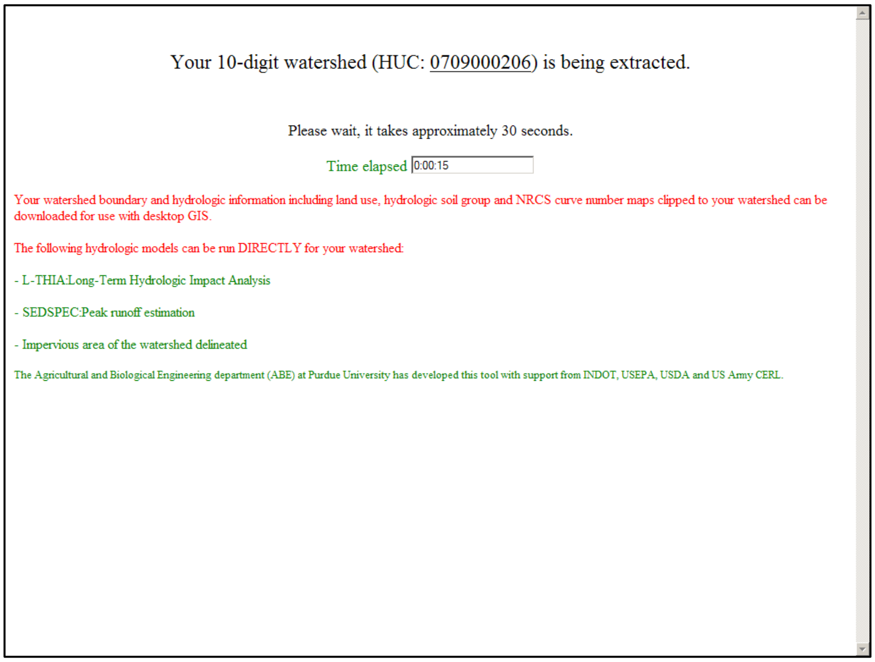
Clicking within the Wisconsin state outline or the on the "L-THIA in Wisconsin" link in the left column takes the user to the challenge grant project page. The challenge grant project page includes a link to the Google Maps interface for online delineation (see Section 2.3.1).



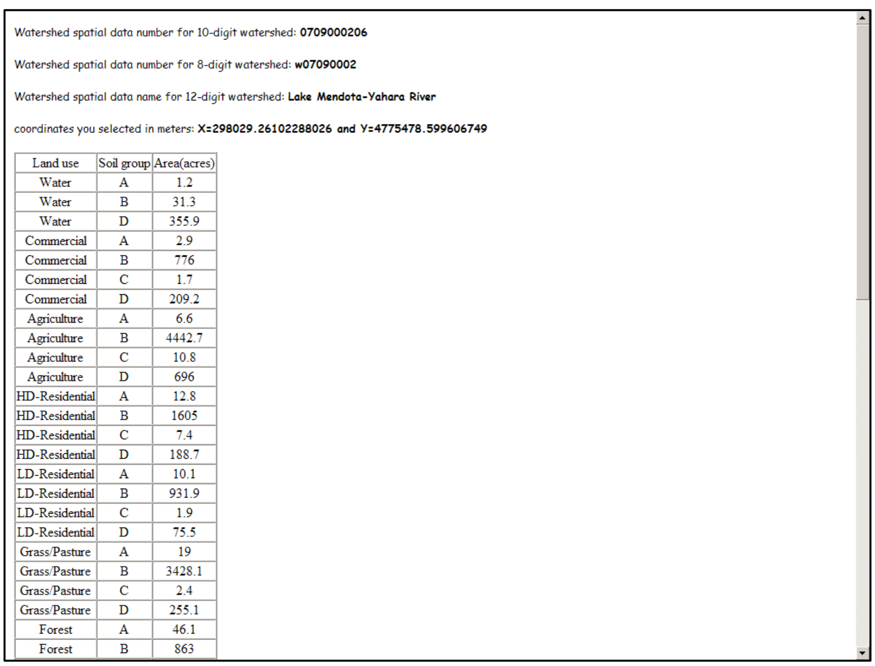


The left hand navigation column of the Google Maps interface provides three ways to locate a point: A) users can search/zoom and click "Delineate", B) users can select a specific 12-digit HUC, or C) users can type in location coordinates (see Section 2.3.1).

Once the user has located their point (using one of the three methods), they can click on the "Delineate" button and then click on the stream whose watershed they want to analyze. The location is sent to the L-THIA engine and the watershed of that point is calculated and delineated. A temporary screen informs the user of the status of the delineation process.



Once the delineation process is complete, the system presents a report page with summary information related to the watershed. Further down on the page is a "Modeling Toolbox" that provides links to various Midwest Partnership tools, as well as several options for downloading the data.


Watershed spatial data number for 10-digit watershed: **0709000206**

Watershed spatial data number for 8-digit watershed: **w07090002**

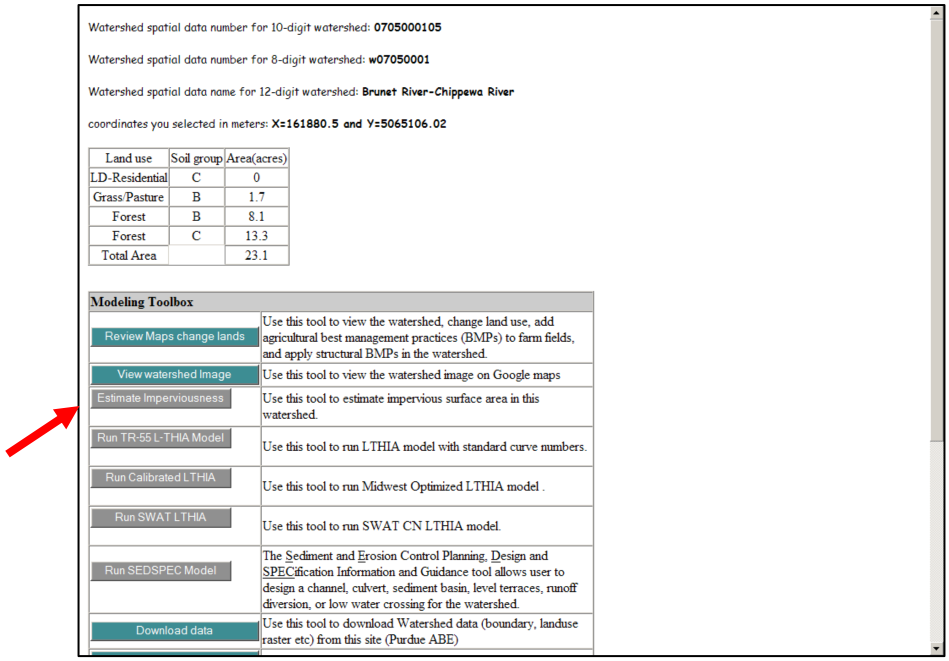
Watershed spatial data name for 12-digit watershed: **Lake Mendota-Yahara River**

coordinates you selected in meters: **X=298029.26102288026 and Y=4775478.599606749**

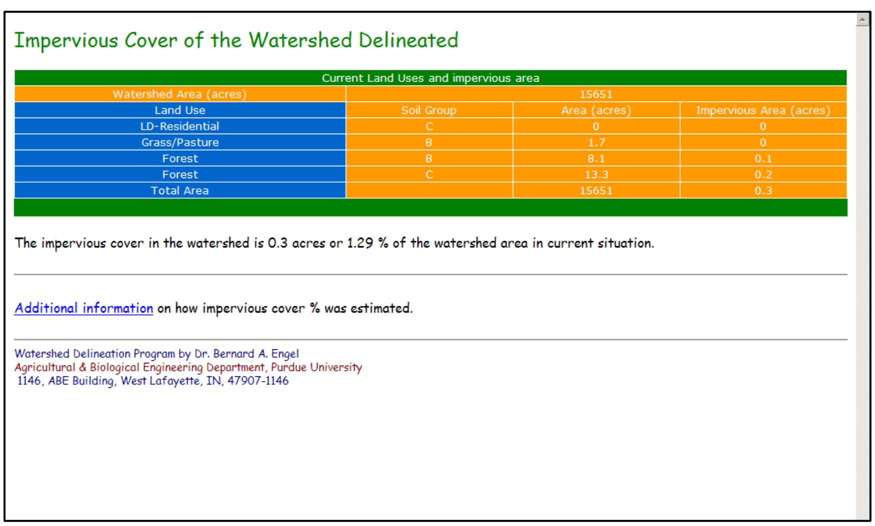
Land use	Soil group	Area(acres)
Water	A	1.2
Water	B	31.3
Water	D	355.9
Commercial	A	2.9
Commercial	B	776
Commercial	C	1.7
Commercial	D	209.2
Agriculture	A	6.6
Agriculture	B	4442.7
Agriculture	C	10.8
Agriculture	D	696
HD-Residential	A	12.8
HD-Residential	B	1605
HD-Residential	C	7.4
HD-Residential	D	188.7
LD-Residential	A	10.1
LD-Residential	B	931.9
LD-Residential	C	1.9
LD-Residential	D	75.5
Grass/Pasture	A	19
Grass/Pasture	B	3428.1
Grass/Pasture	C	2.4
Grass/Pasture	D	255.1
Forest	A	46.1
Forest	B	863

Scroll Down

After delineating a watershed and producing the summary information page, the user can select the "Estimate Imperviousness" option from the "Modeling Toolbox".



When the user selects the "Estimate Imperviousness" option from the "Modeling Toolbox", a new window opens. The new window includes a spreadsheet that shows the impervious surface estimates by land use and soil group.



Outside users of the OWLS delineation engine (for the states within U.S. EPA's Region 5) can create their own page to send a location to delineate; and can grab the resulting outline and display it on Google Maps or view it in Google Earth or GIS software. The process is described online at https://engineering.purdue.edu/~lthia/api_wd.html.

2.3.3. Goal 9: Calibrate Models

Background: In order for planners to have confidence in model outputs, models must be calibrated and validated. Model calibration consists of changing values of model input parameters in an attempt to match field conditions within some acceptable criteria. This requires that field conditions at a site be properly characterized; lack of proper site characterization may result in a model that is calibrated to a set of conditions which are not representative of actual field conditions. Validation is used to determine that a model is an accurate representation of the real system (i.e. that its predictions actually resemble what happens on the landscape).

For accurate estimation of water quality parameters, modelers must validate each model's hydrologic components. To address this need, the Purdue University team developed the Web-based Hydrograph Analysis Tool (WHAT), which uses digital filter-based separation modules, a graphically based separation method, and a statistical component that provides flow frequency and time series analyses. WHAT accesses and uses daily stream flow data from the U.S. Geological Survey's web server and provides an efficient tool for hydrologic model calibration and validation. We proposed linking this model with L-THIA and Digital Watershed.

Grant Goal: Add model calibration capabilities to the decision-support system.

Activities and Progress: Wisconsin DNR contracted with Purdue University's Agricultural and Biological Engineering program to add model calibration capabilities to the Midwest Partnership's suite of decision-support tools. The Purdue team leveraged funding from other initiatives to upgrade WHAT to use the Google Maps interface (see Sections 2.3.1 and 2.3.2). WHAT is accessible online at:

- http://cobweb.ecn.purdue.edu/~what/WHAT_GOOGLE/

The Google Maps interface links to U.S. Geological Survey gauge stations and automates download and processing of U.S. Geological Survey flow data. It prepares various graphical and tabular representations of the data and allows base flow separation analysis which is often needed in calibration of hydrologic models.

During the early portions of this process, the investigators identified the need to extend L-THIA to include such a base flow component. This became apparent when attempting to calibrate L-THIA to predict certain pollutant loads. Pollutant loads that are carried primarily during base flow could not be adequately predicted with the current L-THIA. Thus, to adequately predict the full range of nonpoint source pollutant loads of interest to L-THIA users, it was necessary to introduce a stream base flow capability. (Note that for most applications, L-THIA provides results that are suitable.)

Accomplishment: The L-THIA tool now contains optimized curve numbers for all U.S. EPA Region 5 states.

The Purdue University team completed an optimization tool (L-THIA V2) for the regional calibration of curve numbers and base flow coefficients by developing a FORTRAN code, using the SCE-UA (shuffled complex evolution, developed by University of Arizona) optimization approach to fit the L-THIA model automatically with observed flow. The tool also generates Alpha Factor values and Base-flow Index (BFI) max for estimating base flow for different land uses. The tool has been used to obtain regionalized calibrated curve number parameters from eight gauged watersheds (for calibration) and six ungauged watersheds (for validation) in Indiana. The Purdue team also used the tool to generate regionalized (calibrated) curve numbers for nine watersheds in Wisconsin as a test.

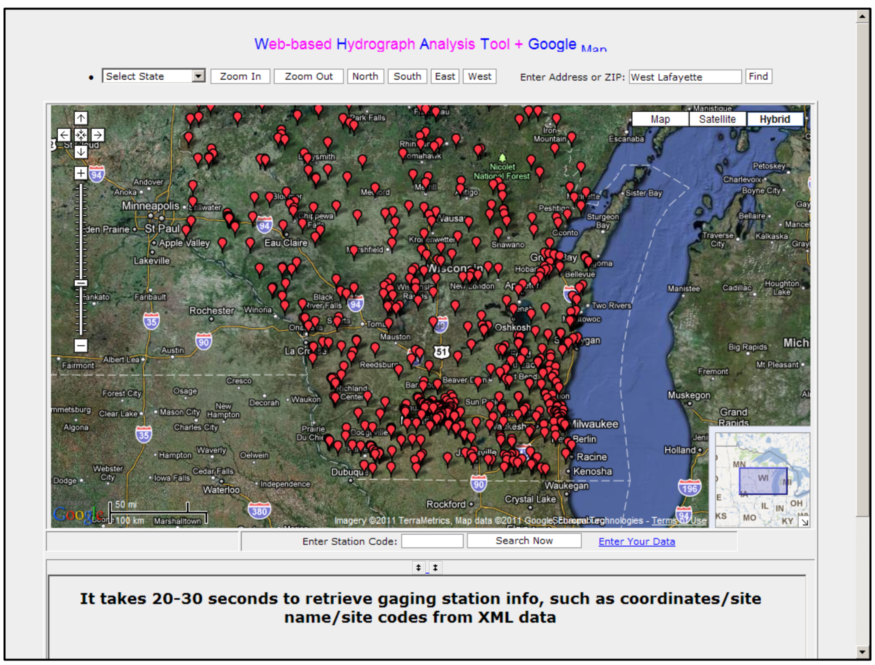
The modified WHAT tool was used to identify 15 U.S. Geological Survey gauges for which flow data has been downloaded. The WHAT tool download automatically separates U.S. Geological Survey flow data into direct runoff and base flow as input for L-THIA V2. The Purdue team also downloaded rainfall data for twenty gauge stations within selected Wisconsin watersheds from National Climate Data Center and processed the digital ASCII files for daily precipitation data. NLCD 2001 land use and SSURGO soils were used in extracting spatial distribution of land use and soil groups.

In order to aid Purdue in the process of deriving regionally-optimized (i.e. calibrated) rainfall-runoff curve numbers for L-THIA in Wisconsin, the Wisconsin DNR provided Purdue online mapping resources as well as spatial data that could be used to identify those watersheds in Wisconsin that have large numbers of reservoirs. Reservoirs can confound the process of rainfall-runoff calibration, and the hydrography Purdue was working with did not adequately identify these water bodies. These resources included links to Wisconsin DNR's Surface Water Data Viewer, which among other things can be used to map watersheds, dams, and water bodies classified as "Reservoir or Flowage" (RF). The Wisconsin DNR provided FTP addresses for downloading the dam and water body data directly. Finally, Wisconsin DNR staff queried the agency's Registry of Waterbodies (ROW) database to identify additional reservoirs and flowages not included in the attributes of the department's open water GIS data layer.

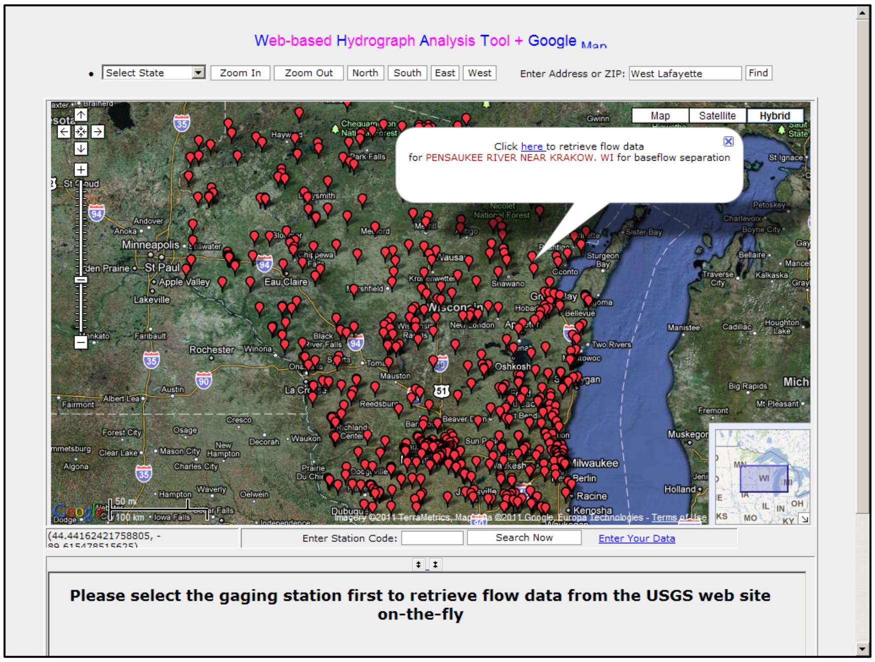
As an addition to this project, the Purdue team produced the Load Duration–Flow Duration Web-based Tool which allows user to pick a U.S. Geological Survey gauge from a Google Map interface and download flow from that location or upload local flow, and upload quality data measurements to use in constructing a load duration curve and flow duration curve set. These products are graphical or downloadable. This tool is available online at https://engineering.purdue.edu/~ldc . The tool is closely tied in to the TMDL process and has video-based and screen-based tutorial materials linked to the page.

The following descriptions/instructions and screen captures illustrate how the Google Maps interface links to U.S. Geological Survey gauge stations and automates download and processing of U.S. Geological Survey flow data as the end-user experiences it.

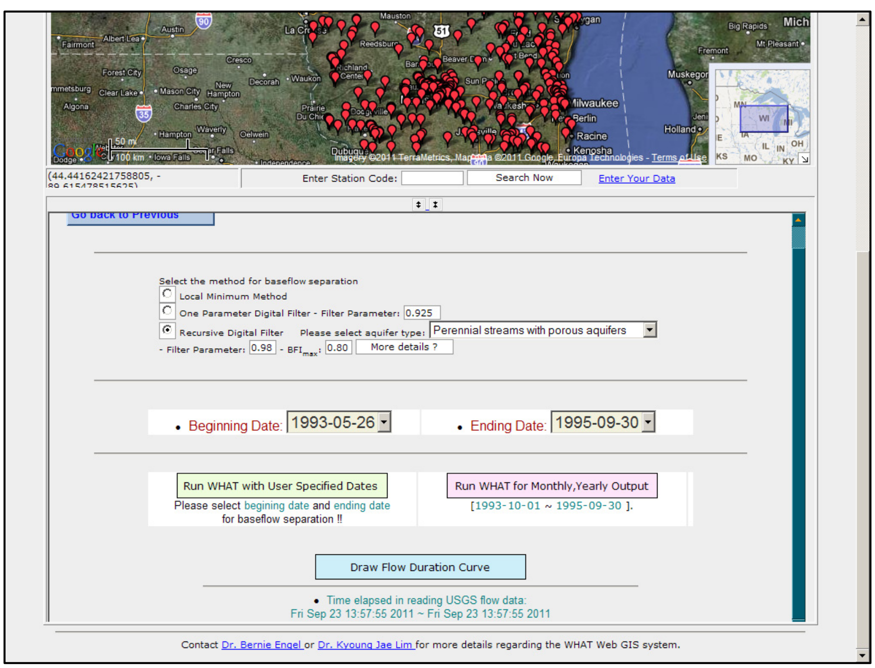
Users access the WHAT tool at http://cobweb.ecn.purdue.edu/~what/WHAT_GOOGLE/. They can then select a state from the drop down menu, navigate using the zoom and pan functions, of enter an address.



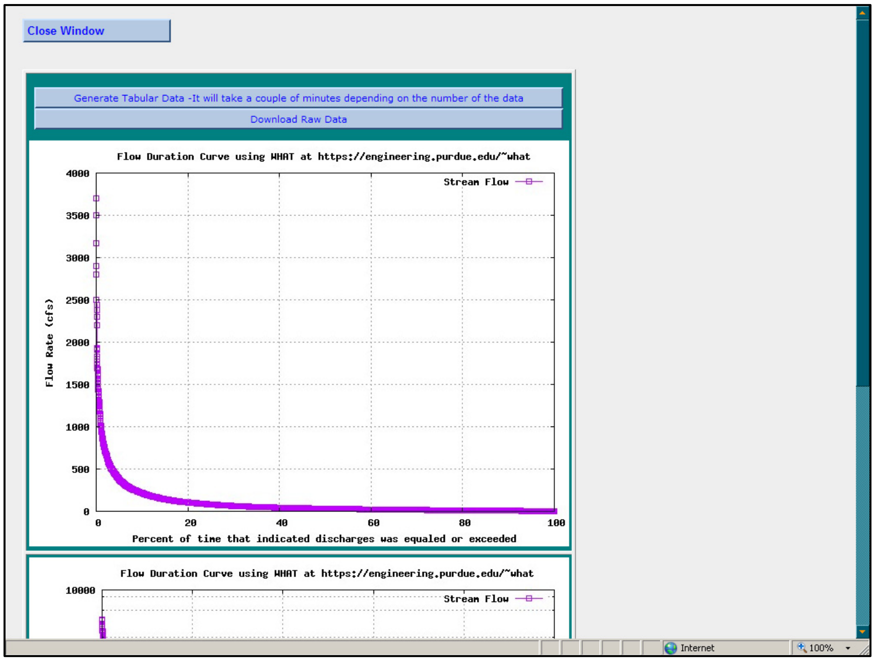
This Google map interface includes standard "pins" that locate the U.S. Geological Survey gauging stations in the area, allowing users to quickly see where flow data has been collected. Clicking on an individual station "pin" opens a dialog box that depicts the name of the gauging station.



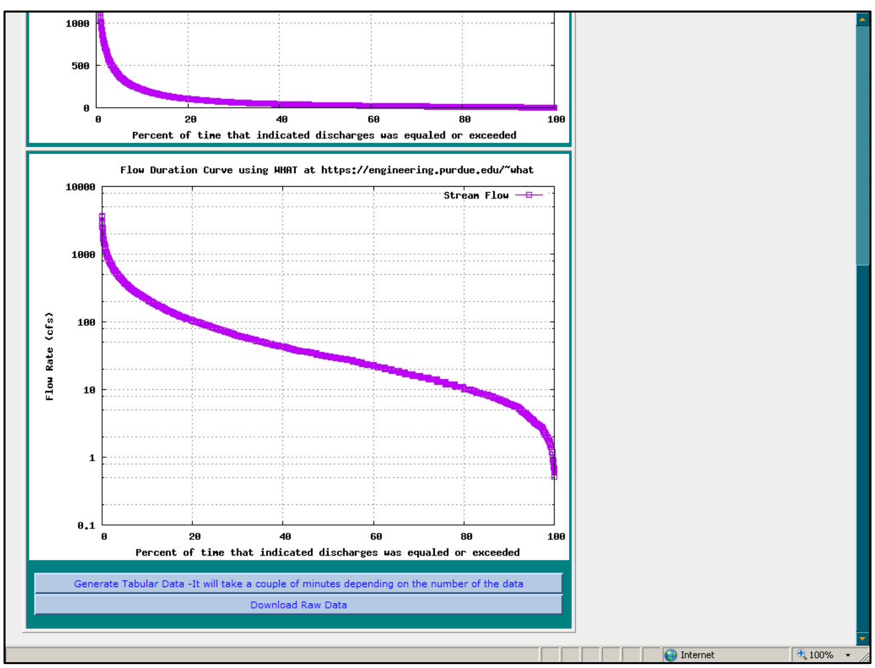
Clicking on the link in the dialog box directs WHAT to retrieve the flow data for the site. Users can select one of three methods for base flow separation and can run WHAT for specified dates or with monthly, yearly outputs.



If the user clicks on the "Draw Flow Duration Curve" button, the load duration tool opens a new window with the flow duration curve.



Users can also choose to generate tabular data or download the raw data underlying the flow duration curve by clicking on one of the buttons on the bottom of the page.



2.4. Technology Transfer and Project Outreach

Outreach and technology transfer play an integral role in the implementation of any decision-support system (Watermolen 2009 and references cited therein). The stated goal of the Midwest Partnership is the development, dissemination, and promotion of web-based, spatial, decision-support systems to enhance watershed management. While our work furthered the technical development of the tools and data sources, it also established a framework to advance the use of such tools by local units of government, regional planning bodies, natural resource managers, and the general public.

2.4.1. Goal 10: Document Project

Background: As Exchange Network partners develop the resources to implement data exchanges, they are made available in the "Network Data Exchanges" section of the Exchange Network website and at the annual Exchange Network National Meetings. This allows future trading partners to take advantage of existing tools and helps prevent duplication of efforts. Users can access these resources and learn more about on-going Exchange Network projects by clicking on the program-specific communities of interest on the website. For example, one listing of projects/developments supports the exchange of water-related data between partners. Consistent with this approach, we felt it important that our project and outcomes be well documented so others could learn from our efforts.

Grant Goal: Make XML schema and protocols available nationally.

Activities and Progress: All data sources, web services, and modeling interfaces incorporated into the project are discussed under the accomplishments for Goals 1-9. With the exception of Wisconsin DNR's watershed assessment data flow, the emergence of web services from the U.S. EPA and U.S. Geological Survey during the course of this project enabled the use of standard, available protocols, and did not require development of additional XML schema. Nonetheless, we took steps to ensure that resources developed as part of the challenge grant efforts were made available to a wide audience.

<u>Conference Presentations:</u> U.S. EPA staff requested that Wisconsin DNR and its partners make concerted efforts to transfer findings from the grant-funded work for broader regional and national applications. In addition to posting information to the U.S. EPA Environmental Science Connector and making the various Midwest Partnership tools freely available, project staff and managers demonstrated tools developed as part of the challenge grant work and presented findings and lessons learned at numerous regional and national conferences and meetings. Appendix A includes a comprehensive list of these efforts. Of particular note, Dreux Watermolen presented at the North American Land Cover Summit in Washington, DC in 2006, U.S. EPA's Environmental Information Symposium in Savannah, GA in 2006, and the Exchange Network National Meetings in New Orleans, LA in 2007 and Chicago, IL in 2010. In addition, Mr. Watermolen and Dr. Yi Shi, Michigan State University, demonstrated the newly developed STORET access and reporting functions of Digital Watershed at the 2010 Chicago meeting. James Hudson presented at the 2007 STORET/WQX Users Conference, and Jerry Sullivan joined Watermolen for a presentation at U.S. EPA's joint GIS Users Group and Statistics Work Group fall meeting in Chicago in 2008. Other significant venues included the Lake Michigan: State of the Lake and Great Lakes Beach Association 2009 joint conference in Milwaukee, WI, the 2010 Annual Meeting of the American Water Resources Association – Wisconsin Section in Madison, WI. Presentation slides and abstracts from many of these meetings are available online (see Appendix A).

2.4.2. Goal 11: Conduct Outreach and End User Testing

Background: At the heart of our efforts is a desire to understand how state and federal agencies can improve their ability to successfully influence widespread adoption of the Internet and GIS innovations that they generate. Such successful adoption will require the transfer of both science knowledge and technology to specific audiences who have needs that these innovations can address.

When implementing the Wisconsin DNR challenge grant, we took steps to address specific factors that have been identified as being critical to the success of technology development and transfer programs (see references cited in Watermolen 2009). To ensure success, planned assistance and support must be an integral part of technology transfer programs. As we carried out our tool development efforts, we actively engaged participants in defining support needs.

In addition, research (e.g., Watermolen 2009 and references cited therein) suggests that various factors including previous computer experience, perceived usefulness/advantage, and past exposure to technology are strong predictors of behavioral intent to use Internet and GIS tools. Similarly, direct experience research, such as the Technology Acceptance Model, suggests that those with greater prior experience with a technology will more likely use it than those who lack such experience and that increased perceptions of ease of use and technology usefulness lead to increased use. Therefore, we sought to engage various practitioners (end users) in testing and evaluating the tools developed by the Midwest Partnership to allow tabular and spatial data discovery, exchange, integration, and analysis. We wanted to make sure these tools meet the needs of state and local watershed practitioners.

> **Grant Goal:** Conduct effective project outreach to ensure transferability and application of technology.

> ***Accomplishment: Wisconsin DNR engaged local, state, and federal agency watershed practitioners in a day-long workshop to assess the functionality and usefulness of the Midwest Partnership's newly developed tools. Feedback was provided to the developers directly.***

Activities and Progress: The Wisconsin DNR hosted an interactive workshop in December 2009 for professionals engaged in activities related to watershed management and GIS. We invited agency staff to learn about the new tools and provide feedback to U.S. EPA and the developers. Participants included staff from the Wisconsin DNR, University of Wisconsin-Extension, Southeastern Wisconsin Regional Planning Commission, East Central Wisconsin Regional Planning Commission, Natural Resources Conservation Service, U.S. EPA Region 5, and the Wisconsin State Cartographer's Office.

This workshop introduced the new interfaces and functions of Digital Watershed and L-THIA, and showed how ATtILA and ReVA were being integrated into the decision-support system. After brief demonstrations, participants were given time for hands-on practice and an opportunity to try out the tools and provide feedback. The workshop also provided an opportunity for participants to learn about efforts to identify county and RPC Internet mapping services that can be linked with these tools (see Section 2.1.3).

End user feedback and related information generated at the workshop was shared with the U.S. EPA Region 5, the Midwest Partnership, and the tool developers. We also document findings from this effort in Chapter 3, "Lessons Learned, Recommendations, and Future Work."

<u>Conference and Workshop Presentations:</u> In addition to the formal end user workshop, project staff made concerted efforts to maintain regular contact with various practitioners throughout the course of the project. These efforts included a number of presentations and workshops at in-state conferences. Appendix A lists conference and workshop presentations resulting from work undertaken as a part of the federal assistance agreement. Of particular note, in 2006, Dreux Watermolen presented "Internet Tools for Planning, Conservation and Environmental Protection" at the Wisconsin County Code Administrators spring conference and "Overview of GIS Related Decision Support Tools" at an East Central Wisconsin RPC and

Bay-Lake RPC GIS primer for decision makers workshop. Watermolen joined Steven Goranson (U.S. EPA Region 5) in presenting “Bridging the Gaps in Environmental Information Sharing” to the Illinois Data Exchange Affiliates and Chicago Metropolitan Agency for Planning in 2007. Further, Watermolen co-presented “Geospatial Decision Support Systems for Land Planning and Natural Resources Professionals” with Adam Mednick and Jerry Sullivan at the 2008 annual conference of the Wisconsin Land Information Association. Watermolen also presented on the “Evolution and Recent Developments of Web-based Decision Support Systems for Watershed Management” at the Lake Michigan: State of the Lake and Great Lakes Beach Association 2009 joint conference and the American Water Resources Association–Wisconsin Section’s 2010 annual meeting. Along with the other listed presentations, these events created opportunities for problem identification, limited user testing, refinement of strategic directions, and creative problem solving with members of the Midwest Partnership and others working nationally to further the Exchange Network technologies and applications.

<u>Web Analytics:</u> Finally, another way to gauge the value of the tools developed as part of this project and assess their use by practitioners is by tracking website statistics. In July 2009, the Purdue University team embedded Google Analytics code into the L-THIA web pages. This product allows us to track accurately the use of the website. From July to October 2009, the U.S. EPA Region 5 L-THIA tools had 1,441 site visitors with about 5,000 page views. Several hundred visitors made return visits, and spent an average 6 minutes on the site. About 90% of the traffic was from U.S. EPA Region 5 cities and 5% from the East Coast of the U.S., including New York, NY and Washington, DC.

3. Lessons Learned, Recommendations, and Future Work

This chapter presents some of the most significant findings and recommendations from our challenge grant work. See Chapter 2, “Project Overview and Accomplishments,” for discussion of progress made on the specific work tasks undertaken by the Wisconsin DNR and Midwest Partnership to meet objectives outlined for each of the 11 goals. The Appendix lists presentations resulting from the Midwest Partnership’s work and related to our project accomplishments, findings, and recommendations. Our observations and recommendations presented here center around four main areas of interest: 1) making local data available, 2) enhancing existing tools, 3) making STORET data more usable, and 4) assisting end users of the various tools.

3.1. Making Local Data Available

3.1.1. Local Governmental Incentives to Make Data Available

County and municipal governments and RPCs are responsible for activities within their respective boundaries. These activities are funded by the citizens and businesses that pay taxes within those jurisdictions and expect services to be provided locally. As such, the benefits these governmental units derive from providing data beyond their political boundaries are not always apparent or recognized. In times of fiscal austerity, citizens may question the value of providing data to others who did not pay for their collection, management, maintenance, and storage.

Many local municipalities attempt to recoup costs associated with providing data outside their boundaries. For example, one RPC charges a $100 fee for each data request from a non-member unit of government, non-governmental agency, or individual that does not exceed a minimal amount of staff time. Requests requiring more staff time are charged on a time and materials basis. In addition, the RPC seeks to minimize its expenses by only transferring files “as is” – i.e. they do no translation of coordinate systems, file format manipulation, or pulling subsets of files.

These concerns and practices hamper the broad sharing of data. In the absence of clear incentives to develop and maintain web services, many local governments will remain content with their current information management practices and may refrain from participation in efforts like Exchange Network data flows.

3.1.2. A Registry of Internet Mapping Sites

Even though the recent state of the economy has resulted in “belt tightening” by many local governments and RPCs, the number of local Internet mapping sites continues to increase. Yet, discovering these sites remains a time consuming challenge. An online registry of web mapping services, either at the national level or on a state-by-state basis, that is collectively maintained and queryable by theme and geography would foster greater data sharing and enable further Exchange Network data flows.

Recent efforts to expand on a GIS business needs survey conducted by the state’s Division of Enterprise Technology and the Wisconsin State Cartographer’s GIS Data Inventory should greatly assist this process for Wisconsin. Our initial foray into identifying Internet mapping services in other Midwest states, however, suggests that Wisconsin is not alone in this need.

3.1.3. Registration of Wisconsin’s Custom Coordinate Systems

Because the Earth is not a perfect spheroid, numerous projection systems have been devised to transfer points from its irregular curved surface to the plane surfaces of maps. When data are stored and distributed in different projections, they must be reprojected so that all layers plot in the same coordinate space. Yet, we found that many web sites that make GIS data available fail to include projection/coordinate system information for those data (Sullivan 2009, Watermolen 2009). As Milla et al. (2005) point out, "[i]t is extremely important to carefully keep track of both the original and reprojected systems" in order to maintain the spatial integrity of the data.

The European Petroleum Survey Group has served as the de facto registry of geodetic datums, map projections, and coordinate system parameters. In 2005, the survey group was absorbed into the International Association of Oil and Gas Producers' Geomatics Committee (http://www.epsg.org/), which maintains and publishes a dataset of parameters for coordinate reference systems and coordinate transformation descriptions. We identified an evident need to register Wisconsin's coordinate systems, as has been done for WTM 83(91), so that all GIS, GPS, CAD, and other geospatial software vendors have access to common parameters.

3.2. Enhancing Existing Tools

Our work with end users resulted in a number of specific suggestions for enhancing existing tools.

3.2.1. General Tool Enhancements

The suite of tools developed by the U.S. EPA and Midwest Partnership reflect a variety of Internet mapping technologies. Many users suggested it would be helpful to modernize and standardize the tool interfaces, both in terms of map functionality and map presentation. Several noted that since people are becoming used to the Google Map and Bing Map interfaces, upgrading to those types of navigational tools could greatly aid users. Standardizing base maps would further enhance the interoperability of the tools by minimizing the "visual awkwardness" when moving between sites/tools.

Our work uncovered several needs related to improved documentation:

- There is some inconsistency in the use of land cover/land use data between the various tools. Some (e.g., ReVA) use data from the National Agricultural Statistics Service (NASS), while others (e.g., L-THIA) use the NLCD. The watershed reports generated by Digital Watershed include a mix of the two. This can be confusing to an uninitiated user. In some cases, the year associated with the NASS data was not indicated. Users suggested that these concerns could be addressed through clearer labeling and inclusion of metadata.

- All Wisconsin state agency ArcIMS sites use Wisconsin Transverse Mercator (WTM) based on NAD83(91), also known as the High Accuracy Reference Network (HARN), as the coordinate system for projecting data. None of these sites, however, have published coordinate system information. According to system administrators, not having the coordinates available minimizes demand on the servers, particularly during high use periods. This, however, greatly limits the utility of these services to support integration with other federal and local data services.

Several users noted that when working with maps and extensive data tables it is helpful to be able to save some sort of map extent or other document to be able to go back to, especially if the user is doing work in a particular area over multiple days/time periods. While some tools allow this, others would benefit from this added functionality.

Finally, as with many new technologies, users suggested making it easier to access the "help" features available with the tools. Some wanted either larger "Help" buttons or a clearer means of highlighting these features (such as larger text or an arrow). Inclusion of a tutorial video(s) or document(s) was noted as something that might be helpful, especially if easily found on the page early in the work process.

Several of these concerns jibe with lessons learned in our previous work to expand use of the U.S. EPA and Midwest Partnership tools. For example, Watermolen (2009, p. 185) reported that standardization of map legends and land use classification schemes would help simplify the user experience, adding pull down menus, "mouse-over" labeling, and similar features could improve many tools, and incorporating additional tutorials, help screens, and similar online technical support would aid users.

3.2.2. Enhancements to Digital Watershed

The users we worked with generally liked the functionality of Digital Watershed. In particular, they liked the connections it provides to other applications, the various data layer options, the links to Google maps, and the printing capabilities that allow adding watershed images to reports. Several commented that it was "nice to have all of the relevant tools available in one bar." Users did, however, note some enhancements that would make Digital Watershed more usable in the local watershed planning and management context.

Several users commented that the Digital Watershed interface had a somewhat dated look. They noted that the map window was relatively small (Several expressed a desire to have the map expand to fit the screen.), that the data were unprojected, and that the map symbology was "a little rough." As stated above, many people are now accustomed to the Google Map and Bing Map interfaces. Upgrading to a similar interface might be beneficial and promote more widespread use of the tool.

Users regularly noted that it is necessary to enable "pop-ups" in order to see the results of the "Identify" function and other features. They suggested adding a "warning" notice to the tool's introductory page to make sure that pop-up blockers are turned off when using the site.

Although users liked having all of the mapping and modeling tools available in a single toolbar, some suggested that organizing these various functions/tools into drop down menus (e.g., map functions in one area, models in another) could help users better understand the different functions and allow self-explanatory text labels rather than the somewhat cryptic icons currently used.

Also, some users noted that the cursor icon does not change when a new tool/function is selected. Clever use of cursor shape could reinforce the different functions of the tools and aid navigation.

Users offered a number of cartographic related suggestions:

- Some suggested the legend font was too small and asked about having the ability to increase text size by an adjustment controlled by the user.
- Some also felt the mapping and modeling icons were too small.
- Others noted that the symbology used for primary roads appeared to be the same as that used for reach impaired streams.

As noted by Watermolen (2009, p. 184), metadata—the background information that describes the content, quality, condition, and other characteristics of a particular data set—foster understanding of the quality and currency of data and are one key to making well-informed decisions and the ability to support and defend them. Users like having access to metadata. They want metadata for all data and image layers. Several suggested that instead of having a separate icon/button for accessing the metadata, the layer names could be made into hyperlinks to the metadata. If metadata were unavailable for a layer, no hyperlink would appear.

We heard a few suggestions related to how various model outputs were integrated into the standard watershed reports. Users asked that land cover statistics (e.g., from ATtILA) be expressed in acres as well as percentages. It was suggested that a link to ATtILA information/website be provided with the ATtILA output, similar to how a link is provided for REVA report metadata.

Users commented that it was helpful that watershed reports can be printed, but they would benefit from being able to save as an electronic document for future use (i.e. they did not want to have to return to the tool and go through the same steps to regenerate a report).

Finally, we noted that Digital Watershed, while generally stable and predictable, is sometimes unavailable or offline. We attribute this to the fact that Digital Watershed sits on a server that is used for research and development activities, as well as production. Moving the system to a dedicated server, separate from these other functions, could greatly enhance its stability and usefulness.

3.2.3. Enhancements to L-THIA

The users we worked with generally liked the functionality of L-THIA and its connections to the OWL and WHAT tools. In particular, they indicated liking the ability to change the information (soil type, land use acres). Others noted the ability to get a quick curve number estimation for any watershed. Some suggested L-THIA could save them time doing subwatershed hydrology work, and another noted how L-THIA could aid their 2020 land use analyses on an entire watershed basis. Others liked the inclusion of Low Impact Development and the ability to account for LID techniques. Users did, however, note enhancements that could improve their use of these tools.

The initial screen for the LTHIA watershed delineation steps includes three location options in the upper left navigation bar. Users noted that when looking at the current layout, it is note necessarily intuitive that a user should scroll down to use the different options.

Users offered a few cartographic related suggestions. They specifically suggested checking the color schemes used, noting that the subwatershed delineation lines appeared to be the same color as some land use lines. Some users also noted that when the HUCS are clicked on , they were not sure which HUCs (8-, 10-, or 12-digit) showed up on the map. Inclusion of a legend on the map would be helpful.

3.2.4. Enhancements to ReVA

Although we incorporated ReVA outputs into the standard watershed reports made available through Digital Watershed, the current ReVA analyses/outputs have limited application within state and local watershed and land use planning processes. There are several reasons for this, related primarily to scale/units of analysis, data sources, and the use of metrics. Each of these concerns is addressed in Wisconsin DNR's review letter to the ReVA project manager (Watermolen 2008) and is touched on briefly below.

ReVA is based on 8-digit HUCs, sub-basins that are too coarse for answering most watershed management questions that state and local practitioners deal with. As one Watershed Management colleague commented "8-digit HUCs are far too large for our uses." In addition, local and sub-state regional governments that engage in land use and comprehensive planning generally work at municipal and county (or, in a few cases, multi-county) scales (see also background discussion in Section 2.3.1). While we recognize that watersheds transcend these political boundaries, we also recognize the importance of conducting analyses and reporting results at scales that are meaningful for decision makers. A more preferred unit of analysis and reporting for many of the metrics included in ReVA would be the sub-watershed (Schueler 1996). Analyses conducted at the ecological landscape and ecoregion scales would be more helpful for many state and local conservation planning efforts.

State and local agencies often have access to more recent and more robust data sources than cached, broad-scale national datasets. For example, ReVA uses NatureServe's information relating to the presence of endangered and threatened species. The Wisconsin DNR's Natural Heritage Inventory (NHI) database provides access to more detailed information related to the occurrence of listed species as well as species designated as Species of Greatest Conservation Need in the state's comprehensive *Wildlife Action Plan*. Management priorities now are being focused on this broader suite of species making the simple analysis of endangered and threatened species that ReVA generates less useful.

The list of data sources found in the draft design document for the ReVA Midwest tool kit is quite extensive, but the data sources actually used to derive the metrics found in the ReVA interface are only a small subset of that list. Unless there is some interest in actually tapping into the additional listed datasets (e.g., through web services), we recommend this be clarified/corrected so the documentation is not misleading as to what is used to generate the metrics.

With respect to both data and metrics, local practitioners generally prefer direct access to the data underlying the metrics, as well as the ability to generate or modify metrics using their own assumptions (see related discussion in Sections 2.1.3 and 2.2.2). Enabling these capabilities would make ReVA more relevant to a broader range of potential users.

3.3. Making STORET More Usable

Because the STORET database remains the most valuable assemblage of water quality data, our efforts to provide access to these data generated considerable interest from watershed practitioners. Our work resulted in several observations and recommendations for making the STORET web services and data more usable.

3.3.1. REST Web Services

During the course of the grant period, the U.S. EPA STORET team fixed several technical issues previously encountered by web service consumers (many of these were identified in our semi-annual reports to U.S. EPA). These efforts enabled users to relatively smoothly chain multiple web services together. It is worth noting, however, that these services were not particularly stable and could be very slow in response from time to time. The MSU team suggested that REST[9] web services could help reduce response time and improve the stability.

3.3.2. Synchronization of Web Services with Downloads

Project staff compared web service downloads of STORET data for the six Region 5 states with U.S. EPA's ArcIMS web services for STORET data and the view of STORET in U.S. EPA's EnviroMapper for Water (ArcGIS Server based). The latter two sources were cached versions that appeared significantly dated, particularly for Wisconsin. Each of the six state STORET datasets was processed into point shapefiles and spatially joined to the new 8-, 10-, and 12-digit HUC themes. A text field was added, "gener_str", and calculated as the text equivalent of the "generated" field, appending a prefixed zero as needed (all but Wisconsin). A calculation of total number of points where "generated" was not equal to the 8-digit HUC code was made. A separate subset was determined where "generated" was equal to 0 or null.

Despite extensive documentation on the STORET download page, we found no adequate metadata about the fields in the STORET downloaded datasets. "Hydrologic" appeared to be a state (or equivalent) reported 8-digit HUC code and was optional. "Generated" appeared to be a derived code, but precise methods were not apparent. The point-in-polygon check proved to be a good QA/QC method for determining systematic patterns of errors and omissions.

Classes of potential errors identified in this analysis included:

- Blunders – For example, the Des Plaines River is not in Pennsylvania; it appears the digits of longitude are transposed.

[9] Representational state transfer (REST) is a style of software architecture for distributed hypermedia systems, such as the web, that consists of clients and servers. Clients initiate requests to servers; servers process requests and return appropriate responses. Requests and responses are built around the transfer of representations (typically a document that captures the current or intended state) of resources (essentially any coherent and meaningful concept that may be addressed).

- Zeroes – Where no Generated HUC 8 code has been provided, a correct code aligned with the newly compiled HUC layer is needed.

- Wrong HUC 8 – There are at least three classes of errors where this is noted. Points along the margins of 8-digit HUCs may now fall in a different 8-digit HUC, due to differences in compilation scale, or the significant redefinition of a HUC boundary. The first case appears throughout the region to a greater or lesser extent. The second case is particularly noteworthy in Wisconsin for the Upper Rock / Crawfish watersheds, and for the Duck-Pensaukee watershed. The third case involves STORET points that land in the Great Lakes. These may be coded to the closest 8-digit HUC onshore, which may or may not have boundary changes (see for example the area south of the Mackinac Bridge). Moving the 8-digit HUC shoreline 400' offshore, as has been suggested by some, would affect some, but not all of these points. The new HUC boundary theme does not provide closed Great Lakes polygons. Other points in the Great Lakes do have a proper Great Lakes code in the Generated file; but use of the Great Lakes code, or the separate flagged field, appears inconsistent.

Solving these data consistency and currency problems will be important to ensure that other analyses, such as presence and frequency of sample data at a point, can be usefully summarized across 8-, 10-, and 12-digit HUCs or other user-defined watershed delineations. Project staff indicated that new web services that are in sync with the downloads already subset at the 10- or 12-digit HUC level would be beneficial.

3.3.3. Access to STORET from Standard Watershed Report

The work conducted by Michigan State University team to make STORET data available via Digital Watershed is unprecedented. Users expressed considerable appreciation for the ease at which access has been provided through Digital Watershed to the various STORET reports.

Users expressed interest in several additional features that would enhance the interface. Most notably, the current monitoring locations ("pins") displayed on the Google Maps interface appear without the watershed boundaries being shown. Users asked if the watershed boundaries delineated through L-THIA and Digital Watershed could be added to the map presentation.

In addition, users noted that while the station report lists parameters sampled, it does not provide values for the results obtained. We received numerous suggestions for making the data available directly from the Google Maps STORET interface.

Users noted then when attempting to get data from a monitoring station that they knew had continuous monitoring data (i.e. thousands of temperature results per station), the system would generate an error message similar to this:

> *SoapFault exception: [Client] Allowed memory size of 16777216 bytes exhausted (tried to allocate 8314061 bytes) in /var/www/storet/wqxwqr.php:30 Stack trace: #0 [internal function]: SoapClient->__call('getResults', Array) #1 /var/www/storet/wqxwqr.php(30): SoapClient->getResults('WIDNR_WQX', '10012179', '', '', '', '', '', '', '', '', '') #2 {main}*

This appears to result from a limitation of how much data can be streamed on the fly.

Finally, several users noted that providing a link to Purdue University's flow/load duration curve tool on the Google Maps STORET interface would tie together several important water quality modeling elements in a single interface.

3.4. Assisting End Users

Several recent efforts have addressed technology transfer on a broad scale (see Watermolen 2009, p. 190 for a brief review). Lessons learned while carrying out our challenge grant work resonate with these earlier efforts, and we encourage state and federal agency personnel to consider these collective findings as they design and implement technology transfer efforts.

Strong partnerships forged with state, local, and tribal governments and environmental agencies through their inclusion on steering committees and similar bodies can inform technology development and transfer efforts. Continuous engagement allows organizations to complement each other's strengths and effectively leverage resources to address shared needs and priorities. For example, local government associations are often committed to regularly publishing print or electronic newsletters for their membership, but are often in need of substantive content. Resource agencies on the other hand often have substantive content they want to share, but are limited in their ability to disseminate it. The needs of both organizations can be met through collaboration. Similarly, Extension educators often are skilled in organizing and promoting workshops, but are sometimes reluctant to be "the expert." This concern can be readily addressed when resource agencies partner with Extension and provide an instructor/expert.

As noted by Watermolen (2009) and references cited therein, effective technology transfer relies on a variety of approaches and techniques. Similarly, end users suggested a number of steps that could be taken to further assist them in using the U.S. EPA and Midwest Partnership tools. We outline these below.

3.4.1. Work Flow Diagrams

Several users noted that due to all of the links between Digital Watershed, L-THIA, Google Maps, U.S. EPA web sites, etc., users can become "lost" in terms of where they are and where they've been in the system. Some users suggested creating schematic, work flow diagram or other documentation to assist users in keeping track. NRCS task guides (http://www.wi.nrcs.usda.gov/technical/taskguides.html) were suggested as an example. Part of this documentation could be a matrix comparing all the web tools in terms of what each does and the order in which they can be used.

3.4.2. "Metatool" to Facilitate Tool Selection and Use

The Wisconsin DNR previously proposed developing a "metatool" to aid users in selecting and using web-based tools and supporting technologies. That proposal included developing a guidebook that presents a comprehensive inventory of web-based decision-support tools, provides a primer on the underlying technologies, and links specific tools to a range of environmental issues. We proposed using this guidebook as the basis for an interactive, algorithmic, web-based guide to facilitate, based on user-defined needs, appropriate selection of tools from within the inventory. The web-based system would include instructions and tutorials for each tool, as well as case studies of known instances of environmental benefits using the inventoried tools, linking the tutorials and case studies to the metatool's underlying database.

3.4.3. International Coastal Atlas Network (ICAN)

The International Coastal Atlas Network (ICAN) is an informal group of over 30 organizations who have been meeting to scope and implement data interoperability approaches for Coastal Web Atlases (CWA). The strategic aim of ICAN is to leverage the expertise of its members to find common solutions to CWA development (e.g., user and developer guides, best practices, standards and web services, expertise and technical support directories, funding opportunities, etc.). ICAN also seeks to encourage and facilitate global operational interoperability to enhance data and information sharing among users, and assist in the translation of coastal science to coastal decision-making. We believe it is important to continue demonstrating the value of making OGC compliant services available to the public. Partnering with ICAN may be one means of doing that.

4. Project Administration

This chapter provides a brief overview of project administration, including information on the Federal Assistance Agreement, project staffing, key collaborators, and key communications with U.S. EPA. See Chapter 2, "Project Overview and Accomplishments," for a discussion of the specific work tasks undertaken to meet objectives. Our most significant findings and recommendations are discussed in Chapter 3, "Lessons Learned, Recommendations, and Future Work."

4.1. Grant Period and Amount

A Federal Assistance Agreement (No. OS-83320901) was awarded to the Wisconsin DNR for the period September 1, 2006 through August 31, 2008 in the amount of $500,000. The project work plan was modified through a no-cost extension on July 14, 2008 to extend the project through March 30, 2010.

4.2. Project Staffing

Dreux Watermolen, Wisconsin DNR's Chief of Science Information Services, served as the overall project manager (principle investigator) for the entire project period and was responsible for oversight of the Wisconsin DNR efforts. Thomas Aten, Wisconsin DNR Business Automation Specialist, provided technical support and assisted with project management. The Federal Assistance Agreement provided funding for a three-year project employee. Jerry Sullivan, a GIS Project Manager, was hired to carry out the day-to-day work of the program. Several Wisconsin DNR staff members and contractors working in the bureaus of Science Services, Watershed Management, and Enterprise Technology Services contributed to program implementation.

4.3. Key Collaborators

As described in Chapter 2 ("Project Highlights and Accomplishment") of this report, we worked with collaborators from various local, state, and federal agencies, as well as several academic scientists in carrying out this project. Please see Chapter 5, "Acknowledgements," for additional collaborators.

Principal collaborators from the U.S. EPA included Michael Bland, Richard Zdanowicz (retired), Tom Brody, Zenny Sadlon, and Glynys (Gigi) Zywicki (Region 5, Chicago).

Throughout the course of our efforts, we partnered with regional planning commission (RPC) staff who have been leaders in making land use information available and applying predictive models in planning. These included Mark Walter and Tony Bellovari at the Bay-Lake Regional Planning Commission and Greg Sanders at the Chicago Metropolitan Agency for Planning.

Drs. Jon Barhtolic and Yi Shi led the work conducted at Michigan State University's Institute of Water Research. Dr. Bernie Engel and Larry Theller lead the Purdue University Agricultural and Biological Engineering team.

4.4. Semi-annual Progress Reports and Communication with U.S. EPA

Jerry Sullivan regularly participated in conference calls and maintained regular contact with project leads in both Region 5 and the partner institutions. This ongoing communication was essential for ensuring project completion.

We provided U.S. EPA Region 5 with written semi-annual progress reports for each six-month period. These reports highlighted work completed by all project partners during the previous six months, documented contractual deliverables, outlined next steps and future plans, and served as a basis for coordinating efforts. We also shared these reports with key staff in U.S. EPA's Office of Research and Development and Office of Environmental Information.

We participated in quarterly in-person status briefings with U.S. EPA Region 5 staff members throughout the project period. These face-to-face meetings provided U.S. EPA project contacts an opportunity to react to written reports and project deliverables, to ask questions and seek additional information, and to provide guidance and direction for future work efforts. The meetings also provided opportunities for Wisconsin DNR program staff to meet with U.S. EPA staff and managers, in addition to the project contacts, to share progress and lessons learned. To this end, Dreux Watermolen and project partners presented aspects of the efforts during a Midwest Spatial Decision-Support Systems Partnership briefing for the U.S. EPA Region 5 Regional Administrator, Deputy Regional Administrator, and Water Program senior management in November 2009.

Various products and deliverables produced during the grant period were posted to U.S. EPA's Science Connector and were shared with the Midwest Partnership.

5. Acknowledgments

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6. Literature Cited, Further Reading, and Background Material

Here, we list all works cited throughout the report, as well as additional sources that we found helpful in defining, developing, and evaluating our demonstration project. These include references related to watershed planning, decision-support technology, technology acceptance, and technology transfer. We hope others will find this consolidated list useful.

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Appendix A – Presentations Resulting from the Midwest Partnership's Work

U.S. EPA staff requested that Wisconsin DNR and its partners make concerted efforts to transfer findings from the grant-funded work for broader regional and national applications. The following presentations resulted directly from work undertaken as a part of the federal assistance agreement and transferred lessons learned from the Midwest Partnership's efforts. Links to conference proceedings, presentation slides, or related sites are provided when these are available on the Internet.

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