MILWAUKEE RIVER BASIN WETLAND ASSESSMENT PROJECT

DEVELOPING DECISION SUPPORT TOOLS
FOR EFFECTIVE PLANNING

DRAFT

Final Report to the U.S. Environmental Protection Agency,
Region V

Wetland Grant #97565801-3

June 2006

Blank Page

MILWAUKEE RIVER BASIN WETLAND ASSESSMENT PROJECT

DEVELOPING DECISION SUPPORT TOOLS FOR EFFECTIVE PLANNING

Final Report to U.S. EPA – Region V
Wetland Grant #97593901

June 2006

Authors:

Joanne Kline, Thomas Bernthal, Marsha Burzynski, Kate Barrett,
Wisconsin Department of Natural Resources

Contributors:

Wildlife Tool: Noel Cutright[1], Donald M. Reed[2], Gary Casper[3], Richard Bautz[4]
Water Quality Tool: Joe Helkowski[4], Kevin Kirsch[4], John Panuska [5]
GIS Support: Janel Pike[4], Tom Simmons[4]
Potentially Restorable Wetland Layer: David Roberts [6]

[1] Retired, Senior Ecologist, WE Energies.
[2] Chief Biologist, Southeastern Wisconsin Regional Planning Commission.
[3] Casper Consulting, formerly Herpetologist, Milwaukee Public Museum
[4] Wisconsin Department of Natural Resources, various positions
[5] University of Wisconsin Extension, formerly Water Resources Engineer, Wisconsin Department of Natural Resources
[6] Natural Resources Consulting, formerly Soil Scientist, Natural Resources Conservation Service

This report was prepared by the Wisconsin Department of Natural Resources under Grant No. 97593901 from the U. S. Environmental Protection Agency, Region 5. Points of view expressed in this report do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

Acknowledgements

The authors thank the following people for their opinions, guidance, creative insight and constructive criticism during all phases of this project from conception to completion.

United States Environmental Protection Agency: Cathy Garra, Sue Elston and Richard Sumner
University of Wisconsin – Madison: Kenneth Potter, Joy Zedler
University of Wisconsin – Milwaukee: Jill Hapner
Wisconsin Department of Natural Resources: Patricia Trochlell, Karen Voss, Dave Siebert, Bob Hay, Andy Paulios, Eunice Padley, Dale Katsma, Melissa Sparrow, Amanda Schwoegler, Bob Watson, Mike Bruch, Will Wawrzyn
Ozaukee County Planning, Resources and Land Management Department: Andrew Struck

Contact for Further Information

Thomas W. Bernthal
Bureau of Watershed Management
Wisconsin Department of Natural Resources
101 S. Webster Street
P.O. Box 7921
Madison, WI 53707-7921
Phone: (608) 266-3033
Email: thomas.bernthal@dnr.state.wi.us

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Executive Summary

Traditional indicators of ecological health or condition are often site-specific and collecting them is expensive in both time and money. The quality of our water sources and wildlife habitat for example is measured by water chemistry samples, bacteria counts, habitat surveys and biotic indices that require time on the ground or in the laboratory. In addition protocols for collecting wetland field data and methods for interpreting the data to assess wetland condition are in the early stages of development, while the number of decisions requiring assessment of wetland condition and cumulative impacts on water resources grows with the rapid pace of land development.

Fortunately, over the last decade, researchers have examined relationships between traditional indicators of ecological health and patterns in the surrounding landscape. Where one can establish a reliable relationship between landscape patterns and actual ecological conditions, the landscape pattern itself becomes a surrogate ecological indicator. Where remote sensing and GIS analysis can apply these relationships to existing local data, ecological assessment becomes rapid and cost effective.

The National Wetland Monitoring Working Group (Sumner 2005) recognizes that the task of developing comprehensive wetland monitoring approaches with limited resources needs to proceed at both the site level and the landscape level. This project focuses on complementing intensive site assessment methods with landscape level assessment at the watershed and subwatershed scale.

The Milwaukee River Basin Wetlands Assessment Project (MRBWAP) synthesizes existing GIS data with our current scientific understanding of wetland, watershed and landscape function to produce planning tools that assess major wetland functions (or ecological services) at the landscape level. We have completed development of tools to evaluate the existing level of quality wildlife habitat and wetland function for protecting downstream water quality in the Basin. As of this writing we continue to work on a tool to evaluate wetland function for floodwater storage and maintenance of stable water flows.

We have also produced a Potentially Restorable Wetlands (PRW) data layer that identifies wetland restoration opportunities within the Basin. By adding this data layer the tools can be used to evaluate the gain in wetland function that could be achieved through restoration. Ultimately these tools can be used by local planners and decision-makers to predict the consequences of differing development and restoration scenarios and prioritize use of limited resources for wetland protection and restoration.

The GIS decision support tools are most effective at the local scale. To better represent local conditions we divided the six watersheds of the Basin into 58 subwatersheds. We have also produced a set of GIS-derived subwatershed metrics that can be used to broadly characterize wetland and watershed condition. These metrics can be used where time, software and available data are not adequate for using the GIS decision support tools. Subwatershed metrics include attributes such as percentage of various land use types, percentage of impervious area, road density, miles of first order streams, acres of existing

wetlands, acres of lost wetlands, acres of wetlands dominated by invasive reed canary grass and acres of potentially restorable wetlands.

The project goal is ***not*** to produce the comprehensive plan for managing the wetlands of the Milwaukee River Basin. Rather we have produced data layers and tools that can be used by local decision-makers to answer questions relevant to them. We have focused on transferring these products to a User's Group from whom we have solicited advice and kept informed of our progress. The potentially restorable wetlands layer will also aid acquisition and restoration efforts in the North Branch Milwaukee River Wildlife and Farming Heritage Area.

As with all GIS–based efforts, the end result is contingent on the quality and currency of the data inputs. All results generated by our tools or application of the subwatershed metrics should always be subject to some form of "ground-truthing" and interpreted with common sense. We are working with three county land and water conservation departments and land use planning departments to ground-truth our Potentially Restorable Wetlands data layer and test the use of the decision support tools in developing various land use plans. The results of their testing will be presented in a second report.

We recommend the mapping of "potentially restorable wetlands" to other Basins and project areas where digital soil and wetland inventory information are available. This layer provides the basis for both the broader subwatershed metrics and the decision support tools produced here. Some areas of the state will not have current and adequate land use or land cover data to employ the decision support tools developed here, but most could support the development of a potentially restorable wetlands layer that can provide a relative assessment of the need for wetland restoration across watersheds or subwatersheds.

The potentially restorable wetlands layer could also be used as an input to more detailed and higher level wildlife or water quality modeling. For example, water quality modeling for TMDL analysis may require higher resolution data and provide a more refined output than our water quality tool is intended to provide, yet the potentially restorable wetlands layer could provide an appropriate input to the model. Specific wildlife population models may require additional data on nesting and breeding habitat and life cycle needs than our wetland wildlife tool provides, yet the potentially restorable wetland layer would provide a valuable input.

Chapter I: Introduction

Growth and change are inevitable, and so are different opinions among citizens and communities about the direction future growth should take. Wetlands are some of the many natural resource elements communities will consider while they examine alternatives for future growth. Wisconsin's comprehensive planning legislation requires communities to evaluate natural resource features that should be protected. Other planning efforts at the state, federal and local level can also benefit from the concepts and tools presented here.

The Milwaukee River Basin Wetlands Assessment Project (MRBWAP) developed tools and methods to support a better understanding of the roles different wetland types play in the landscape. This report summarizes the findings of four years of work developing tools to provide a geographic-based synthesis of landscape information for aiding those charged with making wetland protection, restoration and management decisions. Our hope is that the information provided here will provide the framework for state and local planners and decision-makers to make informed decisions about protecting and restoring wetland resources as they plan for the future.

The Big Picture: Why are we doing this?

We all know that wetlands are important. But what do they actually do? Scientists agree that wetlands are critical for providing diverse wildlife habitat, improving water quality and stabilizing stream flows in rural and urban areas. But, where are the wetlands most important for these functions located? Are there areas where wetlands can be restored to provide important services that have been lost to agriculture or development? How do we decide where the best places to protect and restore wetlands are?

It's been estimated that nearly half of the wetlands once found in Wisconsin have been lost through draining or filling. Given that, it would make sense to say that all wetlands should be protected, and we should restore as many as we can. While philosophically this statement makes sense, from a practical standpoint we must set priorities because we can't restore them all.

The recent explosion in the availability of digital spatial data is providing us the means for the first time to do a comprehensive, geographically focused analysis of wetlands in Southeastern Wisconsin. What this means is that we can use sources of information like wetland location, vegetation type and size, soils, hydrography (rivers, streams and lakes), and land use/land cover to evaluate how wetlands function in the landscape. Further, we can combine this information with what we know about wildlife species requirements, water quality and hydrology to determine where wetlands currently provide crucial functions, or where they could be restored to alleviate a problem or meet an ecological need.

The Milwaukee River Basin (Figure 1) provides us with a valuable laboratory for testing our assumptions related to wetlands and the changing landscape. The basin covers nearly 900 square miles, and is home to more than 1 million people. The northern portion of the basin is primarily in agricultural uses (57%) and other rural uses (forests, 11%; grasslands, 12%); the central portion is rapidly urbanizing and is influenced by two of the fastest growing counties in the state. The lower portions encompass the most densely populated region in the state of Wisconsin. This diversity of landscapes allows us the opportunity to test different approaches for making management decisions considering wetlands and their associated landscapes.

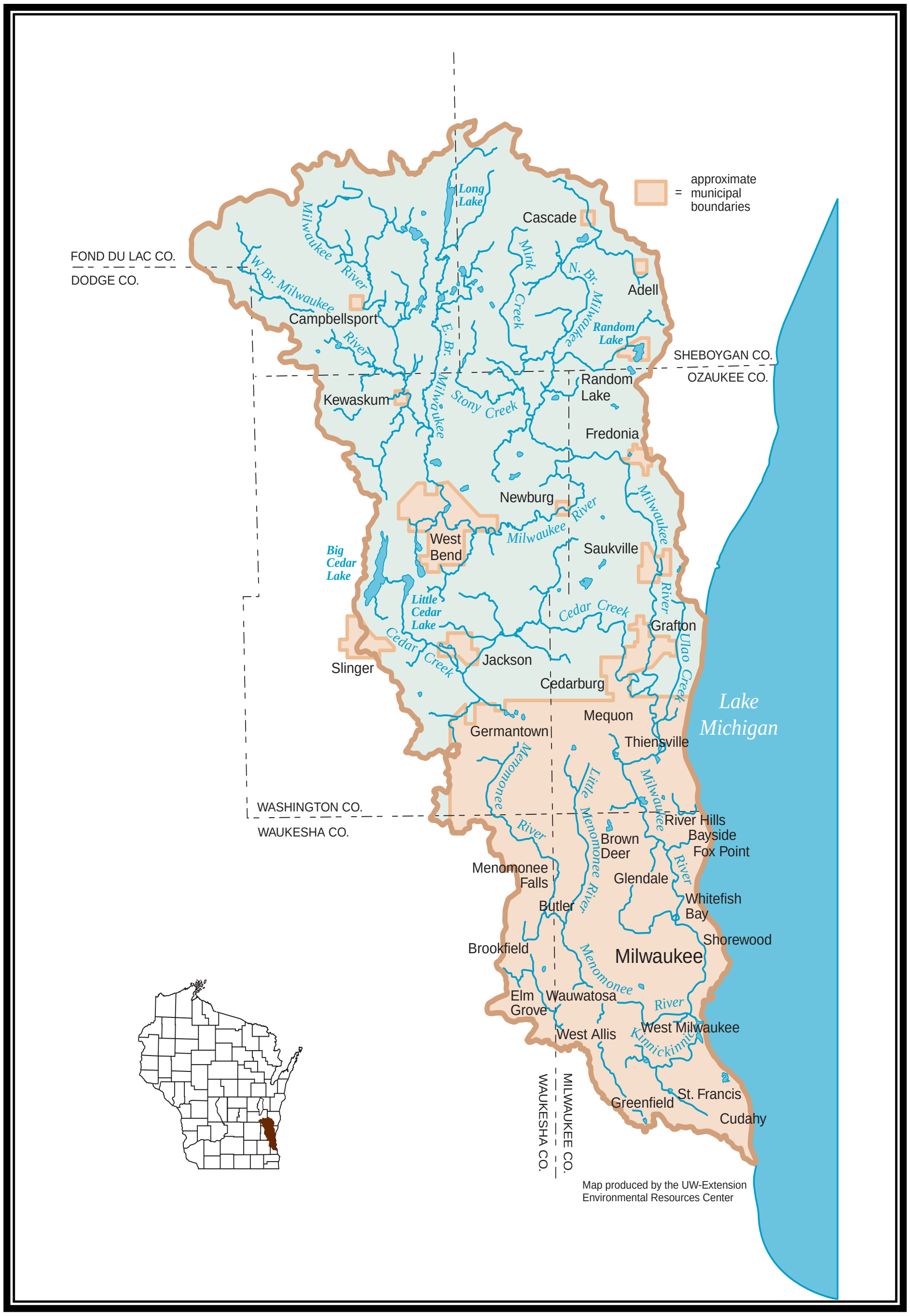


Figure 1. Milwaukee River Basin

The main objectives of this project are to develop methods to aid state, county and local decision makers considering wetland protection and restoration in their areas of interest. For instance, ways this information could be used for wetland protection are to:

- ✓ Predict the consequences of cumulative wetland loss in demonstrated critical areas;
- ✓ Identify existing high-quality wetlands for protection through partnerships, maximizing wetland function and resource value with adjacent lands;
- ✓ Prioritize outreach and partnership efforts for wetland enhancement and rehabilitation projects where wetland health as determined by monitoring is reduced, but adjacent natural or wildlife habitat areas would benefit by increased size or by reduced threats of invasive species.

For wetland restoration, the tools developed can help to:

- ✓ Prioritize wetland restoration to buffer headwater streams where loss of significant adjacent wetland acres has caused reduced base flow to limit habitat for fish and aquatic life;
- ✓ Prioritize wetland restoration for flood storage where wetland loss has caused stream peak flows with above average flooding frequency.
- ✓ Prioritize wetland restoration for wildlife habitat based on location relative to core terrestrial habitat, travel and migration corridors, existing habitat structure and maximizing other wetland functions.
- ✓ Analyze existing hydric soils and topography data to select sites with a high chance of success from those available within priority areas. Sites will be targeted where effects on neighboring lands can be minimized, and wetland functions can be maximized by virtue of their proximity to other appropriate ecosystem features.
- ✓ Prioritize watersheds in which wetland restoration can produce the largest water quality benefits.

Chapter II: Building the Big Picture

The Setting

The Milwaukee River Basin was historically rich in wetlands, left behind as the glaciers retreated 10,000 years ago. Gently sloping land on glacial till, outwash plains and former lakebeds, formed slow, meandering stream systems with extensive associated wetland complexes. The streams and their wetlands were part of a healthy intact ecosystem with high species diversity. Some of this remains today in our Outstanding Resource Waters and State Natural Areas.

This landscape and its fertile soil led to intensive agricultural. Government- promoted wetland drainage, through ditching and drain tiles, claimed lands for farming and an industry that remains a major economic asset in the region. As we converted the land, acres of forests were cleared for crops, miles of streams were dredged to move water off the land, and impoundments were built for milling.

Development also contributed to wetland loss with the historic fill of vast wooded wetlands to build what's now downtown Milwaukee. As the area grew, wetland loss continued. Since the 1980's, when the value of wetlands was recognized, the rate of wetland loss from development has slowed, but continues. The Milwaukee Basin includes some of the most rapidly urbanizing communities in the State, and the rate of land conversion exceeds the rate of population growth.

In addition to the loss of wetland acres, development also affects remaining wetlands and water quality. Wastewater treatment plants and storm sewers add sediment and nutrient enrichment to streams. Impervious surfaces move runoff to waterways faster and without the benefit of wetland filters.

The Consequences

Wetland loss and reduced wetland quality affect both land and water resources. Reduced water quality and changes in drainage patterns lead to shifts in aquatic communities. Mussel species are fewer, fish that are intolerant of pollution disappear, and pollution tolerant species increase in proportion. Fishing and other water-based recreation suffers. Flood events are more common and severe.

Wetland loss also affects wildlife habitat. Wetland based animals are displaced and even those who spend more time on dry land lose the wetlands for their food source or the migration corridors they need to complete their life cycles. Gradually some species die out, and once common species, such as the wood frog, are less frequent (Figure 2).

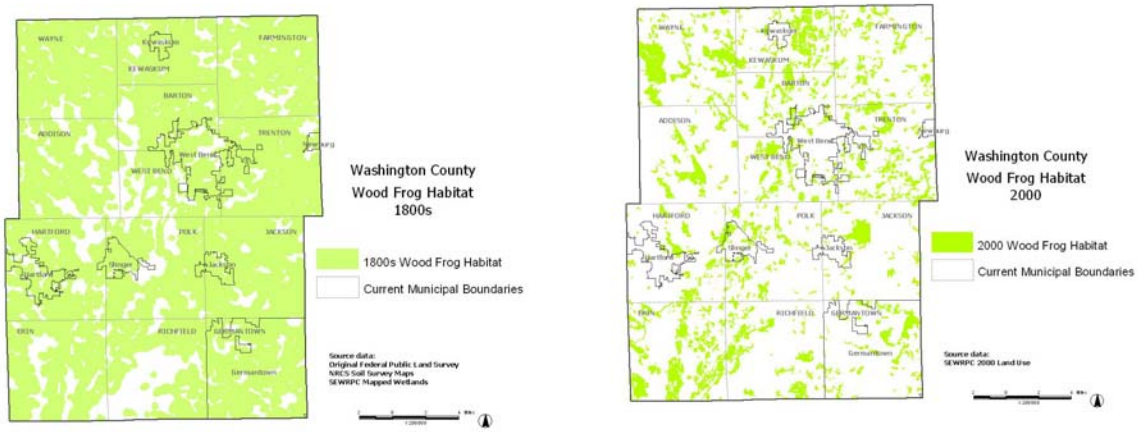


Figure 2. Comparison of Wood Frog Habitat, 1800s to year 2000.

The Role of Wetland Protection & Restoration

MRBWAP does not advocate protecting every remaining wetland, or restoring wetlands in an attempt to return to pre-settlement Wisconsin. Wetlands are, however, like lakes, rivers, fields and forests, an important component of ecosystem integrity. Protection of existing wetlands and restoring former wetlands are both part of a healthy landscape. Voluntary wetland restoration, within the context of local planning, is a way to balance the needs of growing communities and environmental quality.

Wetlands also aren't the solution to all water quality and wildlife habitat problems. Land use, agricultural practices, stormwater management and other engineered solutions work best when they work together with natural features in the landscape.

The term 'restoration' in the narrow sense implies putting wetland acres back on the land where they used to be. Usually this means reversing past drainage to get water back on the land, by filling ditches, removing drain tiles, or excavating wetlands buried under layers of accumulated sediment.

Restoration also has a broader meaning – improving the condition of a wetland that already exists. This broader type of restoration – or 'rehabilitation' – may involve removing sediment, plugging ditches or controlling invasive plant species that reduce species diversity and wildlife use.

Using MRBWAP to Set Priorities

Where does one start to set priorities for wetland protection and restoration, in a river basin that covers over 800 square miles, or in a local community that covers 30?

MRBWAP suggests these as guidelines for decision-makers:

- Use objective scientific criteria to support protection and restoration decisions
- Base wetland protection on existing wetland functions and values, and their threats.

- Base wetland restoration on past wetland loss, and the probability that a restoration will meet specific restoration goals or address your environmental concerns.

The data and decision tools to apply these guidelines and examples of ways to use them are what the MRBWAP is all about. MRBWAP does not make the decisions for you. It informs your decisions once you establish your protection and restoration goals. Depending on your area of concern, flood control, green corridors, a certain wildlife habitat, or a suite of factors to compare alternate development sites, may be what's most important to you.

Regardless of the scale of your area, a larger perspective is needed to define the issues and to identify where restoration can contribute to solutions. The restoration picture needs to include surrounding land uses and drainage systems. Without a landscape level analysis, restoration efforts may not give the needed results or make the most of opportunities.

Some of the questions MRBWAP can answer to guide decisions are:

- How do different areas (watersheds, subwatersheds or municipalities) compare in wetland loss since settlement?
- Where are further wetland loss or degradation a serious threat?
- Where is there greater need to restore specific wetland functions?
- Where are potential successful wetland restoration sites?
- Where may restoration expand existing environmental corridors or increase an existing core habitat patch?

What the MRBWAP is Not

MRBWAP does not provide new data. Its value lies in making use of existing data to answer these and many other questions.

MRBWAP takes existing data, from DNR, SEWRPC, USDA and local communities, makes them compatible, fills in the gaps and puts them together to function as a single unit either alone or with additional data supplied by the user. GIS makes data management, data analysis and preparation of public information possible with far less effort than by using individual data sets.

The results of any analysis will still be seen through a coarse screen. The scale of the coarsest base data limit MRBWA to the landscape level. MRBWA does not eliminate the need for site-level assessment prior to developing actual restoration plans; it screens many potential sites for many different factors to make site-level assessment manageable.

Chapter III: Data

Overarching Approach and Considerations

The Milwaukee River Basin was chosen as the pilot area for this project because of the sheer amount of geo-spatial data that was available. Capturing GIS data can be a time consuming and costly endeavor, often costing five to ten times more than that of the GIS hardware or software for a project. We made the decision early on in the project to use the best available data in order to leverage funding towards tool development rather than data development. This approach would allow us to take advantage of local data that was available, particularly with land use data. This would be critically important when evaluating ground conditions in terms of land use because of the rapidly changing landscape in the southeastern portion of the State. Factors used in determining which data sets to use included:

- ✓ Availability: data needed to be available at low or no costs. Local sources as well as statewide data sets were evaluated
- ✓ Completeness: data needed to cover the entire basin as much as possible for consistency sake. We relied on several sources for the wetlands data primarily because the Digital Wisconsin Wetlands Inventory data was based on aerial photographs dating from as far back as the 1970's. But DWWI data was available for the entire basin. Land use data was ultimately obtained from SEWRPC for most of the basin but we started out with having it only for the SEWRPC counties. A combined layer using WISCLAND land cover and buffered TIGER roads was developed for the non-SEWRPC areas and later was used to fill gaps where their basin boundary, which was used to clip their data, was different than that used by the DNR.
- ✓ Current: How recently the data had been collected provided us a measure of how useful the data would be in determining the "opportunity" factor for a potentially restorable wetland site. As stated before it was important that both the mapped wetlands and land use data were as current as possible in order to reflect ground conditions.
- ✓ Exportability: data needed to be in a geo-spatial format supported by ESRI products (Arc/Info and ArcView)

Data Processing

Data Processing Environment

The major processing steps were performed in Environmental Systems Research Institute's (ESRI) workstation Arc/Info ver.8.3, which is the Wisconsin DNR's standard GIS software. The processing steps included a series of overlay commands that combine the major themes (soils, wetlands and land use), building and restoring topology, and populating the attributes. This processing environment was chosen both for maintaining topological structure, better quality control routines, and for processing speed. ESRI's ArcView ver.3.2a was used for the initial stages of joining tables, generating new shapefiles, and generating summary tables and graphics.

Data Format

Most of the data used in the project were originally provided in a shapefile format. Shapefiles use a very simple storage model for feature coordinates where each shapefile represents a single feature class (point, line, or polygon). Thus shapefiles do not have the processing overhead of a topological data structure such as coverages and have certain advantages such as faster drawing speed. However they lack any topological structure, which defines the spatial relationships between features. This meant there were few tools available to reconcile gaps or overlaps within the data or for performing other quality control operations. Many of the original base data sets used needed some level of pre-processing or quality assurance checks completed before further processing could be performed. So we made the decision to convert the shapefiles to a coverage data model which provided a better set of processing tools.

Data Layers

Input Layer: HYDRIC SOILS

The first criterion for determining if a site has potential for wetland restoration is determining if it can support a wetland. Wetland delineation in part relies on the identification of hydric soils. We made the assumption that the presence of hydric soils where there currently wasn't a mapped wetland was evidence that there had once been a functioning wetland on that site. The definition of a hydric soil is a soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part (59 Fed.Reg.35680, 7/13/94). We used the Natural Resource Conservation Service (NRCS) SSURGO soils data layer and associated soil properties tables because it is an official soil data layer and was available for the entire basin.

Early on we consulted with a local soil scientist, Dave Roberts, from NRCS to determine if soils with hydric inclusions (HYDPART = INCL) should also be considered as an indicator of a potential restoration site. We know that wetlands occur on soils that are not entirely hydric due to their position in the landscape. Dave had local knowledge of which soils would most likely to be hydric in depressions and provided us with a list of the map unit symbols (MUSYM) that we could link to the geo-spatial layer. We considered including these soils acres for our metrics using a measure of 25% of the acres that are actually hydric soils. However without knowing where the inclusions were, we could not predict where the inclusions occurred. And when these soils were displayed on a map, they clearly covered a much larger area than we were comfortable with including in the metrics.

Input Layer: MAPPED WETLANDS

The second criterion is that the site cannot currently be functioning as a wetland. We pulled wetlands data from four sources to give us the more complete and current representation of mapped wetlands in the basin. The Wisconsin Department of Natural Resources (WDNR) is charged with maintaining a statewide inventory of wetlands for the purpose of obtaining an accurate assessment of wetlands across the state. The geo-spatial version of the data is called the Digital Wisconsin Wetland Inventory (DWWI). However we found that the majority of the DWWI data for the basin was based on very old aerial photography (1970's in some cases) and we wanted to get as accurate picture of where the wetlands existed in the basin as possible. We were fortunate to have access to three other data sources to augment the DWWI data: Ozaukee County Land and Water Conservation Department had contracted to have all the restored wetlands mapped in a geo-spatial format and SEWRPC's land use data included several categories that indicated the presence of a wetland. In addition to these sources, we were able to use data from a recently completed pilot project in the area that identified wetlands with a 50% or greater cover of reed canary grass. These data did not supply any additional mapped wetland sites but they did provide us with an additional wetland class, "reed canary dominated".

Input Layer: LAND USE

The last criterion that determines if a wetland can be restored represents opportunity. Wetland restoration opportunty is based on the assumption that present land uses are favorable for restoring the site as a functioning wetland. A fully developed or urbanized site has little opportunity for restoration for obvious reasons. We were fortunate to have access to South East Wisconsin Regional Planning Commissions' (SEWRPC) land use data, which was updated during the project to match 2000 aerial photography. With the rapidly changing landscape in this area of the state, we knew we needed to have the most up-to-date land use data as possible. For areas where we could not get SEWRPC land use data, we filled in with a combination layer of WISCLAND land cover and buffered roads.

Custom Layer: SUB-WATERSHEDS

The Milwaukee River Basin is characterized by a highly urbanized area in the south to a more agricultural and rural region in the north. It is divided into 6 watersheds based on DNR's definition. We realized that analyzing conditions within such in-homogeneous areas would result in "averages" that don't reflect actual conditions anywhere on the ground. The size of each watershed is also much larger than a typical community or local planning area. Local planning areas are typically 36 sq. miles (a Township) or less. So to reduce the effects of in-homogeneity, and to more closely match the scale of local plans, we needed to divide each watershed into smaller hydrologic units. We chose the next smaller division, sub-watersheds or 12-digit HUCs. We followed Federal standards established to create the national Watershed Boundary Dataset and created a sub-watershed layer with 58 sub-watersheds. This layer was also used as an input in the final base layer but is described here because it is one of the few custom layers that we created specifically for this project. The water quality tool further subdivides subwatersheds into "small catchments" as described in Appendix 4 (page 112) and Chapter VI (page 43). Refer to PROCESS APPENDICES (page 74) for a full description of our sources and how the layer was created.

Custom Layer: Drainage Ditches

Ditches represent alterations to the hydrology in an area and have shown to have an enormous impact on surface waters and on wetlands in particular. Understanding where hydrology had been altered is a key piece of the puzzle. However our main source for representing surface water hydrology was the DNR's 24K Hydrology GIS layer which contains very few drainage ditches. The Drainage Ditch geo-spatial layer represents one of the three custom data layers developed for this project.

Ditches that were in the DNR's 24K Hydrology layer were selected out and used to generate the start of the layer. We were able to hire a Limited Term Employee (LTE) to capture the remaining ditches using aerial photos. This was another time when the benefits of being in a data-rich basin paid off. We had at our disposal fairly recent aerial photography from South East Wisconsin Regional Planning Commission for approximately 2/3 of the basin. DNR staff have access to a DOP repository maintained by the Bureau of Technology Services so we were able to get aerial photo coverage for the entire basin. Later in the project we acquired data from several of the cooperating counties and thus able to supplement our data with theirs.

Custom Layer: Reed Canary Grass

We adopted the mapping protocols developed in another EPA funded project, Using Landsat 7 Imagery to Map Invasive Reed Canary Grass *(Phalaris arundinacea)* (Bernthal et. Al, 2004) to acquire data representing wetlands dominated by greater than 50% cover of reed canary grass. The data were generated via classification of satellite data from the Landsat 5 Thematic Mapper sensor and provide a measure of wetland biotic quality. The satellite data was captured October 18, 2000. We processed the data using a combination of unsupervised and supervised classifying routines in ERDAS Imagine image processing software In its native format, the data is stored as a GRID (i.e.raster) therefore we needed to convert to a vector format, to use for building the base layer. Details on the processing steps can be found in Appendix B of the Processing Appendices (page 79).

Base layer: MRBPRWSE

The base layer represents the geometric intersection of hydric soils, mapped wetlands, land use, and sub-watersheds. The first three themes or geo-spatial layers form the foundation for identifying a potential restoration site. Combined they give an estimate of present conditions in order to evaluate if a wetland restoration project is feasible. We added the sub-watershed layer to facilitate generating metrics. The result is an extremely large, complex layer that can be difficult to use. There are 724,400 records in the layer and looks a little like spaghetti when mapped without applying any filters to the data. Thus we recommend that users take the time to study the data dictionary and become familiar with the layer to understand how to use the data for a specific application. We have provided a User Guide and a data dictionary that will help the user.

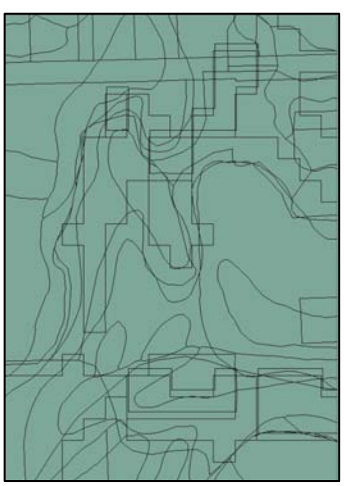


Figure 3. Base Layer "Spaghetti"

One of the major advantages of the base layer is that the user has access to all the attributes from the input layers at his/her disposal. The disadvantage is that the user will need to thoroughly understand the sources and how the layer was generated to take full advantage of the information. We spent a fair amount of time reconciling differences when the attributes from the input layers conflicted with each other. For example, the DWWI may have coded a feature as UPLAND but SEWRPC will have mapped it in their land use layer as a wetland. Only through studying the input layers, comparing dates of the sources, and studying randomly selected features on aerial photographs, could we determine the final wetland classification. We've documented our decisions in the WETLAND_CODING_DECISION_RULES.xls spreadsheet which is provided in the PROCESSING APPENDICES (page ?). We have also provided a User Guide that will help users take full advantage of the base layer and understand how to extract information.

Lessons Learned

The nature of a pilot project is that you learn as you go. The trial and error approach means evaluating results throughout and asking "Does that make sense?" Key members of the team were able to apply real world questions to see if the data lent themselves to answering them. We had productive meetings viewing the data together and making modifications to the process. If we had known early on the number of times we had to re-process sets of data, we would have invested in developing batch routines to expedite the processes.

One such lesson was our attempt to manage the file size. As we started to apply those real world questions we realized that we needed access to the whole range of attributes that came from the input layers. The original values were critical for testing out hypotheses as well as facilitating simple quality control procedures. This was especially evident when we developed the wetland coding decision rules, which can be found in the Data Dictionary for the base layer. Therefore we went back to the source layers and re-processed them keeping all of the original attributes and their original values from the input layers. The result is a very dense, highly complex data layer which may prove unwieldy for most users. A User Guide is provided that instructs users on how to use the layer effectively.

We started processing the data in a shapefile format since much of the source data was provided as shapefiles. It became clear however that the size of the layer was affecting processing speed. In some cases, a process would be set to run overnight only to find out in the morning that it had bailed. We also found that the lack of a topological data structure made it extremely difficult to resolve geometric errors from the overlay processes. We converted to a coverage format but only after spending considerable time trying to make it work as shapefiles.

Table 1: Data Sets Used for the Milwaukee River Basin Wetlands Assessment

BASIC DATA LAYERS			
Name	*Source*	*Source Scale*	*Description*
Basins and Watersheds	WiDNR	1:24,000	Watersheds are the smallest geographic unit and through aggregation, comprise basins and major drainage basins in the state. Both hydrologic units are represented in one layer based on aggregation and are maintained within DNR's GIS Library layer.
Rivers and Lakes	WiDNR	1:24,000	DNR's 24K Hydro layer. Includes rivers, streams, ditches, and lakes as well as other features needed for flow modeling. The ditches were selected out and used to generate the first version of the drainage ditch layer. The layer was also useful for digitizing drainage ditches and generating cartographic products.
Natural Areas	WiDNR SEWRPC		The Bureau of Endangered Resources maintains a geo-spatial layer representing State Natural Areas (SNAs), which are formally designated sites devoted to scientific research, the teaching of conservation biology, and especially to the preservation of their natural values and genetic diversity for future generations. Protected are outstanding examples of native natural communities, significant geological formations, and archaeological sites. Designation is achieved through purchase, cooperative agreements, legal dedication, management plans such as the Master Plans or Feasibility Studies developed in the DNR, and/or Memorandums of Understanding. SEWRPC provided a shapefile identifying tracts of land or water so limited by human disturbance that they contain intact native plant communities.
Stream Order	WiDNR		DNR layer derived from WiDNR 24K Hydro ver.1.

CUSTOM DATA LAYERS			
Name	*Source*	*Source Scale*	*Description*
Drainage Ditches	Digital Orthophotos from the counties	=>1:24,000	Drainage ditches are good indicators of hydrologic alterations to wetlands. The WiDNR 24K Hydro data layer had only limited representations of drainage ditches for this area and at the time there was no one source where we could obtain similar data. We captured drainage ditches for the Milwaukee Basin using Digital Ortho Photography (DOPs) for the area and digitizing features on screen.
Base Layer: i.e. Potentially Restorable Wetlands	WiDNR: input sources vary. Refer to Processing Appendices for more details.	Varies	This is the final product from the project and contains features and attributes from three input layers: hydric soils, wetlands and land use.

CUSTOM DATA LAYERS			
Name	*Source*	*Source Scale*	*Description*
Reed Canary Grass dominated wetlands	WiDNR	30mx30m pixel	Using satellite imagery, WiDNR developed protocols for mapping wetland areas that are dominated by reed canary grass, where the vegetation is essentially a monoculture. These protocols were applied to NASA Landsat 7 image data for the project area.
Sub-watersheds	USGS SEWRPC WiDNR	1:24,000 1:100,000 1:24,000	We defined hydrologic units (drainage areas) at a scale suitable for analysis of variables that affect flood storage capacity, water quality and fish and aquatic life at the level of local planning units that's also seamless with larger units Statewide. This involved starting with USGS Drainage Areas and SEWRPC sub-watersheds and having a team of hydrologic experts refine the boundaries. The USGS hydrologic units were provided in a draft version from the Watershed Boundary Dataset project. The SEWRPC hydrologic units were complete for the basin and have been used extensively in local plans. Neither dataset met the Federal sub-watershed number nor size requirements, therefore existing hydrologic units were regrouped to do so. WiDNR watershed boundaries provided the limiting extent for all subwatersheds.

INPUT DATA LAYERS			
Input	*Source*	*Source Scale*	*Description*
Hydric Soils	NRCS	1:1,000	SSURGO depicts information about the kinds and distribution of soils on the landscape. The soil map and data used in the SSURGO product were prepared by soil scientists as part of the National Cooperative Soil Survey. The data set consists of geo-referenced digital map data and computerized attribute data. Note:The lack of any soil surveys conducted in the City of Milwaukee proper primarily because the area was already developed when the soil survey program started in the early 1930's, prevented us from adequately assessing the potential for wetland restoration in those areas.
Mapped Wetlands	Digital Wisconsin Wetland Inventory SEWRPC Ozaukee County Land and Water	1:24000 1:20,000	The wetland layer includes a series of polygon coverages and point coverages that are digitized from 1:24,000 scale Wisconsin Wetland Inventory (WWI) maps. The point coverage includes information for wetlands smaller than 2 or 5 acres, depending on the county. The DNR Bureau of Fisheries Management and Habitat Protection is the custodian and sole distributor for this layer. SEWRPC 2000 land use data includes several categories that identify wetlands.

INPUT DATA LAYERS			
Input	*Source*	*Source Scale*	*Description*
	Conservation	varies	Ozaukee County developed an inventory of wetland restorations resulting from the efforts of the FWS, NRCS, WDNR, and County Conservation Office. These were provided in a shapefile format. Sites were delineated using project files and air photo interpretation. Site boundaries will be verified/corrected as field visits are conducted.
Land use	SEWRPC WISCLAND + US Census TIGER 2000 Line Files	1:20,000 1:40,000 1:100,000	Southeastern Wisconsin Regional Planning Commission (SEWRPC) land use data showing existing land use development of the Region categorized by single-family and multi-family residential; retail and service; manufacturing, wholesale, and storage; landfill and extractive; transportation, communication, and utilities (except highways, railways, and transmission lines); governmental and institutional; woodland and wetland; recreational; and agricultural and other open lands. WISCLAND landcover data is maintained within the DNR's GIS library and was used to fill areas where SEWRPC's basin did not match WiDNR's basin. To provide a better representation of impervious cover we buffered the TIGER 2000 line files for local roads based on distances that approximate the width of various road classes. These two layers were intersected and then clipped to fill in the gaps.
Sub-watersheds	USGS SEWRPC WiDNR	1:24,000 1:100,000 1:24,000	We defined hydrologic units (drainage areas) at a scale suitable for analysis of variables that affect flood storage capacity, water quality and fish and aquatic life at the level of local planning units that's also seamless with larger units Statewide. This involved starting with USGS Drainage Areas and SEWRPC sub-watersheds and having a team of hydrologic experts refine the boundaries. The USGS hydrologic units were provided in a draft version from the Watershed Boundary Dataset project. The SEWRPC hydrologic units were complete for the basin and have been used extensively in local plans. Neither dataset met the Federal sub-watershed number nor size requirements, therefore existing hydrologic units were regrouped to do so. WiDNR watershed boundaries provided the limiting extent for all subwatersheds.
Reed Canary Grass dominated wetlands	DNR	30mx30m pixel	

References for Chapter III

Aronoff, Stan. 1993. Geographic Information Systems: A Management Perspective. WDL Publications. pp. 35-44

Bernthal, Thomas W., et.al (2004). Using Landsat 7 Imagery to Map Invasive Reed Canary Grass (*Phalaris arundinacea*): A Landscape Level Wetland Monitoring Methodology. Final Report to U.S. EPA – Region V. Wetland Grant #CD975115-01-0

Chapter IV: Subwatershed Metrics

The need for landscape level ecological indicators

Traditional indicators of ecological health or condition have been site-specific and expensive in both time and money. The quality of our water sources and wildlife habitat for example is measured by water chemistry sampling, bacteria counts, habitat surveys and other biotic indices that require time on the ground or in the laboratory. Over the last decade, researchers have examined relationships between these traditional indicators of ecological health and patterns in the surrounding landscape. For example, how does road density relate to measured wildlife species diversity? What land use features correlate best with measured water quality? Where one can establish a reliable relationship between landscape patterns and actual ecological conditions, the landscape pattern itself becomes a surrogate ecological indicator.

Where remote sensing and GIS analysis can apply these relationships to existing local data, ecological assessment becomes rapid and cost effective. Applying landscape level indicators on a periodic basis allows objective and consistent evaluation, and monitoring to inform future land use decisions.

Ecological indicators and wetland planning

Current wetland planning and management decisions are also based mainly on site-specific factors. An individual regulatory decision, or a landowner's interest in voluntary wetland restoration, usually involves an isolated site. Ecological problems and community needs however are seldom isolated and on-site problems may result from off-site factors. For example, poor water quality or lack of base flow in a stream may be due to landscape features further upstream. Where effects are cumulative, they may not be measurable until a combination of impacts over a larger area reaches a certain level.

Without the benefit of a larger picture, site-specific decisions can fail to address identified concerns and not make the most of limited resources. Setting priorities at the level of a river basin or watershed is useful in developing a broad consensus and applying resources available at a scale appropriate to the problem one wants to address before moving to a site level.

Some landscape level factors to consider in making wetland management decisions are the extent of wetlands relative to historic levels, the need for flood storage, or the abundance of specific habitat types within an ecological unit.

The goal of this section is to apply recent developments in landscape level ecological indicators to local data for the Milwaukee River Basin and to provide examples of how these indicators can inform wetland management decisions.

Subwatersheds

As explained in the Chapter I, wetlands by nature are "between dry land and open water" and so a drainage basin, or hydrologic unit, is the natural unit to examine the role wetlands play in the landscape. For water quality and flood control, this seems obvious. It also applies to plant and wildlife habitat considerations since hydrologic connections are frequent corridors for dispersal and migration.

USGS and other agencies have divided and sub-divided land areas into successively smaller hydrologic units. Table 2 below describes the different levels of hydrologic unit codes or HUCs. State water basin planning has focused on the watershed hydrologic unit. The Milwaukee River Basin drains nearly 900 square miles and is divided into six major watersheds.

Table 2. Hydrologic Unit Comparisons

Interagency Hydrologic Unit	USGS Unit	Level	HUC	Size Range	Example
Region	Region	1	2-digit	???	Great Lakes
Sub-region	Sub-region	2	4-digit		Southwest Lake Michigan
Basin	Accounting Unit	3	6-digit		Southwest Lake Michigan
Sub-basin	Cataloging Unit	4	8-digit		Milwaukee River
Watershed	-	5	10-digit	40,000 – 250,000 acres 62.5 – 390 sq. mi.	North Branch Milwaukee River
Subwatershed	-	6	12-digit	3,000 – 40,000 acres 4.7 – 62.5 sq. miles	Silver Creek

At the local level, watershed units have two limitations. First, most municipal jurisdictions are smaller than a watershed and each overlapping jurisdiction requires greater cooperation and adds a layer of complexity. Secondly, many of the landscape level indicators used to quantify natural resource conditions are based on a unit area: e.g. wetland loss per unit area indicates the need for wetland restoration; more miles of high quality streams per unit area indicates a need to protect existing stream-side wetlands. Where land use in a watershed is homogenous, using the entire watershed as the 'per unit area' basis will result in indicators that reflect actual conditions. Where land use in a watershed is not homogeneous, however, averaging factors such as past wetland loss or impervious cover over the whole watershed results in indicators that do not reflect real conditions. Meaningful indicators require dividing each watershed with inhomogeneous land use into smaller hydrologic units.

Work in other States in the eastern US indicate that subwatersheds equivalent to 12- or 14-digit HUCs (North Carolina Department of Environment and Natural Resources,1999) are sufficient to provide meaningful indicators. This scale is also closer to that of local government planning units. For this study, we divided 5 of the 6 watersheds in the Milwaukee River Basin into 58 subwatersheds ranging from 7 to 41 square miles (Table 3). The Kinnickinnic Watershed was not subdivided further since it is completely urban. The subwatershed delineation process is consistent with the Federal Watershed Boundary Dataset and described in Appendix D of the Processing Appendices.

Table 3. Milwaukee River Basin Watershed Characteristics

Watershed Name	Watershed Area (acres)	Number of Subwatersheds	Subwatershed Size Range (acres)
East and West Branches Milwaukee River	170,241	12	5,048 – 26,512
North Branch Milwaukee River	95,789	10	5,064 – 14,416
Cedar Creek	82,724	10	4,594 – 13,309
Menomonee River	87,115	14	2,963 – 12,372
Milwaukee River South	107,455	12	5,647 – 19,367
Kinnickinnic River	21,344	0	NA

Metrics Tables

The Metrics Tables contain the data by subwatershed used for developing potential ecological indicators. Each subwatershed metric was developed from the Base and Custom Data Layers described in Chapter III and based on several data criteria:

- ✓ Metric coverage is available for most, if not all, of the river basin
- ✓ Metric accuracy is appropriate to the subwatershed scale
- ✓ Metric date is a historic baseline or is periodically updated
- ✓ Metric is related to a landscape level ecological indicator

The Metrics Tables are included in Appendix 2. Individual metrics are described below along with several examples of how they can be used. The process to obtain the summary data from the Base and Custom Data Layers is described in Appendix F of the Processing Appendices.

Using any of the metrics requires an understanding of the Base and Custom Data Layers and the conditions under which a metric is a useful indicator. Metrics at the subwatershed scale are not intended to replace site-specific field based methods where more detail is needed.

Subwatershed Code

A unique code assigned to each subwatershed which is an abbreviation for the Subwatershed Name.

Subwatershed Name

The name assigned to each of the 58 subwatersheds in the Milwaukee River Basin.

Watershed ID

Unique code used to identify the DNR watershed. These codes were adopted for consistency reasons from the source layer obtained through WiDNR Watershed

The name of one of the six watersheds previously delineated by WDNR within the Milwaukee River Basin.

Subwatershed Acres

Area in acres within each subwatershed. Subwatershed Acres can be used to convert other metrics to a 'per unit area' basis for comparison among subwatersheds of different size.

Original Wetland Acres*

Acres of subwatershed area that was originally (pre-settlement) wetland. Original wetland acres are estimated as the area of hydric soils, plus areas of known filled wetland, plus the area that is mapped wetland but which occurs over non-hydric soils types. Values are blank in subwatersheds for which soil data are not avail able. This land was developed prior to the county soil surveys that were conducted in the 1960s.

Percent Original Wetland Acres*

Original wetland acres expressed as a percentage of the subwatershed area. This is a measure of the prevalence of wetlands in the pre-settlement landscape.

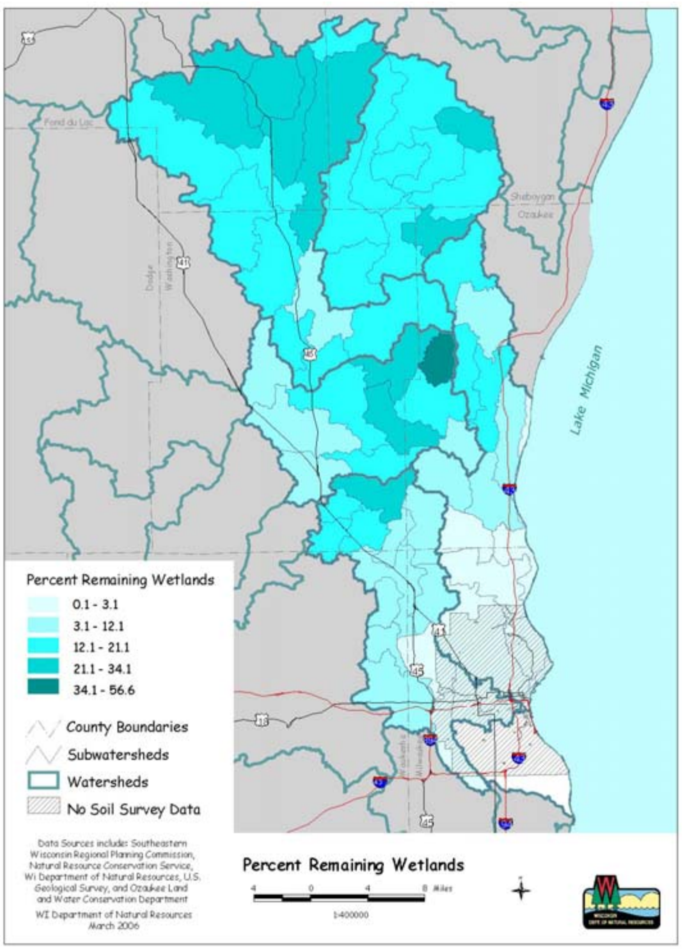


Figure 4. Percent Remaining Wetlands

Remaining Wetland Acres

Remaining Wetland Acres are total wetland acres in each subwatershed based on the Wisconsin Wetland Inventory (DWWI), SEWRPC's 2000 land use mapping and wetlands restorations completed in Ozaukee County through 2001.

Percent Remaining Wetland Acres

Remaining wetland acres expressed as a percentage of the subwatershed area (Figure 4). Studies indicate that streams in subwatersheds with less than six percent of the area in wetlands suffer from frequent flooding and insufficient base flow.

Remaining wetland acres are divided into broad types of wetland plant communities using the Wisconsin Wetland Inventory classification and the Reed Canary Grass Wetlands described below.

Aquatic Bed-Deep Marsh

Submerged or floating-leaved plant communities and emergent plant communities associated with deeper water habitats. All DWWI wetlands in the Aquatic Bed class, and those in the Emergent/Wet Meadow class with L (lake) or W (open water) hydrologic modifiers.

Shallow Marsh

Emergent plant communities with shallow standing water for much of the growing season. All DWWI wetlands in the Emergent/Wet Meadow class with the H (palustrine, standing water) hydrologic modifier.
(photo by Emmet Judziewicz)

Wet Meadow

Wet meadow, wet prairie and sedge meadow plant communities (whether it's RCG or not) All DWWI wetlands in the Emergent/Wet Meadow class with the K (palustrine, wet soil) hydrologic modifier.

Reed Canary Grass

A subset of the Wet Meadow community type, dominated by Reed Canary Grass, based on satellite imagery data.

Wetland Shrub

Shrub lands. In the Milwaukee River Basin these are predominately dogwood and willow shrub carrs. All DWWI wetlands in the Shrub class.

(photo by Emmet Judziewicz)

Wooded Wetland

Broad-leaved and coniferous wooded wetlands, which includes floodplain forests and wooded swamps.
All DWWI wetlands in the Forested class.

Lost Wetland Acres

Original wetland acres within each subwatershed that are no longer wetland. They are estimated as the area of hydric soil that is not mapped as wetland plus areas of known filled wetland on the WWI.Percent Lost Wetland Acres*

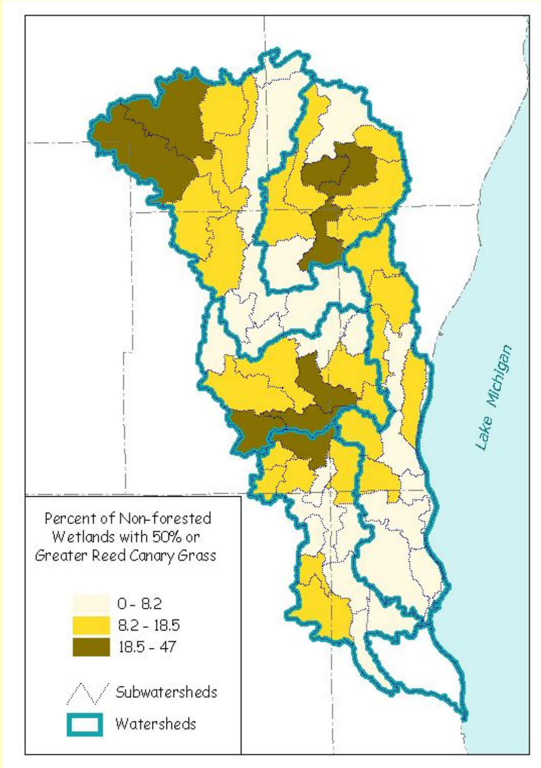
Reed Canary Grass...the extent of an invasive plant species.

This map shows the extent of reed canary grass in the non-forested wetlands in each Subwatershed. Reed canary grass wetlands are important for water quality, but have far less wildlife value than wetlands with more diverse plant communities.

Reed canary grass was mapped within DWWI wetlands using 30m pixel LANDSAT 7 imagery from the summer and fall of 2003. Based on field verification, the accuracy of a supervised classification exceeded 80% for areas where reed canary grass cover exceeded 50%.

The presence of reed canary grass implies a degraded condition and areas in need of restoration or management. Some of these areas may have a viable native plant community below the reed canary grass canopy and so are not necessarily reed canary grass monocultures. The absence of reed canary grass does not imply a condition, since the mapping does not distinguish other vegetation types such as cattail or purple loosestrife.

Two factors limit the mapping accuracy. First, the classification depends on radiation in the near infrared range and so reed canary grass is obscured by open water and woody plant cover. Secondly, the 30m pixel size does not pick up small patches or narrow linear patterns such as those along river corridors.



Percent Lost Wetland Acres

Lost wetland acres expressed as a percentage of subwatershed area.

Potentially Restorable Wetlands (PRWs)

PRWs are areas with hydric soils that are both not Remaining Wetlands, and also have not been converted to an urban land use. Urban land use includes Industrial, Commercial and high or medium density Residential land use codes.

In an early stage of the project, we limited PRWs to areas with hydric soils that are no longer mapped wetland and are in agricultural use. This eliminated undeveloped non-agricultural land, for example, “woodlands” and “unused rural land”. We decided to consider PRWs in all ‘undeveloped’ land to avoid missing some potential restoration sites.

Percent Potentially Restorable Wetlands*

Potentially restorable wetland acres expressed as a percentage of the subwatershed area. Original, Lost and Potentially Restorable Wetland Acres are all lower limits on the actual acres in each class.

The hydric soils needed to estimate Original Wetland Acres are interpreted from NRCS county soil survey data. We know, however, that wetlands occur on other soil types. Even well-drained soils may be wetland if the landscape position is suitable, for example where the water table is close to the surface. Groundwater seep wetlands occur on soils that are highly permeable and sloped.

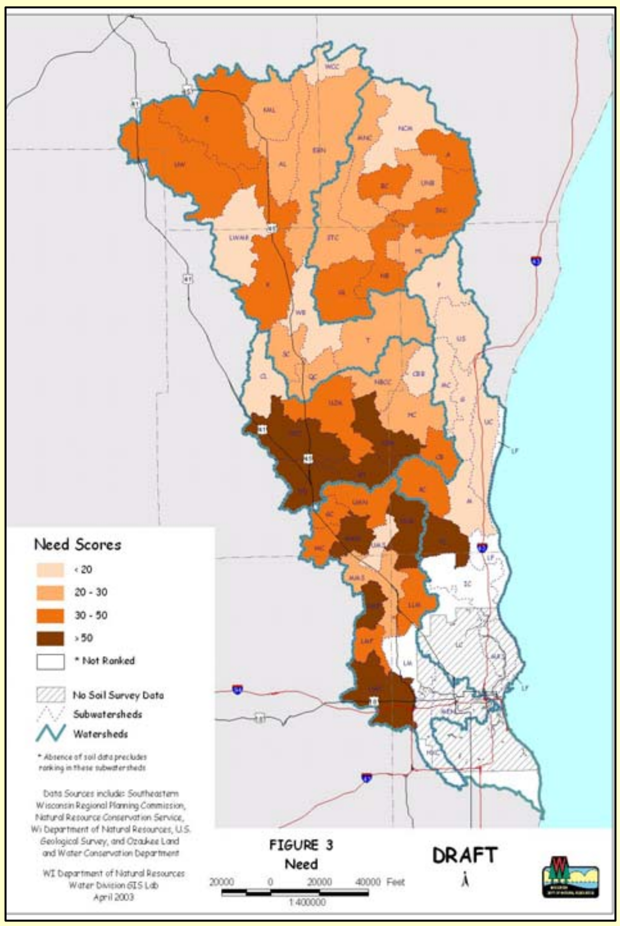
Somewhat poorly drained soils that NRCS does not classify as hydric also may support wetlands in areas with hydric inclusions. For example, Ozaukee silt loam on 0 to 2 percent slopes (OuA) occurs over clay till deposits along Lake Michigan. OuA is not considered a hydric soil, but in topographic depressions, the underlying clay may trap water and allow the formation of hydric soil. These inclusions are soils within a soil map unit that differ from the map unit, and are too small to map separately, but may be up to 25% of the total area. This means that including only soils types (map units) that NRCS considers entirely hydric gives a lower limit on Original, Lost and Potentially Restorable Wetland Acres.

Prioritizing Wetland Restoration . . .

As described in Chapter I, a wetland's type and position in the landscape affect its function. The decision tools described in Chapters . . . consider wetland functions at the site level. To get a general sense of where wetland restoration is needed, at a larger river basin scale, we can consider only wetland acres. The map shows the relative need for wetland restoration throughout the basin based on the following two factors:

- ***The relative amount of wetland lost.*** A subwatershed that has lost more of its original wetland acres has a greater need for restoration than one that has lost less. The relative amount of wetland lost is the ratio of Lost Wetland Acres to Remaining Wetland Acres.
- ***The prevalence of wetlands in the pre-settlement landscape.*** A subwatershed where wetlands played a larger role in natural processes has a greater need for restoration than one where wetlands historically played a minor role. A measure of the role of wetlands in the original landscape is the Percent of Original Wetland Acres.

Priority = Lost Wetland Acres x Percent Original Wetland Acres



Whether or not a soil type has extensive amounts of hydric inclusions depends on both the soil type and the landform where it occurs. NRCS and County soil scientists have identified the soil types and the landscape setting in this region where hydric soil inclusions are likely to form. These soil types are indicated in the BADL (?need to change the reference to the "base layer" since we dropped BADL – Kate?) (see the data dictionary) and so Users who want to consider soil types with hydric inclusions may add them in their own analysis.

Need

Relative score for each subwatershed indicating the priority or need for wetland restoration. Subwatersheds with the highest need score have generally lost the most wetland acres as a percentage of original wetland acres.

Metrics Table B

Stream Miles

Total miles of streams in each subwatershed. This includes waterways mapped on the 24K or 7.5 minute USGS topographic maps, plus

First Order Stream Miles

Total stream miles that are 'first order', that is the waterways furthest upstream, whose water source is from surface runoff and base flow and not other surface water.
First order streams are a measure of the connection between land use and water quality. Local land use has a greater effect on local water where there are a greater proportion of first order streams. Water quality in higher order streams depends to a greater extent on upstream land use.

Ditch Miles

Streams that are ditched or channeled. This includes those waterways that appear as straight line segments on the USGS topographic maps, plus additional drainage ditches interpreted from year 2000 air photos by WDNR or from County waterway records. Ditched waterways increase the efficiency of surface water conveyance. Where ditches drain wetlands the wetland's ability to affect water quality is reduced.

Potential Rehabilitation Wet/ands

Remaining wetland acres that are ditched, dominated by reed canary grass, or indicated as excavated, farmed or grazed on the DWWI.

Protected (and Proposed Protected) Lands

Land acres that are protected by Federal, State, or local governments or private conservation organizations; and areas that are proposed for protection in the Natural Area and Critical Species Habitat Management Plan for Southeast Wisconsin (SEWRPC, 1997).

Contributing private conservation groups are The Nature Conservancy, The Ozaukee-Washington Land Trust, and Cedar Lakes Conservation Foundation.

Protected lands maybe used to identify core habitat blocks where additional restoration can increase core habitat size or connect habitat fragments.

Road Miles

U.S. Census Bureau, 01/01/2000, Wisconsin 2000 Roads: 2000 TIGER line files, Office of Land Information Services, Wisconsin Department of Administration, Madison, WI.

Road Density

Miles of road length per square mile of subwatershed area.
Studies have established road density as a surrogate indicator of surface water quality and habitat fragmentation.

Impervious Cover

Impervious cover was estimated for each land use code my measuring actual impervious acres within a random sample of that land use in the Milwaukee River Basin and then extrapolating to the entire Basin. Measured percent impervious cover for each land use code is listed in Appendix ?.

Impervious cover is well established as an indicator of surface water quality.

Land Use

Land use categories, established by SEWRPC and explained in Appendix ? , are grouped into broad land use classes as a percentage of each subwatershed area to simplify analyses. Metric Table B includes the following classes:

Percent Urban/Developed

Includes urban and rural residential, commercial, industrial, government, transportation and utility land uses (SEWRPC 100 – 700 series)

Percent Agricultural Land Use

Includes pasture land, row and specialty crops
(SEWRPC 800 series)

Percent Natural and Open Space Land Use

Includes woodlands, wetlands, parks and recreational lands
(SEWRPC 900 series)

References For Chapter IV

Arkansan Multi-Agency Wetland Planning Team, The Standard GIS Methodology for Wetland Analysis

Bedford, B.L. 1999. Cumulative effects on wetland landscapes: links to wetland restoration in the United States and Canada. Wetlands, Vol. 19, No 4, 775-788.

Bernthal, T. W. and K. G. Willis. 2004. Using LANDSAT 7 imagery to map invasive reed canary grass (Phalaris arundinacea): A landscape level wetland monitoring methodology. Final Report to the U.S. Environmental Protection Agency Region V. Wisconsin Department of Natural Resources PUB-SS-992 2004, 72 pp.

Center for Watershed Protection. 2003. Impacts of Impervious Cover on aquatic Systems. Watershed Protection Research Monograph No. 1. Center for Watershed Protection, Ellicott City, MD.

Federal Geographic Data Committee. 2002. Federal Standards for Delineation of Hydrologic Unit Boundaries, Version 1.0, March 1, 2002. 52 pp.

Gatti, R. . . . .1997. Influences of Watershed Land Use.

Gersib, R. 1997. Restoring Wetlands at a River Basin Scale. Washington State Department of Ecology Pub No 97-99.

North Carolina Department of Environment and Natural Resources. 1999. NC-CREWS: North Carolina Coastal Region Evaluation of Wetland Significance – A Report of the Strategic Plan for Improving Coastal Management in North Carolina.

Poiani, K.A., B.L. Bedford and M. D. Merrill. 1996. A GIS-based index for relating landscape characteristics to potential nitrogen leaching to wetlands. Landscape Ecology 11:237-255.

Preston, E.M. and B. L. Bedford. 1988. Evaluating cumulative effects on wetland functions: a conceptual review and generic framework. Environmental Management 12:565-83.

RiverLink. 2000. GIS Management Models to Assist Wetland Restoration Efforts in Buncombe and Haywood Counties, North Carolina. Pigeon River Fund. 85 pp.

Tiner, R. W. 2004. Remotely-sensed indicators for monitoring the general condition of “natural habitat” in watersheds: an application for Delaware’s Nanticoke River Watershed. Ecological Indicators 4, 227-243.

Trombulak, S.C. and C.A. Frissell. 2000. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology, Vol 14, No 1 pp 18-30.

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams. Fisheries, Vol 22 No. 6 p 6-12

Wang, L., J. Lyons and P. Kanehl. 2001. Impacts of Urbanization on Stream Habitat and Fish across multiple spatial scales. Environmental Management 28:2, pp. 255-66.

Wang, L., J. Lyons and P. Kanehl. 2003. Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota. Trans. Amer. Fisheries Society 132:825-839.

Zielinski, J. 2002. Watershed Vulnerability Analysis. Center for Watershed Protection, Ellicott City, MD, 22 pp.

Hey, D.L. and J. Wickencamp. 1998. Some Hydrologic Effects of Wetlands. IN: Water Resources in the Urban Environment: Proceedings of the 25th Annual Conference on Water Resources Planning and Management – June 1998. American Society of Civil Engineering.

WDNR WWI classification scheme brochure

Chapter V: Wildlife Habitat Decision Support Tool

Why Wildlife?

Wetland restoration and protection have traditionally been driven primarily for flood abatement and for improving water quality, and secondarily for wildlife value. Many communities have made large investments in flood abatement and water quality modeling, and these wetland functions are well studied and accepted. Recognizing the wildlife value of wetlands has generally been approached backwards – that is, existing green space is mapped and wildlife using it are then recognized. This piggybacks a wildlife value onto parcels that are already recognized for other reasons (usually flood abatement and water quality, sometimes agriculture or parks). Rarely is wildlife habitat a primary reason for preserving green space (an exception is where endangered species critical habitat is recognized).

Delegating wildlife habitat needs to a secondary position has some foreseeable consequences. Since the critical habitat needs of wildlife only partially coincides with the criteria important for flood abatement and for improving water quality, in developing landscapes where wildlife needs are not considered in land use planning we can expect wildlife to decline, and perhaps disappear. Since different species have different habitat requirements, we can expect species with habitat needs not met by land use planning criteria to be most impacted, while species whose habitat needs are met by land use planning criteria should persist. For example, raccoons (a generalist, adaptable species) meet all their needs in typical rural and suburban landscapes, and their numbers are increasing. Scarlet tanagers and spotted salamanders, which require fairly large patches of mature forest, are declining. A recent analysis of Milwaukee County flora and fauna (Leitner et al., in review) documented species losses of 44 percent for amphibians, 47 percent for reptiles, 36 percent for breeding birds, and 37 percent for flora since settlement. Clearly, wildlife needs have not been met by Milwaukee County land use planning, and continuing losses are predicted (*op cit).*

Given the pace of development in the Milwaukee River Basin, land use planning decisions made by the current generation will dictate what kinds of wildlife can survive for future generations to enjoy. At risk are many familiar species, such as ducks and frogs, which enjoy overwhelming support for preservation by the public. Therefore, recognizing their habitat needs, and planning for them, is needed. Our decision support tools include a wildlife element to assist communities in preserving their native wildlife through planning that accounts for the actual needs of wildlife. This direct approach recognizes that wildlife habitat needs are complex, and that upland as well as wetland habitats are required, with proper spatial connectivity.

Our wildlife tool allows a planner to score potential restoration sites for wildlife value based on existing land conditions. This should assist in preserving wildlife on the landscape, and identifying areas with high wildlife restoration and preservation potential, as well as areas where wildlife is expected to be lost. Even where wildlife value is not a primary objective in land use and wetland restoration planning, our tool allows restoration sites to be chosen for maximum benefit to wildlife where other considerations are equal, and we encourage its use in this manner.

Only by proper planning for wildlife needs can a community expect future generations to have the opportunities to do things like catch a treefrog, watch a wood duck feeding, or see a turtle nesting. Having these opportunities preserved within neighborhoods, rather than delegated to parks many miles away, has many benefits for human health and well being, and is simply good stewardship of our natural resources. Such planning is also a proactive solution to "nature-deficit disorder", a condition recognized from studies showing that interaction with nature is essential to the development of mental, physical and spiritual health in children, and to the maintenance of these qualities in adults (Louv 2005). A disconnect from, and lack of appreciation for, nature has also been cited as a major obstacle to recruiting new hunters from today's youth (Nelson 2006).

Approach

Prior to developing the wildlife decision support tool, we evaluated two different approaches for providing information for decision making when considering planning for wildlife habitat preservation and restoration. Below is a brief discussion of each approach along with the rationale for not moving the ideas forward.

Degree of Change

The first tool we evaluated was a system for determining which potentially restorable wetlands would provide the "most bang for the buck" for increasing core wildlife habitat. The approach was to first determine the areas on the landscape that were existing wildlife habitat. Generally these areas were wetlands, forests, grasslands, open water and shrublands (Figure 5). The Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) is a consortium of government and private organizations formed in 1993 to promote development of digital geographic data for the state. WISCLAND Land Cover data layer provided the base for Existing Habitat as well as defining the minimum resolution for new grids. Each cell represents a 30-meter square, or an on-the-ground area of 900 square meters. "Suitable habitat" classes from WISCLAND include Grassland (Level 1 = 150), all Forest classes (Level 1 = 160), Open Water (Level 1 = 200), all Wetland classes (Level 1 = 210), and Shrubland (Level 1 = 250). "Unsuitable habitat" classes are Agriculture, Urban/Developed, Barren, and Cloud Cover.

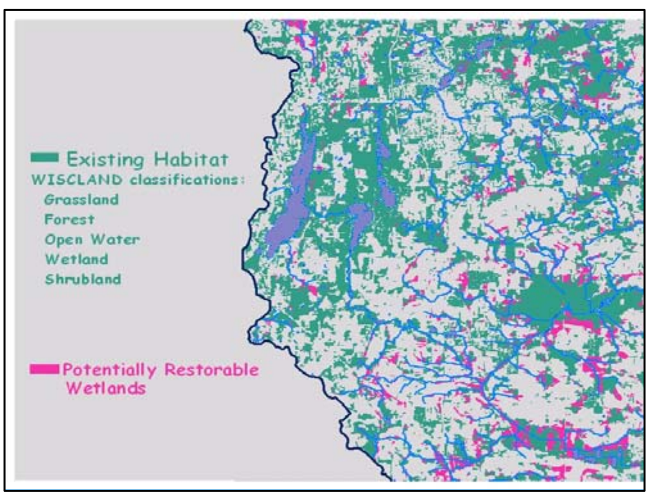


Figure 5. Existing and Potentially Restorable Habitat

The tool attempts to characterize the degree of change that occurs when new habitat is added to existing habitat areas through wetland restoration. The goal is to provide a coarse, first cut, identification of project areas where wetland restoration will result in maximum "habitat change." The tool can also provide a coarse means of evaluating the impacts of loss of habitat. It provides a way to analyze the pattern of existing habitat and evaluate the degree to which individual restoration opportunities add to, or conversion to non-habitat subtracts from, blocks of habitat. It does not attempt to evaluate the quality of existing habitat, but indirectly gets at the issues of fragmentation and juxtaposition, by considering the "habitat surroundedness" of each location on the landscape (each 30 m cell in the WISCLAND land cover map is analyzed separately). It treats open water, wetland and upland habitat the same by simplifying the landscape into "habitat" and "non-habitat."

Existing habitat is classified based on whether it is CORE (surrounded by 80 - 100% habitat), MATRIX (surrounded by 50 - 79% mixture of habitat and non-habitat), EDGE (surrounded by 20 - 49% habitat), and NON_HABITAT (surrounded by less than 20% habitat). The model uses a Nearest Neighbor function for this step that classifies the amount of habitat and non-habitat in the 48 cells (3 cells in each direction around a central cell creates a rectangular grid) surrounding each 30 m cell.

The same process is used to classify the landscape after all potentially restorable wetland sites are converted to wetland. The degree of change between the first classification and the second classification highlights areas of significant improvement after new sites are added. Although it is obviously not possible to restore all sites, the analysis makes this assumption in order to show the ranking of restoration opportunities relative to each other.

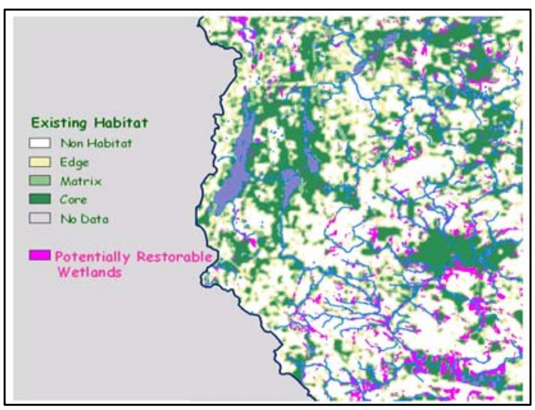


Figure 6. Habitat Classification

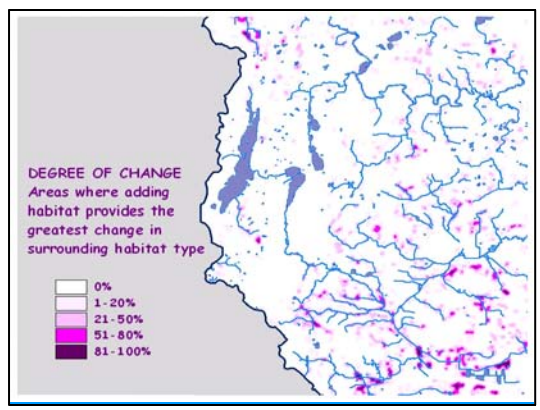


Figure 7. Degree of Change

It should also be possible to do the same "before and after" analysis based on various scenarios of land development resulting in losses of habitat, and based on various, more realistic wetland restoration alternatives.

These existing areas were then evaluated to determine the extent of edge, matrix and core habitat each area contained (Figure 6). Once the existing areas were coded for wildlife habitat type, they were evaluated along with the potentially restorable wetlands to come up with a "degree of change" measurement (Figure 7). The assumption here was that the most significant PRWs provided the greatest change in surrounding habitat type, such as increasing core and matrix habitat.

The advantage to using this approach was that it was relatively easy to determine the PRWs that would significantly add to the existing habitat blocks. This assumes that bigger is better for wildlife habitat. The main drawback to using this approach is that it only uses habitat patch size as the main criterion for selection. There is no way to evaluate the suitability of the habitat for different species of interest.

Taking Wildlife Habitat Context Into Account

The second tool initially evaluated was one developed for the USGS for evaluating suitability of existing habitat for selected wildlife species of interest. This uses a matrix approach, whereby one determines the optimal habitat size and type for particular species. Habitat types are determined and ranked according to the suitability for the species (Table 4). Once all species of interest and their habitat requirements are entered into the matrix, the existing habitat is evaluated to determine the extent to which species are most likely to occur there (Figure 8).

Table 4. Habitat Suitability Rank for Species

Species	Grass-sm <80	Grass-Lgn >80	Forest-sm <100	Forest-lg >100	Open Water	Wet-E-sm <20A	Wet-E-Ig 20-99A	Wet-E-vlg >100A
Virginia Rail	1	1	0	0	1	2	3	3
Blue-winged teal	2	3	0	0	2	1	2	3
Sedge wren	1	3	0	0	0	1	2	3
Woodcock	2	3	2	3	0	1	2	3
Eastern Gray Treefrog	1	1	3	3	0	2	2	2
American Redstart	0	0	2	3	0	0	0	0
All Migrating Birds	1	2	2	3	2	2	2	3

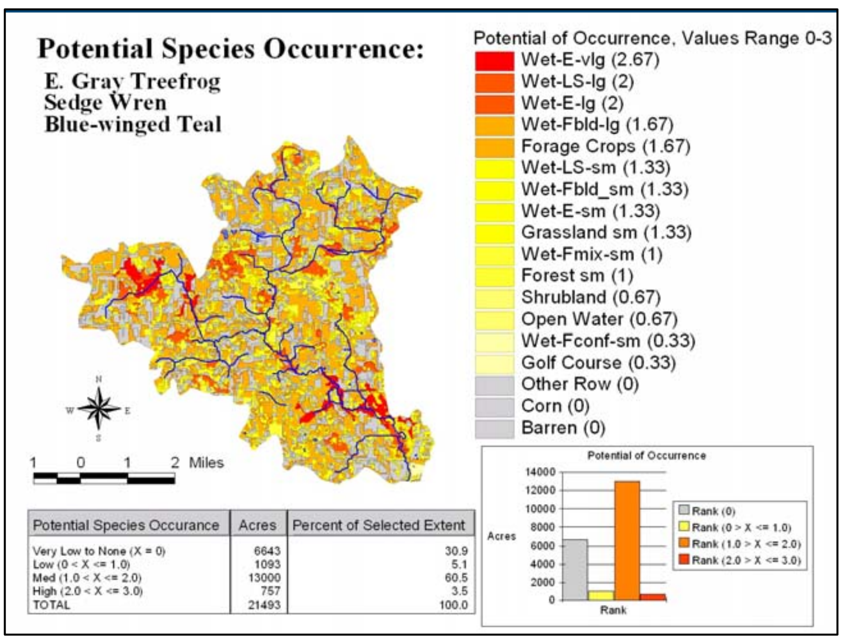


Figure 8. Potential Species Occurrence

The advantages to using this approach are that the habitat requirements of the species of interest are used to generate an analysis of existing habitat. The main disadvantage of this tool is that it lacked flexibility. For instance as discussed below, it does not give the user the ability to determine the relative importance of different habitat types proximal to each other that benefit a particular species.

Development of the Existing Wildlife Decision Support Tool

After evaluating the tools described above, we determined that we would like to develop a tool that builds on the advantages of the two earlier approaches, yet remains flexible to the needs of a diversity of users. We first assembled a group of wildlife experts for the Milwaukee River Basin to provide guidance for tool development. The group consisted of a diversity of scientists that are considered experts in the occurrence of amphibians, reptiles, mammals and birds within the Milwaukee River Basin (see Table ? for matrix only, Appendix 3, page ?? full matrix with explanatory text) for expert membership and affiliations).

The expert group developed an extensive wildlife matrix (see?) for representative species and specific wetland habitats. "Umbrella" species were selected to represent suites of species with shared habitat requirements. The umbrella species concept is based on the idea that conserving certain species will confer a protective "umbrella" to co-occurring species due to shared habitat requirements (Launer & Murphy 1993, Lambeck, 1997). This assumes that if the resource requirements of an umbrella species are met, the requirements of many other species also will be satisfied (Fleishman et al., 2001). Theoretically, management decisions based primarily on the umbrella species will automatically satisfy the needs of other species as well. This approach was developed as a potentially more efficient means to manage ecosystems and abate biodiversity losses by focusing efforts and resources on single species, which may be more easily understood, and better funded and supported, than would more far reaching proposals to protect entire communities.

Umbrella Species

There is broad consensus on the need to focus conservation efforts on the community level, and the umbrella species concept is one way to achieve this. Key to this approach is identifying appropriate umbrella species, the preservation of which will actually convey preservation to a large number of other species as well. Empirical validation that putative umbrella species protect many co-occurring species is rare, but is supported in some cases (Fleishman et al. 2001). Protecting species with large area requirements is not necessarily a good umbrella choice, as area may be only one parameter influencing the integrity of the habitat being considered (Roberge & Angelstam 2004). Selecting multiple umbrella species specific to each taxonomic group (as we do here) is better supported for achieving real conservation (Fleishman et al. 2001, Roberge & Angelstam 2004). Priority should be given to those species whose habitat requirements are similar to, and preferably broader than, all species whose conservation is desired (such as locally endangered or threatened species, or wetland species). The ideal umbrella species would be well studied and its habitat and management requirements well known. Other target species are typically rare, and their habitat and management requirements are not well known. Umbrella species should be sensitive enough to habitat destruction or fragmentation, weed or pest invasion, or other threats, that they can be used to define the minimum acceptable level at which that threat can occur.

Since many of the relevant habitat and management requirements for rarer species are still poorly known, it is important to monitor and test the effectiveness of conservation efforts. It is doubtful that any umbrella species concept model will achieve comprehensive protection of all species within an area. However, when properly selected and validated, umbrella species models may be very useful in directing conservation efforts towards target species suites. We apply it here to limited taxonomic and habitat suites, with validation tests. The umbrella species concept is most useful when coupled with adaptive management conservation efforts that incorporate other strategies for long-term protection of ecosystems.

Table 5. Wildlife Matrix.

MRB Wetland Wildlife Habitat Matrix

Wetland Habitat Context (*umbrella species*)	Land CoverType: Urban/Developed	Grassland	Forest	Cultivated Lands	Surface Water	Open Water Wetlands	Aquatic Bed/Deep Marsh	Shallow Marsh <=5 ac	Shallow Marsh > 5 ac	Wetland Meadow	Wetland Forest broad lvd	Wetland Forest coniferous	Wetland Forest mixed	Wetland Shrub	Reed canarygrass >50%	PROXIMITY FACTORS
Open Water (*Black Tern, Pied-billed Grebe*)	0	0	0	0	1	3	3	1	2	0	0	0	0	0	0	Open water wetlands included only if within 10 m of at least 5 acres of Aquatic Bed/Deep Marsh or Shallow Marsh.
Shallow Marsh (*American Bittern Sora*)	0	0	0	0	0	0	2	3	3	2	0	0	0	1	0	Include reed canary grass if the stand is adjacent(within 10 m) to "2" or "3" wetland types.
Watery Wetland near Grassland (*Blue-winged Teal*)	0	2	0	0	1	3	3	3	3	3	1	0	0	1	1	"2" or "3" wetland types larger than 0.5 acres and within 10 m of grassland & grassland within 10 m of the "2" or "3" wetland types and extending for 300 ft (100 m) from the wetland.
Wet Meadow (*Sedge Wren*)	0	2	0	0	0	0	0	2	2	3	0	0	0	1	1	Shallow marsh included only if within 10 m of the other "2" or "3" wetland types, and mesic grassland adjacent to "2" or "3" wetland types.
Wet Shrub (*Alder / Willow Flycatcher*)	0	0	0	0	0	0	0	0	0	2	0	0	0	3	0	Wetland meadow included only if within 10 m of wetland shrub type & the obverse.
Wet Forest, Coniferous or Mixed (*Veery, Black-and-White Warbler*)	0	0	2	0	0	0	0	0	0	0	2	3	3	2	0	Uplands within 100 m of wetlands and the obverse.
Wet Forest, Deciduous (*American Redstart, Blue-gray Gnatcatcher*)	0	0	2	0	0	0	0	0	0	0	3	1	2	0	0	Uplands within 100 m of wetlands and the obverse.
Deep Marsh and Shallow Marsh (*Muskrat*)	0	1	1	1	1	3	3	2	3	1	1	0	0	1	0	None
Wet Meadow / Grassland (*Meadow Vole*)	0	3	1	1	0	0	0	1	1	3	1	0	0	1	0	None
Wet Forests (*Masked Shrew*)	0	2	3	0	0	0	0	1	1	3	3	3	3	2	0	None
Open Wetlands near Grassland (*Chorus Frog*)	0	3	1	0	0	0	2	3	3	3	1	1	1	2	2	"2" or "3" wetland types larger than 0.5 acre and within 10 m of grassland & grassland over 0.5 acres extending for 1000 ft (300 m) of "2" and "3" wetland types.
Wetlands near Woodlands (*Wood Frog*)	0	1	3	0	0	1	2	3	3	3	3	2	3	3	0	"2" or "3" wetland types larger than 0.5 acre and within 10 m of upland forest & upland forest over 0.5 acres extending for 1000 ft (300 m) of "2" and "3" wetland types.
Wetland/Upland Complex (*Blanding's Turtle*)	0	3	3	1	1	2	3	3	3	2	3	2	3	3	1	"2" or "3" wetland types larger than 0.5 acre within 15 m of "2" and "3" uplands & the obverse within a travel distance of 1000 ft.

For instance, habitat requirements for wood frogs (wetlands near woodlands) are also critical for blue-spotted salamanders, tiger salamanders, American toads, spring peepers, and several other species. The matrix includes all land cover types considered valuable for wildlife habitat, ranked by size. The experts determined that it was not sufficient to only look at the wetland requirements of the umbrella species. Many species require upland and wetland cover types within close proximity to each other in order to satisfy their life history requirements. For instance, Blanding's turtles require connected nesting, over-wintering, and summer foraging habitats. Therefore a complex of multiple wetland and upland types is more important than any specific wetland type. Within the matrix, the different land cover types were ranked from 0 to 3 for each umbrella species associated with a particular wetland habitat context. A score of 0 means that the habitat is not used or is incidental to species requirements. A 1 indicates infrequent use, 2 frequent use, and 3 is required habitat. The expert group identified thirteen different wetland habitat types with one to two umbrella species representing each type. Fifteen land cover types were identified and scored for these umbrella species. Scoring was determined from known habitat requirements for each species, based on the literature, supplemented with the expert panels first hand knowledge of local habitat use.

Once the matrix was established, the next step was to use GIS technology to evaluate the existing wetland and upland habitat based on the proximity factors identified by the wildlife expert group. The full documentation for the GIS based proximity analysis is provided in Appendix 3 (page 103). Proximity factors were not required for the three mammal umbrella species. For some species patch size was also an important. For instance, wood frogs breed in ephemeral wetlands adjacent to suitable forest habitat, which support their terrestrial habitat needs. Studies have shown that many of the species represented by the wood frog umbrella have core terrestrial habitat activity ranges extending up to 290 m from the breeding wetlands (Semlitsch & Bodie 2003). Therefore, species represented by the wood frog umbrella require upland forests within 300 m of suitable wetlands.

Following are some examples of proximity analysis for the wood frog umbrella species within the Cedar Creek Watershed. Figure 9 shows all the wetland types that wood frogs would either require or use frequently. This is only based on wetland and upland types, not proximity of these cover types to each other. Figure 10 shows the wood frog habitat (upland and wetland in dark colors) after proximity analysis. The lighter colors displayed are those that do not meet the proximity criteria. Figure 11 shows the final results of the proximity analysis, with the predicted species distribution after the areas failing the proximity criteria are removed. This result can be further combined with the areas considered potentially restorable wetlands (Figure 12). This information may then be used to determine the best areas to preserve or restore this wetland habitat type (wetlands near woodlands).

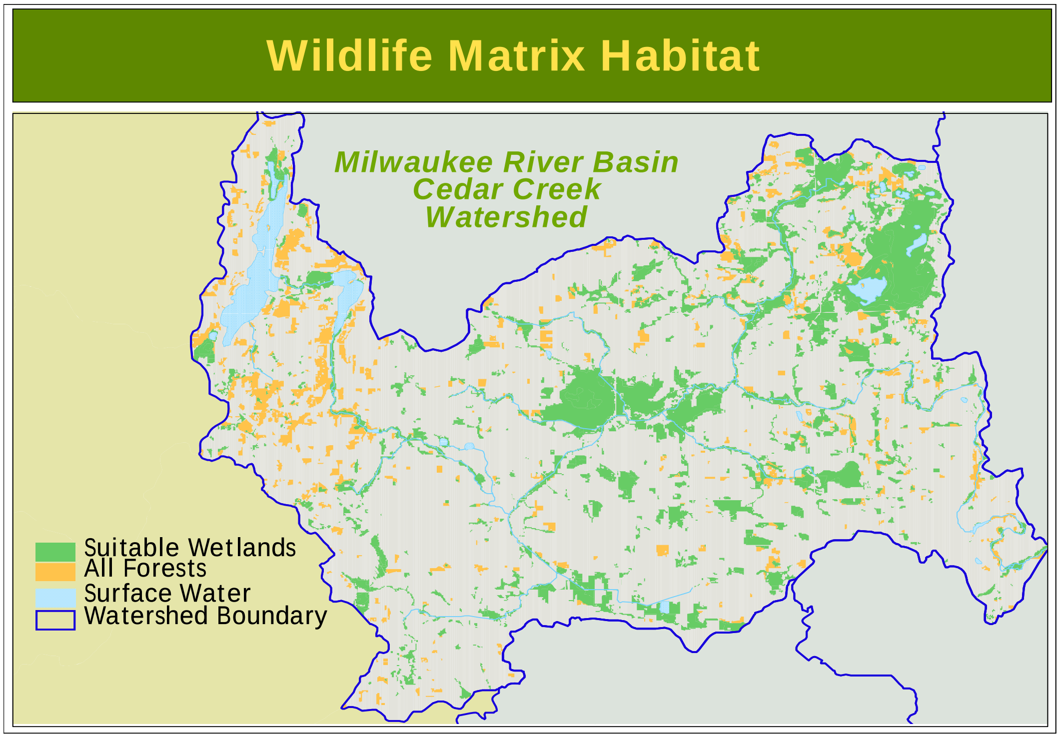


Figure 9. All Potential Wood Frog Wetlands

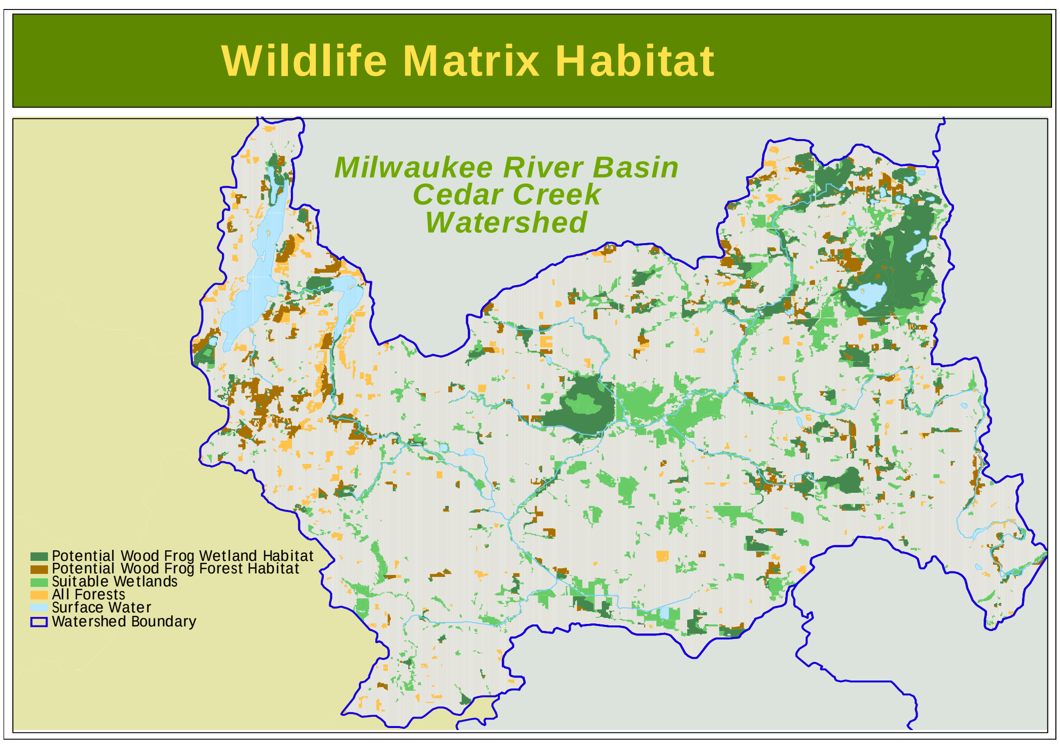


Figure 10. Wetlands Selected from Proximity as Subset of all Wetlands.

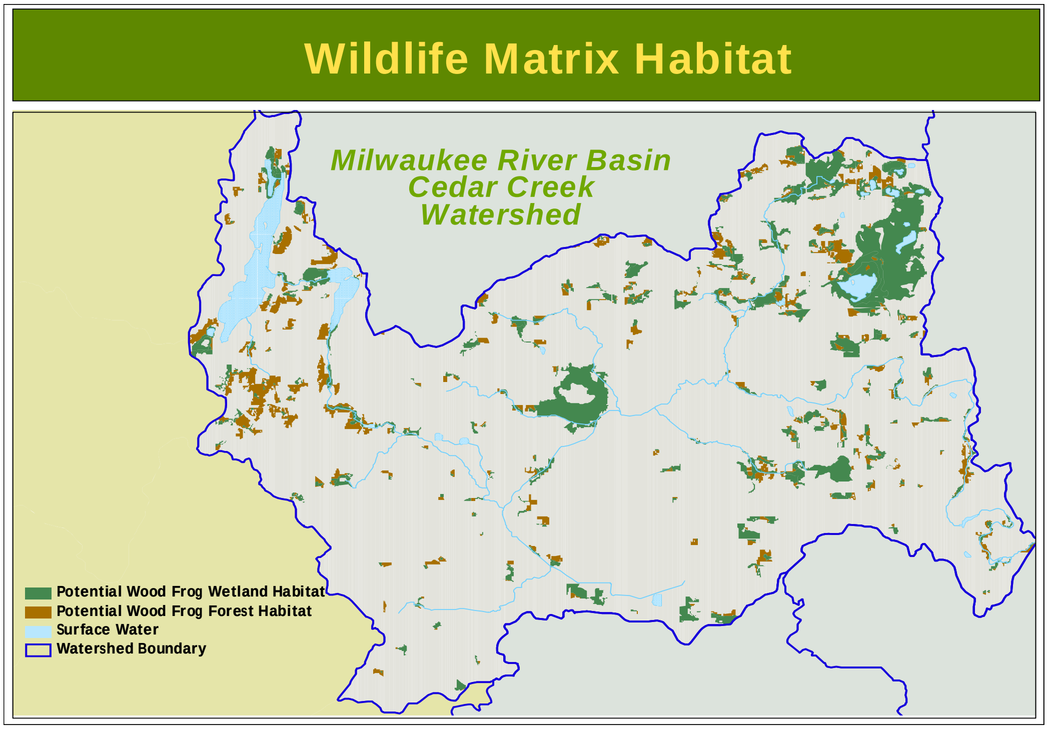


Figure 11. Final Proximity Result for Wood Frog Umbrella.

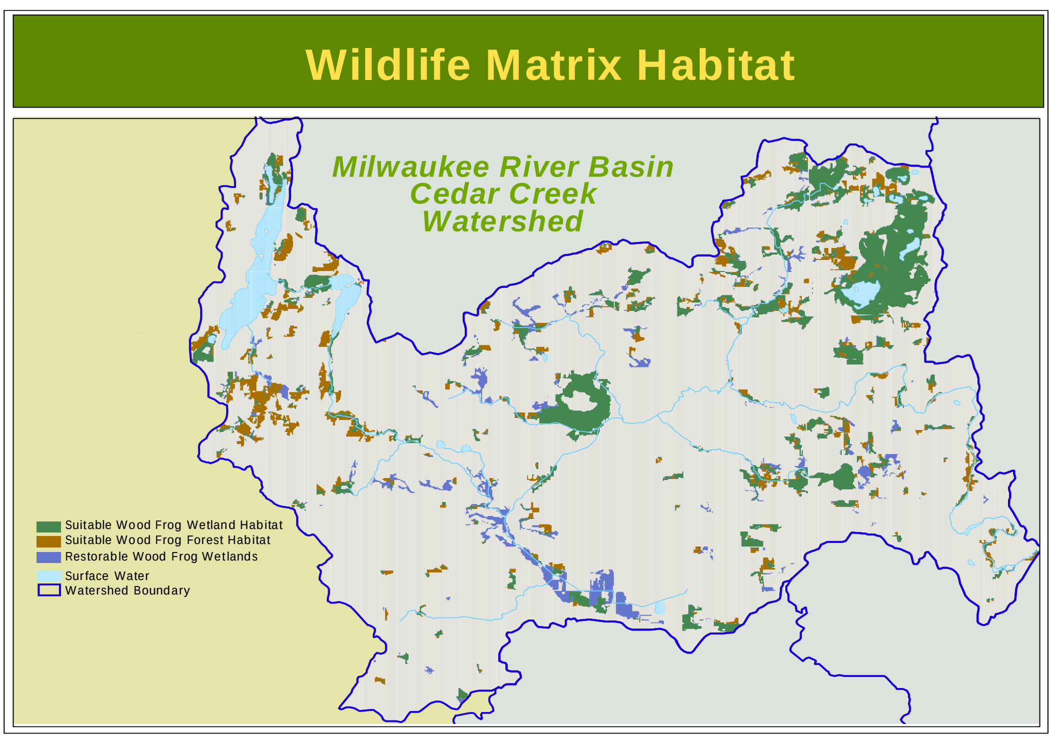


Figure 12. Wood Frog Wetlands with Potentially Restorable.

WILDLIFE TOOL TESTING

We tested the success of our wildlife tool by using independent data sets of occurrence for the umbrella species. We mapped data from the Wisconsin Herp Atlas (Milwaukee Public Museum), the Wisconsin Frog and Toad Survey (Wisconsin Department of Natural Resources), and personal observations from two of the wildlife experts. To reduce possible errors from changing land use, no data older than 1970 were used.

A simple capture test can determine how many of the known species locations are "captured" by the suitable habitat model; that is, they fall within predicted suitable habitat. The Herp Atlas data represent species observations or collection sites, , which were treated as points of known occurrence for capture tests. The calling survey records are points from which a species was heard calling, and therefore represent circles within which the species is known to occur, but it may not physically occupy the entire circle (in fact, it rarely does, since most circles will include roads). A radius representing the effective detection limit of the call defines the circle. For this exercise, we used 1000 ft (300m) as the effective call detection limit. Since frogs only call from breeding wetlands (not uplands), only suitable wetland habitat predicted by the model was used in capture tests. The result is a calculation of how many known calling records are within 1000 ft of predicted suitable wetland habitat.

To test for significance, we treated the study area as either suitable or non-suitable habitat based on the model predictions. For the wood and chorus frogs, only suitable wetland habitat was used, because the independent data set was predicated on calling frogs, which only call from wetlands. The frequency of suitable habitat area relative to the total study area (Milwaukee River Basin), based on the model predications, was calculated. Our null hypothesis was that this actual frequency distribution (equal to the average frequency distribution from an infinite number of random area subsets) did not differ from a subset of actual species observations. We used independent observation data to make sample observation sets of circular polygons with a 1000 ft radius. We performed tests of independence on the frequency of the habitat suitability distribution within these polygons to see if they significantly differed from the expected (actual) frequencies, using chi-square and g-tests on frequency tabulations made in ArcView Spatial Analyst (version 3.2, ESRI, Inc.; see Casper 2003 for more detailed statistical method discussion).

Wood frog tests

For the wood frog observation data set, the predicted suitable habitat (upland and wetland combined) captured 8 of 12 records (66.7%). For the wood frog calling survey data set, the predicted suitable habitat (wetland only) captured (i.e. was within 1000 feet of) 41 of 55 records (74.5%). Combining the two data sets (treating the observation data with a 1000 ft. buffer and using only predicted suitable wetlands), captures 51 of 67 records (76.1%). These capture rates provide high confidence in the predictive ability of the tool.

For wood frog tests of independence, only suitable wetland habitat data were used, because the observation data set was predicated on calling frogs, which only call from wetlands. For our tool, the suitable wood frog wetland habitat occupies 7.03% of the total study area (Milwaukee River Basin). The frequency of suitable wood frog habitat in our wood frog observation data set was 20.98% (Table 6). Therefore these actual wood frog occurrences were highly associated with the suitable wetland habitat predicated in the tool (P<0000,df 1).

Table 6. Tool Accuracy Assessment for Wood Frog Habitat

Study area	Acres	Expected Frequency	Expected Count (where N = 67)	Observed Count (where each polygon = 1)	Observed Frequency
Suitable Wetland Area	39694.6200	0.0703	4.7095	14.0586	0.2098
Non-Suitable Area	525018.3900	0.9297	62.2905	52.9414	0.7902
Total	564713.0100	1.000	67.0000	67.0000	1.000

Chorus frog tests

For the chorus frog observation data set, the predicated suitable habitat (wetland only) captured 21 of 63 records (33.33%). Using suitable uplands as well captures only 4 more records (25 of 63 records or 39.68%). For the tests of independence, the tool predicted that the suitable chorus frog wetland habitat occupies 1.52% of the total study area (Milwaukee River Basin). The frequency of suitable chorus frog wetland habitat in our observation data set was 3.68% (Table 7). There was no significant association between actual chorus frog occurrences and the suitable wetland habitat predicted by the tool (P=0.1628, df 1).

Table 7. Tool Accuracy Assessment for Chorus Frog Habitat

Study area	Acres	Expected Frequency	Expected Count (where N = 67)	Observed Count (where each polygon = 1)	Observed Frequency
Suitable Wetland Area	8599.8600	0.0152	0.9594	2.3162	0.0368
Non-Suitable Area	556113.3400	0.9848	62.0406	60.68384	0.9632
Total	564713.2000	1.000	63.0000	63.0000	1.000

To address possible error in the land use layer, such as unmapped wetlands, we dropped those chorus frog records from the analysis that were not within 1000 ft of any mapped wetland. Since frogs only call from wetlands, such discrepancy indicates an unmapped wetland was present, and the tool would have no chance of predicting these occurrences. This new observation set contained 59 records. All four records thus excluded were examined and wetlands were actually indicated from orthophotography and topographic maps. This changed capture rates to 25 of 59 records (42.37%), and frequency of suitable chorus frog wetland habitat in the observation data set to 3.93%. This did not substantially improve the significance of the association between actual chorus frog occurrences and the suitable wetland habitat predicted in the tool (P=0.1318, df 1).

Blanding's turtle tests

The initial capture analysis treated Blanding's turtle observations as points, since turtles were actually observed. The predicted suitable habitat (upland and wetland combined) captured 37 of 48 records (77.1%). Since several of these records were from roads, with turtles obviously in transit between suitable habitat patches, it makes sense to apply a capture buffer in this exercise. With a 500 foot buffer, an additional 10 records are captured (47 of 48 records, 97.9%). Upon examination, the one record not captured was a result of errors in the land use data (unmapped wetlands at Schlitz Audubon Center, Milwaukee County). Dropping this record from the analysis results in a 100% capture rate. These capture rates provide high confidence in the tool predictions.

For Blanding's turtle tests of independence, both suitable upland and wetland habitat areas were used, since detection was not constrained to a particular habitat as with calling frogs. For consistency with the frog analyses, a 1000 ft radius buffer around each observation point was again used, and the habitat class proportions within these polygons compared to the actual (random) distribution of predicted suitable habitat classes. The Schlitz Audubon Center record was not used. For our tool, the suitable Blanding's turtle habitat occupies 15.19% of the total study area (Milwaukee River Basin). The frequency of suitable habitat in our Blanding's turtle observation data set was 67.71% (Table 8). Therefore, these actual Blanding's turtle occurrences were highly associated with the suitable habitat predicted by the tool ($P<0.0000$, df 1).

Table 8. Tool Accuracy Assessment for Blandings Turtle Habitat

Study area	Acres	Expected Frequency	Expected Count (where N = 67)	Observed Count (where each polygon = 1)	Observed Frequency
Suitable Wetland Area	85804.4400	0.1513	7.1413	31.8230	0.6771
Non-Suitable Area	478908.2700	0.8481	39.8587	15.1770	0.3229
Total	564712.7100	1.000	47.0000	47.0000	1.000

TOOL TESTING DISCUSSION

Highly significant associations between species observations and suitable habitat predicted by the tool can mean that the tool over estimates species distribution. Insignificant associations indicate that the tool is underestimating the species distribution, or that habitat parameters are inappropriate. Repeated testing of tools against independent species data sets helps to identify such errors, and adjusting tool parameters may improve results. We recommend such testing and adjustment when choosing umbrella species and tool parameters.

Our results indicate that our species expert team developed useful tool parameters to indicate wildlife value for woodland associated wetland wildlife species (wood frog umbrella), and wetland wildlife species with complex habitat needs (Blanding's turtle umbrella). We believe the grassland wildlife habitat tool is similarly useful, however, our association tests indicate that chorus frog distribution does not fit the tool parameters well, and perhaps is not an ideal umbrella species. Chorus frogs are known to call from roadside ditches, and other ephemeral depressions that are often not mapped as wetlands, or are small inclusions within wetlands mapped as different wetland types (for example, an ephemeral grassy pool at the edge of a wooded swamp). Nevertheless, we believe that the grassland wildlife parameters inputted to the tool are credible, and encourage further testing against other grassland wildlife species distributions. We also recommend considering the availability of independent species distribution data sets when choosing an umbrella species for tool development. The ideal umbrella species should closely fit a set of available relevant parameters in the land use data sets, while also representing typical habitat needs for a suite of similarly dependent species.

It is important to understand that not all habitat predicted by the tool will actually be occupied by each species in a habitat suite (or even by the umbrella species), because of many other factors determining wildlife distribution. These include colonization likelihood, other species interactions (competitive and dependent), additional habitat requirements, and habitat size, quality and connectivity. For example, while the Blanding's turtle habitat predicted by the tool is extensive, available observations of this species only coincide with approximately 9,634 of the 85,804 acres of the potential habitat predicted by the tool (11%). This could be due simply to lack of survey effort (no systematic surveys have been conducted), or actual absence of the species resulting from other parameters not considered (pollution, excessive mortality, etc). To determine the extent of the tool over-estimation of habitat suitability, systematic presence surveys would need to be conducted.

Typically, the nature of land use data sets, with only general habitat type classes available, will limit the accuracy of habitat suitability tools on fine scales. Despite these limitations this tool can show the user at a glance where there is potential for wildlife habitat. If wildlife value is highly important to the restoration goals, additional investigations (such as surveys, or adding additional species specific habitat parameters) can address wildlife issues outside the limitations of the tool.

COMBINING PROXIMITY OUTPUT TO DEVELOP A HABITAT QUALITY INDEX (HQI)

The information gained from the proximity analysis can also be coded to analyze for habitat quality. In its most simplistic form, an HQI can be developed to measure the degree of spatial overlap for different wetland or species contexts. For instance, all wetlands selected in the proximity analysis as most likely to support wood frogs can be given a score of 1. If this is completed for the other herp umbrellas (chorus frog and Blanding's turtle), then spatially joining the results by summing the HQI scores for each grid cell can provide a simple measure of overlap (values of 1-4) ranking each wetland polygon. We assumed for HQI analyses that all wetlands are valuable to some degree, therefore we started off with a base HQI score of "1" for each wetland polygon. Those wetlands with the highest degree of overlap for the three herp umbrellas analyzed have the highest HQI score (4).

References for Wildlife Habitat Decision Support Tool

Casper, G. S. 2003. Analysis of amphibian and reptile distributions using presence-only data. Ph.D. Dissertation, the University of Wisconsin-Milwaukee. August 2003. 156 pp.

Leitner, L. A., J. H. Idzikowski, and G. S. Casper. In review. Ecological change in Milwaukee County, Wisconsin.

Louv, Richard. 2005. Last child in the woods: saving our children from nature-deficit disorder. Algonquin Books of Chapel Hill, North Carolina.

Nelson, C. (facilitator). 2006. Michigan Hunter Recruitment and Retention Work Group Recommendations. A report presented to Director Rebecca A. Humphries of the Michigan Department of Natural Resources, January 2006. www.michigan.gov/dnr

Semlitsch, Raymond D. & Bodie, J. Russell. 2003. Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. Conservation Biology 17 (5), 1219-1228.

Chapter VI. Water Quality Decision Support Tools: Assessing Relative Wetland Water Quality Functions in the Milwaukee River Basin

Why Water Quality?

Water quality is a reflection of land use. In watersheds in a natural condition, where there has been little human disturbance, wetlands, lakes and streams generally have good water quality. The more land cover is altered -- by construction, development, agriculture, logging, etc. – the more water quality suffers. In the extreme, waterways no longer support fish and wildlife and water-based recreation.

Wetlands in the landscape mean better water quality since wetlands naturally slow water flow and remove the sediment and nutrients in runoff before they reach lakes and streams. Losing key wetlands as part of the changing land cover compounds the negative effect of land use conversion on water quality since the water quality improvement that occurs naturally in wetlands is lost.

Most wetlands, or wetland restorations, have positive effects on water quality. The extent of that effect, however, depends on many factors. Some are site specific, such as size and vegetation type. Some depend on landscape position and factors further up the drainage basin far from where we enjoy water quality benefits or recognize problems. Deciding where wetland protection is most needed, and where wetland restoration may do the most good, means weighing these many local and landscape level factors. How much land use conversion can occur in a watershed before negative impacts start showing up in water? When do we reach a critical point where more land conversion means loss of sensitive species, or when waterways will no longer support even tolerant species?

The purpose of the water quality tool is to develop an objective and systematic assessment tool for local planners concerned with these questions. The approach integrates the need for water quality improvement, with existing and potentially restorable wetlands, to identify where additional wetland restoration effort can provide the most benefit.

The tool has two parts. The first part assesses the water quality of wetlands and other surface waters at the subwatershed level using available soil, surface water, land use and land cover data. This can guide where water quality improvement is most needed. The second part assesses individual wetlands and potential wetland restoration sites, using objective and scientifically based parameters, to identify those that are most likely to contribute to water quality objectives.

Wetlands aren't the only way to address water quality and their role is not likely to be the same throughout the basin. In some areas urban and rural best management practices, engineered storm water control or other measures may be more appropriate.

Project Goals

- Identify subwatersheds with reduced water quality or at risk for reduced water quality in wetlands, lakes and streams.
- Identify remaining wetlands and potential wetland restoration sites that are likely to contribute to water quality.

Products

- Decision tool for estimating current water quality condition of wetlands and other surface waters based on available landscape level data
- Subwatersheds categorized by water quality conditions based on the decision tool
- Decision tool for a coarse filter selection of remaining wetlands and potentially restorable wetlands that may play a key role in surface water quality

Water Quality and Land Use

Over the past 15 years, many studies have demonstrated quantitatively the relationship between various land use factors and water quality. Some of the factors related to water quality are amount of urban and agricultural land, agricultural practices, roads, population density, types of drainage, soil type and slope, the amount of forest cover, turf, buffers, presence of wetlands, and historical land use.

The many factors make it difficult to tease out simple, consistently reliable relationships. Studies that covered a variety of major land uses indicate that within major land use types some patterns emerge.

Urban Lands

In urban areas impervious cover (IC) is a reliable predictor of how severely stream quality indicators change in response to different levels of watershed development. Over 50 studies across the country show a direct relationship between impervious cover and stream quality (Center for Watershed Protection, 2003). Most measure water quality by biological indicators such as species diversity of fish and aquatic insects. Generally, the studies show that most stream quality indicators decline when watershed IC exceeds 10%, with severe degradation expected beyond 25% IC.

Where impervious cover is less than 10%, IC is not a reliable indicator of water quality since it's swamped by other factors that play a greater role. However, where watershed IC exceeds 10% IC alone is a consistently reliable indicator of overall stream quality. Above 25% IC appears to be the sole determinant of water quality.

Other watershed variables that track with urbanization also correlate with water quality, such as population density, road density, percent urban land use. These variables are harder to quantify and use than impervious cover, which is relatively easy to measure (Brown, 2000).

What does "water quality" mean?

The water quality effects of land use conversion on wetlands and other waters fall into three broad categories: changes in hydrologic, physical and chemical, and biological factors.

Hydrologic factors

Development reduces vegetation cover, compacts some soil and paves over others. This causes more runoff, since the new land surface can absorb less water, and requires increased conveyance of stormwater away from the site. So streams receive more runoff, and the runoff gets there faster, with more frequent flood events. Meanwhile, with less water available to infiltrate the ground, streams dry up between rains.

Agriculture increases conveyance and runoff volume with clearing, ditches and drain tiles.

Physical and chemical factors

Over time hydrologic changes cause changes in the stream channel through erosion. With higher peak flows and higher volumes, streams cut deeper and become wider, causing sediment to move downstream. The new channel shape creates unstable banks and shallow water at low-flow conditions. This in turn reduces the vegetation along the stream especially the woody plants that are the basis of the aquatic food chain. Streams that are increasingly unstable and with less cover develop a more simple and uniform habitat structure. Pools fill in, riffles get embedded in sediment, channels are straighter and less sinuous and temperatures have wider extremes.

Development increases the pollutants reaching surface water, such as sediment, nutrients, metals, hydrocarbons, pesticides, bacteria and pathogens. Agricultural land contributes much less runoff volume, but often has a greater sediment load.

Biological factors

The hydrologic, physical and chemical factors associated with land use conversion combine to stress aquatic life so that sensitive species begin to disappear. At higher levels it limits water-based recreation and ultimately affects public health.

Road crossings often pose barriers to fish and other aquatic organisms. Excess nutrients cause excess plant growth, followed by lower oxygen levels. Increased pollutants water becomes toxic to aquatic life. Increased bacteria and pathogens not only limit species diversity but keep people out of the water too.

Agricultural Lands

Studies in less urban watersheds are more limited. Booth (1991) found that water quality in the Pacific Northwest began to decline if more than 25% of forest cover was converted to agricultural land. Wang et al. (1997) found declining habitat quality and reduced species diversity only when agricultural land use exceeded 50%. Most other studies are based on small drainage basins with intensive data collection and are not immediately applicable to landscape level analysis.

An additional limitation (or maybe the cause of there being fewer rigorous studies) is that the relationship between the many agricultural variables and water quality at the subwatershed level is more complex than with impervious cover. All impervious cover causes similar effects, but the agriculture-water quality relationship depends on more variables and their interaction such as the type of crop, soil, slope, buffers, fertilizer rates and other farming practices.

Before applying any of these general results to our area, we need to keep a few caveats in mind. The land use/land cover thresholds for water quality damage are not sharp breakpoints, only averages from many studies under different conditions. They also predict behavior of a group of water quality indicators, not a single indicator. Some species may have lower thresholds and their essential habitat requirements are determined by the most sensitive indicators not the average (include a mussel or brook trout example). Most also focus on first through third order streams and so only apply at the subwatershed level (5 to 50 square miles) or to smaller drainage basins.

Water Quality Decision Tools

Part 1 – Assessment of Water Quality Conditions

The first step in going from the entire river basin to the subwatershed scale is to determine the **amount of impervious cover and agricultural land by subwatershed**. This will provide a coarse indicator of water quality.

The data to do this have long been available and most people familiar with the area are well aware that land use shifts from ultra-urban in the south to rural in the north. The purpose of examining the data on a subwatershed basis is twofold: First, it allows us to quantify that spatial distribution of land use on a hydrologic basis. Secondly, it allows us to apply the land use thresholds apparent from previous intensive studies to identify subwatersheds that may be at a critical stage.

Water Quality Thresholds

Determine the percentage of various land use types in each subwatershed. Classify subwatersheds based on the amount of impervious cover and agricultural land use. Figure 13 shows a graphical representation of the thresholds described below:

- Unimpacted (Still in good condition) – subwatershed typically has 10% or less impervious cover and 25 to 50% or less land in agricultural use.

Streams have a natural channel configuration with stable banks and good populations of pollution intolerant species.

Wetlands need protection.

- Impacted Urban – IC between 10 and 20%
  Streams in these subwatersheds show signs of degradation due to urbanization. Habitat quality is lower so that sensitive species are no longer present.

  Wetland protection is critical; restoration here now can make a difference; planning is needed to reduce or mitigate urban effects

- Impacted Agricultural – > 50 % agricultural use
  Streams have increased sediment load and without buffers begin to show signs of unstable banks. Pollutant load affects intolerant organisms, but the extent is dependent on soil type and farming practices.

  Wetland protection is important and wetland restoration or rehabilitation, particularly through restoring natural hydrologic conditions may improve conditions

- Severely Impacted Urban -- IC > 20?%
  Streams in these watersheds mainly convey storm water flows and no longer support a diverse stream community. Typically stream channels are unstable with channel widening, down-cutting and severe bank erosion. There is little of the pool/run/riffle structure needed to support fish and the substrate no longer provides spawning areas for fish or habitat for other aquatic life. Water quality is poor and high bacterial levels limit water contact recreation. Biological communities are poor and dominated by pollution tolerant species.

  Wetland restoration projects may have little effect on overall water quality.
  Impacted Urban and Agriculture – compounding effect likely to be more severe than the individual factors alone.

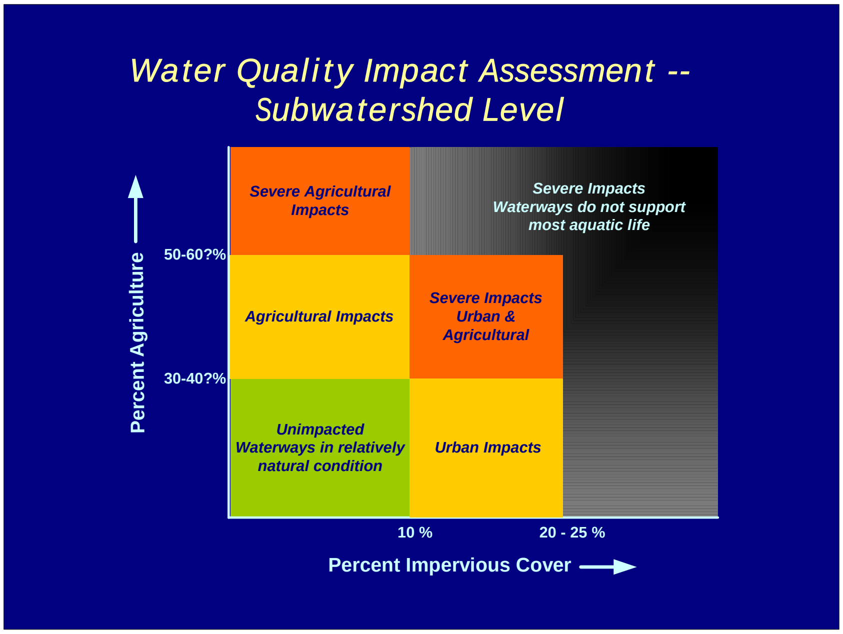


Figure 13. Graphical Representation of Water Quality Threshholds.

Estimating Agriculture and Impervious Cover

Agricultural land use is from SEWRPC 2000 land use data.

Most studies in the literature have relied on 'total impervious cover' – the amount of hard surface regardless of where it directs runoff -- to measure IC at the subwatershed level. 'Effective impervious cover' – the impervious cover hydraulically connected to a drainage system – appears to be a superior metric. The disadvantage to effective IC is that it requires detailed maps of stormwater conveyance, which are not yet widely available in digital format. We used total IC since effective IC is only available for isolated small drainage basins as a result of local stormwater plans.

The best way to measure total IC is directly through satellite imagery or interpreted aerial photography. IC through satellite imagery is not yet available for this area and the time required for interpreting air photos limits that method to areas smaller than an entire watershed or basin. An alternative is to estimate IC indirectly using GIS land use layers.

For a given land use category in the SEWRPC area we randomly selected a sample (N > 20) of sites within the basin. Within each site, we measured IC directly by interpreting and digitizing IC using 2000-year photos. The IC estimate for that land use category is the mean of % IC for the sample sites. Appendix 2 – Metrics lists the impervious cover estimates for each land use code.

For the subwatersheds studied, Figure 14 shows the water quality impacts from agricultural and impervious land cover. Figure 15 shows percent imperviousness by subwatershed.

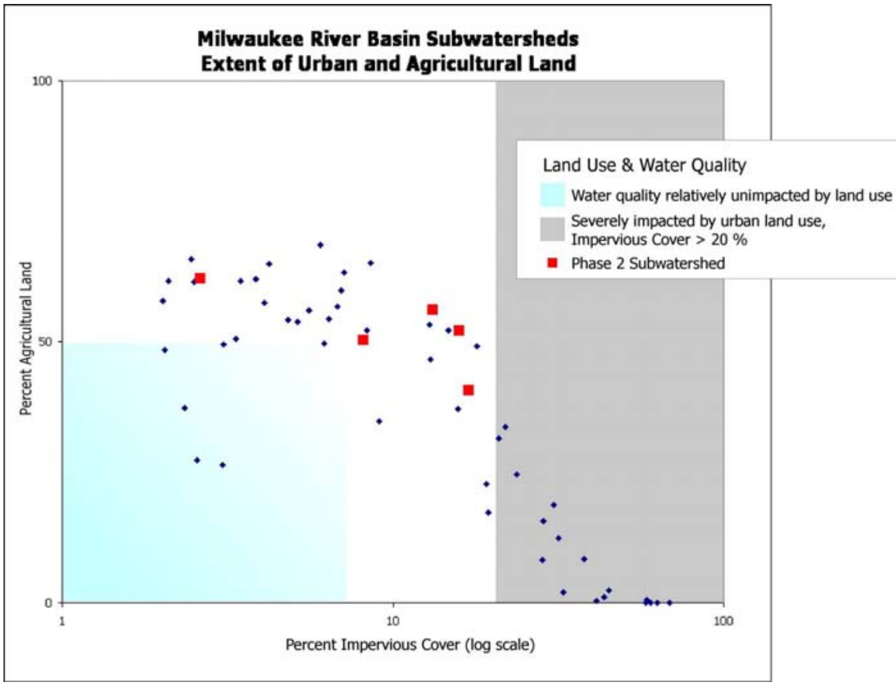


Figure 14. Water Quality Impacts for Selected Subwatersheds.

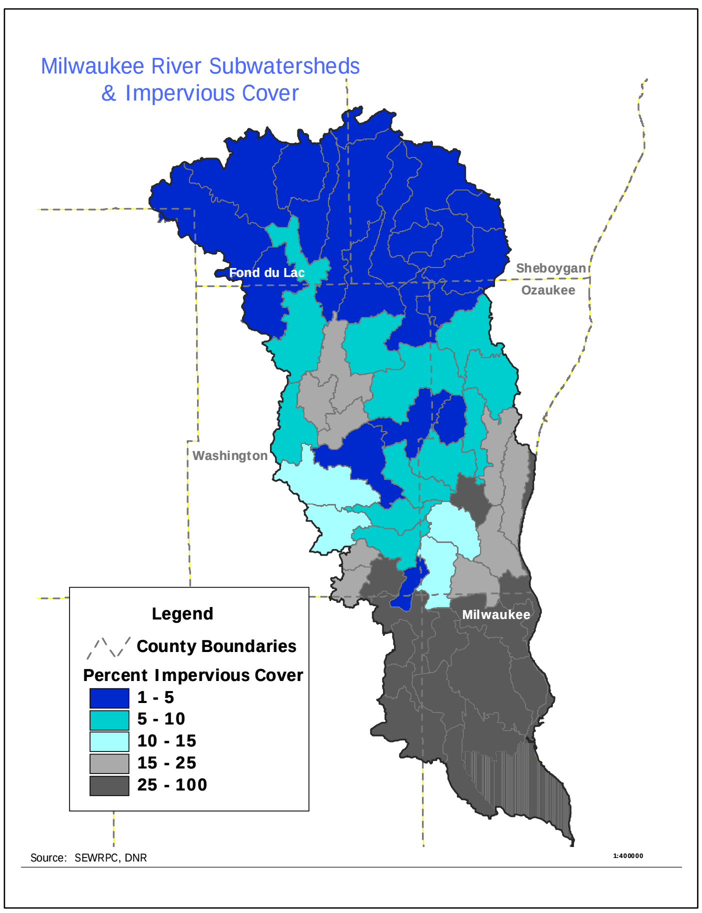


Figure 15. Percent Impervious Cover by Watershed.

Part 2: A Small Catchment Scale Water Quality Tool

Summary Description

The Wetland Water Quality Assessment Tool is designed to allow the user to accomplish a coarse assessment of the cumulative water quality treatment function performed by existing wetlands and estimate potential water quality benefits from restoring wetlands. The tool works at the "small catchment" scale, a term we use to describe a further hydrologic subdivision of subwatersheds, wherever tributaries join. These are roughly equivalent to 14 digit Hydrologic Units (HUs). The goal is to allow a planner to compare the relative significance of the water quality role of the wetlands in different catchments and to target catchments where wetland restoration can potentially yield relatively higher water quality benefits. The output is a relative score for each catchment based on the degree to which its wetlands are able to protect downstream water quality by trapping sediment. It is important to note that all wetlands in a given catchment receive the same rank. We considered incorporating measures of individual wetland characteristics such as width and vegetation type, but decided these would have made the programming and user interface with the tool too cumbersome. Further discrimination among wetlands in the same catchment is best done through site level assessment.

This decision support tool is needed to better factor existing wetlands into watershed water quality and other planning processes. When combined with the potentially restorable wetland layer the planner can also evaluate different "before and after" wetland restoration scenarios in terms of the relative increase in sediment trapping that could be gained through wetland restoration. The required data inputs are GIS layers with topography (Digital Elevation Model), hydrography, a land use layer with assigned Soil Conservation Service (SCS) runoff curve numbers (210-VI-TR-55, Second Ed., 1986; NRCS, WDNR and SEWRPC 2004), unit area pollutant loads (Bannerman et. al.,1894), wetland area, catchment area, and long term continuous rainfall/snowmelt data for the region of interest. Future work should explore the use of a simpler tool for use in areas where detailed topography and land use data are not available.

The tool uses the input data to calculate two factors for each catchment: the relative sediment loading to its wetlands and the relative sediment trapping efficiency of its wetlands. These are brought together in a simple equation to estimate the relative amount of sediment trapped by wetlands in each catchment:

Relative Sediment Loading × Relative Wetland Trapping Efficiency =
Relative Sediment Trapped by Wetlands

The result is translated into a unit-area (kg/ha) load by dividing the "relative sediment trapped by wetlands" by the area of the catchment size in order to factor out the effect of catchment size. The result is used to compare relative wetland sediment trapping among catchments and develop a ranking scheme for this function. "After restoration" scenarios can be considered by changing the sediment load and SCS Curve Number inputs for potentially restorable wetland areas to the input values these areas would have as wetlands. A comparison of the "before and after" results generated by the tool can give the planner an indication of which catchments may be the most fruitful to target for restoration. Because of the coarseness of the input data and the lack of flow routing the calculated unit-area loads should not be used for design purposes.

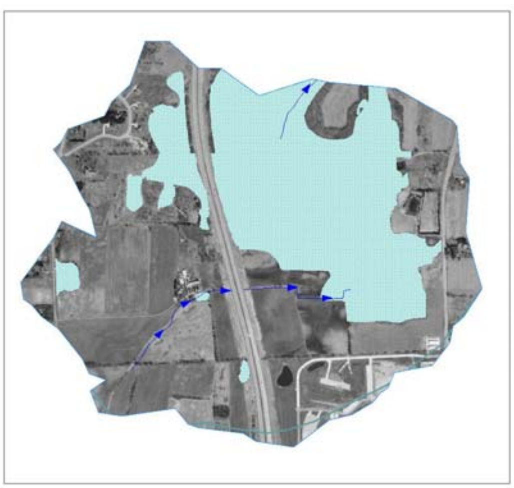
Concepts and Considerations in Design of the Water Quality Tool

The Use of Sediment Trapping As a Measure of Wetland Water Quality Function

One significant challenge in developing a tool for assessing the water quality improvement function of wetlands is defining what parameter(s) as well as what forms (soluble or particulate) of the pollutant will be considered. This approach uses as its basis the relative comparison of the hydraulic residence times in wetlands which will impact sediment removal from the water column. This, in turn, influences both total phosphorus and nitrogen removal. The tool uses total suspended solids (TSS) as the parameter of interest, and assesses the potential for removal via settling. We assume the hydraulic residence has a direct impact on pollutant removal potential i.e. the longer the residence time, the greater the anticipated removal. We use P-8 (Program for Predicting Polluting Particle Passage thru Pits, Puddles, and Ponds) Urban Catchment Model Version 2.4 (Walker 2000), hereinafter referred to as "P-8," to calculate the percent of sediment removal based on hydraulic residence. To calculate the sediment loading per catchment we assigned unit area pollutant loads to distinct land uses based on literature values (Bannerman et. al.,1984.)

Why Delineate Small Catchments

A second challenge for tool design is determining the scale at which this planning tool should be applied. A wetland by wetland analysis is too cumbersome to be practical for some planning uses, or may require finer data on individual wetland characteristics than is available. Sediment trapping efficiency is a first approximation of the cumulative contribution to water quality provided by the wetlands in each small watershed. The P-8 model (Walker 2000) treats the catchment as a simple system with the entire catchment area contributing overland flow through one wetland. As the number of wetlands lumped together for analysis and the complexity of their placement increases the model assumptions are increasingly violated. Relative trapping efficiency is best used to compare small catchments to each other in terms of the relative contribution of their wetlands to overall water quality.



The catchment shown here (Figure 16) closely approximates the P-8 model (Walker 2000) assumption of one wetland with one drainage area. Arrows show direction of flow of the small stream into and out of the main wetland in this catchment.

Figure 16.Catchment 65: A Headwaters Catchment of Quaas Creek Subwatershed

Figure 17. . Catchment 345: The Main Stem of Quaas Creek

The catchment shown here (Figure 17) is more complex, with linear narrow wetlands along the course of the stream, and some wetlands located away from the stream corridor. For the Milwaukee River project we had subdivided six 10 digit HU watersheds into 58 sub-watersheds equivalent in size to 12 digit Hydologic Units, or 16 to 63 sq mi. As we examined the land use and placement of individual wetlands in the subwatersheds the need became clear for further hydrologically based subdivisions of these subwatersheds into what we refer to as "small catchments. At this finer scale wetland distribution over the landscape more closely approximates the P-8 model assumption of flow from one drainage area through one wetland. Further subdivision also increases the homegeneity of land use within the resulting small catchment and therefore makes the results more reliable. Figure 18 shows the hierarchy of watershed delineations within the Milwaukee River Basin.

For the entire Milwaukee River Basin 622 small catchments were delineated. The rule for delineation of catchments was to create catchments wherever two stream segments intersected. The method of delineation is described in Appendix 3.

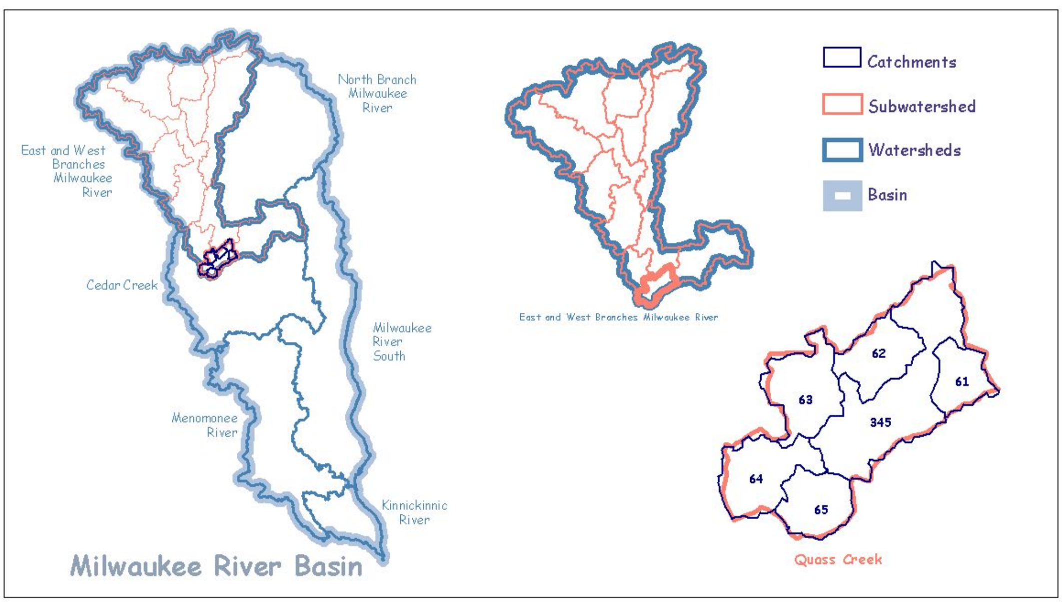


Figure 18. Hierarchy of Catchment Delineation

Estimating Relative Future Sediment Trapping Gained from Wetland Restoration in a Catchment

For evaluating differing restoration scenarios, the tool can be run a second time with all or a subset of the Potentially Restorable Wetlands converted to wetland. Restoring cropland to wetland removes a source of sediments and nutrients, slows runoff and increases the effective treatment area for trapping sediment. The tool reflects these changes by removing the restored areas from consideration as sediment sources, by changing the SCS Runoff Curve Number for these areas to the Curve Number used for wetlands, and by adding the restored wetland areas to increase the total effective wetland treatment area for the catchment. The tool is run a second time with the new inputs representing "after restoration" conditions. The result is a coarse estimate of the relative future sediment trapping that could be provided by wetlands after restoration using a method that is consistent with the existing conditions analysis. The difference between the future and existing sediment trapping is a coarse estimate of the relative gain due to restoration.

Factors Considered but not Included in the Tool

To keep the tool more manageable the basic unit of analysis is the catchment rather than the individual wetland. Two important factors that affect an individual wetland's function for downstream water quality improvement were not included in the tool but should be given consideration should the user wish to take the analysis further. These are the width of the wetland relative to overland flow direction and the vegetation in the wetland. Though longer flow lengths will allow greater potential for settling fine particles we found that the definition of a given wetland polygon's width can be problematic, especially for linear wetlands that vary greatly in width. We decided that the wetland:watershed size ratio used in the tool indirectly accounts for this factor. Though vegetation roughness clearly affects flow and favors particle settling, seasonal release of decomposed vegetation confounds setting a simple, direct relationship between vegetation type and sediment trapping.

Water Quality Tool: Analytical Steps

This section describes in more detail the data sources and analytical steps the tool uses to derive results for existing conditions and restoration scenarios.

Assessing Relative Sediment Loading

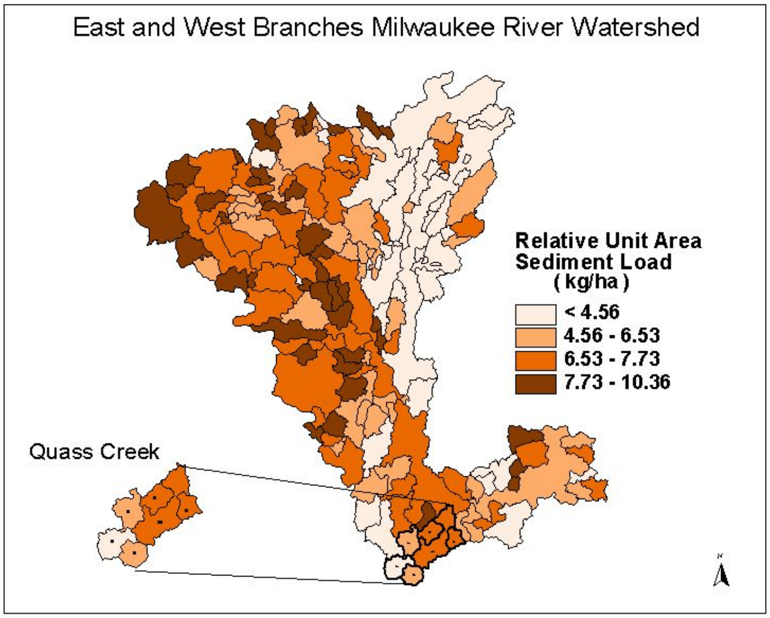
The first step in assessing wetland sediment trapping is to consider the sediment load coming into the wetland via local flow from the drainage area. The term "relative load" is used for this study so as to be clear that the results are not a precise, accurate measure of the actual sediment loads for these catchments. The relative sediment load was generated based on the SEWRPC (Southeastern Wisconsin Regional Planning Commission) land use coverage for each catchment. SEWRPC land use coverages were converted into grids with each land use classification assigned a relative load based on literature values expressed in kg/ha of phosphorus and loads calculated using SLAMM (Source Loading Management Model) Version 9.1 (http://winslamm.com/) (Pitt and Voorhees 2005). Phosphorus was used as a surrogate for total suspended solids because it best represented the fine particle sizes that are transported through the drainage network into potential receiving waters and wetlands and best matched the particle distributions used to estimate wetland trapping efficiency in P-8 (Walker 2000).

Table 9. Relative loads assigned to different land uses.

Description	Pollutant Rank (kg/ha)
Rural Residential/ Farm	0.04
High Density Residential	1.12
Medium Density Residential	0.58
Low Density Residential	0.10
Commercial / Undeveloped	1.50
Industrial	1.50
Free-ways / transportation	1.04
Streets	0.80
Railroad right-of-way	0.04
Park / Golf Course / Open Space	0.10
Row Crops - Mixed Agriculture	1.00
Open Space	0.30
Wetland	0.00
Open Water	0.00
Forest	0.09
Government (600 series) classified as General Urban	0.60
General Urban	0.60
Airports	0.40

The SEWRPC land uses were lumped together by percent connected impervious surface and to correspond with the SLAMM standard land use files (Walker 2000). Each grid cell was then assigned a sediment load by land use allowing a total relative load for each catchment to be calculated through summing grids.

Figure 19 shows the relative ranking of sediment loads routed to wetlands in each catchment of the East/West Branches Milwaukee River Watershed



The **total** sediment load can be misleading due to the strong effect of catchment size. Because the catchments were delineated strictly on a hydrologic basis, there is a large variation in the size of the catchments. We therefore report relative unit-area loads rather than relative total loads.

Figure 19. Relative Unit-Area Sediment Load: East/West Branches Watershed and Quass Creek Subwatershed

Assessing Relative Wetland Sediment Trapping Efficiency

In considering the hydraulic residence time for wetlands the tool uses the drainage area of the catchment, the wetland area in the catchment and a composite SCS curve number calculated by taking the area-weighted average of all the land use/soil type/slope combinations in the catchment. All wetlands are assumed to have a mean depth (volume to surface area ratio) of 1.5 feet. Effective Wetland Treatment Area is derived by subtracting out ditched wetland area, as described below.

The development of a detailed hydrologic model for each wetland is not practical for a screening tool of this type, however the watershed hydrology is a significant variable in estimating the hydraulic residence time. A daily time step continuous water balance simulation hydrologic model was used to address the climate variability but interpreted in such a way as to keep the approach simple enough to implement within a screening framework. The P-8 Model (Walker 2000) was run using 6 values of the watershed area to wetland area ratio (WSa/WLa) ranging from 1 to 1000 and 6 values for the SCS curve number ranging from 50 to 90. The model was run in continuous mode for 20 years using hourly rainfall /snow melt data for Milwaukee, Wisconsin. A regression equation was then developed for the total suspended solids (TSS) removal predicted by P-8 for each of the 6 curve number values. By using the TSS removal predicted by P-8, the wetland sediment trapping efficiency is estimated by first order settling for fine particles carrying phosphorus. The predicted removals were then classified into quantiles relative to each Watershed.

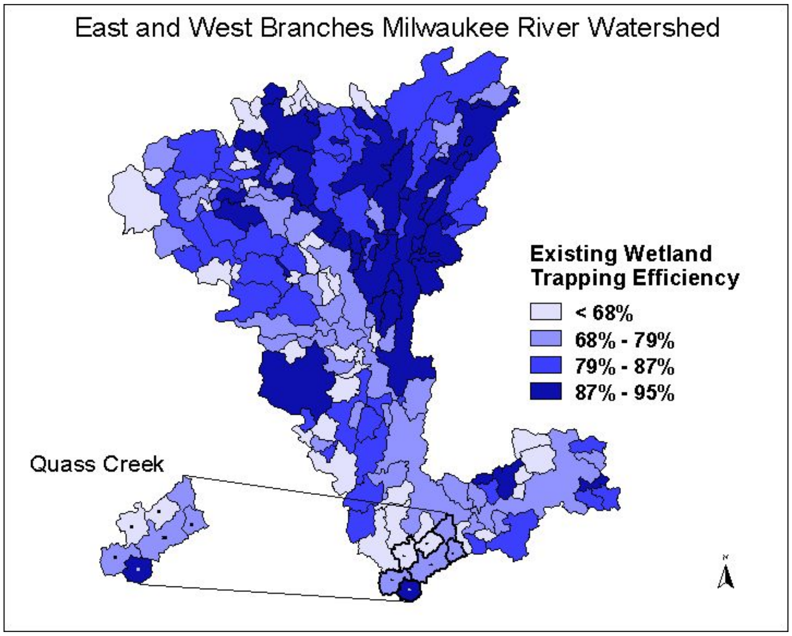


Figure 20. Wetland Trapping Efficiency: East/West Branches Watershed and Quaas Creek Subwatershed

Adjusting "Effective Wetland Treatment Area" for the Effect of Drainage Ditches

The wetland area in each catchment was adjusted to account for the effect of any drainage ditches running through the wetlands of the catchment. Drainage ditches through wetlands reduce the hydraulic residence time to near zero. The calculation of the actual amount of flow that is "short circuited" through drainage ditches would require delineation of mini-catchments for each ditch system. This would be too time and data intensive for most planning applications. Instead the method assumes that the area of the ditch itself plus a 30m buffer on each side is unavailable to remove sediment via particle settling, and is subtracted from the wetland area to account for an "effective wetland area." The 30m buffer is based on best professional judgment recognizing that the loss of "effective wetland treatment area" is likely greater than the removal of just the ditch area would account for. The tool requires the user to identify drainage ditches. These are given a 30 m buffer on both sides and the total area of wetland within the "ditch + buffer" is subtracted from the wetland area for use in further calculations.

Assessing Relative Unit-Area Sediment Load Trapped by Wetlands

The ultimate metric of interest is how much of the sediment load delivered to the wetlands of a catchment is trapped there. The tool calculates a relative "sediment load trapped by wetlands" through multiplying the relative sediment input by the relative wetland trapping efficiency. To adjust for variance in catchment sizes this is converted to a unit-area load for each catchment. The resulting classes for the catchments of the Quaas Creek Subwatershed are shown below.

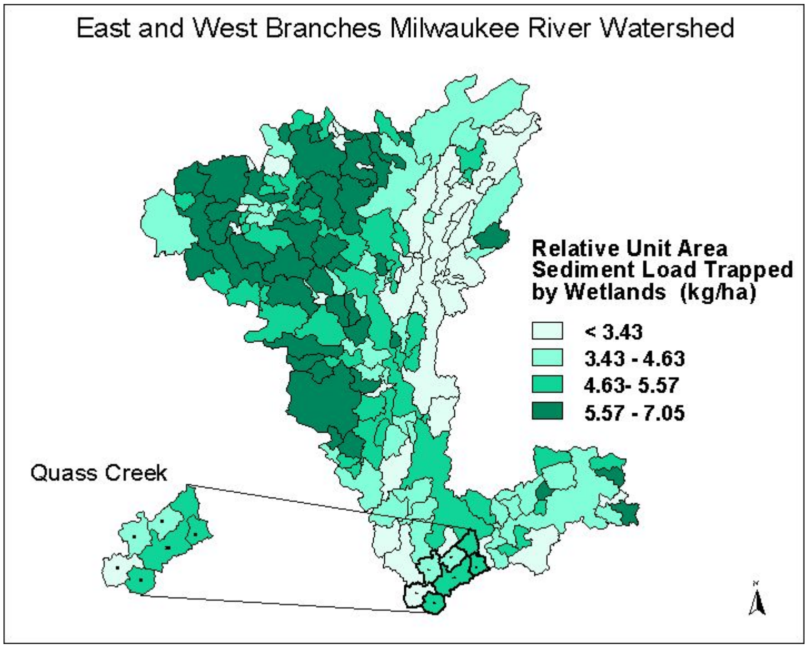


Figure 21. Ranking of Catchments for Unit Area Sediment Load Trapped by Wetlands: East/West Branches Watershed and Quaas Creek Subwatershed

Figure 21. Ranking of Catchments for Unit Area Sediment Load Trapped by Wetlands: East/West Branches Watershed and Quaas Creek Subwatershed shows a comparative picture of what existing wetlands are doing for water quality in the catchments of the East-West Branch Watershed and the Quaas Creek Subwatershed. Note that some of the eastern catchments with high wetland trapping efficiency (Figure 20) show smaller unit area sediment loads trapped by wetlands. This is because they have lower unit area sediment loads coming into wetlands (Figure 19).

These results can inform water quality planning decision-makers of the role existing wetlands play within a planning area in sediment and nutrient retention to protect downstream surface waters.

Targeting Restoration to Increase Potential Wetland Contribution To Sediment Trapping

The steps outlined above can yield a characterization between catchments of the relative contribution of **existing** wetlands to downstream water quality using sediment trapping as the measure. One can also characterize their relative **future** maximum sediment trapping contribution after the restoration of all Potentially Restorable Wetlands in the catchments. This is accomplished by adding the area of potentially restorable wetlands to the existing wetland area in each catchment and running the sediment loading grid and the P-8 model again. The increase in relative sediment trapping in catchments "after restoration" allows one to identify catchments where wetland restoration can yield the biggest relative benefits for downstream water quality. Users need to remember that the tool can only be used for relative comparison among small catchments, rather than predicting actual sediment trapping results. The simple equation is:

"Potential Future Sediment Trapping After Restoration" –"Existing Sediment Trapping" = "Increase in Relative Sediment Trapping due to Restoration"

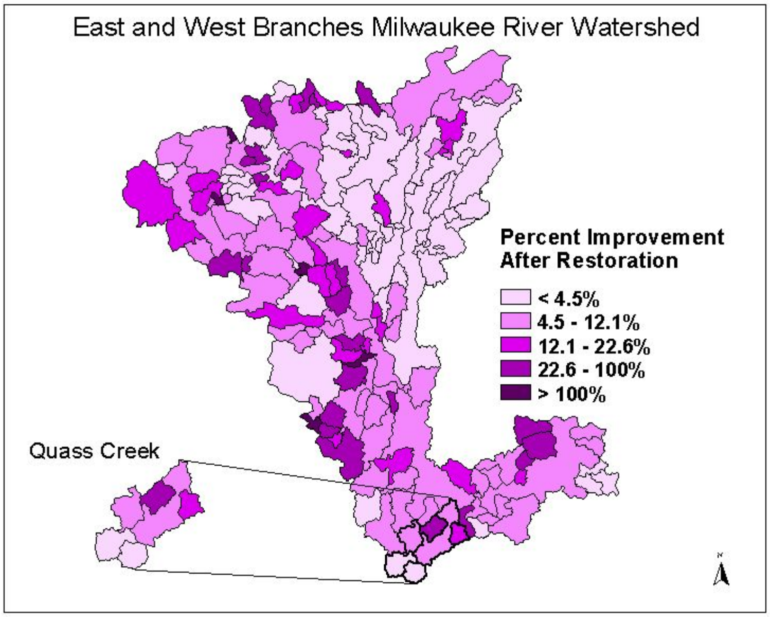


Figure 22. Percent Improvement After Restoration: East/West Branches Watershed and Quaas Creek

Figure 22 shows which catchments of the East and West Branches Watershed could gain the most improvement in sediment trapping from restoring **all** PRWs in every catchment. More realistic alternative restoration scenarios can also be analyzed with the water quality tool.

Realistically, not all areas shown as potentially restorable in Quaas Creek can actually be restored due to land use change, technical barriers, or lack of landowner interest (Washington County Land and Water Conservation Division 2005). Nevertheless, the tool can generate a first approximation of "target" catchments where wetland restoration is likely to provide relatively higher potential water quality benefits. The tool can generate results for any set of restoration scenarios the user wishes to analyze. For instance a planner with knowledge of specific restoration site potential within a region of interest can use the tool to generate more realistic results by only selecting feasible areas for the "after restoration" step.

Discussion of Water Quality Scenarios

Much of the analysis considered above can be intuitively grasped by visual inspection of overlays such as Figure 23. The water quality tool allows the analysis to be automated and consistent given the necessary inputs. Rather than relying solely on the "change due to restoration" analysis however, we offer the following general considerations for planners confronting different existing sediment loading and wetland trapping conditions.

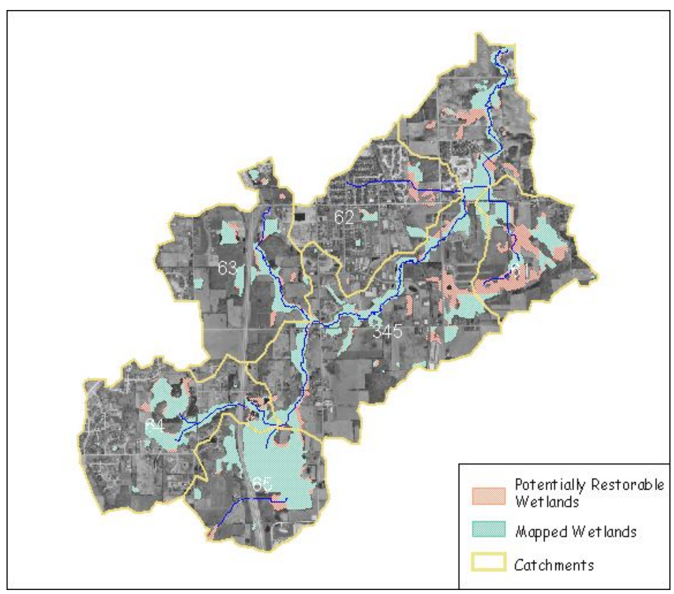


Figure 23. Existing wetlands and potentially restorable wetlands in Quaas Creek

- Wetlands in catchments with very high sediment loading may be dominated by invasive species, such as reed canary grass, or be susceptible to invasion. They would likely be overwhelmed by receiving additional stormwater. Water quality treatment planners in such areas should focus first on upland treatment and runoff reduction rather than relying on gain from additional wetland restoration.

- Where sediment loading is low, and existing wetland trapping efficiency is high, protection of existing wetlands and upland stormwater treatment could be the focus of conservation efforts. Existing wetlands could be expected to be in relatively good condition. Restoration priorities may be on expanding habitat function in the catchment.

- Where loading is in the medium ranges, existing wetlands are providing low to medium trapping, and the catchment has a large number of potentially restorable wetland acres, the restoration of PRWs could be worth pursuing, with willing landowners. As sites are visited the feasibility of restoration can be factored into later iterations of the tool as site data refines the number of restorable acres.

References for Water Quality Assessment Decision Support Tool

Arkansan Multi-Agency Wetland Planning Team, The Standard GIS Methodology for Wetland Analysis

Bannerman et. al., 1984. Evaluation of Nonpoint Source Pollution Management in Milwaukee County, Wisconsin. Report No. PB84-114164, US EPA, Region V, Chicago, Il.

Bedford, B.L. 1999. Cumulative effects on wetland landscapes: links to wetland restoration in the United States and Canada. Wetlands, Vol. 19, No 4, 775-788

Bernthal, T. W. and K. G. Willis. 2004. Using LANDSAT 7 imagery to map invasive reed canary grass (Phalaris arundinacea): A landscape level wetland monitoring methodology. Final Report to the U.S. Environmental Protection Agency Region V. Wisconsin Department of Natural Resources PUB-SS-992 2004, 72 pp.

Center for Watershed Protection. 2003. Impacts of Impervious Cover on aquatic Systems. Watershed Protection Research Monograph No. 1. Center for Watershed Protection, Ellicott City, MD.

Federal Geographic Data Committee. 2002. Federal Standards for Delineation of Hydrologic Unit Boundaries, Version 1.0, March 1, 2002. 52 pp.

Hey, Donald L., and J. Wickencamp. 1998. *Some Hydrologic Effects of Wetlands.* IN: Water Resources in the Urban Environment. Proceedings of the 25th Annual Conference on Water Resources Planning and Management. June, 1998. American Society of Civil Engineering.

Gatti, R. . . . .1997. Influences of Watershed Land Use.

Gersib, R. 1997. Restoring Wetlands at a River Basin Scale. Washington State Department of Ecology Pub No 97-99.

Natural Resources Conservation Service, Wisconsin Department of Natural Resources and Southeastern Wisconsin Regional Planning Commission. 2004. Assignment of SCS runoff Curve Numbers to SEWRPC land use inventory units.

North Carolina Department of Environment and Natural Resources. 1999. NC-CREWS: North Carolina Coastal Region Evaluation of Wetland Significance – A Report of the Strategic Plan for Improving Coastal Management in North Carolina.

Pitt, Robert and John Vorhees. 2005. SLAMM (Source Loading Management Model) Version 9.1. (http://winslamm.com/)

Poiani, K.A., B.L. Bedford and M. D. Merrill. 1996. A GIS-based index for relating landscape characteristics to potential nitrogen leaching to wetlands. Landscape Ecology 11:237-255.

Preston, E.M. and B. L. Bedford. 1988. Evaluating cumulative effects on wetland functions: a conceptual review and generic framework. Environmental Management 12:565-83.

RiverLink. 2000. GIS Management Models to Assist Wetland Restoration Efforts in Buncombe and Haywood Counties, North Carolina. Pigeon River Fund. 85 pp.

Soil Conservation Service (SCS) runoff curve numbers (210-VI-TR-55, Second Ed., June 1986)

Tiner, R. W. 2004. Remotely-sensed indicators for monitoring the general condition of "natural habitat" in watersheds: an application for Delaware's Nanticoke River Watershed. Ecological Indicators 4, 227-243.

Trombulak, S.C. and C.A. Frissell. 2000. Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities. Conservation Biology, Vol 14, No 1 pp 18-30.

Walker, William. 2000. P-8 (Program for Predicting Polluting Particle Passage thru Pits, Puddles, and Ponds) Urban Catchment Model Version 2.4. http://wwwalker.net/p8/

Wang, L., J. Lyons, P. Kanehl, and R. Gatti. 1997. Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams. Fisheries, Vol 22 No. 6 p 6-12

Wang, L., J. Lyons and P. Kanehl. 2001. Impacts of Urbanization on Stream Habitat and Fish across multiple spatial scales. Environmental Management 28:2, pp. 255-66.

Wang, L., J. Lyons and P. Kanehl. 2003. Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota. Trans. Amer. Fisheries Society 132:825-839.

Washington County Planning and Parks Department. 2005. Potentially restorable wetland study for the Quaas Creek and the Upper Cedar Creek subwatersheds in Washington County, Wisconsin.

Wisconsin Department of Natural Resources. 1992. Wisconsin Wetland Inventory Classification Guide. PUBL-WZ-WZ023.

Zielinski, J. 2002. Watershed Vulnerability Analysis. Center for Watershed Protection, Ellicott City, MD, 22 pp.

Acronyms Used in this Chapter
HUs - HydrologicUnits.
IC – Impervious Cover
PRWs – Potentially Restorable Wetlands
SCS – Soil Conservation Service, now Natural Resources Conservation Service (NRCS)

SEWRPC - Southeastern Wisconsin Regional Planning Commission
SLAMM - Source Loading Management Model

Chapter VII: Floodwater Storage Decision Support Tool

Why Flood Storage?

Wetlands can provide flood storage and contribute to the stability of flow and water levels of associated streams and lakes in their watersheds. With urbanization land use changes often result in greater surface runoff and less infiltration, with flooding as an unintended consequence. Wetland loss decreases available flood storage and increases the severity and frequency of floods that can result in property damage and threaten human safety (cite?). In addition to property damage we know that as wetlands are lost, streams become more "flashy," with more frequent and higher peak flows and lower minimum flows between rainfall events. This lack of stability leads to degraded stream habitat quality, with bank erosion and subsequent sediment deposition occurring with higher flows, and temperature impacts at low flows. Studies in southeast Wisconsin show that watersheds with less than 6 percent wetlands have experienced de-stabilized stream flows (Hey and Wickencamp, 1998).

Wetlands contribute to the maintaining the natural flow regime of other surface waters in several ways:

- Riparian wetlands connected to streams can store overbank floodwaters and slowly release water, thereby decreasing downstream flooding. This benefit is lost if the wetland is disconnected from the stream by a structure such as a dam or levee.
- Wetlands connected to lakes can also store water reducing the lake level rise during wet periods. If the wetland is filled and built upon, that storage is effectively lost.
- Wetlands connected to streams and lakes can temporarily store surface runoff from upland areas before it reaches the waterbody, changing the timing of discharge.
- Wetlands in closed depressions also store surface water, with slow release through recharge to groundwater or evapotranspiration, depending on the permeability of underlying soil. Because they are not directly connected to other surface waters, they have little immediate effect on stream flows or lake levels, but can have positive effects on flow rates of downstream waterbodies.
- Wetlands in groundwater discharge areas are important for providing baseflow to streams and lakes. Where they are unmodified (no drainage ditches or tiles)subsurface water gradually moves through saturated soils and into streams and lakes. Were they are modified by drainage ditches, water moves in larger volumes off site more quickly, which can contribute to both downstream flooding and reduction of base flow.

These qualities are known but to what extent do different types and assemblages of wetlands in any given watershed offset the de-stabilizing effects of urbanization, and agricultural drainage? Where can restoration of wetlands produce the greatest benefits? To date wetland characteristics are being incorporated into sophisticated hydrological models such as the WDNR Hydrology Tool (Budsberg and Djokic, 2006) Typically these models require specialized knowledge and more expensive software than many GIS users have available. The following section documents our work to date to develop a decision support tool to answer these questions in a more accessible way.

Consideration of Existing Models and Tools

Our goal was to develop a tool that takes into account the contributions of existing wetlands and the potential benefits of potentially restorable wetlands (PRWs) for contributing to hydrologic stability. First we reviewed literature to determine the most important features for determining wetland contributions to hydrologic stability. We also examined the Spatial Wetland Assessment for Management and Planning Tool (SWAMP) (Sutter, 2001) to see if the tools developed for wetland effects on streams will meet the needs of this project. Because of its reliance on using the hydrogeomorphic (HGM) class of individual wetlands, we were not able to use SWAMP directly. The state of Wisconsin does not employ HGM classifications into its wetland inventory. However, the information provided in the technical documentation (Sutter, 2001) and the other literature reviewed, have proven very useful for this project.

We are also evaluating the usefulness of the WDNR Hydrology Tool, which provides the user the opportunity to employ several models to evaluate land use scenarios to predict the effects of land use change on stream hydrology. These tools consider existing wetlands as contributing to available storage (or sinks) for the delineated watershed. While the predicted outcomes do provide some relationships between wetlands and stream flow, they are specifically directed at the stream response in relationship to storage. The models contained within the hydrology tool will be very useful for evaluating site specific scenarios, but do require the user to have specialized knowledge of use of hydrology models, and do require more expensive software tools than the average GIS user may have on hand. Therefore we did not choose to employ them for this project.

Considerations

Wetlands serve different hydrological functions depending on their landscape position. Wetlands located in headwater areas serve as a buffer between upland landscapes and perennial streams. They store water from land runoff, precipitation and groundwater discharge. Headwater wetlands may have some intermittent channels, but they do not receive appreciable overbank flow from these channels, but have the ability to influence flows and water quality of downstream perennial streams (Sutter, 1999).

Like headwater wetlands, depressional wetlands receive their water from precipitation, upland runoff and groundwater discharge. These wetlands are not directly connected to surface waters, so do not perform water quality functions. However they do store large amounts of rainfall and overland runoff, which in their absence could enter nearby streams.

Wetlands adjacent to rivers and streams have the most direct effect of providing short-term floodwater storage. These floodplain wetlands store water resulting from both upland runoff and overbank flows from rivers.

These wetland types work in aggregate to stabilize stream flows and prevent localized and downstream flooding, but because they deliver different hydrologic services, any method to compare specific wetlands must take their individual contributions into account. For this project we are first developing tools to examine contributions of wetlands for maintaining hydrologic stability at the sub-watershed (landscape) scale. While some may wish to take this analysis further to the scale of individual wetlands, the combined resolution of our data may not be appropriate for creating scoring for wetlands. In addition, as with water quality and wildlife habitat, while individual wetlands provide important services and should be considered valuable whether isolated or as part of a larger complex, it is the combined effect of these wetlands within a given geographic area that provide the greatest benefit.

We have not completed the developing a tool that we believe meets all our criteria: user-friendliness, clear, sufficiently accurate and reliable. Part of the difficulty lies in choosing a method that works at the coarse resolution and precision of the data we expect to be available to land use and water quality planners. Part also lies in choosing the focus of functional analysis. Within the hydrologic function lie four distinct subfunctions; storage of precipitation and surface runoff, floodwater storage, groundwater recharge and shoreline stabilization. It has been difficult to lump all four into one tool and difficult to choose which one to hone in on.

We describe below the approaches we have tried and are considering. We expect to continue work on this tool outside the grant.

Data Analysis Methods for Examining Wetlands for Hydrologic Stability

The following data sets would be used for developing this tool:

- Subwatershed boundaries, and possibly small catchment boundaries
- Hydrography (24k hydrography layer and drainage ditch layer)
- Topography – Digital Elevation Model (DEM)
- Soils
- Wetlands
- Land Cover/Land Use
- Potentially Restorable Wetlands
- 100 year floodplain boundaries (or surrogate)

Process steps for Landscape Scale Analysis

The Milwaukee River Basin study area has been divided into 58 Subwatersheds. These subwatersheds can be examined using the subwatershed metrics from Chapter IV to determine which would most benefit hydrologically from wetland restoration.

The most simplistic approach to examining current wetland effects on hydrology consider that all wetlands provide some sort of storage for rainfall and runoff events that help stabilize stream flows. First, one would determine which subwatersheds would benefit most from increasing storage. Consider the following:

- What is the percentage of remaining wetlands within each subwatershed?
- What is the percentage of wetlands in each of the landscape positions? This could be defined as percentage of headwater, isolated depressional (terrene in HGM terms) and floodplain.
- What is the percentage of impervious land cover in each subwatershed?

Hey and Wickencamp (1998) found that rivers within watersheds with low percentages of wetlands tended to also contain higher percentages of impervious surfaces causing decreased infiltration leading to greater runoff, and unstable stream flows. In addition, wetlands in headwater and depressional areas provide storage only from rainfall and runoff, while riverine (floodplain) wetlands provided the added benefit of floodwater (overbank) storage.

- Which subwatersheds have lost the most wetlands (and therefore storage)?
- Which subwatersheds have the highest percentage of potentially restorable wetlands?

  Subwatersheds that have lost the highest percentage of wetlands, would most likely benefit from increased storage. Those subwatersheds that never historically had a high percentage of wetland coverage may not benefit as greatly unless impervious land cover is high. In addition, those areas with higher percentages of potentially restorable wetlands will afford managers the opportunity to design wetland restorations that will help provide the stream stabilizing effects of increasing storage.

A simplified scoring system for the subwatersheds will be devised to help managers determine areas (subwatersheds) that may benefit most from targeted wetland protection and restoration. The use of the small catchments delineated for the water quality tool will also considered for finer resolution.

References for Floodwater Storage Decision Support Tool

Hey, Donald L. 2001. *Modern Drainage Design: the Pros, the Cons, and the Future.* Presentation at the Annual Meeting of the American Institute of Hydrology, October 14-17, 2001, Bloomington, Minnesota.

Hey, Donald L. *Wisconsin Ecological Flood Reduction Study.*

Hey, Donald L., and J. Wickencamp. 1998. *Some Hydrologic Effects of Wetlands.* IN: Water Resources in the Urban Environment. Proceedings of the 25th Annual Conference on Water Resources Planning and Management. June, 1998. American Society of Civil Engineering.

Sutter, Lori A. 1999. *NC-CREWS: North Carolina Coastal Region Evaluation of Wetland Significance. A Report of the Strategic Plan for Improving Coastal Management in North Carolina.* Division of Coastal Management. North Carolina Department of Environment and Natural Resources.

Sutter, Lori A. 2001. *Spatial Wetland Assessment for Management and Planning (SWAMP). Technical Discussion.* NOAA Coastal Services Center. Publication No. 20129-CD. Charleston, South Carolina, USA.

Chapter VIII: Putting it all Together

Overview

Before using any of the products of the MRB project, we advise the User to become familiar with the scope and limitations explained in Chapter 1 and with the assumptions that underlie the base data layers, the custom data layers and the decision tools. Some general considerations are repeated here.

- The MRB project is a 'first step' in wetland planning. Its products are intended for a Level 1 or landscape level analysis. Where this analysis leads to specific sites, decisions to develop further plans at those sites will require a Level 2, or on-the-ground, assessment.

- MRB project products are intended to be used in conjunction with other planning tools to help meet wetland-related goals of State and local governments, public and private conservation organizations and individual landowners.

- MRB project data is not intended for regulatory use. Floodplain and wetland boundaries are based on the best available data as of 2000. The least accurate data is at a scale (1:24000) and so most site-specific projects will require a field evaluation to determine actual boundary locations.

- The MRB project uses generally accepted methods to compare the potential of different wetlands to provide three broad classes of wetland functions. It assumes, however, that all wetlands have value and deserve protection. Site-specific factors will cause actual wetlands, and potential restoration sites, to vary in the type and degree of functions they provide.

- Existing and restored wetlands are not intended as a substitute for other best management practices used to control flooding and to maintain water quality and wildlife habitat.

How Reliable is the PRW Layer? -- PRW Verification

Before applying any of the products or Wetland Function Decision Tools, the PRW layer requires verification of how well it predicts actual potentially restorable wetlands. PRW verification is in progress through on-the-ground inspection in two ways: first by checking random points across the entire Milwaukee River Basin, and secondly by checking PRW areas within each of three subwatersheds selected for detailed application of the Decision Tools.

Over the entire Basin, we selected 30 randomly located points for field verification within *each* of the 58 subwatersheds – 20 points are within individual PRWs chosen to cover a broad size range; and 10 points are within areas that did not meet PRW criteria.

Within each of the three Phase 2 subwatersheds, PRW polygons were checked for the presence of PRW criteria, and also for the accuracy of PRW size and shape. Where

observers confirmed PRWs, they also conducted a Level 2 assessment of wetland restoration potential as preparation for testing the decision tools.
Results for both efforts will be included in a subsequent report. Preliminary results for the random verification of PRW points indicate accuracy of PRW occurrence exceeds 90% in the North Branch Watershed, and exceeds 80% in the East-West Branch and Cedar Creek Watersheds. Land use changes that postdate the base data account for most of the discrepancy between mapped PRWs and actual conditions. Wetland and soil base data did not contribute significantly to errors in mapped PRWs. All PRW map errors are confined to PRWs less than 1 acre in size or to subwatersheds that include areas of rapid development.

Accuracy of random non-PRW points also exceed 90%. All discrepancies are a result of points falling within mapping units that are small, narrow and attributed to scale error, or to the PRW criteria omitting soil types known to have hydric soil inclusions.

Using the Results

Voluntary Wetland Restoration and Wetland Compensatory Mitigation

Efforts to restore and rehabilitate wetlands, whether driven by voluntary conservation programs, compliance with municipal stormwater requirements, or requirements for wetland compensatory mitigation, all rely on locating potential project sites.

Searches for potential wetland restoration sites using specific program goals require time-consuming map reviews and screening before any planning can begin. The identified PRW locations reduce the site search effort. By combining PRW sites with the Subwatershed Metrics that clearly show which areas have the most restorable wetlands, and where historical wetland loss has had the greatest cumulative effect, we can promote restorations that address ecological needs beyond their project boundaries.

National recommendations for future wetland mitigation include using watershed assessment to guide replacement of wetlands based on functional values beyond those at a specific site, through consideration of past wetland loss and current water quality goals. Selection based on PRW locations and Subwatershed metrics are a first step to comply with these recommendations by enabling increased wetland compensation within affected hydrologic units and that addresses basic functional values.

Improved Basin Planning

The MRB project will take Wisconsin's "State of the Basin" reporting to the next level by providing a much improved wetland component. The limited information to assess wetlands in the first such report (August 2001) was the impetus for this project. State wetland data lags far behind the of other surface water resources. The 2001 report lists only the remaining number of acres of broad wetland types within each of 5 watersheds.

The MRB project allows planners a more meaningful view of wetland resources and past wetland impacts. First, it describes a finer scale by examining wetlands by type within each of 58 subwatersheds. Secondly, it attributes at least a qualitative measure of function to wetlands and potential wetlands, in place of wetland area alone, and allows comparison of functions both between and within watersheds. Thirdly, by addressing sediment trapping, flood storage and biodiversity separately, it forges a missing link between wetlands and other surface waters and to adjacent upland habitat.

Tool for Local Comprehensive Planning

Just as wetlands are only one element of a Basin Plan, natural resources – including wetlands -- are only one element of a comprehensive land use plan. Other major factors contributing to local land use plans are development, transportation and open space recreational goals.

The MRB project is an informational tool to build planning capacity relative to wetlands. Used along with local data and local planning priorities, the MRB project can help target restoration to meet an ecological need, inform choices among different land use options, and guide strategies to accomplish local goals.

The following are a few examples of how the User can apply elements of the MRB project. Each product and decision tool can be used alone or in combination. In addition, each decision tool includes variable index values that may be modified to reflect local interests.

The Ozaukee Washington Land Trust – Setting Protection Priorities

The Ozaukee Washington Land Trust has identified several large project areas within the Milwaukee River Basin with specific long-range land protection goals. The Trust works with willing land owners using a variety of protection methods such as conservation easements, conservation development, and transfer of development rights. To be most effective the Trust needs ways to allocate available staff time and financial resources among hundreds of potential properties with a wide range of conservation value.

By combining local parcel data with the MRB project PRW and Wildlife HQI layers, the Land Trust can rank parcels within each project area by objective criteria such as size, potential for wetland restoration, proximity to existing wildlife habitat or other protected lands, and the potential to connect otherwise fragmented environmental corridors. Often simply viewing the spatial relationships is enough to identify hot spots where protection effort is more likely to have a larger conservation impact.

The MRB tools also aids in leveraging protection funds. For example, the Milwaukee Metropolitan Sewerage District (MMSD) land conservation plan funds the purchase of critical land and conservation easements in undeveloped floodplain areas to help reduce the risk of future flooding. Using the MRB data, the Land Trust can identify specific wildlife habitat and water quality sites that coincide with MMSD's critical sites and work with local governments in its project areas to obtain additional benefits while meeting MMSD's main flood control objective.

At the City of Mequon, which has identified habitat for several species listed in the State Comprehensive Wildlife Conservation Plan, the Trust plans to modify the Wildlife Decision Tool to include additional factors in the Habitat Quality Index.

Land Use Planning – Inform Decisions on Alternative Scenarios

Because protecting or restoring every wetland isn't realistic, and because no single wetland can provide all wetland functions, and because restoration of any given wetland may not be practical, a main application of the MRB project is to help decision makers understand and compare different combinations of land use options, or alternative scenarios, that are on the table.

Comparison informs our understanding of why wetlands are worth saving. It helps integrate existing natural resources into wetland restoration plans by matching location, size, and type with the need to enhance a specific function or to optimize a combination of functions based on local choices.

Zedler, J. B. 2003. Wetlands at your service: Reducing impacts of agriculture at the watershed scale. Frontiers in Ecology and Environment. 1(2), 65Ð72.

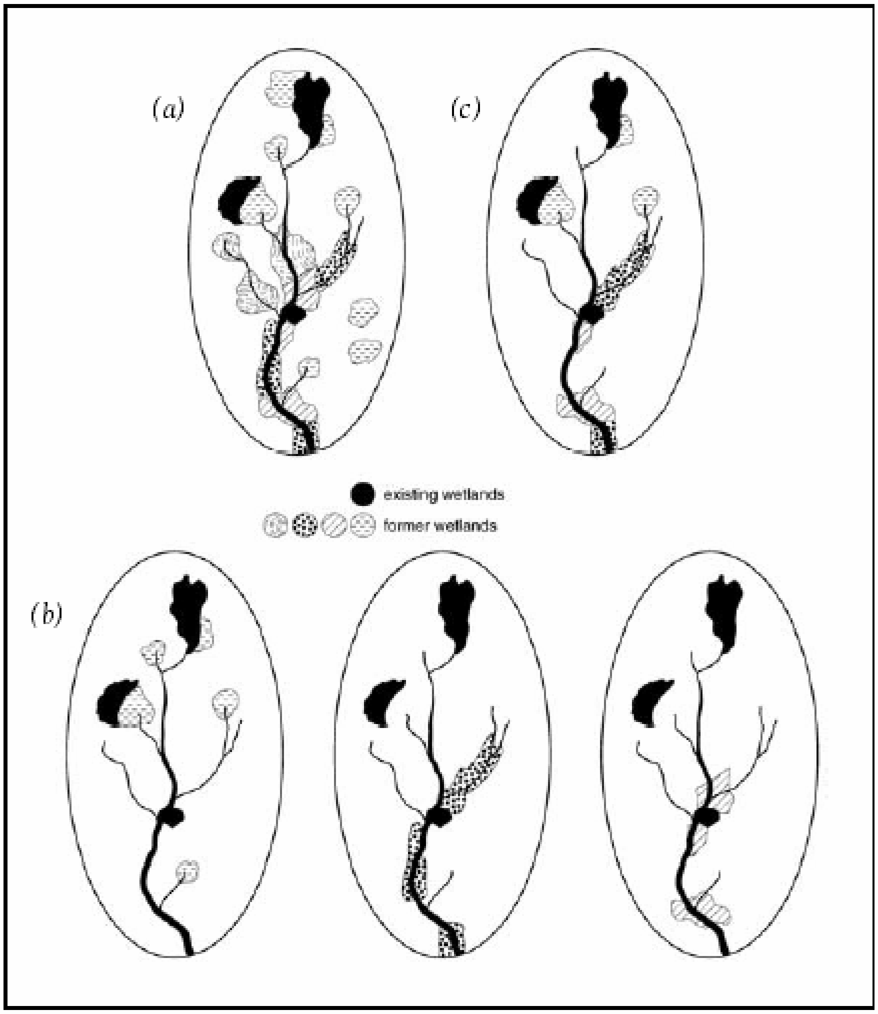


Figure 2. *Stylized graphic of an agriculturally dominated watershed. (a) Historical wetlands, with existing remnant habitat blocks indicated in black. (b) Alternative restoration scenarios designed to maximize individual ecosystem services, extrapolating from the limited literature on functions of agricultural wetlands. Left: biodiversity might benefit most from large wetlands near existing habitat blocks. Center: flood abatement may be most effective where riparian floodplains are restored. Right: water quality could be improved most by restoring wetlands downstream of tributaries with the highest nutrient-loading rates. (c) Multi-purpose design for restoring wetlands. The highest priority might go to sites identified in two or more of the designs in (b). Note that the area restored would likely be smaller than the areas drained in (a) or desired in (b).*

Appendices

Appendix 1: Processing Appendices

Objective

The following appendices give a step-by-step description of the processing performed to create data layers used in the project and for developing the decision support tools. These include the input layers that were used to create the base layer as well as three custom layers and the Wildlife Habitat Quality Index and the Water Quality Tool. The intended audience for these appendices is people trained in Geographic Information Systems or similar technologies and whose responsibility will be to do the same processes in other basins around the state.

The final appendix covers "Lessons Learned". Because of the nature of a pilot project, adjustments were made along the way when we encountered problems or learned more efficient ways to achieve an end result. Some changes were due to processing limitations of the computer while others were because of the limitations of the data. We hope that the Lessons Learned section will help others avoid some of the same problems and shorten the time period to create the PRW layer.

Processing Environment

We used Environmental Systems Research Institute (ESRI) workstation ArcGis v.8.2 for converting shapefiles to coverages, building topological structures and other analytical functions on coverages and grids. We used Environmental Systems Research Institute (ESRI) ArcView v.3.2a for generating preliminary shapefiles, running summary tables for quality control, and developing the habitat and water quality tools . The processes were done in a Windows NT desktop environment.

- Appendix A: Hydric Soils
- Appendix B: Mapped Wetlands
- Appendix C: Land Use
- Appendix D: Sub_watersheds
- Appendix E: Potentially Restorable Wetlands (PRW)
- Appendix F: Processing Metric Tables
- Appendix G: Drainage Ditches
- Appendix H: Lessons Learned
- Appendix I: Wildlife Habitat Quality Index (WHQI)
- Appendix J: Water Quality Tool

APPENDIX A - HYRIC SOIL

Hydric Soil Geo-Spatial Data Processing
Milwaukee River Basin Wetlands Assessment Project

Objective

Create a GIS data layer of hydric soils using Natural Resources Conservation Service's (NRCS) SSURGO soils. Hydric soils are a key component to identifying sites of potentially restorable wetlands. This layer will be one of the input layers for developing the base layer for this project.

Data Sources

Note: These steps must be done on each county separately before merging into one final layer because the HYDPART and HYDGRP classifications are not same between counties.

Natural Resource Conservation Service (NRCS): Through a cooperative agreement between Wisconsin DNR and NRCS, the county SSURGO soils are maintained in the DNR's GIS Library as individual data layers, which are tiled by county. Soil properties are also maintained by DNR in a series of tables. This process was done for Sheboygan, Fond du Lac and Dodge county soil data.

a. Load county shapefile or coverage and it's properties table into ArcView v.3.2a. The nomenclature used for the table by NRCS is <county FIPS number>pro.txt. The naming convention used for the shapefiles is **<county_abbrev>.shp.**
b. Turn off all fields in the property table except MUSYM, HYDPART, and HYDGRP. This ensures that only these attributes are carried over to subsequent layers.
c. Join the property table and the shapefile attribute table using MUSYM as the join field. The source table is the property table and the destination table is the shapefile attribute table. The remaining attributes should be SHAPE, AREA, PERIMETER, MUSYM, HYDPART, and HYDGRP.
d. Convert to another shapefile to retain the HYDPART and HYDGRP fields. The naming convention used is **<county_abbrev>_hydric.shp**.
e. Check for NULL values in HYDPART and HYDGRP fields. These usually represent polygons that are not true "soils" and thus are not assigned soil properties. This can be checked quickly by running a temporary summary file on the selected records with NULL values. The value "UN" for undetermined was used for these features and follows NRCS' model. However NULL values are also a way to discover slivers or other processing errors. First determine that they are slivers by calculating the total area and then use the ELIMINATE command to resolve. Any feature that has a NULL value and is larger than ___ should be manually corrected.
f. Convert the shapefile to a coverage format using ArcGIS Toolbox. Topology is automatically created in this process.
g. Create editing tolerances using an Arc Macro Language (aml) program. The following tolerances were set:
    - Weed 0.658
    - Grain 0.658
    - Fuzzy 0.658
    - Nodesnap closest 5.0 (this can be changed interactively in ArcEdit)

- Dangle 0
- Edit 25 (this can also be changed interactively in ArcEdit)

South East Wisconsin Regional Planning Commission (SEWRPC): SEWRPC data is tiled by township. Since NRCS' tables are county specific, it was necessary to first generate a county soil layer to which the soil properties table was later joined.

The APPEND command requires that the attribute tables on the all the input layers match exactly. This ensures that the attributes from each input layer is carried through to the output layer from the command. SEWRPC calls the primary key in their attribute tables TAG so we added the MUSYM field and populated by copying the values from TAG to the new field.

a. In ArcView, load each township file in a county and merge these into one county-wide shapefile using the GeoProcessing Wizard. It is recommended that users adopt a naming convention for these files for consistency and for managing data layers over time.
b. Open the new shapefile's attribute table and add a new field called MUSYM and define as a CHARACTER field and width of 8. This matches NRCS' field definition on the geo-spatial layers. Calculate the values for the new field by copying the values in the TAG field.
c. Load NRCS' properties table for this county and turn off all fields except MUSYM, HYDPART, and HYDGRP
d. Run a summary file on the MUSYM field in the attribute table. Run another summary file on the MUSYM field in the property table and compare the two for values that do not match. For the join to work properly, they must be identical. In some cases such as WATER or G.P. (gravel pit), the values may be slightly different and can be corrected by changing the value in the attribute table to match the property table. Refer to the published soil survey to reconcile any valid soil types with NULL values.
e. Join the property table to the shapefile attribute table using MUSYM as the join field. The property table is the source table and the attribute table is the destination table.
f. Delete the TAG field. The remaining attributes should be SHAPE, AREA, PERIMETER, MUSYM, HYDPART, and HYDGRP.
g. Convert to a new shapefile using the same naming convention that was used for NRCS data.
h. Check for NULL values in HYDPART and HYDGRP. These should only be features that are not soil types such as G.P. (gravel pits) or W (water). Calculate HYDPART and HYDGRP to UN for these. Any features that are valid soil types that have NULL values should be investigated further to determine why they have a NULL value. A visual check is often the best first step to determine the nature of the error. Refer to the published soil survey to resolve errors.
i. Convert to a coverage format using ArcGIS Toolbox.
j. Set editing tolerances using an Arc Macro Language (aml) program.
k. Run a DISSOLVE using the ALL argument to eliminate the township boundaries. This will dissolve adjacent features, which have the same MUSYM, HYDPART and HYDGRP values.

Hydric Soil Layer

This is the second input layer that will be used for generating the Potentially Restorable Wetlands base layer.

a. Merge all the county hydric soil layers into one coverage using Arc's MAPJOIN command.
b. Check for slivers by querying for features with NULL values in each of the attributes. Small slivers can be resolved by using Arc's ELIMINATE command and include the KEEPEDGE and AREA arguments. The KEEPEDGE ensures that any slivers that occur along the outside edge will not be eliminated. These should be kept to ensure the maximum extent of the layer matches the basin. Any features along the edge that have a NULL value for any attribute were visually checked and either merged with adjacent features by eliminating the arc that separates them or manually populating the attributes.
c. Overlaps did occur within the SEWRPC counties along county boundaries. These were found because one or more of the attributes were blank. A visual inspection of the original data showed that there was an overlap in the coverage between the counties. The records were corrected by referring to the original data to determine if the MUSYM was the same and manually editing the attributes. The overall area that this amounted to was very small.
d. Clip to the Milwaukee Basin boundary using the coverage, BASINCLIP. This coverage was generated from the Department's GIS layer, WSDRMGT.shp, which contains the official basin boundaries adopted by the DNR.
e. Build for polygon topology.
f. Check for NULL values again. Create a summary file on MUSYM and include AREA_SUM. This is used after the intersecting process to ensure that the amount of hydric soils remained constant throughout.
g. Dissolve on all attributes to reduce the number of polygon features. This command will eliminate boundaries between polygons that share the same attributes.

Quality Control/Quality Assurances (Qa/Qc)

Due to the sheer volumn of data and lack of any batch routine to expedite the process, we only checked for slivers, dangles, and gaps for quality control on the geometry. The advantage of the coverage format is the range of tools available in Arc/Info to check for these and resolve. Commands like DISSOLVE and ELIMINATE were an efficient way to eliminate boundaries that were artifacts from the overlay process and to reduce the overall size of the layers.

Quality control checks were done after each major processing step and any issues or errors were resolved before proceeding to the next step. We ran a summary table on each major attribute to ensure the domain was correct and there were no anomalies. As with most of the summary tables, sum_area was included which gave us another measure after each processing for outliers. Once the final hydric soil layer was completed, LABELERRORS was run to ensure there was consistency between polygons and labels and to prevent the loss of any attributes in later steps.

We also used a summary file using the MUSYM attribute and including sum_acres to do random checks against the HYDPART and HYDGRP values in the attribute table against the original property tables from NRCS. We found that there were some soil mapping units that were considered hydric in one county but not in another. This forced us to generate a county specific shapefile after each table to join to ensure the right properties were aligned with the right mapping unit. We consulted with local NRCS staff to help us resolve any questions.

Notes on Processing Soil Data: When we began the project, SSURGO certified soils were not available for the SEWRPC counties but SEWRPC had the preliminary layers available. We decided to use these as we were advised that the final certification process rarely resulted in changes to the geometry of the soil boundaries. During the processing of these layers, we encountered conflicts between the MUSYM values in the geo-spatial layer and the NRCS soil property tables. We documented them for quality control purposes. However eventually the certified soils layers were made available and we replaced them in this layer. These data did not have the same conflicts between the attribute table and the property tables.

APPENDIX B - MAPPED WETLANDS

Wetland Geo-Spatial Data Processing
Milwaukee River Basin Wetlands Assessment Project

Objective

The objective is to develop a layer that represents the mapped wetlands in the Milwaukee River Basin that will be used as an input for creating the Potentially Restorable Wetlands layer. We knew we would use the Digital Wisconsin Wetlands Inventory (DWWI) as the base wetlands since it has statewide coverage and therefore the process could be used in other parts of the state. But we wanted to supplement these data with other data *where available* to identify wetlands that may not be captured or identified in WWI and which may be more current than WWI. For example SEWPC captures agricultural lands that have gone fallow as lowland pasture but DWWI may not have included years ago. However because wetlands from SEWRPC are included in the third input layer, Land Use, the mapped wetland layer created in these processes does not contain ALL mapped wetlands. Only the final PRW layer has all mapped wetlands in the basin.

Data Sources

Wisconsin DNR's Digital Wisconsin Wetland Inventory (DWWI):

a. Merge township tiles obtained from the Bureau of Fisheries and Habitat into individual county shapefiles.
b. Merge the county layers into one shapefile using the GEOPROCESSING WIZARD
c. Clip to the Milwaukee Basin boundary using the coverage, BASINCLIP. This coverage was generated from the Department's GIS layer, WSDRMGT.shp, which contains the official basin boundaries adopted by the DNR.
d. Convert to a coverage format using ArcGIS ToolBox.
e. Set tolerances using Arc Macro Lanaguage (aml) program.
f. Check for slivers in ArcEdit by querying on any user-defined attribute that has a NULL value. Visually check a random number of the selected features to determine nature of the slivers. List the AREA of selected features to look for larger features that suggests they are the result of a processing error. The key is looking for features with an unusually high AREA value. Check against the original data and manually edit in ArcEdit if necessary. After verifying that none of the selected features are processing errors, calculate their total area to ensure that eliminating them will not have a negative impact on any analysis or metrics.
g. Resolve by using Arc's ELIMINATE command and the KEEPEDGE and AREA arguments. Check again and if any slivers remain along the basin boundary, manually edit in ArcEdit using edit feature = arc.
h. BUILD for topology
i. DISSOLVE on WETCODE to eliminate township boundaries
j. Use the BUILD command to restore topology.
k. Use LABELERRORS to ensure proper polygon/label relationship

SEWRPC Wetlands: Included in the Land Use Layer

The wetlands from SEWRPC are included in the Land Use layer and therefore there is no processing described in this Appendix. We evaluated the land use classifications developed by

SEWRPC and relying on the field experiences of several members, decided that the following features were considered mapped wetlands: LUCODE = 816, 910, 950, and any LUCODE that had a suffix of "G". Refer to **Appendix C – Land Use** for more details.

Ozaukee Restored Wetlands:

Ozaukee County contracted with Jill Hewitt in 2000 to digitized restored wetlands. Jill provided the data in a shapefile format which was referenced to Ozaukee County Coordinate System.

a. Convert shapefile into a coverage and projected to WTM83/91
b. Set tolerances
c. Clip using BASINCLIP layer and restore topology using BUILD command
d. Use LABELERRORS to ensure proper polygon/label relationship
e. Check for any features with NULL values. There were none.
f. Check for slivers. When converted to coverage there was one small sliver that was deleted in ArcEdit and restored topology using BUILD command
g. Use DROPITEM to drop attributes not required.

Note: there were two features in the original shapefile that did not contain any AREA values. We found that these were for point symbols and were added to the database late in 2002 after Jill did the bulk of her work but were not included in her analyses. These were dropped for our project.

Reed Canary Grass Project data (Using Landsat 7 Imagery To Map Invasive Reed Canary Grass, *EPA grant #CD975115-01-0*)

This layer doesn't give any new geometry but does provide one of the few indicators of wetland ***quality*** that we were able to use in the project. The raw data is in raster format (grid) and had to be converted to a vector format (coverage) for further processing.

a) Source data is from the project, Using Landsat 7 Imagery To Map Invasive Reed Canary Grass, which used Landsat Imagery to identify reed canary grass monocultures. Raster data output from that project was converted to vector format using Arc's GRIDPOLY command.
b) Added new field, RCG_CODE and coded areas classified as heavily dominant and areas classified as co-dominant with values of 1. All other wetland areas that were classified as "Absent to sub-dominant" kept their value of 99 from the original data. The background polygon was given a value of -88 to prepare layer for intersection with hydric soil layer. This ensures that features that are on uplands retain a value of –88. If this step is not completed, these features assume the 99 code after the intersect process is completed.
c) Generate new coverage using ArcPlot RESELECT command to select out just the reed canary grass features. In Arc, we used the RESELECT command along with the writeselect command to generate a new coverage.

Mapped Wetlands Layer

There is no Arc/Info command that will combine more than two layers that share the same geographic space, at a time. Since we had three sources we used an iterative process to generate the final wetland layer.

a. Use IDENTITY command to merge DWWI wetlands with Ozaukee County Wetlands. Named temporary coverage TMP_WETL. The attributes tables from each input layer are retained in the output layer from the IDENTITY command but features from one layer will have NULL values from the other layer.

b. Check for any slivers or other errors that might have occurred as result of IDENTITY. There were none.
c. Selected features that had a NULL value for PROJECTTYP and after ensuring that they were not errors (visually checked against the original data from Ozaukee County), coded them as NA for this attribute. Since the DWWI data covered the entire basin, there were no attributes from this layer that were NULL.
d. Use IDENTITY command to merge TMP_WETL with Reed Canary Grass wetlands. Even though the DWWI data were used as a mask for classifying these data, the process of converting a raster data set to a vector format creates artifacts that will not match the original wetland boundaries used as a mask. Therefore there are some features that are coded as being reed canary dominated but not classified as wetlands from either of the other two data sources. Because they are artifacts from the conversion process, we did not classify these features as wetlands.
e. Add DIS_WETL item and populate features using the following criteria:
   - Features coded as W include -
     - All DWWI features where CLASS = Aquatic bed, Emergent/wet meadow, Forested, Scrub/Shrub, Flats/unvegetated wet soil, Open Water, and Wet
     - Any record that is coded as Enhanced, Created, or Restored in PROJECTTYP
     - Any feature that has a GRIDCODE of 1, indicating reed canary grass wetlands. The remaining features were coded "X"

Quality Control/Quality Assurances (Qa/Qc)

Note: The description below was written while developing the steps which ensured most were captured while fresh in our minds. It is not intended to give every detail of the process but give the user an idea of the considerations if trying to replicate in another basin of the state.

<u>Check for slivers:</u> A sliver is normally created when two or more data sets, that are adjacent to each other, are combined into one data layer or coverage but whose edges do not match exactly, which results in gaps. In the coverage data model these gaps are given a record but will not have any user-defined attributes assigned. The first step is to determine if the slivers can be dealt with in a batch command such as ELIMINATE or through manual editing.

a. In ArcEdit, select slivers by querying on any user-defined attribute that has a NULL value. Visually checked a random number of the selected features to determine nature of the slivers. List AREA of selected features to determine if any features were selected using this query that are NOT slivers but may be other types of errors. The key is looking for features with an unusually high AREA value. These were checked against original data and manually edited.
b. List all user-defined attributes on selected features to verify that all fields are NULL. Any with a valid value should be further verified to determine why one field is NULL but not others. In this case, there were none.
c. After these edits are completed, the remaining features with NULL values should be checked again to confirm that they are slivers. These are resolved by using Arc's ELIMINATE command with the following arguments:

   Eliminate wetpw924 wetpw924_el keepedge poly area

The KEEPEDGE argument will retain sliver polygons that are neighbors to the background or universal polygon. Eliminated any remaining slivers that were along the universal polygon in ArcEdit using edit feature = arc. Edit tolerances were

weed = 0.658
grain = 0.658
nodesnap closest 5.0
intersectarcs all

Attributes: We relied primarily on summary tables to check attribute accuracy.
Confirm Wetland Classes: We generated a summary table on the WETL_CLASS to ensure the classes were unique – i.e. no spelling errors – and they matched the data dictionary. Through a series of queries on each wetland class, the other attributes were checked to be sure the WETCODE or PROJECTTYPE values supported that the features were wetlands.

Confirm features with DIS_WETL code = "W" . That same approach was used to confirm that features that were coded as non-wetlands (DIS_WETL = 'X") were non-wetland types in WETCODE and had a value of "NA" in PROJECTTYP.

Examples of how we used the results from summary files:

DIS_WETL = 'X'
Select features that are coded as DIS_WETL = 'X". We verified the accuracy by generating a summary file on the following fields:

- WETL_CLASS: results showed Excavated Pond, Filled/drained wetland, Former Wetland, Road, Surface Water, and Upland
- LU_CODE: results showed no values that indicated a wetland with the exception of 950. However when this code is coupled with MUSYM = "Water", it is indicative of surface water not a wetland. We reconciled these in the final layer.
- PROJECTTYP: all have value of NA in this field.
- GRID-CODE = 1: a value of '1' indicates reed canary grass. However all the features with this value have a LU_CODE that indicates it is in a landuse category other than a wetland. These features have all been coded as either WETL_CLASS = 'Former wetland", "Upland", or "Road" (when LU_CODE = '400'). In the cases where they are coded as a Road, these were visually inspected and the primarily fall on the road features that came from TIGER 2000. It appears that the reason for the disparity is due to resolution differences between sources.

"DIS_WETL" = 'W'
Summary tables:

- WETL_CLASS: results showed 10 records that were coded as "Surface Water". These were corrected. All has LU_CODE = 950 and MUSYM = 'Water" but were also coded as having reed canary grass. Our decision rules classify these features as surface water and not a wetland.
- LU_CODE: those with a non=wetland code have been coded in Ozaukee County wetlands data as having been a restored, created, or enhanced wetland. Those features with a LU_CODE in the 900's series but not 910 also have a WWI code that indicates a wetland. It was felt that these could very well have been missed as a wetland in SEWRPC's data and so the WWI over-rides on these features.

APPENDIX C - LAND USE

Land Use Geo-Spatial Data Processing
Milwaukee River Basin Wetlands Assessment Project

Objective

Develop a GIS data layer of land use in the Milwaukee Basin. This layer is an input layer for the development of a final "potentially restorable wetlands" layer. Originally there was no land use data available in the northern portion of the basin, an area not generally serviced by the South East Wisconsin Regional Planning Commission (SEWRPC). We created a composite layer for that area using WISCLAND land cover data supplemented with a buffered road layer. We felt that this would be the closest to representing “land use” using what data was currently available.

During the later stages of the Phase I, the counties in the northern area contracted with SEWRPC to generate similar land use layers as they had done for the seven counties in their jurisdiction. With the exception of a few small areas along the basin boundary, we ended up with a consistent land use layer for the entire basin. We relied on the composite layer to fill in along the boundary where land use data was not available because SEWRPC’s basin boundary is different than DNR’s.

Data Sources

<u>SEWRPC 2000 Land Use:</u>

DNR Regional staff had previously merged the township tiles into county shapefiles so we were able to skip that step.

a. In Arcview, merge county tiles into one shapefile
b. Convert shapefile to a coverage format.
c. Set tolerances
d. Check for slivers and overlap features by querying on each attribute for NULL values. We found significant problems resulting from the shapefile-to-coverage conversion. There were over 800 features with NULL values but when checked against the original shapefiles, they all had valid LU_CODES. Upon closer check we found that these features were often part of a multi-part feature meaning that what appeared to be more than one discrete polygon, were actually only one record in the shapefile attribute table. When these were converted to the coverage data model and topology was built, only one of the features retained the original attribute values. Through a series of trial and errors, we attempted to find a solution using a batch command or tool. After several unsuccessful attempts, we corrected these manually by viewing the original shapefile in ArcView and correcting in Arc/Info on the coverage version. Any gaps that we found along the county boundaries were resoled through the next step.
e. Use Arc's ELIMINATE command to reduce number of small polygons. For Milwaukee River Basin, we used an AREA threshold of 500.00 sq. meters. The ELIMINATE command merges selected polygons with adjacent polygons that have the largest shared border and the largest area.
f. Clip to Milwaukee Basin using BASINCLIP

<u>SEWRPC 2000 Land Use for Northern Portion of the Basin:</u>

Through a cooperative agreement between SEWRPC and Sheboygan and Fond du Lac counties, we were able to obtain land use data from SEWRPC for the northern portion of the basin that fell in these two counties. This provided us with consistent land use data for almost the entire basin. The exceptions were a small portion in Dodge County and areas along the basin boundary because SEWRPC's basin is delineated differently than DNR's. (?basin_difference.jpg?) We used the combined WISCLAND/Buffered Road layer to fill these areas.

We received the updated data after we had completed processing on the final base layer. Since only the northern two counties' data was updated, we clipped out the northern part of the base layer and only processed the new data for that area of the basin. The same steps used on the final base layer was repeated for the part of the basin and this layer was then merged back with the data in the sourthern part of the basin. We created two new clip layers to facilitate this process using the Department's county library layer as the source.

<u>WISCLAND Land Cover</u>

a. Original grid layer was clipped using GRIDCLIP command in Arc/Info using bounding coordinates that would encompass entire project area. This command only carries forward the VALUE item and converts it to GRID-CODE.
b. Convert to a vector or coverage format using GRIDPOLY command and called the output layer: MI_WLCPOLY.
c. Set tolerances using Arc Macro Language (aml) program.
d. Clip MI_WLCPOLY using CLIP_NOBASIN coverage and called output layer: MI_WLC.
e. Add LU_CODE item to the attribute table to prepare for the UNION step. Develop a cross walk table to assign LU_CODES to WISCLAND features. The land use classifications (text descriptions) were developed from the LU_CODES and these cover the major portion of the basin. Eventually the GRID-CODE may be dropped.

Note: Features with a GRID_CODE of 255 were re-coded at a later date using Digital Orthophotos as a backdrop. The approach was to look at a feature on the ground and if it appeared to be part of a larger area, then the GRID_CODE from the adjacent feature was assigned to the feature. For areas that were completely in the cloud area, we made a decision on the LU_CODE to assign based on photo interpretation and nearby features that appeared to be similar on the photo.

<u>Buffered Roads:</u> U.S. Census Bureau TIGER 2000 Line Files

a. Clip TIGER 2000 roads by clip cover for non_sewrpc area (CLIP_NOBASIN)
b. Add item for buffering roads based on road class (BUFFITEM)
c. Buffer using ArcViews BUFFER routine
d. Use Xtools "Convert Single Shape to Multi Shape"
e. Clip with clip cover for the non-SEWRPC area. This eliminates small slivers caused by rounded buffered areas that will fall outside actual basin boundary.
f. Add new field to distinguish these features from WISCLAND features in next step
g. Merge/Intersect layer with Clipped version of WISCLAND layer for non-SEWRPC area.

<u>Land Use Layer</u> The process described here reflects the steps used to derive the land use layer before we received the updated land use for Fond du Lac and Sheboygan counties. The operations were fairly similar and so we felt they only needed to be described once.

a. Using the MAPJOIN command, the northern data, which was comprised of WISLAND and Buffered Roads, were combined with the southern data, which was SEWRPC's land use data.
b. Set processing tolerances
c. Developed a cross walk table for assigning LU_CODES based on GRIDCODES and vice-versa. Coded attributes based on the tables.
d. Checked for slivers or gaps and features with NULL values.
e. Ran summary files to verify the values were unique.

APPENDIX D - SUB-WATERSHED

Sub-watershed Processing
Milwaukee Basin Wetland Project

Abstract
The Milwaukee River Basin (8-digit Hydrologic Unit Code - HUC) covers 861 square miles, which DNR divides into 6 watersheds (10-digit HUCs). The smallest, the Kinnickinnick Watershed, is completely urbanized and not considered further for wetland restoration potential. The remaining five watersheds range from 266 to 129 square miles, and are in-homogeneous with respect to land cover and major features used to examine wetland function, such as extent of impervious surface, topography and soil type.

Analyzing conditions within such in-homogeneous areas will result in "averages" that don't reflect actual conditions anywhere on the ground. The size of each watershed is also much larger than a typical community or local planning area. Local planning areas are typically 36 sq. miles (a Township) or less.

To reduce the effects of in-homogeneity, and to more closely match the scale of local plans, it's necessary to divide each watershed into smaller hydrologic units. We chose the next smaller division, sub-watersheds or 12-digit HUCs.

Wisconsin intends to follow Federal standards established to create the national Watershed Boundary Dataset. Ultimately this dataset will be a seamless nationally consistent database of hydrologic units based on scientific hydrologic and mapping principles (Federal Geographic Data Committee, 2002). We chose to follow the current draft Federal guidelines both to seek consistency with the final dataset and to advance the Federal project by proposing boundaries based on site-specific data wherever possible.

Major requirements of the standards are that all hydrologic units, including sub-watersheds, be defined along natural hydrologic breaks based on land surface, surface water flow and hydrographic features, rather than administrative or political boundaries. Because sub-watersheds are subdivisions of a higher-level hydrologic unit, they also must share common boundaries with the existing hydrologic units in the next higher level of the hierarchy – in this case, watersheds. Each hydrologic unit is generally divided into 5 to 15 smaller units, with sub-watersheds typically between 10,000 and 40,000 acres (15.6 to 62.5 sq. mi.), but never less than 3,000 acres (4.7 sq. mi.). Using these guidelines we identified 58 sub-watersheds nested within the six HUC level 4 watersheds.

Objective
Create a sub-watershed data layer for purposes of generating "per unit area" metrics for the Milwaukee River Basin. The smallest drainage unit, that currently exists statewide, is the watershed or the equivalent of USGS Hydrologic Unit level 4. In the Milwaukee River Basin there are 6 of these major watersheds. Some of these have relatively homogeneous land use. For these cases using the entire watershed as the "per unit area" basis will result in metrics that reflect actual conditions. Where land use in a watershed is highly non-homogeneous, however, averaging parameters such as past wetland loss, or growth rate over the entire watershed will result in a number that has no relation to what's on the ground.

Data Sources

USGS: Drainage basin data from USGS: USGS provided preliminary drainage basin boundaries which provided us a first cut of the sub-watershed boundaries. The data were provided in Arc/Info coverage format in UTM Zone 16 projection.

a. Append Coverages: data from USGS arrived as several coverages in various stages of editing. These were combined into one layer using Arc's MAPJOIN command. The MAPJOIN command requires that the attribute tables of all the input layers be identical to one another. MAPJOIN recreates topology
b. Topological consistency was verified in ArcEdit using arc as edit feature and selecting for dangles and overshoots. Edit tolerances and process steps were as follows:
c. Weedtolerance 0.658
d. Grain 0.658
e. Nodesnap closest 5.0
f. Intersectarcs all
g. Select dangles
h. List length however a visual check was also used on the longest ones
i. Delete
j. Build nodups nodiffs
k. Save
l. There were no user-defined attributes to check so slivers were found by simply checking for polygons with small area values. None were found.
m. Project Data to WTM83/91: Projected coverage to WTM83/91 using Arc's PROJECT command. A project file was created using the paramaters provided by USGS as well as those for WTM83/91.
n. Topology restored with BUILD command.

DNR: Watersheds from DVGISLIB

a. Clip out Milwaukee River Basin watersheds using ArcPlot SELECT command and writing to a select file.
b. Created a new coverage using Arc's RESELECT command with the select file an input. Using this command retains the attributes from the original layer and automatically builds polygon topology.
c. Add additional attributes with ADDITEM command

SEWRPC: Sub-watersheds from South East Regional Planning Commission SEWRPC hydrologic units were used as a check on the delineation of the sub-watersheds for three reasons: 1) as a check on the way the sub-watershed boundaries were drawn:
2) to show the relationship between DNR sub-watersheds and the SEWRPC drainage areas, since many of the local plans use the latter: and 3) to use USGS sub-watersheds as a base, rather than either of the SEWRPC's units, since neither of the SEWRPC units meet the Federal size and number standards.

a. Converted shapefiles to coverage format using ArcToolbox. This process automatically builds polygon topology
b. Projected to WTM83/91
c. Used Arc's ELIMINATE command to clean up slivers. This step eliminated a few small partial sub-watersheds along the border that must have been artifacts from a clip routine from SEWRPC

d. Renamed several sub-watershed features using the TAG attribute in order to make a unique sub-watershed name.
e. Added WSHED_ID field for DISSOLVE step. Populated this new field by using the first three characters of TAG field.
f. Dissolved on new field to generate sub-watersheds that more closely match USGS in size.

Sub-Watershed Boundary Delineation

Map Compilation:

Compare DNR watershed boundary with closest USGS boundary

a. Print the USGS 7.5 minute quad maps of the area with the DNR watershed boundary and the USGS/SEWRPC hydrologic units. Use symbology to keep all themes visible where lines overlap. The paper map needs to cover the entire DNR watershed *and* any intersecting USGS/SEWRPC sub-watershed.
b. Regional water staff was asked to do a quick scan of the entire boundary and point out areas where they can resolve any discrepancy based on their site-specific experience or data.
c. Decide at what measure remaining differences between DNR and USGS warrant further review. For the North Branch Watershed we used 0.5 inches at 1:24000 or 1000 ft. This level eliminated about 80% of the watershed boundary from further review. A finer measure would require more review time than we have available. Best number needs to be evaluated for each watershed.
d. Identify the boundaries for further review. Put an imaginary rectangle over any unresolved incongruous area. Determine the dimensions of the rectangle by allowing the entire area to just fit within the rectangle. Areas for further review are those where the shortest dimension of the rectangle exceeds the predetermined 0.5 inches. Note: Using 0.5 inches captured some areas that are too small for concern, but the typical area captured exceeds 160 acres. The largest discrepancy was over 1000 acres.

Heads up Digitizing

Use current DNR watershed boundary for W4, but modified the areas to more closely match sub-watersheds in USGS project. The following criteria were established for deciding which boundaries to digitize:

a. Less than 0.5 in, assume difference isn't significant
b. More than 0.5 in, discrepancy area is apparently internally drained, so difference is not significant for W4; it may be for USGS
c. More than 0.5 in, DNR boundary looks better, clear cut case
d. More than 0.5 in, USGS boundary looks better or ambiguous, send to Jim B. for expert review

We converted the shapefile to a coverage format and built topology. In ArcEdit, we corrected any digitizing errors that were found.

Populated the attributes with unique swshed_code and swshed_name. We used the SEWPRC naming convention when the name was unique. Otherwise we assigned names and codes using the major stream in the sub-watershed. Initially we did not include the Kinnickinnic River Basin in this layer because sub-watersheds were not developed as part of the project. However we found later that it was useful to include to facilitate several overlay operations and for running summary tables.

Quality Control/Quality Assurance (QA/QC)

We printed out the maps at a scale of 1:24K so they could be overlaid on the USGS 7.5 minute topographic maps, which were referred to often during the delineation step. Attribute accuracy was checked using a summary table to ensure there were 58 unique occurrences and spelling was checked by a core team member.

APPENDIX E: POTENTIALLY RESTORABLE WETLANDS

Processing the Potentially Restorable Wetland
Milwaukee Basin Wetland Project
Coverage Name: MRBPRWSE

Objective
Create a GIS data layer that represents areas of potential wetland restoration sites using hydric soils, wetlands and landuse data as the base layers. The theory is that if an area can be identified as an historic wetland but is not currently mapped as a wetland and if the area is in agricultural production or non-developed, rural areas, then it may represent a potential site for wetland restoration.

This data layer is designed for landscape level analysis. Existing data sets were used as the base layers. Minor inconsistencies at county and township boundaries were manually corrected in ArcEdit. No attempt was made to resolve inconsistencies in different classification systems.

INPUT LAYERS
- Hydric Soils
- Wetlands
- Landuse

Potentially Restorable Wetlands

a. Merge preliminary wetlands layer (MIWETL00) with hydric soils layer (MIHYDRICS) using Arc's IDENTITY command. Output layer is called MIHYDWETL
b. Set tolerances
c. In INFO, select features that have a wetland LU_CODE = '950' and a soil MUSYM = 'water'. Re-code these in WETL_CLASS as 'Surface Water' and code the DIS_WETL code to 'X'. These represent areas that are classified as open water but which are different than the Open Water wetlands from the Wisconsin Wetland Inventory. They can only be coded properly after this merge step.
d. Re-run summary statistics on WETL_CLASS to find any NULL features or mis-coded features. When creating summary tables, include AREA_SUM to help qa/qc against boundary file at a later step. Correct any errors found in summary table.
e. Merge MIHYDWETL with MILANDUSEE layer to create MIBASEPRW layer using the IDENTITY command.
f. Add items ACRES, MATRIX_CLS, DIS_WETL, SOURCE, MOD_CODE and populate according to the data dictionary. We populated the attributes in INFO to get faster processing time. Refer to the values defined in the data dictionary.
g. Intersected MIBASEPRW layer with the sub-watersheds so that features could be grouped by sub-watersheds. This facilitates the process of developing metrics by sub-watershed. The new layer is called MRBPRWS. The INTERSECT command creates a new coverage by overlaying two sets of features. The output coverage contains only those portions of features that are in the area occupied by both the input and intersect coverages.
h. Ran ELIMINATE command on the layer to reduce the number of very small features. In the MRBPRWS layer, there were over 32,000 records with a 0.00 value in ACRES

simply because of the precision used on this field and due to size of the feature. These features only represented a total of 55.00 acres so the ELIMINATE command was used to merge these with neighboring features with the largest shared border. The output layer is called MRBPRWSE

i. Ran LABELERRORS to ensure polygon/label relationship was correct. No label errors found.
j. We ran summary statistics on several attributes and compared them against the input layers.

Definitions

Defining what was an "original" wetland versus "lost" or "mapped" meant thoroughly evaluating the various combinations of attributes from the three input layers. We felt this information would be useful to other users and help understand how a feature was given any particular value.

Original Wetland are any areas that has hydric soils conditions (HYDPART = ALL) or are currently mapped as a wetland or a filled or drained wetland.

Formulas (query) for determining original wetlands:

HYDPART = "ALL" (selects all hydric soils)
DIS_WETL = "W" (this includes all features that are currently mapped as a wetland)
CLASS = "Filled/drained wetland" (adds to the set those areas that have been mapped as a filled or drained wetland)

Total Original Acres = 118,237.1700

Remaining Wetlands are any areas that are currently mapped as a wetland from any one of the sources that we used to generate the wetland layer.

Formulas (query) for determining remaining wetlands:
DIS_WETL = "W".

We added the DIS_WETL field to facilitate generating a simple query on a remaining wetland. Refer to the WETLAND_CODING_MATRIX.xls for a description of what is classified as a wetland for this project.

Total Remaining Wetland acres = 82,564.6300

Lost Wetlands are any areas that falls under the definition of an original wetland but are not currently mapped as a wetland. These include records that have the following criteria:

Formulas (query) for determining lost wetlands:

HYDPART = "ALL" and DIS_WETL = 'X'
CLASS = "Filled/drained wetland" (there are more CLASS values that occur as a LOST wetland but these are picked up in the first query)

Total Lost Wetland Acres = 35,672.5300

In theory the total number of remaining wetland acres subtracted from the total number of original wetland acres should equal the total number of lost wetland acres. This automatically works out when running statistics on this layer but that is an artifact of the coding schema used.

Quality Assurance/Quality Control (Qa/Qc)

Perhaps the most time consuming part of the qa/qc for this layer is assuring that the attribute codes followed the decision rules we developed for the project. We spent a lot of time evaluating the different combination of attributes from the sources used to determine what WETL_CLASS value a record would receive.

Hydric Soils

In the process of combining the hydric soils, wetlands and land use layers it is anticipated that there will be some loss of overall acres in any one of these categories. Tracking what we originally started with in each category provides a level of confidence in using the data for analysis.

Remaining Wetlands

Select DIS_WETL = “W” and ran summary table on WETL_CLASS. All are valid wetland classes. Sum area = 333660624.36 s.m. Then selected on WETL_CLASS on all the valid wetland classes and sum area = 333660624.36 also.

All have WETCODE that is a wetland class or SEWRPC codes that were considered wetlands (816, 910, 950 that do not have MUSYM = ‘W” for water, and those with a “G” suffix)

All are coded as REMAINING = ‘Yes’

Original Wetlands

Query ORIGINAL = ‘Yes’, total records are 367,902.

To confirm that the combinations add up the same and are coded “W”, we ran another query that starts with HYDPART = “ALL”, then add Select DIS_WETL = “W”, add WETCODE contains “$” , and add, WETL_CLASS = “Former wetland”. Total features selected = 367902. From this set select ORIGINAL = ‘Yes’ to confirm that the same 367,902 records are indeed coded as original.

APPENDIX F - PROCESSING METRIC TABLES

Milwaukee Basin Wetland Project

Description

The metric tables provided us a means of developing potential ecological indicators or "per unit area" metrics for the Milwaukee River Basin. They were generated from the base layer, MRBPRWSE, which contains the sub-watershed boundaries. The sub-watershed boundaries and their unique codes were embedded in the base layer through an overlay process to facilitate developing the metric tables. Summary tables from ArcView v.3.2a are similar to an Arc/Info file that is generated with the FREQUENCY command. Both produce a list of unique code occurrences and may include summary items that are totaled for each unique occurrence. Additional fields were added to each summary statistics table in order to calculate percentages or other metrics.

Land Use Metrics

Tables:

MRB_LANDUSE_SWS.DBF: aggregates the summary tables which were run for each sub-watershed on the LU_CODE categories and total acres for each of those categories. This table is ultimately joined with the PIC_LUCODES.DBF table and then exported to create the PIC_MRB_SWS.DBF. There is also an Excel version of the same file.

PIC_LUCODES.DBF: contains all the possible landuse categories in the basin, the landuse codes, and the percent of impervious cover for each category.

PIC_MRB_SWS.DBF: percent of impervious cover by sub-watershed. Generated as a summary table from MI_LUCLASS_PIC.DBF on the SWS_CODE field and includes the name of the sub-watershed and the total amount of impervious acres for each sub-watershed.

SUM_PICBYSWS.DBF: summary of percent of impervious cover by sub-watershed.

Process:

1. In ArcView, generate summary tables on landuse categories for each sub-watershed:
   Using the attribute table of the base layer which includes sub-watersheds, (MRBPRWSE) each sub-watershed's landuse was summarized on LU_CODE and includes total area and total acres for each landuse category. (each table was named as <sub-watershed code_luclass.dbf>). Tables are located in ~GIS\metrics\landuse folder.

2. In Excel, aggregate sub-watershed summary tables in to one table:
   It is important that you convert to MS Excel format or the edits will be lost when you save the file. Then convert to tab delimited text (called **mrb_landuse_sws.txt)** format and open in Arcview.

3. Add percent impervious cover (PIC) values:
   In ArcView, add pic_landuse.dbf and join to the mrb_landuse_sws.txt table, using the LU_CODE field. This will imbed the PIC values for each landuse category. Export this table to a DBF format. (called PIC_MRB_bySWS.dbf)

4. Calculate impervious cover acres for all landuse categories in each sub-watershed:
   Add this new table and in edit mode, add a new field, called C_ACRES, to PIC_MRB_SWS.dbf table and populate the field using the following equation:
   a. ([lu_acres] * [pic]) / 100).

5. Imbed sub-watershed AREA to PIC_MRB_SWS.dbf to generate final summary table:
Join sub-watershed table, subwtshed_table.dbf to PIC_MRB_SWS.dbf using swshed_code. Before the join, turn off all fields except SWSHED_CODE and AREA and give AREA an alias name of swshed_area (use table properties for alias).

6. Generate final summary table:
Generate a summary table using the sws_code field and include sum_ic_acres, first_sws_name, and first_sws_area. New table called sum_picbysws.dbf.

7. Calculate percent of impervious cover for each sub-watershed:
Add two new fields to this new table: SWS_PIC (sub-watershed percent impervious cover) and swshed_acres. Calculate swshed_acres using the formula: ([swshed_area] * 0.0002471044). Calculate SWS_PIC using the formula ([IC_ACRES] / [SWS_ACRES]) * 100.

Wetland Metrics:
DESCRIPTION: To fully understand the impacts of lost wetlands for a given sub-watershed, we realized that we needed to understand the loss relative to how much wetlands existed in the subwatershed prior to European settlement. Straight acres lost can be misleading since two sub-watersheds may have lost the same amount of wetlands but percent lost relative to what was there originally could be very different.

<u>Tables:</u>
Mrbprwse_original_sws.dbf: amount of original wetland area by sub-watershed
Mrbprwse_Lost_sws.dbf: amount of lost wetland area by sub-watershed
Mrbprwse_Remaining_sws.dbf: amount of remaining wetland area by sub-watershed
Mrbprwse_prw_sws.dbf: amount of prw area by sub-watershed
Subwtshed_table.dbf: subwatershed codes, names, total area and total acres
Mrbprwse_wetlands_metrics.dbf: final wetlands metric table (also in Excel format)

<u>Process:</u>
1. Generate tables for original, lost, and remaining wetlands, each summarized on SWSHED_CODE and includes sum_area. There will be a unique record for each sub-watershed code in the table with total area of each category.

2. In Table>Properties, turn off the COUNT field, which is automatically generated from the SUMMARIZATION operation and give the SUM_AREA an alias that corresponds to the category. For example, in the mrbprwse_original_sw.dbf the alias for SUM_AREA would be original_area. This gives each total area in each table a unique name which is critical for the next step.

3. Join these tables to the Swshed_table.dbf using the swshed_code.

4. Export to a new dbase table and open in Excel. Save as Excel file for adding and calculating new fields.

5. Add fields to calculate amount of each category in acres and percent of each category. Formulas to use are:
   - Acres = (Area * 0.0002471044)
   - Percent = (Lost_acres/swshed_acres) * 100 (ex)

6. Add field to calculate NEED: formula is: Need = (Lost Wetland Acres / Remaining Wetland Acres)*% Original Wetland Acres

7. Export as Tab delimited text so the table can be used in ArcView.

Non-Forested Wetlands Dominated by Reed Canary Grass
Building metrics for reed canary grass (rcg) infestation in non-forested wetlands/subwatershed:

Tables:

Process:

1. ([WETL_CLASS] = "Reed canary grass wetland")
   (selects all wetlands that have a 50% or greater cover of rcg)
2. ([WETCODE].Contains ("T").Not)
   (Use the "Select from Set" option and this will select from the first set only those reed canary grass wetlands that do NOT have "T" in the wetcode. This will unselect all FORESTED wetlands but also any Filled/drained wetland with a "T" in the wetcode as well as those with WET in that field.)
3. ([WETCODE] = "WET") and ([WETL_CLASS] = 'Reed canary grass wetland")
   (Use the "Add to Set" option. This query puts back in to the selected set those that are classified as "WET" in DWI but are a rcg wetland)
4. ([WETCODE].Contains ("$")) and ([WETL_CLASS] = 'Reed canary grass wetland")
   (This last query puts back in to the selected set those wetlands that were filled or drained but because SEWRPC now has them mapped as wetlands should be included. It is our assumption that if these were wooded before they likely are not a FORESTED wetland now.)

5. Create summary file using SUBSHED_CODE field and include sum_area. Skip acres because so many have zero values and this can be calculated later. Name = reedcg_sws.dbf. Open Table Properties and turn off COUNT and rename SUM_ACRES to TOT_RCG in the ***alias*** column

6. ([DIS_WETL] = "W")
7. ([WET_CODE].Contains ("T").Not)
   Use "Select from Set'. These two queries are used to select all non-forested wetlands

8. Create summary file using SUBSHED_CODE field and include sum_area. Name = sws_nonforested_wetl.dbf. Open Table Properties and turn off COUNT and rename SUM_ACRES to TOT_NONFOREST in the ***alias*** column
9. Join these two tables to the SUBSTWSHED attribute table using SUBSHED_CODE as the joining item.
10. EXPORT to a new dbf table. Name = sws_with_perc_rcg.dbf. Remove all joins from SUBWTSHED table.
11. Add this to the ArcView project and under Theme select “Start Editing”. Add new field called PERC_RCG and define as TYPE = NUMBER, WIDTH = 5, DECIMAL PLACES = 1. Fill in zero’s for any subwatershed that has no rcg (Menomonee).
12. Calculate the new field as: ([tot_rcg] / [tot_nonforested]) * 100. Save
13. Join to the attribute table of SUBWTSHED on SUBSHED_CD.
14. Open Legend Editor and under Legend Type: select Graduated Color using PERC_RCG as the field. Select color scheme and modify number of classes as needed.

APPENDIX G – DRAINAGE DITCHES

Drainage Ditch Geo-Spatial Data Processing
Milwaukee Basin Wetland Project

Objective

To capture drainage ditches in the study area to compliment the surface water hydrography data layers currently available. Drainage ditches are a key to determine man-made alterations to wetlands in terms of hydrology. They provide a useful indicator of an historic wetland as well as indicating restoration opportunities.

Data Sources

WDNR 24K Hydro: The Wisconsin Department of Natural Resources (WDNR) has developed a statewide 1:24,000 scale hydrography GIS database (24K Hydro) that represents all surface water displayed as blue lines and areas on the 7.5 minute US Geological Survey (USGS) topographic maps. Ditches in WDNR 24K Hydro are defined as any single, solid or dashed, blue line labeled as a ditch or canal; OR any single, solid or dashed, blue line that follows man-made linear features or appears too straight to be termed a “natural” stream.

Drainage Ditches

Using the 24K Landnet data layer (Public Land Survey System features), the project area was divided into smaller units to facilitate tracking progress across the basin. By selecting out the townships and sections using an overlay selection operation, we used the attribute table from the 24K Landnet and exported to a new table. This was printed out and intended to be used in hard copy by tracking progress in each section. In practice this proved to be somewhat cumbersome since we found that we need to cross several sections at a time to digitize a feature.

In ArcView, we turned off all attributes in WDNR 24K Hydro table except for those used for the project. Select hydro features where LINEAR_TYPE = ‘DC’ and converted the selected features to a new shapefile.

Added additional attributes to the new layer that included several as defined in the Department’s Locational Data Standards.

We relied on background layers such as hydric soils, topographic lines from Digital Raster Graphics, and mapped wetlands, to name a few to assist with visual interpretation from Digital Orthophotos (DOPs).

Questions to ask when looking at an area/section:
Look for features in SEWRPC or City of West Bend layer to see if a ditch was defined by them.
Using the DOP, determine if the feature on the ground matches the criteria for this project.
What connecting hydrologic feature does the ditch drain into? Be sure to have the wetlands layer turned on in order to see if the ditch drains through or into a wetland.
Where is the beginning and where is the end of the ditch? Are either easy to find?

We tested an automated process for assigning CON_TYPE codes using overlays of drainage ditch layer with other GIS layers. However we found that the process was not very reliable based on several factors. In many cases, the ditch would flow through a wetland into a stream and within a short distance to a road ditch. It was impossible to completely remove the human decision element in the process. We found it was more efficient to assign codes during the digitizing process while someone was actually reviewing all the layers at that time.

Quality Control/Quality Assurance (QA/QC)
A thorough quality control process has not been completed on this layer at this time.

APPENDIX H: LESSONS LEARNED

Shapefiles versus Coverage formats:
We started out using shapefiles because much of the source data was provided in that format and most other users have access to ESRI's ArcView v.3.2a desktop software. ArcView provides an efficient and user-friendly set of tools such as joining tables, creating new shapefiles, and running summary files. However we found that as the various layers grew in size and complexity, the processes began to fail and would quit before they were completed.

The other compounding factor was the lack of topology on shapefiles. Topology explicitly defines spatial relationship between features and is defined in three major concepts:

- Connectivity: Arcs connect to each other at nodes
- Area definition: Arcs that connect to surround an area define a polygon
- Contiguity: Arcs have direction and left and right sides

So we converted the shapefiles to coverages for running complex processes and for quality control purposes.

Each of these provides an efficient way to check for processing errors. It ensures that there are no overlaps or features sharing the same geographic space. This was especially important when we started to develop metrics on the sub-watersheds. AREA and PERIMETER are automatically updated on coverages when building topology.

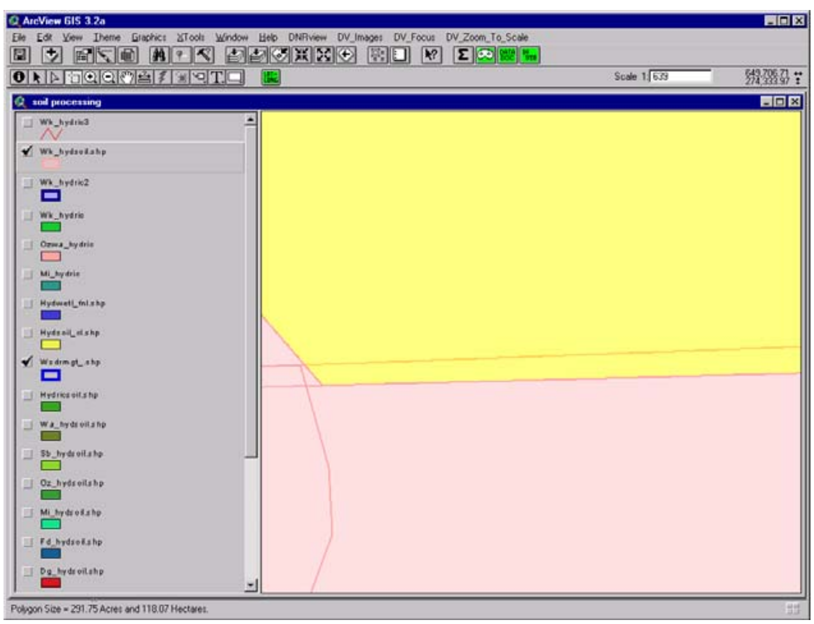


Image 1: An example of an overlap that occurred along county boundaries. Note the feature in yellow extends beyond the pink boundary, which represents the northern edge of another feature. In this case, the shared geography would actually be counted twice in AREA if left in a shapefile format.

Keeping Data Current
We spent a fair amount of time re-processing the input layers in an effort to keep up with more up-to-date data. Feedback from one of the first User Group meetings was that we take advantage of local data whenever possible. The presence of the South East Wisconsin Regional Planning Commission (SEWRPC) meant we were lucky to be able to do just that for a large portion of the basin. Whatever the theme, their data is consistently mapped across their region. This was particularly important for land use data because of the rate of development that occurs in this area of the State.

Normally SEWRPC's jurisdiction would extend as far north as Washington and Ozaukee counties. That was the case when we began the project and so we immediately began working on a strategy to address access to other land use data in the northern portion of the basin or the non-SEWRPC counties. These were Fond du Lac, Sheboygan, and Dodge. In 2005 we received the updated land use data from SEWRPC and we reprocessed the land use input layer and then regenerated the PRW base layer. Then in 200__ we obtained land use data for the Fond du Lac and Sheboygan portion of the basin. SO we went through that process again. The lack of a batch routine that would have facilitated that process, delayed work on the decision support tools.

Using Non SSURGO Soils
SEWRPC provided geo-spatial soils at the beginning of the project but the data had not been SSURGO certified. The assumption was that there would be no changes to the geometry after certification so we began processing the soils data right away. Later we learned the geometry did indeed change in a few townships and we were forced to run the process a second time. The certification process also corrected many of the errors we found when comparing the MUSYM in the attribute tables to the soil properties table. In retrospect we might have saved ourselves hours of processing but it would have also forced a significant waiting period to complete the final layer. During that time we learned valuable lessons about the processing environment that allowed us to make adjustments and end up with a better product in the end.

Verifying the Basin Boundary:
The first basin boundary layer that was used was not checked against the official layer maintained by the Department. When it became clear that we would need a basin layer for clipping purposes, one was created by selecting the basin out of the official layer and generating a new coverage with the boundary as its sole feature. During one of the quality control checks we found that there were several areas along the boundary where features did not have values in the attributes but were too large to be considered slivers. Upon further checks, we found that one of the input layers had been clipped with an earlier version of the basin and another had been clipped with the more current, official version. We discovered that there had been a few modifications made to the Milwaukee River Basin boundary in the last update and therefore we had been working with two versions. If we had created the clipping coverage right from the beginning, we would have avoided this problem and the need to redo some of the earlier processing.

Creating a Simpler Version of the Potentially Restorable Wetlands Layer (PRW):
When it became apparent early on that the final Potentially Restorable Wetland (PRW) layer was going to be very large and therefore cumbersome to use, we decided to retain only those

attributes that would address if a site was a PRW. By using a *dissolved* version of the input layers prior to intersecting with each other, we would end up with a simpler version of the PRW layer.

Each layer was dissolved on the main attribute: HYDPART from the soils layer, WETL_CLASS from the wetlands layer, and LUCODE from the land use layer. After intersecting these three layers however, we found that the attributes often contradicted each other and made it difficult to determine the true ground condition. For example, SEWRPC's LUCODE of 950 was sometimes a wetland feature but we could only determine that by evaluating the underlying soil type. So we needed the MUSYM field to determine the WETL_CLASS for those features. We also realized that retaining the raw data in the final PRW layer provided additional opportunities to test out hypothesis and facilitated more rigorous quality control checks on the data.

Rehabilitated Wetlands

The original intent of the project was to identify sites for wetland restoration. We developed a matrix to help us determine how to code features that had conflicting attributes from different data sources. It was through this process that we discovered an opportunity to identify sites for wetland rehabilitation. We ended up with two classes: cropped wetlands and reed canary grass wetlands. We assumed that both were functioning as wetlands but with limitations.

Appendix 2. Metrics Tables

Appendix 3. Wildlife Decision Support Tool Processing Documentation

Documentation for Wildlife Decision Support Tool

This document shows how the wetland and upland data were processed for the wildlife habitat decision support tool. The analyses documented in this report are based on information provided in the Milwaukee River Basin Wetland Wildlife Habitat Matrix (matrix), which was prepared by the wildlife habitat expert group (described in chapter ?).

The matrix shows how different wetland types provide habitat for a wide variety of wildlife species based on the umbrella species concept (see page ? for explanation). There are 13 wetland habitat types represented in the matrix. Of these, 10 of the types offer the most suitable habitat for wildlife if adjacent to particular wetland or upland habitat types. In those instances, we rely on proximity factors described in the matrix to determine the methods used to analyze the data to select the wetland types that meet the constraints of the proximity factors.

Following is a description showing how some of the proximity analyses were completed. This document does not describe the entire process for each of the 13 habitat types, but rather gives the reader an overview of the most rigorous of the analyses.

Considerations common to all wetland habitat context analyses:

Goal: Conduct a GIS-based assessment for wetland (and some upland) areas suitable for wildlife species.

Base file for all analyses: base_hqi.shp (49175 records)

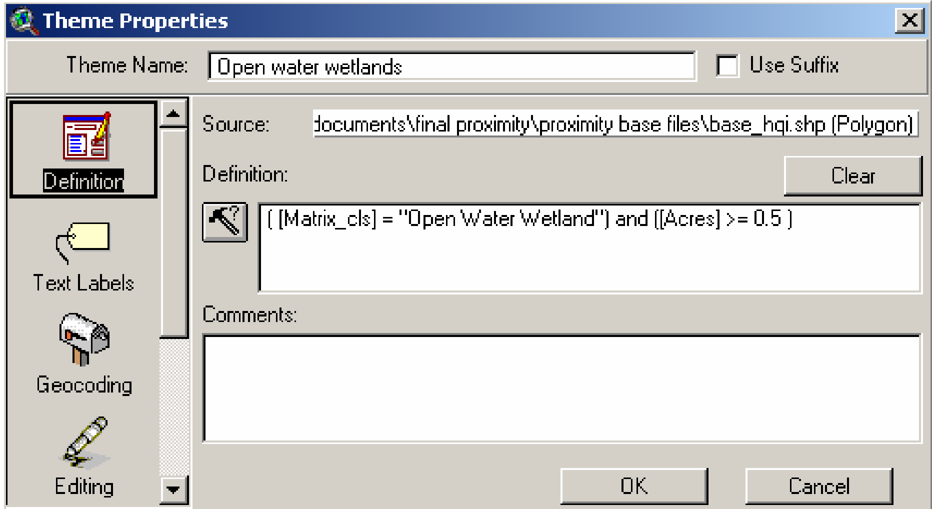
- Because of scale limitations, only wetland polygons of at least 0.5 acre were included in the analyses. This removes the potential for wetland “slivers” to be selected. These slivers are most likely an artifact of data processing, rather than representing a true wetland polygon.
- Only the wetland/upland types with a matrix value of at least a 2 (frequent use) or 3 (required habitat) are included in the analysis

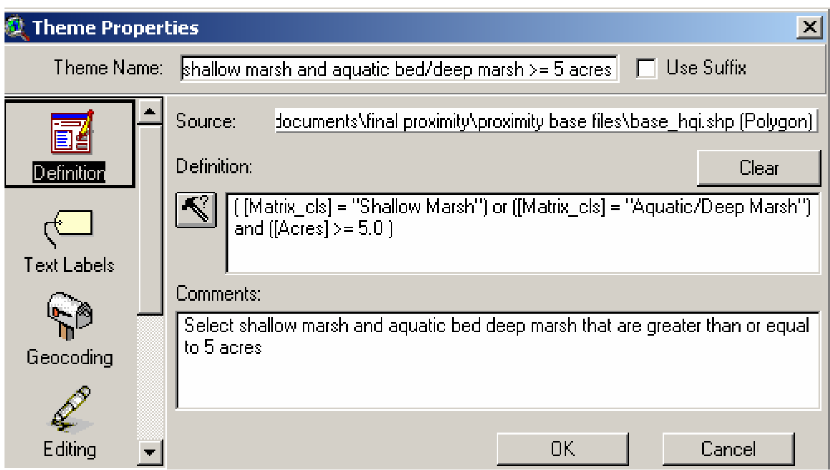
Simple Proximity Example: Open Water Wetland Habitat Context (Black Tern umbrella)

Factors: Select open water wetlands that are within 10 m of aquatic bed/deep marsh or shallow marsh that are 5 acres or larger.

Process:

1. Define the base file to show open water wetlands at last 0.5 acres (173 records).





2. Define the base theme to show shallow marsh and aquatic bed/deep marsh greater than or equal to 5 acres:

3. With the open water wetland theme active, use "select by theme" to show the open water wetlands within 10 m of shallow marsh and aquatic bed/deep marsh >+ 5 acres (31 features). Convert to shapefile (oww_prox_existing.shp).
4. Merge the file created in #3 above to the file created in # 2 above to create the final file showing the wetlands presenting the open water wetland habitat context for the umbrella species identified (Black Tern, etc.). The file is called oww_context_existing.shp.
5.

Shallow Marsh Wetland Context (American Bittern, Sora umbrella species)

Factors: Select aquatic bed/deep marsh, shallow marsh, and wetland meadow polygons >= 0.5 acres. Include reed canary grass if it is within 10 m of the other "2" and "3" wetland types.

1. Define the base theme to show the wetlands in the matrix coded a 2 or 3 (aquatic bed/deep marsh, shallow marsh, wetland meadow).
2. Define a second base theme to show reed canary grass (rcg) wetlands >= 0.5 acres.
3. Select the rcg features within 10 m of the first file. Make into a shapefile called rcg_prox_sh_marsh.shp.
4. Merge this file with the file defined in step 1. Save as shallow_marsh_context_existing.shp., (9570 features)

Watery Wetland Near Grassland Context (Blue-winged teal umbrella)

Factors: Select the wetlands with matrix values of 2 or 3 that are within 10 m of grassland. Also, select grasslands that are within 10 m of the 2 or 3 wetland types. Include only those portions of grassland that extend for 300 ft (100 m) from the edge of the adjacent wetlands.

Process:

1. Define the base theme to show the wetlands coded with a 2 or 3 in the matrix.
2. Define the base theme to show only grasslands.
3. Select wetlands within 10 m of the grasslands. Convert to shapefile (ww_prox_grass.shp)
4. Select grasslands within 10 m of wetlands identified in #3. Convert to shapefile (grass_prox_ww.shp)
5. With the file created from step 3, create a buffer extending for 100 m from the edge of the wetlands (buff_ww_prox_grass.shp).
6. Use the buffer shapefile to clip the grassland file. Convert to shapefile (grass_prox_ww_clipped.shp).
7. The two files created for this context are the clipped upland file from step 6, (grass_prox_ww_clipped.shp) and the wetland file from step 3 (ww_prox_grass.shp).

Wetland Meadow Context (Sedge Wren Umbrella)

Factors: Select only shallow marshes that are within 10 m of the wetland types with 2 or 3 matrix values, and grasslands within 10 m of the "2" and "3" wetlands.

Process:

1. Define base theme to show shallow marsh >= 0.5 acres.
2. Define base theme to show wetland meadow >= 0.5 acres.
3. Use select by theme to select shallow marshes within 10 m of wet meadow. Create shapefile from this selection.
4. Merge the shallow marsh theme to the wetland meadow theme.
5. Define base theme for grassland.
6. Select grasslands within 10 m of the merged theme from step 4, create shapefile.
7. The two files created for this context are the upland file from step 6 (grass_prox_wet_meadow_existing.shp) and the wetland file from step 4 (wet_meadow_context_existing.shp).

Wetland Shrub Context (Alder/Willow Flycatcher)
Factors: Include wetland shrub habitats >= 0.5 acres that are within 10m of wetland meadows, and wetland meadows >= 0.5 acres within 10m of wetland shrub.

Process:
1. Define base theme for wetland meadow >= 0.5 acres
2. Define base theme for wetland shrub >= 0.5 acres
3. Select wetland meadows within 10 m of wetland shrubs
4. Select wetland shrubs within 10 m of wetland meadows
5. Merge themes from steps 3, 4 together to create the shapefile (wet_shrub_context_existing.shp).

Wetland Forest, Coniferous or Mixed Context (Veery, Black and White Warbler umbrella)

Factors: Include only coniferous or mixed forested wetlands within 100 m of upland forests. In addition, include upland forests if within 100 m of coniferous or mixed forested wetlands.

Process:

1. Define base theme to include the wetland types given a 2 or 3 in the matrix that are >= 0.5 acres.
2. Define base theme to include upland forest.
3. Select wetlands from step 1 above that are within 100 m of forests.
4. Select upland forests that are within 100 m of wet forests.
5. The two files created for this context are wfcm_prox_forest_existing.shp (wetland file) and uplforest_prox_wfcm.shp (upland file).

Wet Deciduous Forest (American Redstart, Blue-gray Gnatcatcher umbrellas)

Factors: Include broad leaved deciduous and mixed forests wetlands that are within 100 m of upland forest. In addition, include upland forests within 100 m of broad leaved deciduous and mixed forest wetlands.

Process:

1. Define base theme to include the wetland types given a 2 or 3 in the matrix that are >= 0.5 acres.

2. Define base theme to include upland forest.
3. Select wetlands from Step 1 above that are within 100 m of upland forests.
4. Select upland forests that are within 100 m of wet forests defined in step 1.
5. The two files created for this context are wet_decid_forest_prox_uplforest.shp and uplforest_prox_wet_decid_forest.shp.

Deep Marsh and Shallow Marsh (Muskrat).

Factors and Process: No proximity factors. Select wetlands >=0.5 acres with a “2” or “3” matrix value. This includes Open water wetlands, Aquatic Bed/Deep Marsh and Shallow Marsh. Save file (deep_shallow_marsh_existing.shp).

Wet Meadow/Grassland (Meadow Vole umbrella)

Factors and Process: No proximity factors. Select the polygons >= 0.5 acres that are given a “2” or “3” matrix values. These include upland grassland and wetland meadow. Save file (wet_meadow_grassland_context.shp).

Wet Forests (masked shrew umbrella)

Factors and Process: No proximity factors. Select the polygons >=0.5 acres for habitats given a “2” or “3” in the matrix. These include upland forests and grasslands, , wetland meadow, wetland forest/deciduous, wetland forest/mixed, wetland forest/coniferous, wetland shrub. Save file (wet_forests_context.shp).

Open wetlands near grassland (chorus frog umbrella)

Factors: Select polygons >=0.5 acres with a “2” or “3” in the matrix that are within 10 m of grassland. In addition, select grasslands within 10 m of “2” and “3” wetland types. Only include the portions of grasslands that extend for 300 m from the edge of the adjacent wetlands.

Process:

1. Define wetlands with a “2” or “3” in the matrix.
2. Define grasslands >=0.5 acres.
3. Select wetlands defined in step 1 that are within 10 m of the grasslands from step 2. Save file (open_wetl_prox_grass_existing.shp).
4. Create buffers with file from step 3. Buffers should be extending for 300 m from the edge of the wetlands.
5. Select grasslands that are within 10 m of the wetlands in step 3.
6. Use the buffer file to clip the grasslands. Save file (grassland_prox_open_wetl_clip_existing.shp).

Wetlands near woodlands (wood frog umbrella)

Factors: Select polygons >=0.5 acres with a value of “2” or “3” in the matrix that are within 10 m of upland forests. In addition, select upland forests >= 0.5 acres within 10 m of these wetlands. Only include the portions of forests that extend for 300 m from the edge of the adjacent wetlands.

Process:

1. Define wetlands with a “2” or “3” in the matrix and >= 0.5 acres.
2. Define forests >= 0.5 acres.
3. Select wetlands within 10 m of forest. Save file (wetl_woodl_prox_uplforest_existing.shp).
4. Create buffers from the edge of the wetland using the file created in step 3. The buffer distance should extend for 300 m from the edge of the wetlands.
5. Select forests that are within 10 m of the wetlands defined in step 3.
6. Use the buffer theme to clip the forests to include only those portions that extend for 300 m from the edge of the wetlands. Save file (uplforest_prox_wetl_woodl_clip_existing.shp).

Wetland/Upland Complex (Blanding’s turtle umbrella)

Factors: Select wetlands >=0.5 acres given a “2” or “3” matrix value that are within 15 m of upland forest and upland grassland. Select the upland forests and grasslands >=0.5 acres that are within 15 m of the wetlands. Only include the portions of the uplands that extend for 300 m from the edge of the wetlands.

Process:

1. Define base theme for all wetlands >= 0.5 acres given a “2” or “3” in the matrix.
2. Define theme for grasslands and upland forests >= 0.5 acres.
3. Select wetlands defined in step 1 that are within 15 m of the uplands. Save file (wetl_upl_wetlands_prox_uplands_existing.shp).
4. Buffer the wetlands by 300 m from the edge using the file created in step 3.
5. Select the uplands that are within 15 m of the wetlands from step 3.
6. Use the buffer theme created in step 4 to clip the uplands selected in step 5. Save file (uplands_prox_wetlupl_complex_clipped.shp).

Process for completing proximity analysis using potentially restorable wetlands in addition to existing wetlands.

Goal: We were interested in seeing how many acres of wildlife habitat could be created and used by the umbrella species listed in the wildlife habitat matrix.

Considerations: The potentially restorable wetlands were added to the base file as shallow marsh. They were given the value of shallow marsh because most wetland restorations result in creating shallow marsh habitat.

- We created a new file called mrb_prw2_hqi to use as the base file for this proximity analysis. This file is a combination of the base file from the proximity analysis using exiting wetlands, and the PRWs coded as shallow marsh.
- We only needed to run this proximity for "restoration" for those wetland contexts that included shallow marsh with a value of a "2" or "3" (8 of the 13 wetland contexts). This includes open water wetlands; shallow marsh' water wetlands near grasslands; wet meadow; deep/shallow marsh; open wetlands near grasslands; wetlands near woodlands; and wetland/upland complex.
- Since the process is the same as with the exiting wetland proximity, we will not reiterate the process here. Please refer to the previous pages for each of the analyses. The only difference is using the base file that defines PRWs as shallow marsh.

Documentation for Developing a Habitat Quality Index Using the Wildlife Proximity Analysis Information

This section provides documentation for coding and processing the files created during the wildlife proximity analyses, and combining them to create a wildlife habitat quality index (HQI). Please see the wildlife tool chapter (page?) for an explanation of the HQI concepts.

Wildlife Wetland HQI process

The process defined in this section is based on the wetland proximity output for the existing wetlands, described earlier in this appendix (page?). All the processing described here was completed using ArcView 3.3.

1. Use the base_hqi.shp file as the file from which to make a wetland hqi base file.
2. Define the theme on matrix_cls and select only those that are wetlands within the wildlife matrix.
3. Create a shapefile out of this selection (wetland_hqi_base.shp).
4. Add a field to the table in the shapefile created in step 3. Call the field, base_hqi. The field type is a number, the size of the column should be 5, with no decimal places.
5. Give each wetland in this file a base_hqi value of 1.
6. Bring each of the wetland proximity final files into the view.
7. For each of the proximity wetland files (there should be 13), add a new field that would identify it as an hqi field. For this project, we used the umbrella species name (or a portion of one) with _hqi as the field name. For instance, for the open water wetlands habitat context (with black tern as umbrella), the new field is tern_hqi. As with the wetland base file, the field should be a number, 5 characters long, with no decimal places.
8. Code each of the proximity wetland files according to the value in the matrix. For instance, for the open water context (tern umbrella), the open water wetlands matrix class should be given a value of 3 in the hqi field, while the shallow marsh > 5 acres will be given a two. Do this for each of the wetland proximity files.
9. Spatially join each of the wetland proximity files to the wetland_hqi_base.shp file. Hint: it helps to go to the table properties for each of the proximity files, and uncheck each of the fields except for the hqi field. This will keep the table view cleaner as you continue to join files.
10. Once all files are joined to the base file, create a new shapefile (wl_wetland_hqi_existing.shp). You will find that there are a lot of blanks within each of the hqi fields for each of the species. This is because these are the wetlands that were not coded as a "2" or "3" in the matrix. For those umbrella species that require proximity between wetlands or wetland/uplands, the blank spaces should be given a value of 0. For those without proximity factors (bittern/sora, muskrat, vole and shrew), the wetland types should be given the same values as given in the matrix for each of these types.
11. To calculate the total HQI for each wetland, create a new field called hqi_total. Create an expression in the field calculate area to sum all the hqi fields for a grand total. Based on the highest score any individual wetland may have is 26.

The process is the same above for calculating the upland HQI, using the final output files for the proximity analysis. The range for upland HQI is 3 to 17 for individual polygons.

Appendix 4: Wetland Water Quality Assessment Tool Documentation

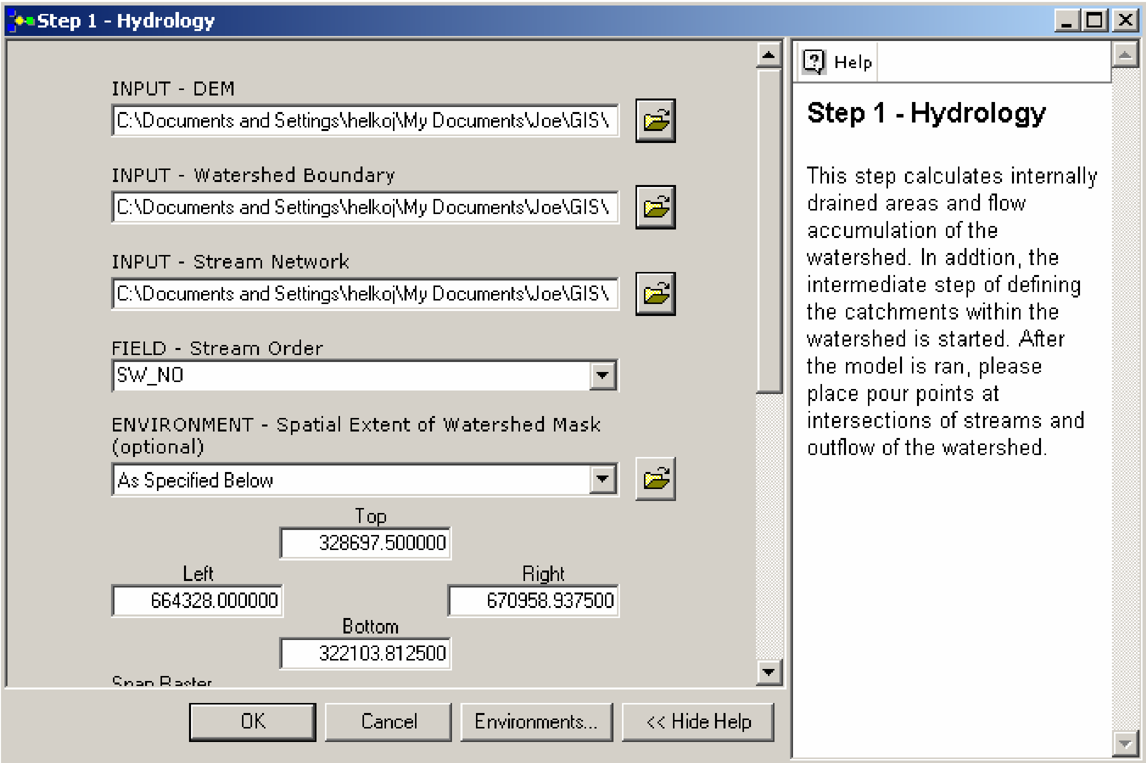
Wetland Water Quality Function Assessment Tool

Assessing the water quality contributions of the wetlands of the Milwaukee Basin is a two part process. The first part is to spatially define wetlands and drainage areas and the second part is to assess wetlands and their impact on water quality within those drainage areas. The following discussion focuses on the first part of the process.

Geospatially Defining Wetlands and Small Catchments

The task of spatially defining wetlands and their associated catchment areas throughout the Milwaukee Basin is an essential first step in designing a tool in GIS that would be useful to local planners for when assessing the cumulative effects of wetlands on downstream water quality. This GIS decision support tool serves to capture the relationship between a wetland and its catchment area that best represents its functionality for protecting downstream water quality. Water quality benefits are assessed by estimating the relative level of fine sediment trapping provided by existing wetlands. In addition the tool can be used to target areas where the water quality benefits from restoration can be maximized. It was also the goal of this project to investigate a way to help automate technical geoprocessing steps to allow users to assess wetlands that may not have advanced GIS knowledge and skills. To accomplish these goals, a three step process was developed that only requires the user to provide essential input data, such as the spatial boundaries of wetland areas, other water bodies, topography and land use.

There are three steps in the Wetland Tool to identify and define a wetland and catchment area in GIS: Hydrology, Delineating Catchments, and Defining Wetlands. These steps must be following in sequential order, and each one is further discussed in detail in the following sections. After the successful completion of the steps in the Wetland Tool an assessment of the sediment trapping role wetlands play in each catchment can then be carried out. For this study, the scoring was done manually, but progress is being made to automate that process. The following figure is an example of the user interface of the Wetland Tool for the Hydrology step.



The interface screen for the Hydrology Step in the Wetland Tool. The user is required to identify the location of each required input data in addition to identifying key fields within data that will be referenced during the automated process. For instance, what field contains stream order in the stream network line feature class.

***Step 1 - Hydrology** (Calculating Flow Accumulation)*

In this first step, it is the objective to determine proper flow accumulation. The flow accumulation raster will serve as the basis for delineation of catchments throughout the basin in Step 2.

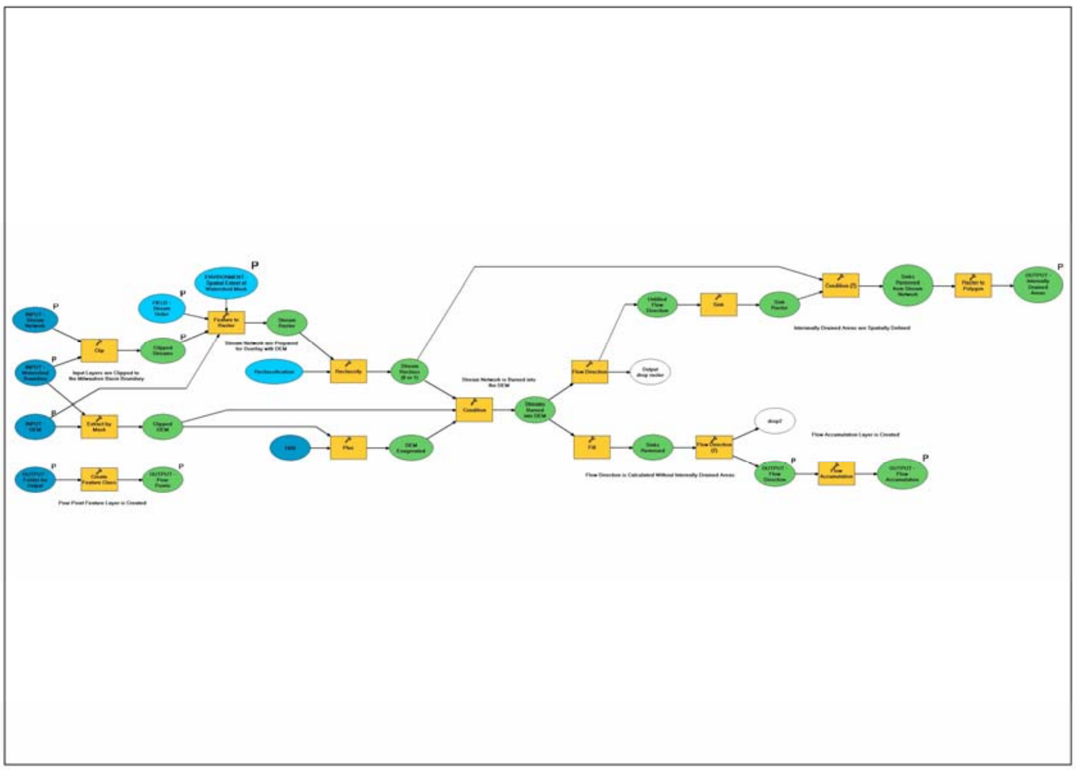
Required Inputs:

- 30 meter Digital Elevation Model (DEM) raster
- 1:24,000 digital hydrographic stream network line feature class
- Milwaukee Basin boundary polygon feature class

Description:

After supplying the required input data, the Hydrology Tool will walk through a series of geoprocessing steps to calculate flow accumulation for the basin, which is an essential component for delineating catchments areas that will be discussed in greater detail in Step 2. Upon initiation, the tool first clips the DEM and stream network to the boundary of the basin. The next step in this process is the calculation of flow direction, but the DEM must be conditioned to insure all water will flow downstream. The burning process is carried out by converting the stream network to grid cell based data format and overlaying it with the DEM. All elevation grid cells outside the stream network are then exaggerated by an arbitrary number, and, turn the areas surrounding the stream network into cliffs. The idea is that any water flowing will now be forced in the direction of a known stream. Also, as mentioned earlier, to insure proper flow direction all sinks in the DEM are identified and filled. Flow direction throughout the basin can now be simulated.

In the final step in this process, flow accumulation is calculated from the flow direction. The following figure shows the outline of the geoprocess used in these calculations.



Step 1 - Hydrology

Step 2 – Delineating Catchments *(Defining and Delineating Catchments)*

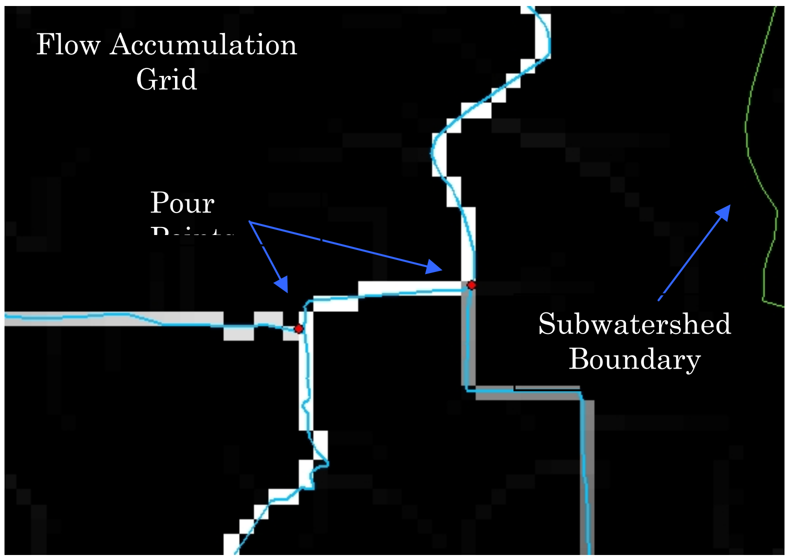
Once Step 1 has successfully completed, the next step is initiated to delineate the individual catchment areas within the subwatersheds throughout the Milwaukee Basin. This tool requires four input files (data layers), and the user must define the points at which the catchment boundary delineations will take place.

Required Inputs:

- Flow accumulation raster (automatically displayed)
- Flow direction raster (automatically displayed)
- Clipped stream network line feature class (automatically displayed)
- Empty pour point feature class (automatically displayed)

Description:

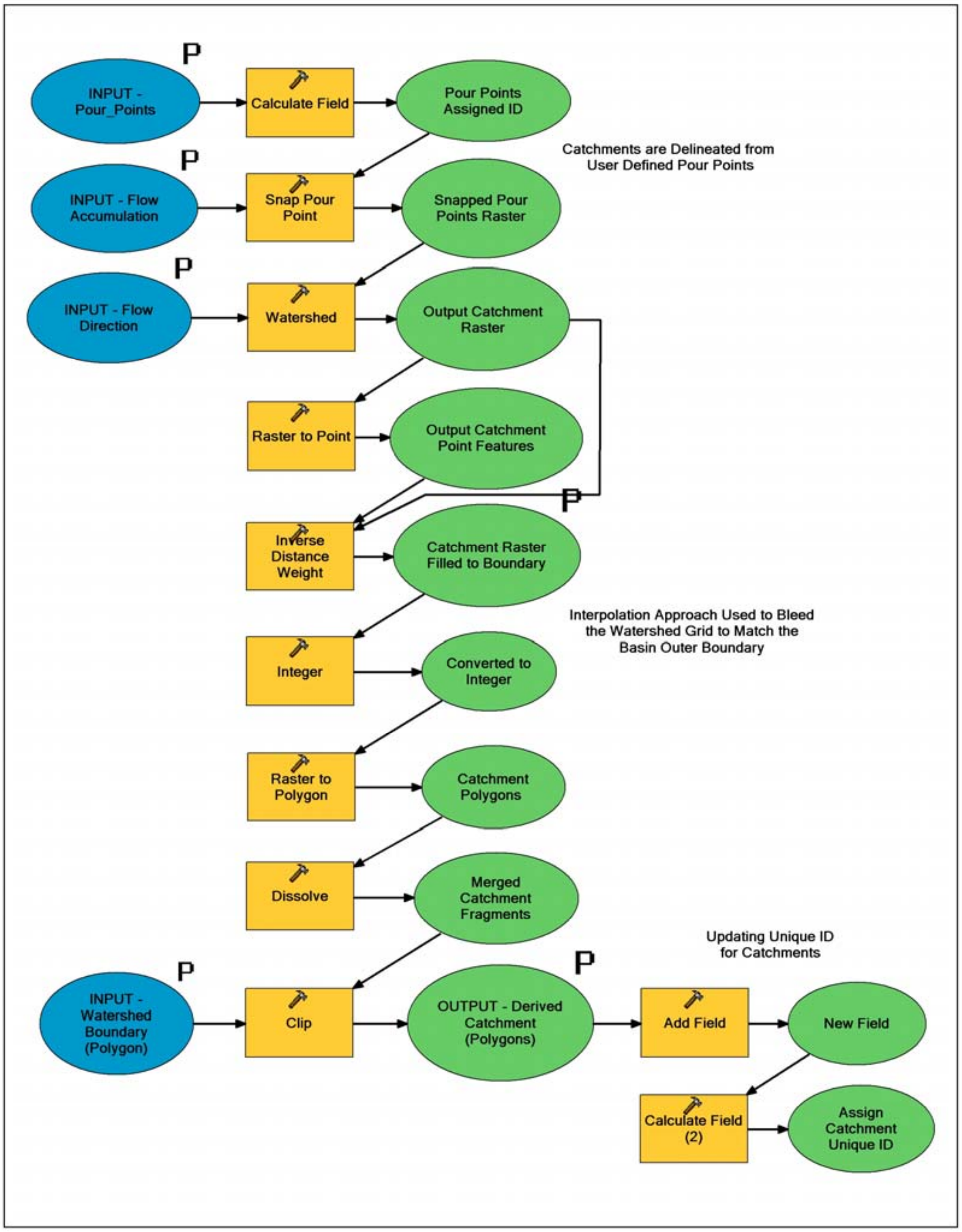
A tool bar was customized to allow the user to add and position pour points. A pour point is the location, most downstream, that is used to delineate a watershed or catchment. The catchment boundaries are determined relative to this user-chosen point. In this study, contributing areas for each individual stream order are identified as catchments and pour points are placed at every stream intersection. After all pour points are created Step 2 of the second geoprocessing model is initiated.



Pour points are placed at each intersection of a lower order stream entering into a higher stream order. The blue line represents the 1:24,000 stream network overlaid on top of the fill accumulation raster layer displayed here as gray scale grid cells.

In this automated process, the pour points are snapped to the nearest grid cell of the flow accumulation layer and then converted to a raster. The catchment for each pour point is then delineated from the flow direction data layer. These resulting catchment boundaries do not always coincide with the subwatershed and watershed boundaries delineated earlier in the project (see Subwatershed Metrics Chapter). This is most likely the result of rounding errors from the DEM, used in Step 1 to calculate flow direction, and differences in the process initially used to delineate the original Milwaukee River Basin watersheds versus the process described here. To compensate for these differences, a simple approach is devised.

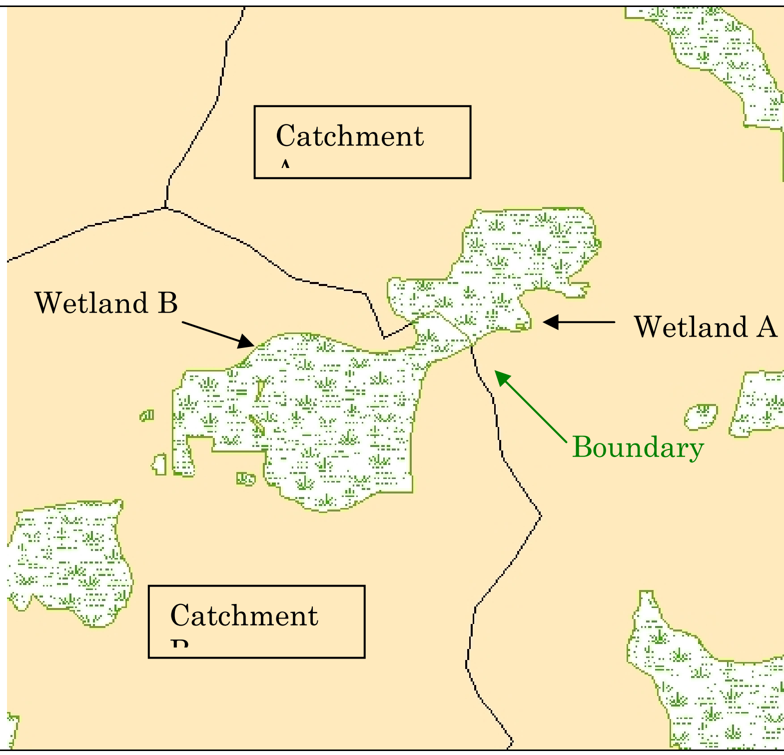
Catchment boundaries are forced to overrun the basin boundary by interpolating values representing the neighboring catchments in those grid cells empty of values. Inverse Distance Weighing is then used to perform the interpolation, which calculates grid cell values using a linear weighted combination of neighboring sample points. Once all gaps in the basin are filled using the previously mentioned process, the catchment raster is converted to a polygon feature class and each catchment is assigned an unique ID. See the following figure for an outline of the process described for Step 2.



Step 2 - Watershed Delineation

Step 3 – Defining Wetlands *(Identifying Wetland Class Groups)*

For the purposes of this study and discussion, an "individual wetland" or "wetland" refers to a group of wetland classes meeting three criteria: land use, associated catchment, and proximity of a wetland class to another. The first criterion to be discussed is the land use. A wetland must be comprised of any land use being defined as aquatic bed, cropped wetland, emergent wet meadow, flats or unvegetated wet soil, forested wetland, open water wetland, reed canary grass wetland, scrub or shrub wetland, or unclassified wetland. For this study, an individual wetland may be comprised of one or more of these wetland classes. The second condition, associated catchment, assumes that an individual wetland's immediate sediment trapping functionality is specific to only one catchment. Wetlands located on the boundary of the catchment will be further divided based on that boundary (see figure below). The final criteria, proximity of a wetland to another, is based on a set upper limit distance that non-contiguous separated wetlands can spatially be from each other before they are no longer considered as part of one functioning wetland, but separate wetlands. Land use features, such as roads, may spatially sever the connectivity of fragmented wetlands on the immediate land surface as indicated in a two-dimensional coverage dataset; but considering subsurface water flow, a predetermined maximum distance limit between these fragmented wetlands preserves their connectivity for purposes of further analysis. This limit is further discussed later in the description of the geoprocesses involved in defining wetlands.



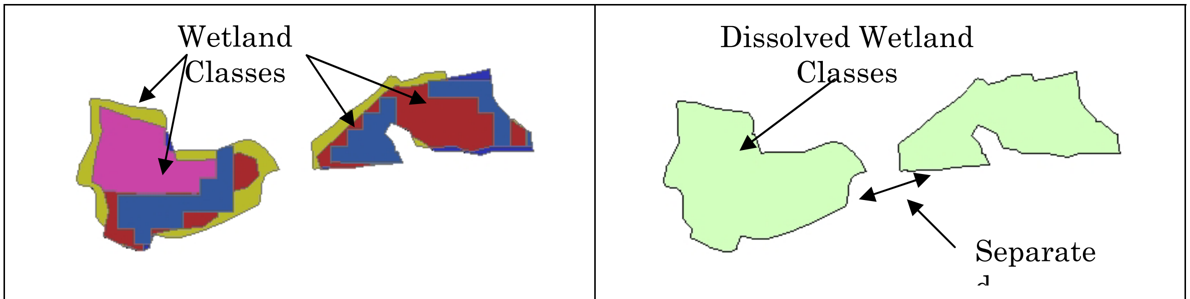
The large wetland is further divided by the boundary of the catchments.

Required Inputs:
- Land use polygon feature class or coverage
- Milwaukee basin boundary polygon feature class
- Catchment boundaries polygon feature class (automatically displayed)

Description:

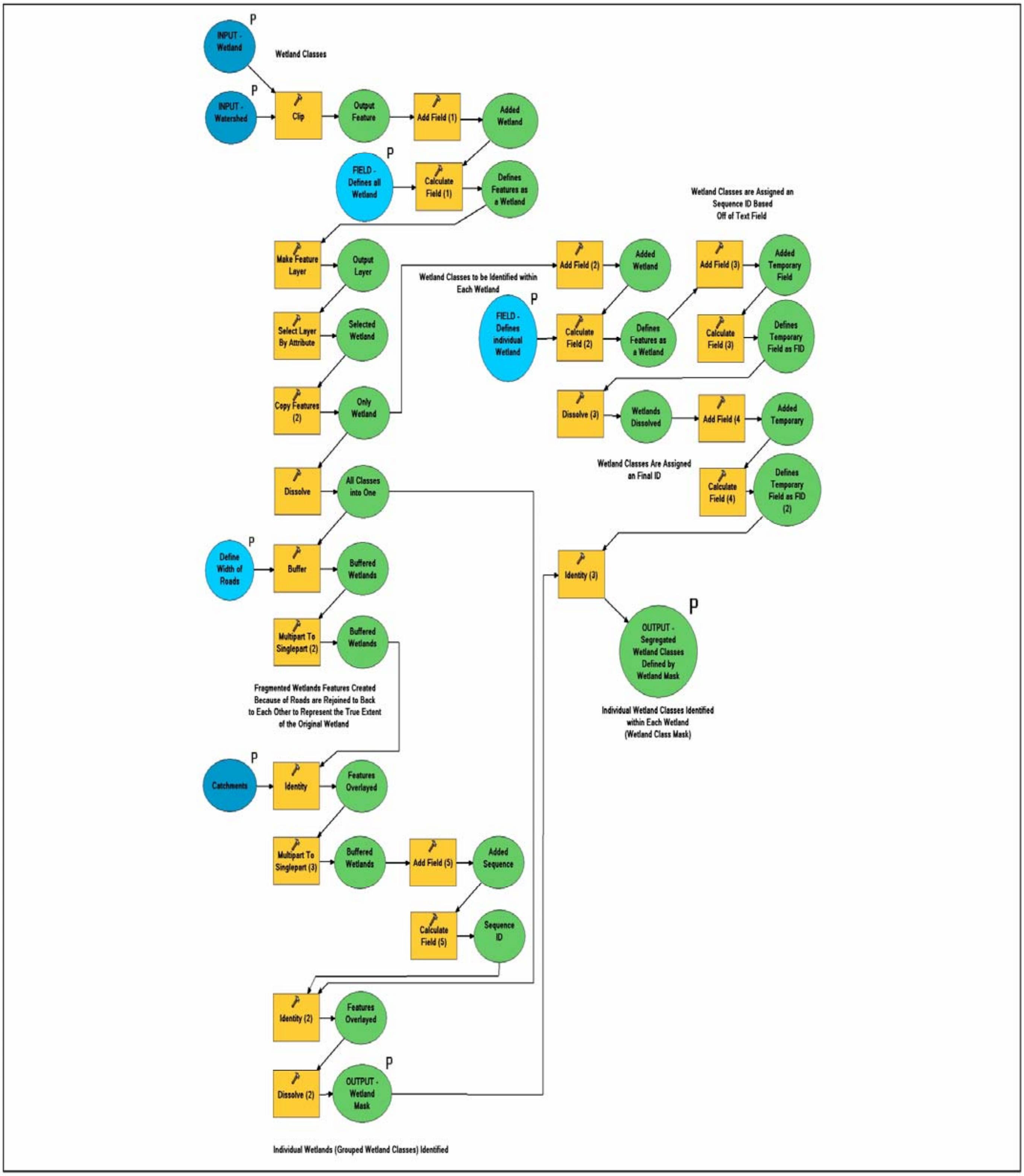
The final output feature datasets are masks outlining the spatial extents of each individual wetland and the wetland classes making up each wetland. The process starts by calling in the land use data layer and clipping it to the basin boundary. Next, all wetland classes are selected and exported into a new feature class (the user is required to define the field which contains the land use types in the input land use data layer). Here, the process now divides into two subprocesses: wetland mask and wetland class mask.

For determining an individual wetland, all wetland classes are dissolved to one polygon feature and then separated into individual polygons (see figure below). Next, the proximity of each polygon to its neighbor is assessed through a buffering procedure. In this particular instance most wetland features were arbitrarily separated by roads represented as impervious areas in the land use data layer. To reconnect those fragmented polygons, the average width of the highway was used to define the buffer around each polygon and identify polygons that would be merged back together to represent a single functioning wetland. Finally, several steps follow to assign a unique ID to each individual wetland.



Wetland class features are dissolved into a single feature and then separated based on spatial discontinuity.

The wetland class mask will serve to identify the actual area of each wetland class making up an individual wetland to be used during the scoring process to be discussed later. In this subprocess, wetland class features are simply dissolved according land use type and then assigned a unique ID. Finally, the dissolved features are overlaid with the previously created wetland mask and separated. Each new wetland class feature is additionally assigned the unique ID of the corresponding wetland. Then each wetland class feature is assigned to each feature in the wetland mask (see following figure). This implied relationship will be necessary during the procedures to score wetlands based on weights that are assigned to each wetland class.



Step 3 - Defining Wetlands