Leech Lake River Watershed Restoration and Protection Strategy Report

wq-ws4-31a

June 2017

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Cover photo: Kerr Lake (Cass County) from CSAH 5 looking south.

Project dollars provided by the Clean Water Fund (from the Clean Water, Land and Legacy Amendment).

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Document number: wq-ws4-31a

Contents

List of Tables

List of Figures

Key Terms

ACOE: United States Army Corps of Engineers

Assessment Unit Identifier (AUID): The unique water body identifier for each river reach comprised of the USGS eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus, chlorophyll-a, or Secchi disc depth standards are not met.

DNR: Minnesota Department of Natural Resources

DRM: Leech Lake Band of Objibwe Division of Resource Management

EPA: Environmental Protection Agency

HSPF: The hydrologic and water quality model Hydrologic Simulation Program Fortran.

Hydrologic Unit Code (HUC): A Hydrologic Unit Code (HUC) is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Upper Mississippi River Basin is assigned a HUC-4 of 0701 and the Leech Lake River Watershed is assigned a HUC-8 of 07010102.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

IWM: MPCA's Intensive Watershed Monitoring, which includes chemistry, habitat, and biological sampling.

LLAWF: Leech Lake Area Watershed Foundation

LLBO: Leech Lake Band of Objibwe

MDA: Minnesota Department of Agriculture

NGO: Non-governmental Organization

NRCS: Natural Resources Conservation Service

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain or improve conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds to improve conditions, and in impaired watersheds to eventually meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or Pollutant Source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or Biological Stressor): This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

SWCD: Soil and Water Conservation District

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

USFS: United States Forest Service

Executive summary

The Leech Lake River (LLR) Watershed consists of approximately 854,659 acres (1,335 square miles) in the northern part of the Upper Mississippi River Basin. The watershed includes parts of Beltrami, Cass, and Hubbard counties. Major communities in the watershed are Laporte, Benedict, Walker, Federal Dam, Boy River, Whipholt, Longville, and Hackensack. The watershed also includes part of the Leech Lake Reservation (Leech Lake Band of Ojibwe). The LLR Watershed has approximately 277 total river miles, and contains over 750 lakes with a total acreage of 166,374 acres. The watershed is located in Minnesota's Northern Lakes and Forest ecoregion. It is a largely forested, with about 46% of the land privately held, with the remaining portion of land state, county or federal public land, or held by tribal landowners.

The LLR Watershed is situated in the heart of Minnesota's premier lake country and contains some of the most pristine natural resources in Minnesota. The forests and surface waters of the watershed support a very high degree of biodiversity. One-half of Minnesota's naturally producing muskellunge lakes and a quarter of the natural muskellunge habitat in the United States is located in the LLR Watershed. Forests in the watershed boast the largest number of breeding eagle pairs in the lower 48 states, as well as many other healthy wildlife populations. The State Action Plan for Minnesota Wildlife identified 89 "species of greatest conservation need," including 29 species that are federal or state endangered, threatened, or of special concern within the watershed. The surface water resources within this watershed are highly prized for their recreational value, attracting several hundred thousand vacationers to the area each year. However, the surface waters within this watershed are experiencing increased pressure from development, subsequent loss of shoreline and aquatic habitat, and invasive species. State demographers project a population growth of up to 60% by 2030. Stormwater runoff from development, roads, and other nonpoint sources threaten water quality. Invasive species threaten biodiversity and healthy ecosystems. The protection of these surface waters is critical for sustaining the local economy and natural heritage and character of this unique watershed.

Twelve stream segments in the watershed (Assessment Unit Identifier (AUIDs)) were assessed for aquatic life use; eight of these were assessed for aquatic recreation use. Ten of the twelve stream segments fully support aquatic life use. The remaining two segments did not support aquatic life use and were determined to be impaired. Both aquatic life impairments were the result of poor fish and/or macroinvertebrate communities. In both cases, natural wetland influence and the corresponding lack of habitat heterogeneity were determined to be the cause of the poor aquatic communities. Only one of the eight segments assessed for aquatic recreation was found to be impaired (Kabekona River, Hubbard County – *E. coli* bacteria). Local watershed partners have initiated a water quality monitoring plan (2016) to gather information on the present conditions of the stream. It is anticipated that this comprehensive monitoring approach, along with the ongoing efforts towards working with local landowners to implement best management practices (BMPs) (e.g. buffer initiative), will be an effective strategy in de-listing the stream in the near future. The LLR Watershed has a high density of lakes with good water quality. Eighty-five lakes were assessed for aquatic recreation. Hart Lake in Hubbard County, one of the few shallow lakes in the LLR Watershed, was the only lake found to not support aquatic recreation use due to nutrient/eutrophication biological indicators.

Acknowledging that a protection strategy is important for all lakes and streams within the LLR Watershed in maintaining existing high quality waters, but also realizing that limited implementation funds will be available, the LLR Watershed Technical Team utilized all available knowledge about the water resources of the LLR Watershed to focus implementation strategies. As detailed in sections 3.2 and 3.3, the following geographic areas (HUC-12s) were designated as the highest priority for initial implementation of strategies for water quality protection (Figure 24). However, all strategies outlined in Section 3.4 will be encouraged and pursued as important, and as implementation funds are available.

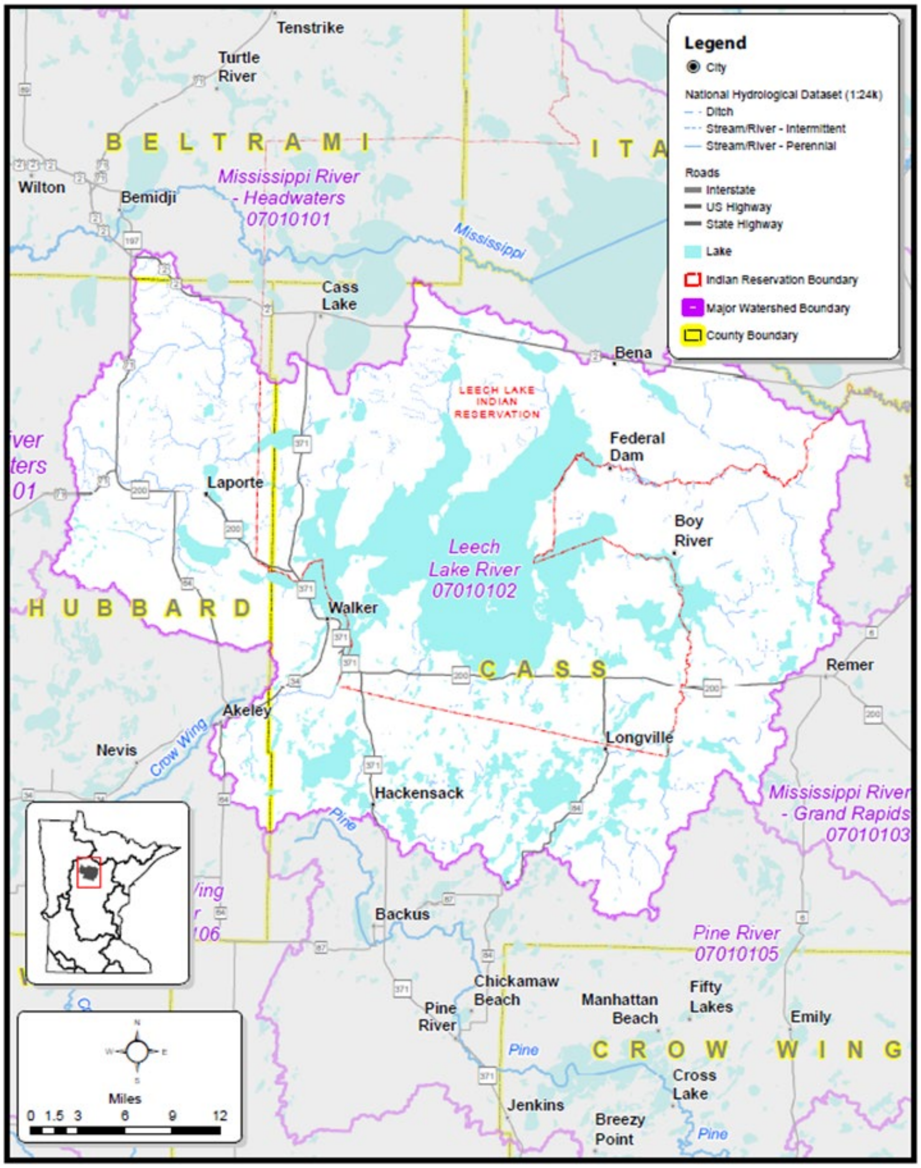
Streams:

- Headwaters of the Necktie River (HUC 070101020101); contains high value trout streams.
- Bungashing Creek (HUC 070101020102); Bungashing Creek is designated an exceptional water.
- Kabekona River (HUC 070101020204); Kabekona and Garfield lakes and adjacent lands.

Lakes:

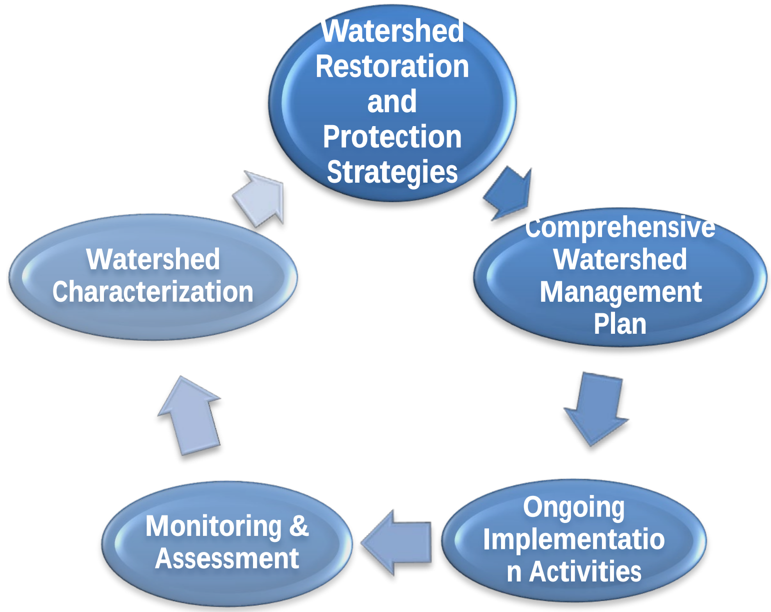
- Man Lake (HUC 070101020303); high value chain of lakes in the Boy River Chain and Stony Lake, with documented declining water quality trend.
- Woman Lake (HUC 070101020305); high recreational value Woman Lake Chain and Ponto Lake, declining water quality trend and highest ranked lake in the state for phosphorus sensitivity significance.
- Inguadona Lake - Boy River (HUC 070101020403); declining water quality in Inguadona Lake and critical areas of Boy River between the city of Longville and Inguadona Lake.
- Leech Lake Main Basin (HUC 070101020507); Leech Lake and all bays (excluding Kabekona Bay) and adjacent high value lakes (May and Long).
- Kabekona River (HUC 070101020204); Kabekona and Garfield Lakes and the land area between the two lakesheds.

Figure 1: Map of Leech Lake River Watershed



In this high quality watershed, the primary strategy is implementing protection efforts to maintain existing water quality conditions. However, in some isolated cases improvements to water quality conditions are desired and achievable. Strategies for protection include maintaining natural land cover in forests, encouraging cover crops in agricultural lands, and reducing runoff in urban areas. Vigilance to shield this watershed from the negative impacts of storm water runoff from development, loss of forest cover, and other human-induced land altering impacts, will protect water quality. The three priority lakes with declining, yet still above average, water quality will be monitored and aggressive restoration strategies implemented to reduce further declines.

What is the WRAPS Report?



The state of Minnesota has adopted a "watershed approach" to address the state's 80 "major" watersheds (denoted by 8-digit hydrologic unit code or HUC). This watershed approach incorporates **water quality assessment, watershed analysis, civic engagement, planning, implementation, and measurement of results** into a 10-year cycle that addresses both restoration and protection.

As part of the watershed approach, waters not meeting state standards are still listed as impaired and Total Maximum Daily Load (TMDL) studies are performed, as they have been in the past, but in addition the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to help state agencies, local governments and other watershed stakeholders determine how to best proceed with restoring and protecting lakes and streams. The Watershed Restoration and Protection Strategy (WRAPS) report summarizes past assessment and diagnostic work and outlines ways to prioritize actions and strategies for continued implementation to protect water quality.

Purpose	• Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning. Summarize Watershed Approach work done to date including the following reports: • Leech Lake River Watershed Monitoring and Assessment • Leech Lake River Watershed Biotic Stressor Identification
Scope	• Impacts to aquatic recreation and impacts to aquatic life in streams • Impacts to aquatic recreation and aquatic life in lakes.
Audience	• Local working groups (local governments (county, municipal, township), Soil and Water Conservation Districts (SWCDs), Mississippi Headwaters Board, nonprofits, lake associations) • State agencies (MPCA, DNR, BWSR, MDOT, etc.) • United States Forest Service/Chippewa National Forest • Leech Lake Band of Objibwe

Additional Leech Lake River Watershed Resources-

USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Leech Lake River Watershed: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022266.pdf

Minnesota Department of Natural Resources (DNR) Watershed Health Assessment Framework (Watershed Report card) for the Leech Lake River Watershed:

http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_8.pdf

Sucker Creek – Cass County, photo courtesy of MPCA

1. Watershed Background & Description

The LLR Watershed consists of approximately 854,659 acres (1,335 square miles) in the northern part of the Upper Mississippi River Basin. The watershed includes parts of Beltrami, Cass, and Hubbard counties. Major communities in the watershed are Laporte, Benedict, Walker, Federal Dam, Boy River, Whipholt, Longville, and Hackensack. The watershed also includes part of the Leech Lake Reservation (Leech Lake Band of Ojibwe).

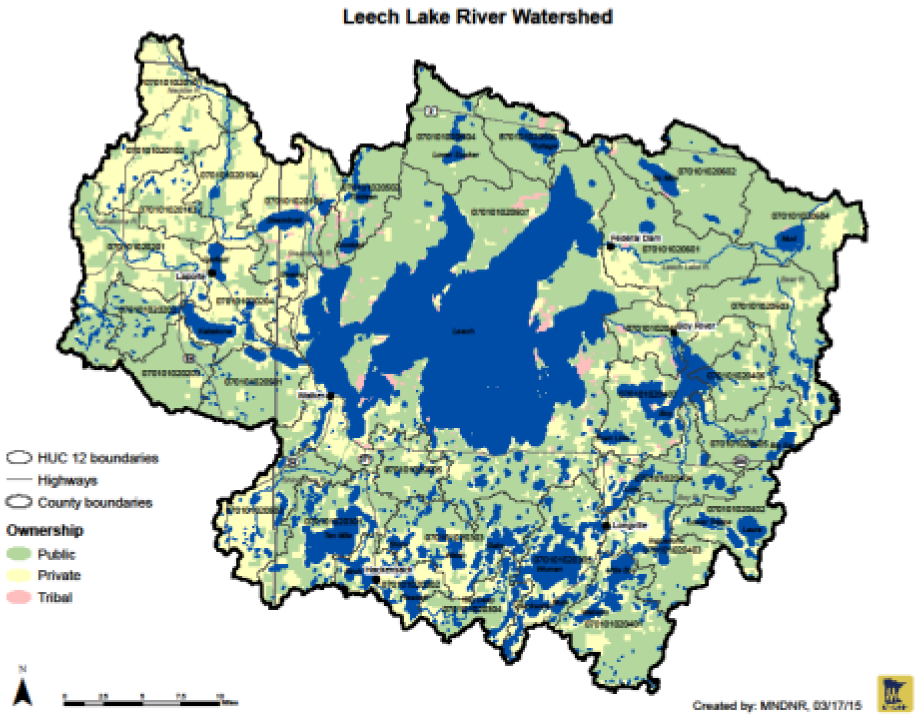
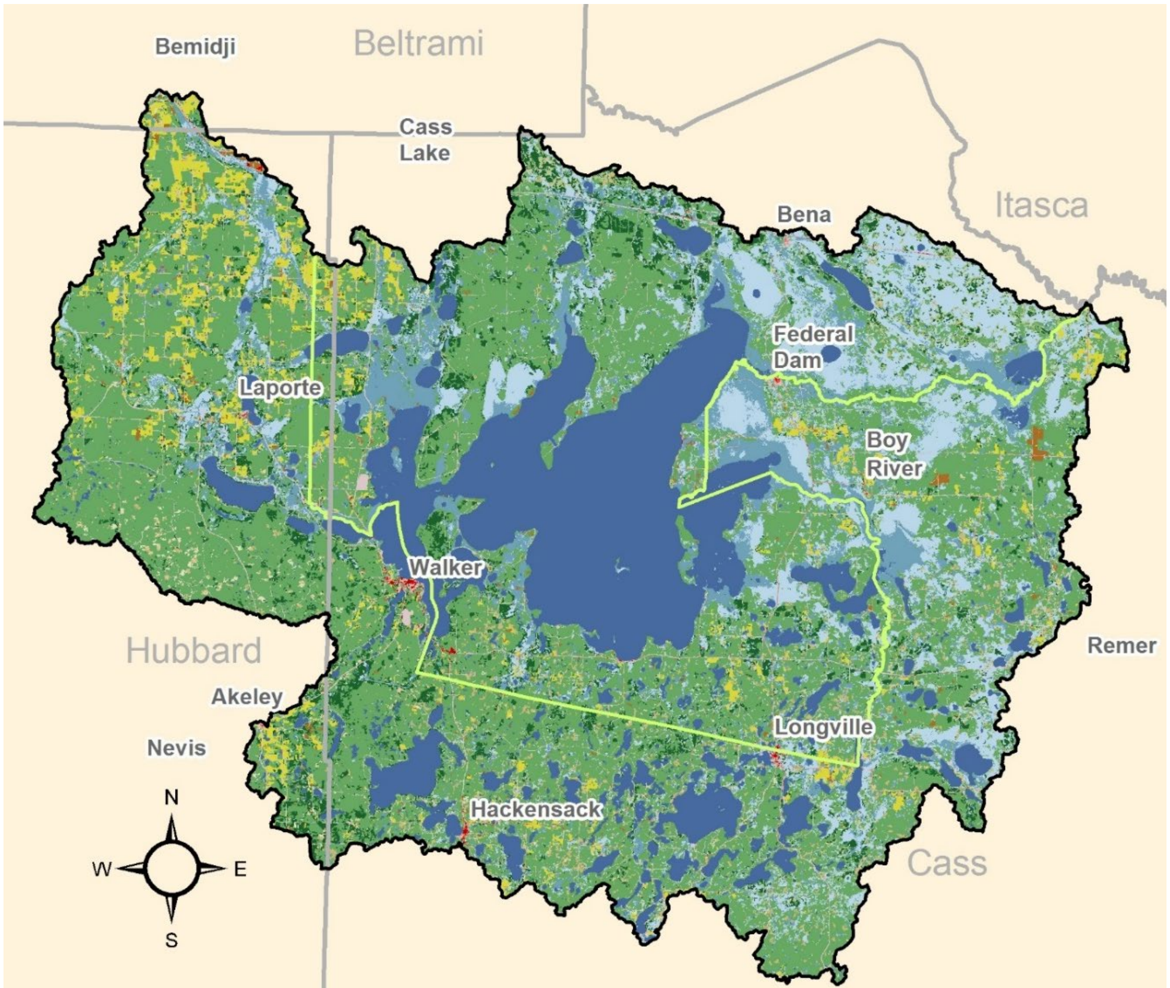


Figure 2: Land ownership within the Leech Lake River Watershed

The LLR Watershed has 277 total river miles and contains over 750 lakes with a total acreage of 166,374 acres. The watershed is located in the Northern Lakes and Forest ecoregion of Minnesota. This watershed is largely forested, with about 46% of the land privately held, and the remaining portion (54%) of land either state, county or federal public land, or land held by tribal landowners (See Figure 2).

This region of Minnesota has complex surface geology formed over many episodes of glaciation. The patterns of vegetation reflect the complex and patchy distribution of glacial deposits. Historically, jack pine, white pine, and red pine forests were very common. Mesic forests (well-balanced moisture levels) of sugar maple, basswood, paper birch, aspen, and northern red oak are widespread. There are expansive areas of acid peatland communities such as black spruce bogs and poor swamp forests, along with rich swamp forests of white cedar and black ash. Sedge meadows and alder and willow swamps occur along streams draining the flat lake plains and along the Mississippi and LLRs (see Northern Minnesota Drift and Lake Plains Section, DNR). Since this watershed has few water body impairments other than mercury—those present are mostly due to natural conditions—protection of the existing high quality waters will be the primary focus of the LLR WRAPS project going forward. Local governments and watershed stakeholders will play a key and important role in “keeping clean waters clean” for future generations to enjoy.

Figure 3: Land use in the Leech Lake River Watershed



Aerial View of Mule Lake Wildlife Management Area – Cass County, photo coutesy of LLAF

2. Watershed Conditions

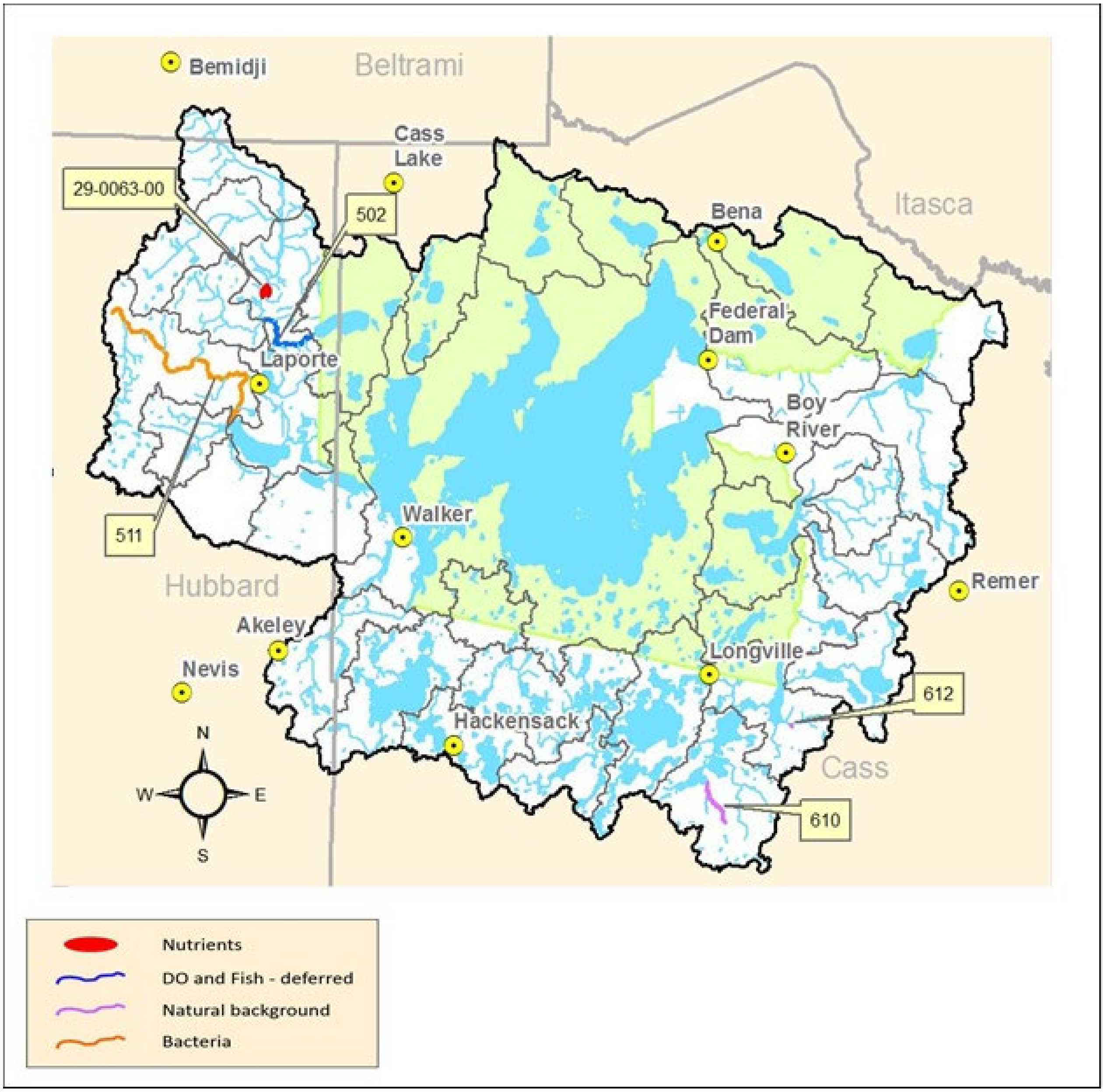


Figure 4: Location of water resources not currently meeting the Aquatic Recreation (Nutrients, Bacteria) and Aquatic Life DO, Fish Bioassessment) standards

The LLR Watershed is situated in the heart of Minnesota's premier lake country and contains some of the most pristine natural resources in Minnesota (see Figure 3). The forests and surface waters of the watershed support a very high degree of biodiversity. One-half of Minnesota's naturally producing muskellunge lakes and a quarter of the natural muskellunge habitat in the United States is located in the LLR Watershed. Forests in the watershed boast the largest number of breeding eagle pairs in the lower 48 states, as well as many other healthy wildlife populations. The State Action Plan for Minnesota Wildlife identified 89 "species of greatest conservation need," including 29 species that are federal or state endangered, threatened, or of special concern with in the watershed.

The Natural Resources Conservation Service (NRCS) estimates that there are 427 farms within the watershed; over half of those farms are smaller than 180 acres (NRCS 2016). Only 0.6% of the land within the LLR Watershed is used for row crop production. Rangeland accounts for another 4.2% of agricultural related land use within the watershed. Despite years of intensive logging, the majority of the watershed remains forested (57.9%). Open water accounts for the next largest land cover percentage. The vast expanse of Leech Lake, as well as the other numerous lakes within the watershed, amount to 19.4% of land area. Many lakes within the LLR Watershed continue to produce a rich wild rice crop. Wetlands occupy 16.1% of the watershed. Currently, only 1.8% of the watershed is developed. See Land use Summary section of the Leech Lake River Watershed Monitoring and Assessment Report for additional land use information.

The surface water resources within this watershed are highly prized for their recreational value attracting several hundred thousand vacationers to the area each year. However, the surface waters within this watershed are experiencing increased pressure from development, subsequent loss of shoreline and aquatic habitat, and invasive species. State demographers project a population growth of up to 60% by 2030. Stormwater runoff from development, roads, and other nonpoint sources threaten water quality. Invasive species threaten biodiversity and healthy ecosystems. The protection of these surface waters is critical for sustaining the local economy and natural heritage and character of this unique watershed.

Many lake associations/citizens throughout the watershed actively participated in water quality monitoring through the Citizen Lake Monitoring Program. In an effort to fill lake data gaps, Cass County Environmental Services (ESD) and Hubbard Soil and Water Conservation District (SWCD) are monitoring several lakes in the watershed through grants and local water plans. The DNR and Cass County have worked together to identify sensitive shoreland areas on all lakes greater than 500 acres in Cass County. These sensitive shoreland areas represent the most critical fish and wildlife habitat areas for protection and will be evaluated for zoning re-classification to Resource Protection Districts.

In addition, the Leech Lake Area Watershed Foundation (LLAWF) successfully continues toward its mission to fund, promote, and enable activities that will protect the natural environment of the Leech Lake Watershed. Through their efforts, numerous land conservation projects have been implemented since 1997, including preserving and protecting over 20 miles of wild shoreline.

The WRAPS for this watershed began in 2012. Since then, watershed monitoring data has been collected through an intensive watershed monitoring (IMW) approach where chemical and biological monitoring was conducted on the streams within the watershed. In addition, chemical monitoring was completed by local partners on select lakes within the watershed through the Surface Water Assessment Grant program.

2.1 Condition Status

In 2012, the Minnesota Pollution Control Agency (MPCA) began an IWM effort of lakes and streams within the LLR Watershed. Nineteen stream sites were sampled for biology at the outlet of variable sized subwatersheds. As part of this effort, the MPCA staff joined with local partners to complete stream water chemistry sampling at the outlets of five subwatersheds. In 2015, lakes and streams with sufficient data to make an assessment were assessed for aquatic life, aquatic recreation, and aquatic consumption use support. During this process, 12 stream segments (AUIDs) were assessed for aquatic life; 8 of these were assessed for aquatic recreation use. Eighty-five lakes were assessed for aquatic recreation. The results of the monitoring and assessment are summarized in the following sections. Please refer to the Leech Lake River Watershed Monitoring and Assessment Report (MPCA 2016) and the Leech Lake River Stressor Identification (SID) Report (MPCA 2016) for full monitoring and assessment details. Some of the waterbodies in the LLR Watershed are impaired by mercury; however, this report does not cover toxic pollutants. For more information on mercury impairments see the Statewide Mercury Reduction Plan. Impaired wetlands are not addressed due to an evolving understanding of wetland processes relative to impairment status.

Through continuing work and future iterations of the watershed approach, additional water bodies may be monitored and assessed in the future.

Streams

Ten out of twelve stream segments fully supported aquatic life use (See Table 1). The remaining two segments did not support aquatic life and were determined impaired. Both aquatic life impairments were the result of poor fish and/or macroinvertebrate communities. In both cases, natural wetland influence and the corresponding lack of habitat heterogeneity were determined to be the cause of the poor aquatic communities. Wetlands have a significant influence on aquatic ecosystems within the LLR Watershed. The flushing of organic matter from wetlands into streams causes dissolved oxygen (DO) levels to decline significantly. This phenomenon was observed during intensive water chemistry monitoring at locations on the Boy River. DO levels likely fluctuate as a result of wetland influence on other systems such as the LLR, Steamboat River, and lower Kabekona River. Several stream segments were not assessed for aquatic life due to prevalent wetland conditions within the monitoring site. Only one of the eight segments assessed for aquatic recreation was found to be impaired (Kabekona River, Hubbard County – *E. coli* bacteria). Data on the Kabekona River also suggested that reach reflected elevated turbidity/total suspended solids (TSS) levels, which were near the impairment threshold for this parameter. However, based on the high scores for the other aquatic life parameters, it was determined to be fully supporting for aquatic life indicators. Local watershed partners have initiated a water quality monitoring plan (2016) to gather additional information on the present conditions of the stream. It is anticipated that this comprehensive monitoring approach along with the ongoing efforts towards working with local landowners to implement BMPs (e.g. buffer initiative) will be an effective strategy in de-listing the stream in the near future.

Table 1: Assessment status of stream reaches in the Leech Lake River Watershed

Aggregated HUC-12 Subwatershed *Note: AUID = 07010102 + last 3 digits.	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life Indicators				Aqua. Rec Ind.
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
0701010201-01 Steamboat River	550	Necktie River	Unnamed ditch to T145 R32W S16, east line	MTS	IF	IF	IF	-
	502	Necktie River	Pokety Creek to Steamboat Lake	NA	-	NA	MTS	MTS
	505	Bungashing Creek	T145 R33W S34, south line to Necktie R	MTS	MTS	IF	IF	-
	527	Pokety Creek	T144 R33W S24, north line to Necktie R	MTS	-	IF	IF	-
	507	Steamboat River	Steamboat Lake to Leech Lake	NA	-	IF	MTS	-
0701010202-01 Kabekona River	511	Kabekona River	Headwaters to Kabekona Lake	MTS	MTS	MTS	IF	EXS
	611	Sucker Branch (Sucker Creek)	Lester Lake to Kabekona Lake	MTS	MTS	IF	IF	-
	528	Kabekona River	Kabekona Lake to Leech Lake (Kabekona Bay)	NA	-	EXS	MTS	MTS
0701010205-01 Leech Lake	530	Shingobee River	Unnamed creek (Howard Lake outlet) to Unnamed creek (Anoway Lake outlet)	MTS	MTS	MTS	IF	MTS
0701010203-01 Woman Lake								
0701010204-01 Boy River	610	Spring Creek	Headwaters to Wabedo Lake	MTS	EXS	IF	IF	-
	524	Boy River	Woman Lake to Rice Lake	NA	-	IF	MTS	MTS
	612	Unnamed creek	Headwaters to Northby Creek	EXS	EXS	IF	IF	-
	520	Boy River	Inguadona Lake to Boy Lake	MTS	MTS	MTS	MTS	MTS
	538	Swift River	Little Swift Lake to Swift Lake	MTS	MTS	IF	IF	-
	518	Boy River	Boy Lake to Leech Lake	NA	-	IF	MTS	MTS
0701010206-01 Bear River								
0701010206-03 Sixmile Brook	515	Sixmile Brook	Sixmile Lake to Leech Lake River	MTS	MTS	IF	IF	-
	501	Leech Lake River	Leech Lake to Sixmile Brook	MTS	-	IF	MTS	MTS

Aggregated HUC-12 Subwatershed *Note: AUID = 07010102 + last 3 digits.	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life Indicators				Aqua. Rec Ind.
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Bacteria
0701010206-01 Leech Lake River	606	Leech Lake River	Mud-Goose Lake Dam to Mississippi River	MTS	-	EXS	MTS	MTS

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information; -- = No Data, **NA** = Not Assessed. HUC 12's are listed in aggregated form to follow Leech Lake River Watershed Monitoring & Assessment Report format.

Lakes

The LLR Watershed has a high density of lakes with good water quality. Of the 86 lakes assessed for aquatic recreation, Hart Lake was the only lake found to not support aquatic recreation use. Hart Lake is one of the few shallow lakes in the LLR Watershed. The shallow depth allows nutrients to be recycled from the bottom sediments during wind events causing internal loading.

Most lakes within the LLR Watershed are deep and have the ability to assimilate phosphorus within lake bed sediments. Those two characteristics help limit internal nutrient loading and reduce the amount phosphorus being transferred to lakes located downstream (and ultimately into Leech Lake). The high connectivity between waterbodies within the LLR Watershed may increase the risk of eutrophication due to nutrient loading from land use or other human activities.

LLR Watershed lake conditions were assessed using a variety of parameters including: DO, conductivity, pH, temperature, total phosphorus (TP), chlorophyll-a (Chl-a), and Secchi transparency depth (a measure of water clarity). Water quality parameter measurements were compared to the normal range for each lake type in addition to state water quality standards. Aquatic life standards were not available for lakes at the time of this study and report. Aquatic recreation standards are determined by trophic status using TP, secchi depth and Chl-a as indicators. See Appendix 3.2 of the Leech Lake River Watershed Monitoring and Assessment Report or Appendix 1: in this document for the detailed lake assessment results of the lakes within the LLR Watershed. A summary of the number of lakes that are fully supporting (FS), non-supporting (NS), or had insufficient data (IF) to be assessed are provided in Table 2.

Table 2: Lake Water Quality Assessment Summary by Aggregated HUC 12

Aggregated HUC 12 Name	FS	IF	NS	Total
Steamboat River	2	0	1	**3**
Kabekona River	7	0	0	**7**
Leech Lake	16	4	0	**20**
Woman Lake	34	4	0	**38**
Boy River	21	2	0	**23**
Bear River	2	0	0	**2**
Six mile Brook	1	0	0	**1**
Leech Lake River	1	0	0	**1**
Total	**84**	**10**	**1**	**95**

The lake eutrophication standards for the LLR Watershed Ecoregion (Northern Lakes and Forest) are: TP < 30 ppb, Chl-a < 9 ppb, and Secchi depth > 2.0m. For lakes to be assessed for aquatic recreation use, samples must be collected over a minimum of two years between June through September with a minimum of eight individual data points for TP, Chl-a, and Secchi. Lakes where TP and at least one of the response variables (Chl-a or Secchi) exceed the standards are considered impaired, or NS of aquatic recreation use. Lakes with less than eight individual data points or less than two years of data are not assessed due to IF. Lakes with sufficient data for assessment that meet the water quality standards are considered FS of aquatic recreation use.

2.2 Water Quality Trends

Streams

Year-to-year weather variations affect water quality observation data; for this reason, interpreting long-term data trends minimizes year-to-year variation and provides insight into changes occurring in a water body over time. Table 3 below illustrates the general water quality trends from one MPCA Milestone Monitoring Station located just downstream of LLR Watershed. The Minnesota Milestone Program was designed to collect water quality data at designated river sites over a long period of time. This data is then used to get an understanding of the overall health trends of Minnesota's rivers. The trend analysis shown in Table 3 was performed using the Seasonal Kendall Test for Trends. This nonparametric analysis has the advantage of being robust to outliers, missing values, and values less than detection limits, can account for seasonal differences, and is now commonly used to analyze water quality trends. See link to the June 2014 report Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites for additional Milestone Site trend information.

Table 3: Watery quality monitoring trends from the pour point of the Leech Lake River Watershed

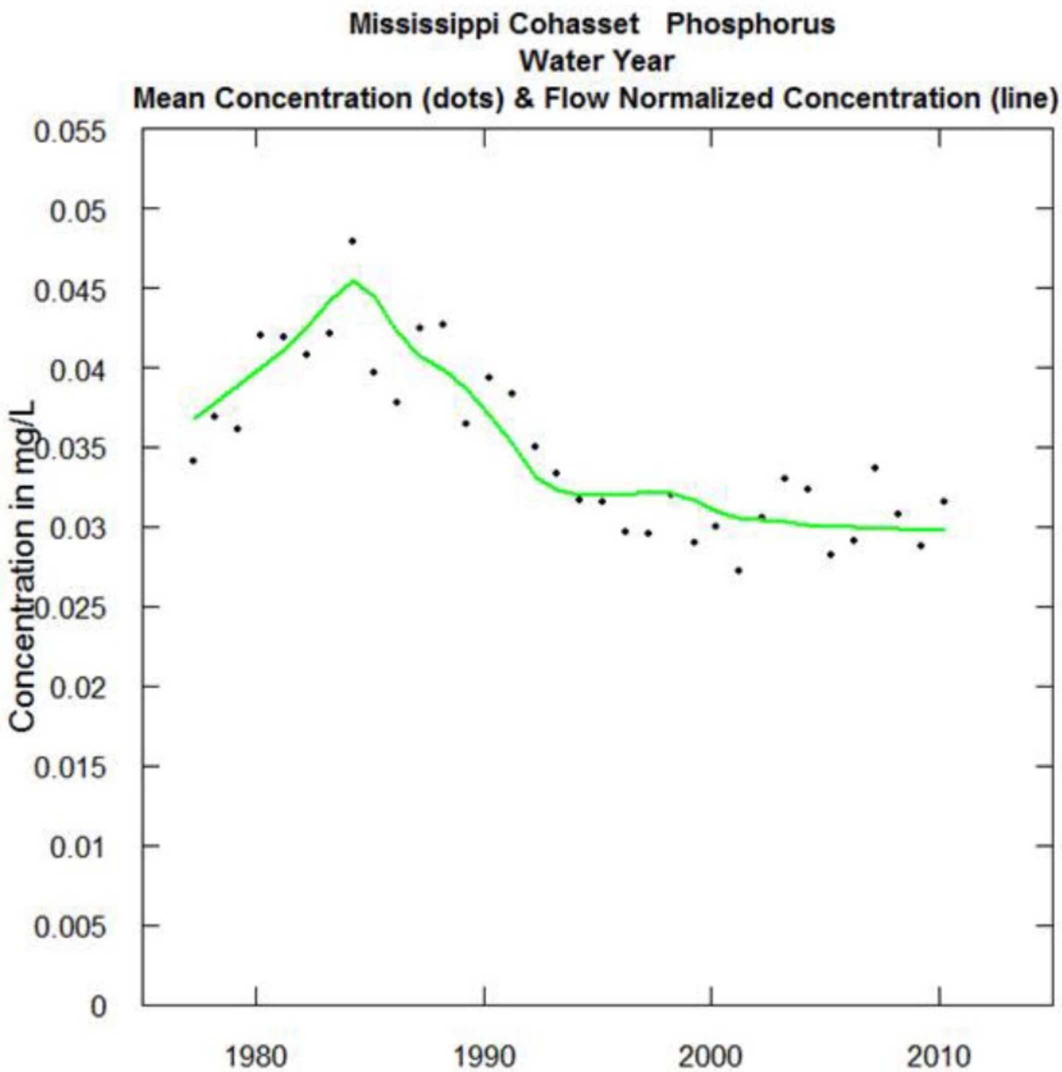
		Parameter					
Monitoring Station	Monitoring History	Total Suspended Solids	Total Phosphorus	Nitrite/ Nitrate	Ammonia	Biochemical Oxygen Demand	Chloride
UM -1186 (S000-154) Mississippi River at MN-6 Bridge 8 SW of Cohasset. (Situated downstream of the confluence of The Leech Lake River).	1967 – 2010	Decrease	Decrease	No Trend	Decrease	Decrease	Increase

See link for more information on MPCA's Milestone Program - Minnesota Milestone River Monitoring Program

Long-term stream water quality trends are best reflected from the MPCA Milestone Monitoring Site UM-1186 (Mississippi River at MN-6 Bridge eight miles southwest of Cohasset (S000-154). This station is situated downstream of the confluence of the LLR and Mississippi River. Green Decrease indicates an improving trend in water quality for that parameter while red Increase indicates a degrading trend in water quality for that parameter. The Milestone Monitoring trend for TP at Site UM-1186 is shown below in Figure 5.

The Minnesota Milestone Program was discontinued in September 2010, and replaced with the current intensive watershed approach of assessing the rivers in Minnesota and the Watershed Pollutant Load Monitoring Network. Currently, there are two Watershed Pollutant Load Monitoring Sites (WPLMN) within the LLR watershed where data has been obtained. While no long-term trends can be determined from these WPLMN stations at this time, data from these sites may prove valuable in establishing water quality trends in the future. While early historic data is limited, a general water quality trend determination was made for this LLR watershed based on the available Milestone data at Site UM-1186. In general, water quality trend data at this Mississippi River site suggests that a decreasing trend or no trend is apparent for the monitored parameters except for chloride, where a trend increase was being observed. While data here suggests there is no long-term trend for nitrogen downstream from the LLR Watershed, nitrogen trends have been generally increasing across the state of Minnesota. For more information on nitrogen trends in Minnesota see the June 2013 MPCA report Nitrogen in Minnesota Surface Waters.

Figure 5: Mean phosphorus concentrations at Mississippi Cohasset Milestone Monitoring Site



Lakes

The MPCA coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program (CLMP) and the Citizen Stream Monitoring Program (CSMP). Like the permanent Watershed Pollutant Load Monitoring Network, having citizen volunteers monitor a given lake or stream site monthly and from year to year can provide the long-term picture needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes that occur in the years between intensive monitoring years. In evaluating trends for lakes within the LLR Watershed data from the CLMP was utilized.

The Seasonal Kendall test was applied to all June through September transparency data for each lake with a minimum of eight years of data required to run the test. The median transparency was calculated and charted along with the minimum and maximum measurements for each year. The summer-median and a smoothing technique were used to draw the regression line. The trend (Rk) was calculated based on all available data for the period, rather than summer-means, as is the case in the TSI-trend year file. The Rk, number of years, slope, p-value, and significance of the trend were reported for each lake. Significance of the trends was derived from the Rk (± confidence interval) and p values. The p values, significance, and narrative description are summarized in Table 4. Eight lakes listed in Table 5 are shown to have gradual declining water clarity trends. It is important to note that these eight lakes are currently meeting water quality standards for aquatic recreation. However, these trends emphasize the need for vigilance in the effort to protect these lakes from further decline and possible future impairment status.

Table 4: Trend significance, p values, and narrative description

p value	significance	description
>0.10	0 & ±1	- no trend
0.10-0.19	±2	- weak evidence of a possible trend
	±3	- evidence for a possible trend
	±4	- evidence for a trend
≤0.01	±5	- strong evidence for a trend

Table 5: Leech Lake River Watershed Lake Water Quality Trends

Lake	Lake ID	Date Range	Transparency Trend
Baby	11-0283	1995-2014	Improving
Barnum	11-0281	2001-2014	No trend
Benedict	29-0048	1987-2014	No trend
Big Deep	11-0277	1998-2014	No trend
Birch	11-0412	1989-2014	Improving
Blackwater	11-0274	1988-2014	Improving
Child	11-0263	1987-2014	No trend
Cooper	11-0163	1993-2014	Improving
Garfield	29-0061	2006-2014	No trend
Girl	11-0174	1987-2014	No trend
Grave	11-0086	2004-2014	No trend
Hunter	11-0170	1988-2014	Improving
Inguadona (South Bay)	11-0120	1989-2014	No trend
Inguadona (North Bay)	11-0120	1989-2014	Declining
Island	11-0257	2001-2014	No trend
Kabekona	29-0075	1990-2014	Improving
Kerr	11-0268	1997-2014	No trend
Kid	11-0262	2001-2014	No trend
Leech (Ah-Gwah-Chin)	11-0203-02	1986-2014	No trend
Leech (Main Basin)	11-0203-01	1990-2014	No trend
Leech (Shingobee Bay)	11-203-04	1976-2014	Improving

Lake	Lake ID	Date Range	Transparency Trend
Little Boy	11-0167	1989-2014	No trend
Little Sand	11-0092	1981-2013	No trend
Little Webb	11-0311	2005-2014	No trend
Long (Main Basin)	11-0142-02	1992-2014	Declining
Long (S.W. Bay)	11-0142-04	1993-2014	No trend
Lower Trelipe	11-0129	2001-2014	No trend
Man	11-0282	1995-2014	Declining
McKeown	11-0261	1995-2014	No trend
Mule	11-0200	1991-2014	No trend
Pleasant	11-0383	1994-2014	Improving
Ponto	11-0234	1998-2014	Declining
Portage	11-0490	1997-2014	No trend
Sand	11-0279	2002-2014	No trend
Shingobee	29-0043	2005-2014	Declining
Steamboat	11-0504	2004-2014	No trend
Stony	11-0371	1997-2014	Declining
Ten Mile	11-0413	1974-2014	Improving
Trillium	11-0273	1988-2014	Improving
Upper Trelipe	11-0105	2001-2014	Improving
Wabedo (NE Bay)	11-0171	1977-2014	No trend
Wabedo (SW Bay)	11-0171	1993-2008	Declining
Widow	11-0273	1984-2014	Improving
Webb	11-0311	2004-2014	No trend
Woman (Main Basin)	11-0201	1987-2014	Improving

2.3 Stressors and Sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated. Biological SID is done for streams with either fish or macroinvertebrate biota impairments, and encompasses both evaluation of pollutants and non-pollutant-related factors as potential stressors (e.g. altered hydrology, fish passage, habitat). Pollutant source assessments are done where a biological stressor ID process identifies a pollutant as a stressor as well as for the typical pollutant impairment listings. Section 3 provides further detail on stressors and pollutant sources.

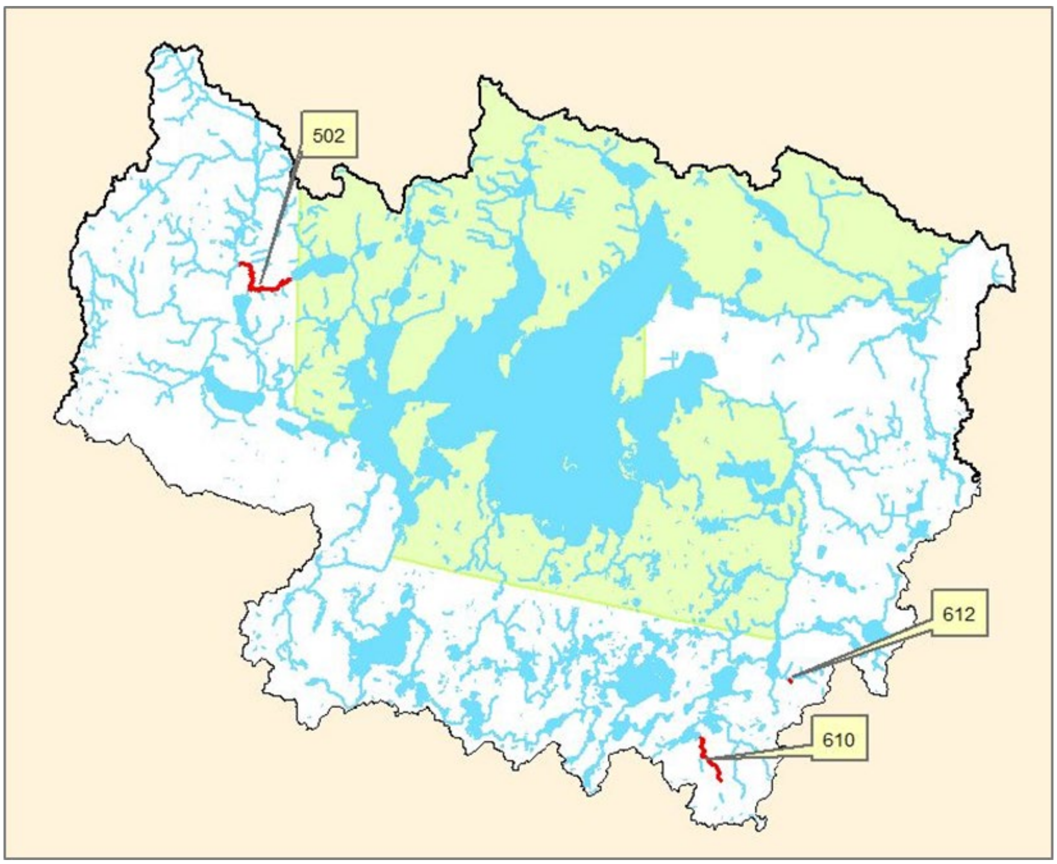
This Leech Lake River SID Report documents the efforts that were undertaken to identify the causes, and to some degree the source(s) of impairments to aquatic biological communities in the LLR Watershed. Information on the SID process can be found on the United States Environmental Protection Agency's

(EPA) website http://www.epa.gov/caddis/. The LLRW is situated mostly within a non-agricultural, mostly-forested region of north central Minnesota. Agricultural land usage is primarily in the northwestern part of the watershed. Most of the agriculture is animal rearing, with most of the fields being used for hay, rather than for row crops. Major portions of the LLRW are within the Leech Lake Reservation, or the Chippewa National Forest. As such, development in much of the watershed is very low density. Another major landscape factor in LLRW is the extensive wetland acreage, much of it being the palustrine type.

Three Assessment Unit Identification (AUID) reaches on three streams were brought into the SID process because they were determined to have substandard biological communities via the 2012 IWM and Assessment phase of this WRAPS project. Upon further investigation of these sites during the SID process, these streams were determined to be stressed by low DO. The Spring Creek and Unnamed Creek impairments received a CALM categorization of 4D, where the stressor (DO) was determined to be natural. The Necktie River AUID DO impairment is being deferred due to need for a different DO standard for low gradient, wetland dominated rivers. See location of the three impairments in Figure 6

- Spring Creek (AUID 07010102-610) - Macroinvertebrates
- Necktie River (AUID 07010102-502) - Fish
- Unnamed Creek (AUID 07010102-612) - Fish and Macroinvertebrates

Figure 6: Stream reaches (in red) with Aquatic Life Use impairments. The green-shaded area denotes the Leech Lake Reservation within the Leech Lake River Watershed.



Overall SID Conclusions for the LLRW

The SID process identified one stressor (low DO) for the three biologically impaired stream reaches (Table 6). For Spring and Unnamed Creeks, the natural background review committee met and determined that the low DO concentrations (and thus also the poor fish community) are due to natural causes, in this case, enhanced wetlands due to high numbers of upstream beaver impoundments. Beaver dams are also likely acting as migration barriers for fish. The fish community in the lower Necktie River (AUID-502) is also influenced (or limited) by low DO levels. The low DO impairment for the Necktie River is being deferred currently. It has been recognized by the MPCA that a special DO standard is needed for north central and northeastern Minnesota low gradient streams that are highly influenced by abundant natural wetlands. Thus, there are no biological stream impairments at this time that require a TMDL.

A flooded riparian area on Spring Creek due to a beaver dam just above the culvert on CSAH-47, July 9, 2014 – Photo courtesy MPCA

Table 6: Summary of stressors causing biological impairment in LLRW streams by location (AUID).

					Stressor					
Stream	**AUID Last 3 digits**	**Reach Description**	**Biological Impairment**	**Impairment Category**	Dissolved Oxygen	Phosphorus	Sediment/Turbidity	Connectivity	Altered Hydrology*	Channel alteration
Necktie River	502	Pokety Creek To Steamboat Lake	Fish	Deferred assessment	o					
Spring Creek	610	Spring Creek	MI	4D	o					
Unnamed Creek	612	Northby Creek	Fish and MI	4D	o					

*Includes intermittency and/or geomorphology/physical channel issues

o = A stressor, but anthropogenic contribution, if any, not quantified. Beaver dams are included as a natural stressor.

Pollutant Sources

Pollutant sources were identified for point and nonpoint sources in the LLR Watershed. There are four municipal wastewater facilities and eight industrial wastewater facilities that require NPDES permitting (Table 7). None of the point sources require pollutant reductions beyond their current permit conditions or limits.

A variety of nonpoint sources may be contributing phosphorus to lakes and streams in the Leech Lake Watershed. These include, but are not limited to: shoreland disturbance, urban stormwater, riparian and non-riparian failing septic systems, agricultural grazing and cropland management, land conversion, groundwater contamination, in-lake sediment phosphorus release (internal loading), wetland overflows, upstream lake loading, nutrient loading and erosion from varied sources within the watershed, such as roads, poor hydrology management, and developed land uses.

Table 7: Point Sources in the Leech Lake River Watershed

HUC-10 Subwatershed	Point Source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
Kabekona River	Northstar Materials Inc. dba Knife River Materials	MNG490038	Industrial Stormwater	No	Kahlstorf Pit (J1-1442, D1-2951). Discharge to TH #200 Ditch.
Kabekona River	Gladen Construction Inc.	MNG490145	Industrial Stormwater	No	Hubbard County Pit (J1-1442). Stormwater and dewatering contained on site under normal conditions. If large runoff event were to occur, stormwater/ dewater would overflow and enter Kabekona Creek, which is approx. 1/4 mi south of site.
Boy River	Longville WWTP	MNG580208	Municipal Wastewater	No	Controlled discharge to unnamed wetland, then Boy River.
Leech Lake	Akeley WWTP	MN0052345	Municipal Wastewater	No	Tile line discharge to unnamed ditch.
Leech Lake	Aggregate Industries Inc. - Multiple Sites	MNG490073	Industrial Stormwater	No	Aggregate Industries-Walker RMC (E2-3273). Discharge to an unnamed low area (not mapped as a wetland) which discharges to May Lake.
Leech River	Federal Dam WWTP	MN0063487	Municipal Wastewater	No	Continuous discharge to Leech Lake River.
Leech River	USCOE Leech Lake Rec Area WWTP	MN0110027	Municipal Wastewater	No	Periodic/seasonal (May-Oct) discharge to Leech Lake River.

2.4 TMDL Summary

Some of Minnesota's most important surface water resources exist within the LLR Watershed. This includes the third largest lake in Minnesota, the focal point resource of the watershed, Leech Lake.

Leech Lake is the largest lake within the watershed encompassing an area of 112,000 acres and is renowned for its world-class recreational opportunities and cultural resources.

Hundreds of other high quality lakes and miles of streams exist within the LLR Watershed. The bountiful pristine surface water resources combined with the wealth of accompanying resources and features (e.g. forestland - including the Chippewa National Forest, Leech Lake Reservation, availability of public land, plentiful wildlife, and cultural resources) provide an exceptional appeal for this North Central Minnesota watershed situated in the Upper Mississippi River Basin.

The IWM and WRAPS processes helped to confirm that the abundant surface water resources within the watershed are predominantly healthy and that the need for the protection of these resources is vital in sustaining the way of life for the area while protecting the recreational opportunities cherished by the citizens of Minnesota and throughout the United States.

Of the numerous surface water resources assessed in the 2016 assessment cycle for this watershed, only two surface water resources (Hart Lake – Hubbard County, Kabekona River – Hubbard County) were added to the Draft 2016 Impaired Waters List under the EPA category 5 classification. Information gathered from the WRAPS Technical Team discussions throughout the WRAPS project and the Professional Judgement Group (PJG) meeting held on February 19th, 2015, suggested that developing a TMDL for the Category 5 impairments should be deferred and subsequently pursued if the water resource is not delisted or re-categorized in the next IWM cycle, which is currently scheduled to start in 2022.

The LLR Watershed has a high density of lakes with good water quality. Of the 85 lakes assessed for aquatic recreation, **Hart Lake** was the only lake found to not support aquatic recreation use. With a maximum depth around 10 feet, Hart Lake is one of the few shallow lakes in the LLR Watershed. The shallow depth allows nutrients to be recycled from the bottom sediments during wind events causing internal loading. Several factors came into consideration for the decision to defer a TMDL study specifically for Hart Lake. This included the ongoing MPCA consideration for developing a lake nutrient standard specifically for shallow lakes within the northern lakes & forests ecoregion of Minnesota and the natural background contribution of nutrients within Hart Lake's subwatershed. The lake currently provides high quality habitat for wild rice and various waterfowl species. Development density on Hart Lake is very low with one residence along the lakeshore.

The **Kabekona River** is a high quality trout stream, which reflected elevated bacteria Escherichia coli (*E. coli*) levels based on monitoring data gathered in the summers of 2010-2011. Since that timeframe, BMPs were implemented upstream of the monitoring site. The Hubbard SWCD and the MPCA is currently working with the Kabekona Lake Association to obtain additional supporting bacteria monitoring data in the effort to delist this stream from the 303d list. Discussions through the WRAPS Technical Team and PJG meetings supported the TMDL deferment based on the proposed monitoring strategies (including additional monitoring stations) and subsequent follow up discussions as needed with local landowners and the city of Laporte.

Two stream reaches were classified under EPA category 4D for three stressors. These stressors were attributed to natural background conditions within the watershed, which included the presence of beaver dam activity. See the Leech Lake River SID Report for specific stressor identification information within the watershed. See Table 8 below for impairment listings and the EPA category definitions.

Table 8: Draft 2016 Impaired Waters List – Leech Lake River Watershed

Water body name	Water body description	Year added to list	AUID	County	Affected use	Pollutant or stressor	*EPA Category
Hart	Lake	2016	29-0063-00	Hubbard	Aquatic Recreation	Nutrient/eutrophication biological indicators	5
Kabekona River	Headwaters to Kabekona Lake	2016	07010102-511	Hubbard	Aquatic Recreation	*Escherichia coli*	5
Spring Creek	Headwaters to Wabedo Lake	2016	07010102-610	Cass	Aquatic Life	Aquatic macroinvertebrate bioassessments	4D
Unnamed Creek	Headwaters to Northby Cr	2016	07010102-612	Cass	Aquatic Life	Aquatic macroinvertebrate bioassessments	4D
Unnamed Creek	Headwaters to Northby Cr	2016	07010102-612	Cass	Aquatic Life	Fishes bioassessments	4D

*EPA Category definitions
Category 4D = The waterbody does not meet applicable criteria, but no pollutant can be identified; therefore, a TMDL will not be developed at this time.
Category 5 = Water quality standards are not attained and a TMDL is required.

2.5 Water Quality Protection Considerations

Protecting high quality waters is essential to avoid future water quality degradation and to ensure resiliency to the impacts of land use and climate change. The ecological services provided by healthy watersheds may be impossible to recreate once compromised. It is widely recognized that protection of existing high quality waters— “keeping clean waters clean”—is more cost effective than trying to restore impaired waters, which even with rigorous TMDLs established and costly implementation, may never meet Minnesota’s surface water standards. Protecting healthy watersheds and water bodies is the state’s most cost effective approach to ensure that the economic and ecosystem services provided by heathy waters remain intact and provide Minnesotans with quality waters to enjoy and drink generations from now.

The LLR Watershed contains some of Minnesota’s most pristine and high quality lakes and streams, highly valued for recreational use and noted for their exceptional resource value. The use and enjoyment of these waters and surrounding natural resources is critical to the economic sustainability of the communities in this watershed. There are minimal conventional (other than mercury) water quality impairments in the LLR Watershed; those found upon monitoring are related primarily to natural background conditions. Subsequently, there will be no TMDL restoration plans completed during this WRAPS cycle for this watershed. The watershed is scheduled for the next IWM/WRAPS cycle in 2022. At that time the newly assessed impairments (e.g. Hart Lake for nutrients and a segment of the Kabekona River for *E. coli* bacteria, both in Hubbard County) will be reevaluated. The overall strategy for this WRAPS is protection to “maintain and/or improve water quality” in the LLR Watershed.

The Technical Team (Team) that developed this plan is hopeful that it will be a model plan and guidance for water quality protection in future WRAPS. The process used to develop protection strategies for the

LLR Watershed closely aligns with "WRAPS Protection Strategy Guidance" developed by the MPCA and the Minnesota Department of Natural Resources (DNR). See Appendix 2 for full guidance and a fact sheet.

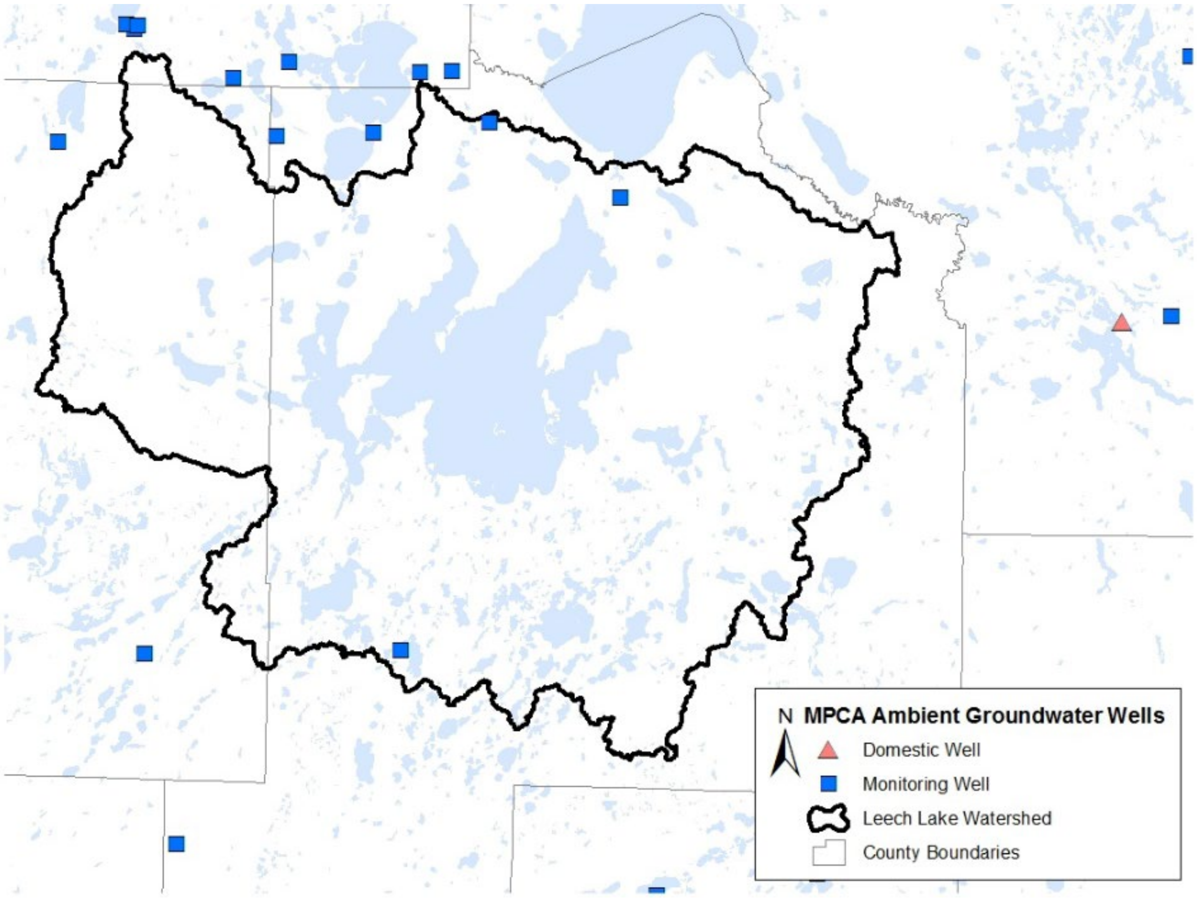
Acknowledging that a protection strategy is important for all lakes and streams within the LLR Watershed, but realizing that limited implementation funds will be available, protection strategies will be focused on priority waters in the watershed, including: 1) streams of exceptional value and recreational use; and 2) lakes with declining water quality trends, highest biological significance, outstanding recreation and resource value, and susceptibility to future development and/or land use conversion. See Section 3.0 for specific prioritization tools and water quality protection strategies.

Groundwater and Hydrogeology

With its abundance of natural resources, the LLR watershed ranks as one of the most ecologically diverse watersheds, not only in Minnesota, but also in the country. This wealth of resources is quite evident in the numerous high quality lakes and streams, along with the significant flora and fauna species that characterize this watershed. However, another vital resource exists discreetly beneath the surface helping to supply the citizens of this watershed and the Upper Mississippi River Basin a clean drinking water supply. Approximately 75% of Minnesota's population receives their drinking water from groundwater resources, indicating that clean groundwater is essential to the health of its residents. The vast forestlands, which cover approximately 60% of the LLR Watershed, greatly help safeguard and allow for effective replenishment of this resource. The overall protection strategy theme for water quality of "keeping forests forested" is one of the primary strategies proposed through this WRAPS process, with the goal of protecting all the water resources within this watershed and downstream receiving areas (see Section 3.4).

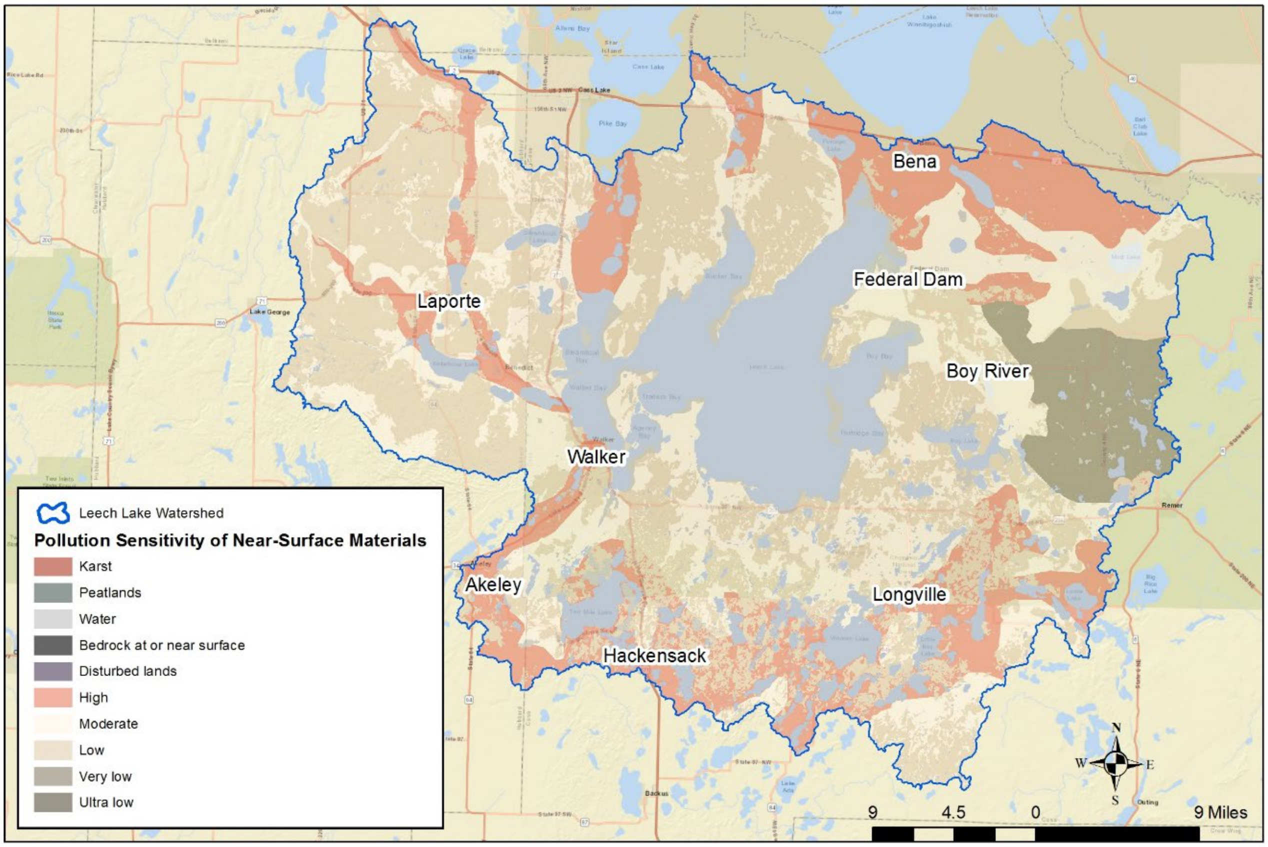
The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These Ambient Groundwater wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state and local partners are used to supplement reviews of groundwater quality in the region. There are currently three MPCA Ambient Groundwater Monitoring wells within the Leech Lake River Watershed. Two of the ambient groundwater wells are located in the northern portion of the watershed, while the third is located in the southern region (Figure 7). From 2010 to 2016, these wells were sampled once per year and tested for over 100 different analytes. During this time period, 32 analytes were detected in 12.7% of all samples. The most frequently found detections were calcium, chloride, magnesium, phosphorus, sodium, strontium, and sulfate. The majority of these constituents do not have maximum contaminant level (MCL) standards, with the exception of chloride and sulfate. Chloride has a primary standard of 250 mg/L while sulfate has a secondary standard of 500 mg/L and neither exceeded these limits. In 2012, one of the wells was tested for 123 contaminants of emerging concern (CECs). CECs are predominantly manmade chemicals, although some may be naturally occurring or endocrine active chemicals, and include pharmaceuticals, fire retardants, pesticides, personal-care products, hormones, and detergents (Erickson et al., 2014). There were two detections identified: phenol and DEET (N, N-diethyl-meta-toluamide). Phenol is an organic compound, often found in plastics while DEET is an active ingredient in insect repellents. However, DEET was also found in the quality control blank samples, and is not considered a concern.

Figure 7: MPCA ambient groundwater monitoring well locations within the Leech Lake River Watershed



The DNR, in cooperation with the Minnesota Geological Survey, is working on a hydrogeological atlas focused on the pollution sensitivity of the bedrock surface. It is being produced county-by-county, and is awaiting completion for those counties within the LLR Watershed. Until the hydrogeological atlas is finished, a 2016 statewide evaluation of pollution sensitivity of near-surface materials completed by the DNR is utilized to estimate pollution vulnerability up to ten feet from the land surface. This display is not intended to be used on a local scale, but as a coarse-scale planning tool. According to this data, the LLR Watershed is estimated to have primarily low to moderate, with some high, pollution sensitivity areas scattered throughout the watershed, most likely due to the presence of sand and gravel Quaternary geology (Figure 8).

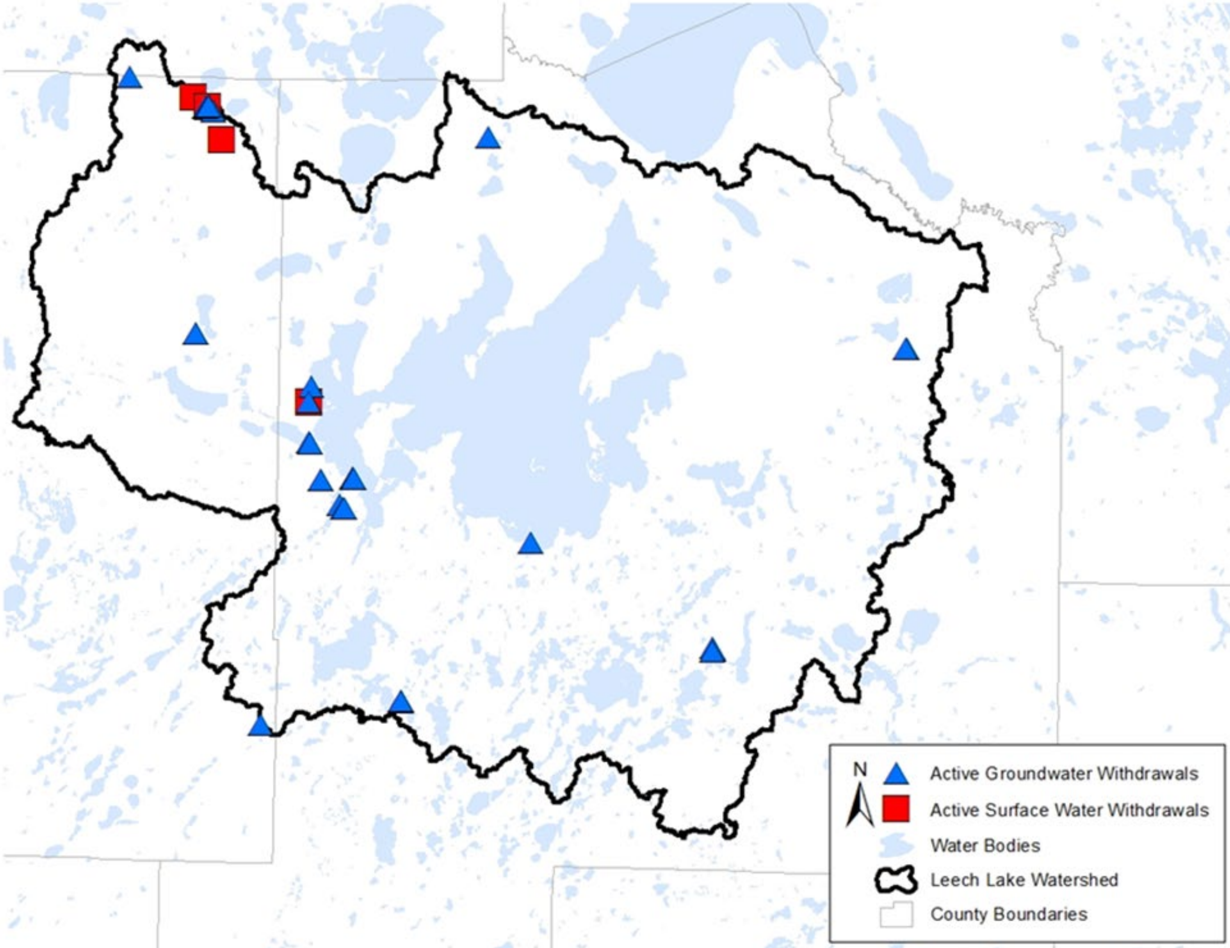
Figure 8: Leech Lake River Watershed – Pollution Sensitivity of Uppermost Aquifers – (Map courtesy of DNR)



Groundwater protection should be considered both for quantity and quality. Quantity is based on the amount of water withdrawn versus the amount of water being recharged to the aquifer. At this time, groundwater withdrawals in the LLR Watershed appear to have declined over the last 20 years, with only a recent spike in groundwater use in 2015 (See Figure 9). However, water table elevation (above sea level) for DNR observation wells within the watershed have displayed significant declines in water level elevations trends over the most recent 20 years of data collected. This is a possible indicator that water table levels are going down. It is estimated that the development pressure is moderate to high within the watershed, where land is converted from farms, timberland and shoreline to recreational usage and lake and country homes (NRCS 2014), but this has not been reflected in water supply demands yet. Overall groundwater withdrawals have been declining, but the watershed's water table has exhibited some signs of decline. While fluctuations due to seasonal variations are normal, long-term changes in elevations should not be ignored.

According to the most recent DNR Permitting and Reporting System (MPARS), in 2015 the withdrawals within the LLR Watershed were utilized for water level maintenance (37.9%), water supply (34.7%), non-crop irrigation (13.2%), industrial processing (10.5%), agricultural irrigation (6.5%), and special categories (0.22%). From 1996 to 2015, withdrawals associated with power generation and water supply have decreased at a significant rate, while water level maintenance has increased at a significant rate over this time period. These withdrawals include four community Public Water Suppliers (Akeley, Hackensack, Laporte and Walker) with an approved Drinking Water Supply Management Area.

Figure 9: Locations of active status permitted high capacity withdrawals in 2015 within the Leech Lake River Watershed



There is limited amount of groundwater quality data available specifically for the LLR Watershed. Although there have been detections in ambient and CEC sampling, there were no exceedances to the MCL. Baseline water quality data indicated that the North Central region is categorized as very good water quality when compared to other regions with similar aquifers. There were relatively very low numbers of arsenic MCL exceedances for drinking water in private wells for this area (Figure 10). The pollution sensitivity of near-surface materials is primarily low to moderate, but areas of high sensitivity should be monitored, especially for nitrates (Figure 11), which were identified as a concern in this region, in order to inhibit possible water pollution.

Figure 10: Leech Lake River Watershed – Pollution Sensitivity of Wells and Arsenic Results (Map courtesy of MDH)

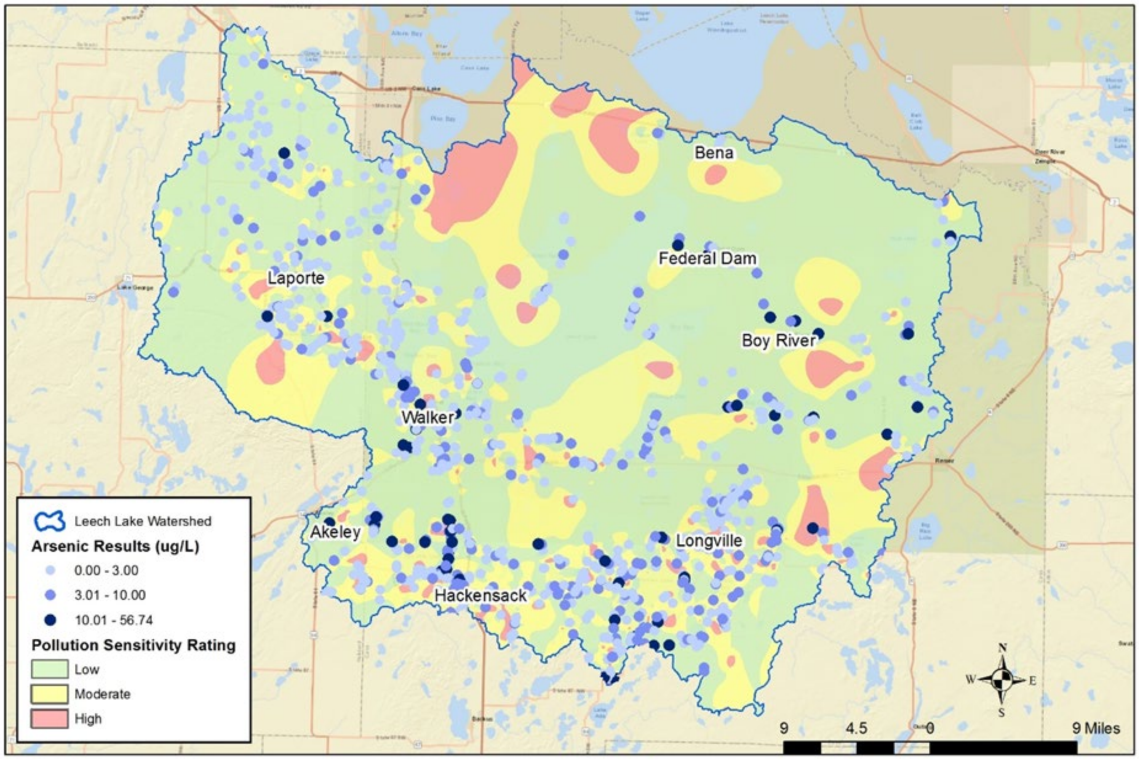
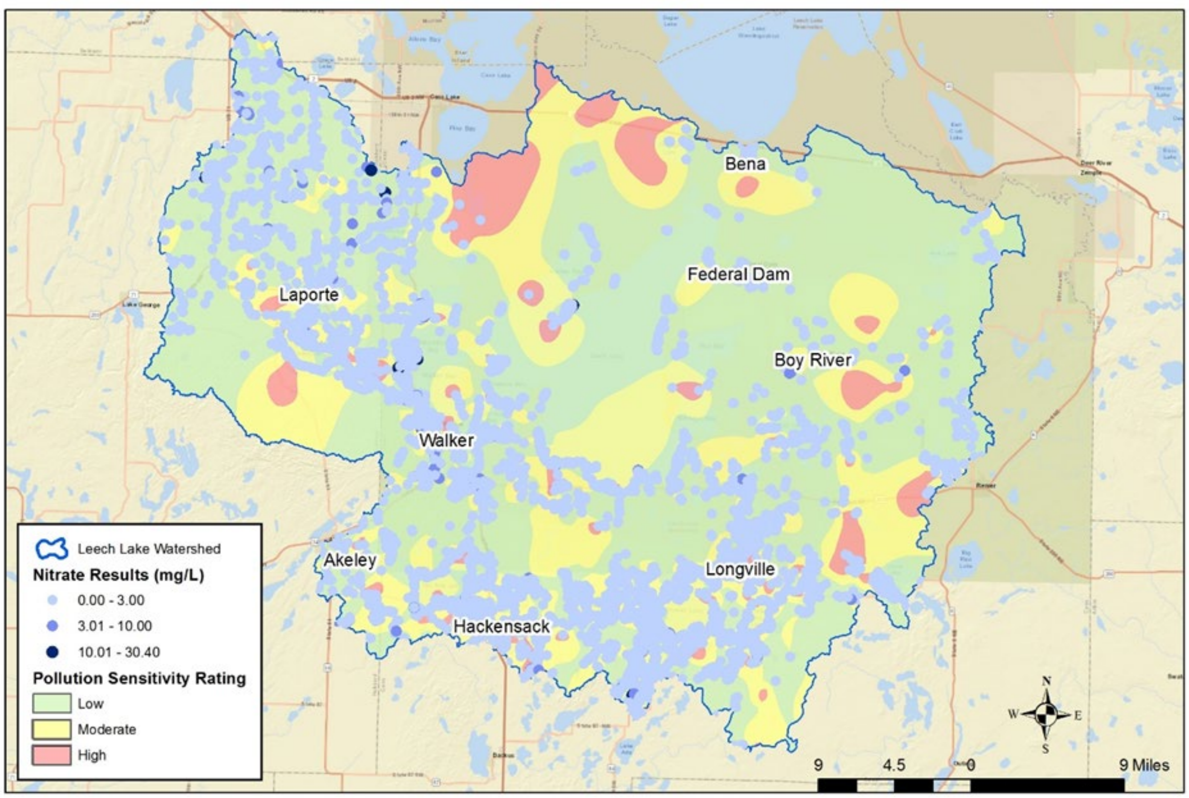


Figure 11: Leech Lake River Watershed - Pollution Sensitivity of Wells and Nitrate Results (Courtesy MDH)



Additional and continued monitoring will increase the understanding of the health of the watershed and its groundwater resources and aid in identifying the extent of the issues present and risk associated. Increased localized monitoring efforts will help accurately define the risks and extent of any issues within the watershed. Adoption of BMPs will benefit both surface and groundwater. For additional hydrogeology and groundwater quality information on the LLR Watershed, see Pages 21 through 25 of the Leech Lake River Watershed Monitoring and Assessment Report.

3. Prioritizing and Implementing Water Quality Protection Strategies

The Clean Water Legacy Act (CWLA) requires that a WRAPS report summarize priority areas for targeting actions to improve or maintain good water quality, and identify point and nonpoint sources of pollution with sufficient specificity to geographically prioritize watershed restoration and protection actions. In addition, the CWLA requires including an implementation table of strategies and actions that are capable of cumulatively achieving pollution load reductions for point and nonpoint sources to maintain or improve water quality.

This section of the report provides the results of prioritization and strategy development for protection of water quality in the LLR Watershed. Implementation of the strategies in this plan will largely depend on incorporating the strategies into the management plans of local, state, federal, and tribal government entities and nonprofit organizations, which were highly involved in developing the protection strategies. Successful implementation and achievement of goals will require continued collaboration among these entities and a commitment to seek funding for implementation of the protection strategies. Hubbard, Cass, and Beltrami counties are committed to the incorporation of key strategies in their newly revised or to-be-revised local water plans. Other committed agencies and organizations include: the MPCA; various divisions of the DNR; the Minnesota Board of Water and Soil Resources (BWSR); NRCS serving Cass and Hubbard counties; Chippewa National Forest/U.S. Forest Service; Army Corp of Engineers/Leech Lake Dam Recreational Area; Leech Lake Band of Ojibwe; LLAWF; The Nature Conservancy (TNC); Mississippi Headwaters Board (MHB); Minnesota Forestry Resources Council; and municipalities and townships in the watershed.

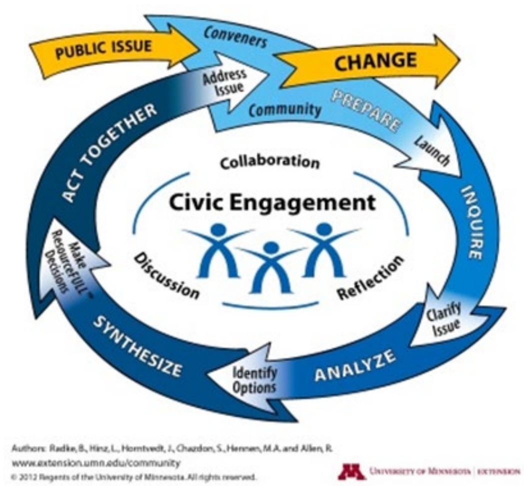
Voluntary implementation of BMPs by landowners, lake associations, and residents of the watershed will also be critical for successful implementation of this WRAPS. It will be imperative to create social capital (trust, networks and positive and collaborative relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective and ongoing civic engagement is fully a part of the overall plan for moving forward with water quality protection of some of Minnesota's most iconic waters.

For lakes, the amount of TP measured is an indicator of water quality. Phosphorus is contributed to lakes and streams primarily as a result of land disturbance and runoff to receiving waters. Once high levels of phosphorus are attained in lakes, sediment loading (internal loading) can also be a contributing factor. The resulting effects of land disturbance on water quality can be captured by calculating the relative amount of disturbed land within the watershed. Modeling by fisheries researchers with the DNR suggests: 1) that TP concentrations will remain near natural background levels when less than 25% of the land in a lake's watershed is disturbed (a lake's watershed is the sum of all local catchments upstream from the pour point of the lake) and; 2) we can be reasonably assured that TP will remain low in perpetuity if 75% or more of the land in the watershed is permanently protected (i.e. public ownership, conservation easements, or other permanent protection programs). The more land disturbance in a lake's watershed, the greater the need for water quality protection to eliminate contributing sources of phosphorus.

The researchers found when there was greater than 40% "anthropogenic" land disturbance there were significant changes in a lake's TP and impacts to fish populations. Land use and disturbance modeling and long-term mean TP provide the basis for setting phosphorus reduction goals for specific waterbodies in the LLR Watershed and evaluating progress towards those goals over the next 10 years. A discussion of methodology for setting phosphorus reduction goals is found in Section 3.3. Specific phosphorus reduction goals for priority lakes are detailed in Section 3.4.

3.1 Civic Engagement

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement (CE). Specifically, the University of Minnesota Extension's definition of CE is "Making 'resourceFULL' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." A resourceFULL decision is one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on CE is available at http://www1.extension.umn.edu/community/civic-engagement/.



Stakeholder and Public Engagements and Meetings

The LLR Watershed WRAPS was guided by a variety of stakeholders involved at various levels throughout the four-year project. They were both informed and given many opportunities to provide input on the identification of priority lakes and streams and strategies for restoration and protection of water quality. These stakeholders included representatives of local governments (county, township and municipal), lake associations, the business and education community, interested public, and numerous professionals from state government agencies, joint powers boards, Chippewa National Forest, Leech Lake Band of Ojibwe, the LLAWF and other non-profit organizations.

A CE stakeholder team met several times after the kick-off event to develop a CE strategic plan using a "strategic doing" model developed and facilitated by the University of Minnesota Watershed Planning Team. The model mapped assets (local expertise, relationships, organized coalitions, champions, ongoing communications, and past efforts with influence) for effective CE in the watershed. The plan guided CE activities throughout the remainder of the project. The CE Stakeholder Team was also involved in a scoping session facilitated by the University of Minnesota Extension staff to identify other education opportunities in the community that Extension could assist with delivery.

The CE Stakeholder Team coordinated a "Values-Driven" Conservation Priorities mapping project referred to as the "zonation model"; details can be found in Section 3.3.2. The four-step process of selecting conservation features for the map data layers, value weighting of the features, running the map algorithms, and synthesizing the data took place from March 2014 through December 2015. The final model was a critical tool used to identify priority areas within the watershed on which to focus protection activities.

The MPCA along with local partners and engaged state agencies in the Leech Lake WRAPS also recognized the importance of public involvement in the WRAPs process. A number of public meetings were held and periodically project updates were publicized in local media and numerous organizational newsletters. Since the waters of the LLR Watershed are pristine and healthy, the general CE theme throughout the project was "Healthy Waters: Let's Keep Our Clean Waters Clean." CE activities focused on growing a communications network for the public and targeted stakeholders and establishing a watershed identify that would build ownership and incentive that would engage participants in future implementation of water quality protection strategies as identified in this WRAPS plan.

Table 9 is a chronology of public and stakeholder meetings held since the WRAPS kickoff in May 2012.

Table 9: Public and Stakeholder meetings held for the Leech Lake River WRAPS

Date	Location	Focus of Meeting
5/10/2012	Walker, MN	Leech Lake River WRAPS Kick-Off Public Meeting
6/20/2012	Hackensack, MN	Association of Cass County Lakes (ACCL) Meeting- Lake Stakeholders
7/18/2012	Hackensack, MN	Initial Meeting of CE Stakeholder Team
9/6/2012	Hackensack, MN	CE Communications Planning; Strategic Planning
9/28/2012	Walker, MN	Association of Cass County Lakes (ACCL) Legislative Forum and Stakeholder Input
3/14/2013	Hackensack, MN	CE Stakeholder Team Meeting Strategic Doing Model Completion
4/29/2013	Walker, MN	Education Scoping Meeting – Invited Stakeholders
8/25/2013	Hackensack, MN	Stakeholder Presentation- Union Congregational Church
10/23/2013	Hackensack, MN	CE Stakeholder Team- Strategic Plan Implementation
1/22/2014	Walker, MN	WRAPS Partner and Stakeholder Meeting
3/3/2014	Backus, MN	HSPF Informational Meeting for Stakeholders
3/19/2014	Hackensack, MN	Zonation Model- Stakeholder Initial Meeting
4/15/2014	Hackensack, MN	Zonation Model Conservation Features Setting Meeting
6/16/2014	Hackensack, MN	Zonation Model- Values Setting Meeting
8/27/2014	Hackensack, MN	WRAPS Public Update Meeting
9/26/2014	Hackensack, MN	ACCL Meeting- Lake Association Stakeholders
10/28/2014	Northern Lights, Walker, MN	Workshop "Land use Decisions and Their Impact on Clean Water" for elected officials and community leaders
11/20/2014	Backus, MN	Stakeholder Meeting/RESPEC Presentation on Modeling
12/18/2014	Walker, MN	Leech Lake Association Meeting/Dinner
1/5/2015	LaPorte, MN	Hubbard County League of Women Voters
2/11/2015	Nevis, MN	Grazing Workshop for Agricultural Producers
2/17/2015	Hackensack, MN	Stakeholder CE Stakeholder Team- Zonation Planning and Phase III CE activities
2/19/2015	Walker, MN	Professional Judgement Meeting - professional review of Phase I monitoring and input on listings of waters.
3/26/2015	Walker, MN	Zonation Model Synthesis Meeting- Stakeholders

Date	Location	Focus of Meeting
4/9/2015	Cass Lake, MN	Meeting with LLBO Division of Resource Management (DRM)
5/8/2015	Hackensack, MN	Stakeholder Strategy Planning Session
7/13/2015	Hackensack, MN	ACCL Presentation- Lake Stakeholders
8/19/2015	Longville, MN	Boy River Stakeholder Zonation Model Meeting
9/2/2015	Walker, MN	Public Meeting
9/23/2015	Walker, MN	Stakeholder zonation model meeting- Leech Main region
9/23/2015	LaPorte, MN	Stakeholder zonation model meeting-Hubbard County
6/30/2016	Walker, MN	Public Meeting – Information/Update on the WRAPS project

Public Notice for Comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the State Register from February 13, 2017 to March 15, 2017 with five comment emails/letters received. Comments were addressed through response letters by the MPCA.

Civic Engagement Accomplishments and Future Plans

Phase I CE activities focused on informing the public and key stakeholders about the project and opportunities to engage in "Keeping Clean Waters Clean." Phase I CE activities included participation in a regional Legislative Forum, presentations to various community groups, press articles about the project in local media, articles in lake association newsletters, an article in the LLAWF newsletter (distribution 5,000), and two presentations to the Association of Cass County Lakes. Early activities also included updating the MPCA watershed page and planning with the MPCA staff for a generic water quality video on WRAPs that could be tailored to specific watersheds.

During Phase II, CE activities focused on implementation of the CE strategic plan for communications and stakeholder engagement. Specific activities included: launching an eight-part "Healthy Waters" press series published in six local newspapers to help citizens understand the impact of good water quality on their lives; three citizen leaders participated in a Citizen Leadership Training sponsored by the University of Minnesota Extension; presentations to various community groups including a Grazing Workshop for agricultural producers; a Land use Training workshop for elected officials; a public meeting to present the WRAPS monitoring and modeling results; a presentation to the Rotary Club of Walker; and additional articles in organizational newsletters. The Intensive Water Monitoring Summary was sent to all WRAPS partners. The four-step process for the Values-Driven Zonation model was started with stakeholder participation throughout the process.

During Phase III, the final stage of the WRAPS project, the Zonation Model was completed and was used by stakeholders and a technical team to identify priority areas in the watershed for water quality protection, which in turn helped to inform the identification of specific protection strategies as detailed in Section 3.4. Three stakeholder meetings were held throughout the watershed in August and September of 2015 to present the zonation model results to stakeholders and receive their input on protection strategies. A Technical Team of professionals used stakeholder input and the tools detailed further in this section to identify specific strategies within the LLR for water quality restoration and protection actions. A draft of the WRAPS plan will be disseminated to the public and stakeholders who participated in the project for their final review and comment.

Even before finalization of the WRAPS plan, the strategies for water quality protection were incorporated in to the Hubbard and Cass County water plans, which were being revised. Inclusion in these water plans will help insure a funding opportunity (i.e. Clean Water Funds) for implementation of the identified strategies. The city of Walker is supportive of implementing the stormwater mitigation strategies identified in the plan. Other entities, such as the LLAWF, the MHB, Chippewa National Forest, the Leech Lake Band of Ojibwe, TNC, Association of Cass County Lakes and other key WRAPS partners are fully committed to implementing the strategies in the WRAPS plan as funding is available. Civic engagement in the WRAPS is just the beginning of "keeping the waters of the LLR Watershed clean". The value of the WRAPS plan will be determined by the degree of collective implementation of protection strategies that are accomplished by the next ten-year monitoring cycle. Civic engagement at all levels—public, key stakeholders, local, state, and federal governments, and nonprofits—will be the key to maintaining and/or improving the excellent quality of waters in the LLR Watershed.

3.2 Targeting of Geographic Areas for Water Quality Protection

A Technical Team of professionals assembled to identify, participate in, and review outcomes of the modeling, tools, and other prioritization processes that were used to establish priority water quality protection strategies in Section 3.4 and identify target waterbodies and geographic areas for water quality protection in the LLR Watershed. The Team consisted of representatives from the LLAWF, TNC, Hubbard and Cass County SWCDs, MPCA, DNR, Leech Lake Band of Ojibwe, U.S. Forest Service/Chippewa National Forest, the MHB, and Emmons & Oliver Resources (EOR). Other local, state, and federal government representatives, lakeshore property owners, lake associations, key nonprofit organizations, municipal and townships officials, and citizens of the watershed participated at various opportunities to prioritize actions detailed in the following sections.

Figure 12: Leech Lake River WRAPS Technical Team, photo courtesy of DNR

Front Row (Left to Right): Phil Votruba, MPCA; Julie Kingsley, Hubbard SWCD; Paula West, LLAWF; Heather Baird, DNR Fisheries; Tim Terrill, MHB.

Back Row (left to right): Sam Malloy, Leech Lake Band of Ojibwe; Kelly Condiff, Cass County SWCD; Doug Kingsley, DNR Fisheries; Todd Holman, TNC; Doug Schultz, DNR Fisheries; Lindsey Ketchel, LLAWF;

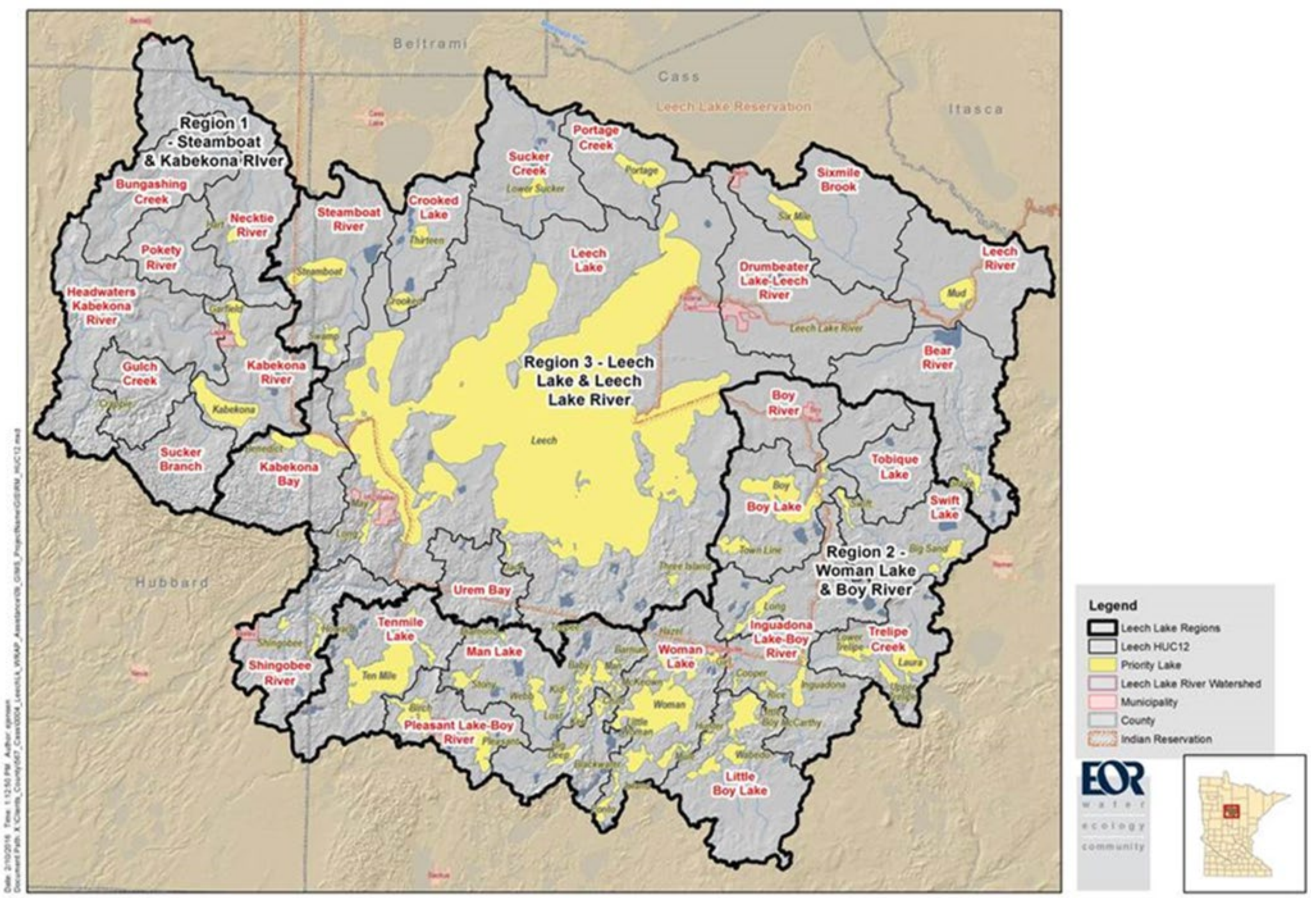
Darrin Hoversen, DNR Hydrologist.

Not pictured: Dave Morley, Chippewa National Forest: Megan Funke and Pat Conrad, Emmons & Oliver Resources.

The LLR Watershed is one of Minnesota's 80 major watersheds with a designated 8-digit hydrologic unit code (HUC). The watershed can be broken down further into 33 smaller minor watersheds designated as HUC12s. Within the land area of a HUC12, multiple lakes and/or streams can be identified. Further, each lake within a minor watershed will have its own land drainage area, or lake shed, that will impact the water flow and nutrient impacts to that specific lake.

The Team divided the LLR Watershed in to three distinct subregions, strategically selected based on primary water flow, each of which includes multiple HUC 12s. See Figure 13: Leech Lake River Watershed HUC12 watersheds and three subregional boundaries.. The subregions included: 1) the Boy River Headwaters and Chain of Lakes; 2) Leech Lake and its adjacent minor watersheds; and 3) the Hubbard County portion of the LLR Watershed. To identify and prioritize water quality protection strategies for each subregion, meetings were held where agencies, organizations, lake associations, municipal and township officials, and citizens interested in the protection of water resources in that geographic area could review and comment on the outcomes of the various tools detailed in Section 3.3, and provide anecdotal information and concerns to help prioritize strategies for each subregion. Their engagement in the subregional meetings was critical to building trust and relationships that will translate into a willing engagement in implementation of key protection strategies. See Appendix 3 for a list of subregion HUC12s and land ownership map of each subregion.

Figure 13: Leech Lake River Watershed HUC12 watersheds and three subregional boundaries.



3.3 Tools Used to Identify Priority Geographic Areas and Protection Strategies for the Leech Lake River Watershed

There are 360 miles of perennial streams and 400 lakes or bays larger than 10 acres in the LLR Watershed. It is recognized that given the existing high quality of the waters in the LLR Watershed, protection of all surface and groundwater is vital. However, the reality is that funding will be limited and priorities for protection need to be established to make the most cost-effective use of available implementation funding. A comprehensive review of the prioritization tools by the Team and other participants at the subregional meetings described above resulted in the detailed list of strategies in Section 3.4 for the protection of lakes and streams in the LLR Watershed.

Because the LLR Watershed project is one of the first protection-oriented WRAPS in Minnesota, the project team chose to use multiple prioritization models to evaluate which ones fit best with local water resources, as well as which tools were deemed to be most valuable by watershed partners and stakeholders. A secondary benefit to using multiple approaches is that a lake or stream that scores as a high protection priority using different tools is typically an indication that multiple benefits may be gained by investing in protection measures in these lakesheds or subwatersheds. Since this approach is new in Minnesota, it is hoped that it can serve as a pilot to inform other watershed projects where surface water protection is a high priority.

A variety of tools were used, reviewed, and compared to identify:

- priority stream segments and protection strategies;
- priority lakes and their sources of phosphorus loading, phosphorus sensitivity and potential phosphorus management strategies;
- lakes at risk to water quality degradation;
- natural resource attributes and hydrologic features and functions in the watershed; and
- geographic areas of high conservation potential.

3.3.1 Identifying Priority Streams

Identification of priority streams in the LLR Watershed was based on: 1) prior designations by the DNR and the MPCA for high quality recreational and ecological value; and 2) declining/impaired water quality as determined through the IWM and watershed assessment process. The following streams/rivers in the LLR Watershed are considered a priority for protection of water quality.

- **The headwaters of the Necktie River** in northern Hubbard/southern Beltrami County are designated trout stream waters. The headwaters of the Necktie River support a Brook Trout population sustained entirely by natural reproduction. This trout population is a unique resource in this area of the state. The connection to the underlying groundwater aquifer provides clean and cold water that allows the Necktie River to support Brook Trout. The DNR Fisheries has purchased easements along the river to protect the immediate riparian areas and provide access for fishing. In addition, there has been habitat improvement work along with regular beaver control to protect and enhance the habitat for trout.
- **Bungashing Creek** in northern Hubbard County has been designated by the MPCA as "exceptional use water," which is defined as high quality water with fish and invertebrate (e.g. crayfish, insects, mussels) communities at or near undisturbed conditions. These conditions mirror what might be expected under pre-settlement conditions. Bungashing Creek contains Brook Trout populations that are sustained entirely by natural reproduction and contains high quality trout habitat. New state water quality standards currently being revised will incorporate a tiered aquatic life use (TALU) framework for rivers and streams that builds upon existing water quality standards to improve how water resources are monitored and managed. The TALU

framework will protect exceptional use waters to maintain the current healthy condition of fish and invertebrate communities. For more information on TALU, see: https://www.pca.state.mn.us/sites/default/files/wq-s6-33.pdf

- **Kabekona River** in northern Hubbard County is a designated trout stream. The Kabekona River above Kabekona Lake supports a Brook Trout population that is sustained entirely by natural reproduction, and it routinely produces trophy fish. Like the other streams noted in this section, the trout population provides a unique resource in this area of the state. The connection to the underlying groundwater aquifer provides clean and cold water that allows the Kabekona River to support Brook Trout. The DNR Fisheries has purchased easements along the river to provide access for fishing and to protect immediate riparian areas. There has been habitat improvement work along with regular beaver control to protect and enhance the habitat for trout. Efforts to improve road crossing structures has also been important in protecting the trout stream; to date three road crossing have been replaced with properly sized and placed crossings. Water quality monitoring data gathered on this stream in 2010 to 2011 through the Cass County Citizens Lake and Stream Monitoring Project suggested that this stream has an aquatic recreation impairment for Escherichia coli (*E. coli*) bacteria. Since this data was collected, some restoration practices have been implemented within this subwatershed. The MPCA is working with the Hubbard SWCD to develop a monitoring plan to collect additional water quality data to reevaluate the status of this section of the river and is discussing additional BMPs with landowners. No TMDL is planned for this stream during this IWM/WRAPS cycle.
- **Upper reaches of the Necktie River**, just north of Hart Lake in Northern Hubbard County. This section of river was originally 8.5 miles long. Channelization efforts in the early 1900s abandoned the natural stream channel and dug five miles of a straight, channelized stream. In addition to this loss of stream length, the slope was increased which increases the water's velocity. All this has likely increased erosion rates and downstream sedimentation. Before channelization, the normal predictable pattern of riffles, runs and pools with varying widths and depths provided habitat areas for many species and their different life stages. With channelization, all these differing habitats and variability are lost and replaced with a uniform width and depth channel. This has created an unstable stream and limited habitat for the animals that inhabit the stream. The stream now uses parts of the original cutoff meanders, the new straightened channel, or both in different locations and water levels.

3.3.2 Identifying Priority Lakes and Management Approaches

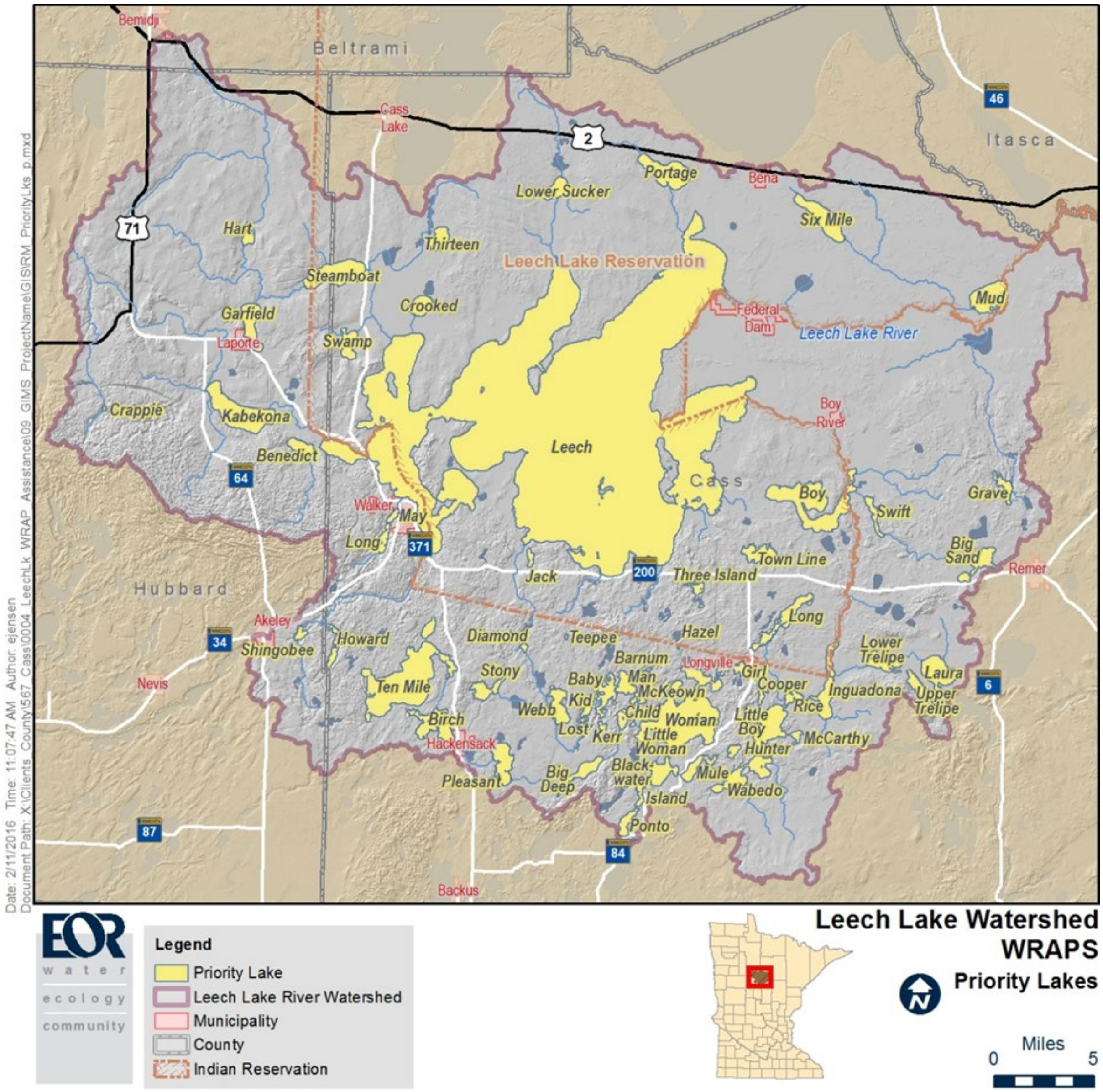
The objective of the tools detailed in this section was to prioritize the watershed's 700+ lakes into a smaller subset of lakes that will be the priority focus of protection efforts over the next 10 years. In addition, phosphorus management strategies and feasible phosphorus load reduction goals were identified for each priority lake to guide the selection of protection strategies in Section 3.4 of this WRAPS report.

Lake Prioritization Criteria:

61 priority lakes (out of over 750 lakes in the watershed) were chosen for protection (Figure 14) based on the criteria of having one or more of the following attributes:

- One of the top 25 largest lakes in the LLR Watershed by surface area;
- Water quality data and/or lakeshed evaluations and protection assessments where available;
- DNR designated tullibee (cisco) refuge lakes, trout lakes, and critical wild rice lakes;
- Lakes among the DNR's priority fisheries management focus;
- MPCA/DNR lakes of highest sensitivity to additional phosphorus loading (Phosphorus Sensitivity Significance);
- Lakes included in the Cass County Large Lakes Assessment;
- DNR Shoreline Sensitivity Assessments completed;
- Lakes of critical importance to the US Forest Service or Leech Lake Band of Objibwe;
- Lakes included in Hydrologic Simulation Program Fortran (HSPF) modeling;
- Lakes with an active lake association; and
- Lakes of biological significance.

Figure 14: Priority lakes in the Leech Lake River Watershed



This map illustrates all priority lakes chosen based on the following criteria:
- One of 25 largest lakes in the Leech Lake River Watershed
- DNR designated Tullibee (cisco) or Trout lake
- Lakes included in the Cass County Large Lakes Assessment
- Lakes with an active lake association
- Lakes with a DNR Fisheries protection focus
- MPCA/DNR Lakes of Phosphorus Sensitivity Significance (Highest Ranking)
- DNR Lakes of Biological Significance Impaired Lakes

Descriptions, data sources, and categories of lake characteristics used to prioritize the lakes in the LLR Watershed are summarized in the table in Appendix 4: Table 10 and Table 11 and the accompanying Figure 15 through Figure 19 summarize the priority lake's physical characteristics and protection planning considerations including: biological attributes (Figure 15), trophic state (Figure 16), long-term water quality trends (Figure 17), phosphorus load management strategies (Figure 18), and lakes of biological significance (Figure 19).

Table 10: Characteristics of the 61 Priority Lakes in the Leech Lake River Watershed

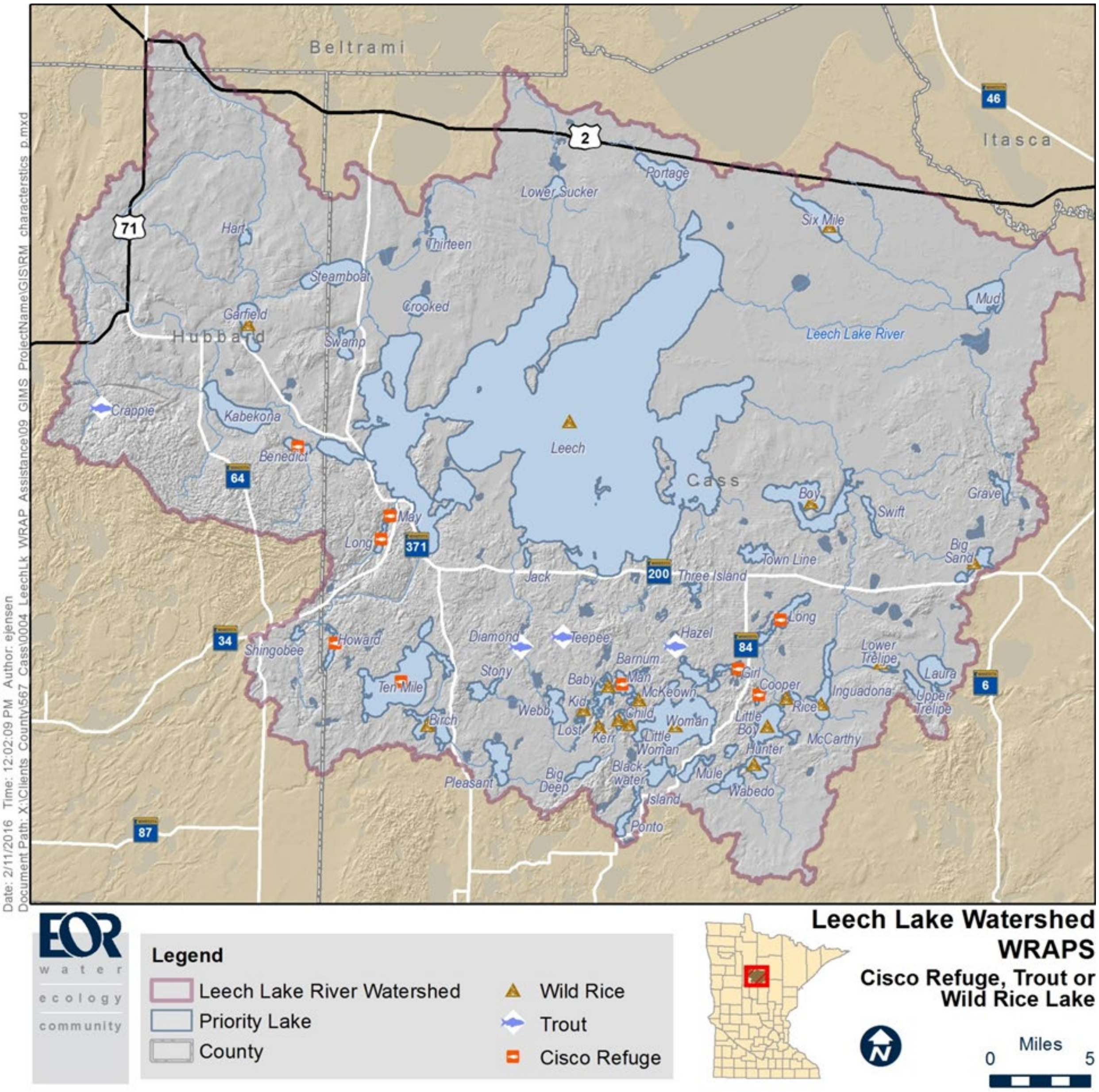
LAKE	DNR ID	COUNTY	SURFACE AREA (acres)	% of Depths < 15 feet	TULLIBEE	TROUT	WILD RICE	LCH. LK. RESERV.	RIPARIAN FOCUS	In HSPF	TROPHIC STATUS	WATER CLARITY (ft)	WATER CLARITY Trend
Baby	11028300	Cass	729	55			●			●	M	14	↑
Barnum	11028100	Cass	147	63							O	17	→
Benedict	29004800	Hubbard	471	42	●						O	11	→
Big Deep	11027700	Cass	530	25						●	O	21	→
Big Sand	11007700	Cass	730	86			●			●	M	10	--
Birch	11041200	Cass	1,256	62			●			●	M	14	↑
Blackwater	11027400	Cass	758	62						●	M	14	↑
Boy	11014300	Cass	3,647	62			●	●	●	●	E	8	--
Child	11026300	Cass	283	50			●				M	12	→
Cooper	11016300	Cass	133	--	●						M	13	↑
Crappie	29012700	Hubbard	23	26		●					--	--	--
Crooked	11049400	Cass	551	41							M	9	--
Diamond	11039600	Cass	77	75		●					--	--	--
Garfield	29006100	Hubbard	954	61			●			●	M	11	→
Girl	11017400	Cass	414	72	●						M	14	→
Grave	11008600	Cass	369	--							O	17	→
Hart	29006300	Hubbard	208	100							E	4	--
Hazel	11029500	Cass	15	63		●		●			--	--	--
Howard	11047200	Cass	372	--	●						O	15	--
Hunter	11017000	Cass	176	--							O	29	↑
Inguadona (N Bay)	11012001	Cass	354	52			●	●	●	●	M	9	↓
Inguadona (S Bay)	11012002	Cass	764	51			●	●		●	M	11	→
Island	11025700	Cass	183	--							M	20	→
Jack	11040000	Cass	141	--				●			O	16	--
Kabekona	29007500	Hubbard	2,435	27	●		●			●	O	13	↑
Kerr	11026800	Cass	80	--			●				M	17	→
Kid	11026200	Cass	166	--			●				M	13	→
Laura	11010400	Cass	1,248	--				●			M	4	--
Leech (Main Basin)	11020301	Cass	101,995	50			●	●	●	●	M	9	→
Leech (Shingobee Bay)	11020304	Cass	319	--			●	●	●	●	M	12	↑
Leech (Kabekona Bay)	11020302	Cass	970	40			●	●	●	●	M	13	--
Little Boy	11016700	Cass	1,423	45			●			●	M	11	→
Little Woman	11026500	Cass	36	99			●				--	--	--
Long SW Bay	11014204	Cass	273	--	●						M	19	→
Long Main Basin	11014202	Cass	643	--	●						M	19	↓
Long	11048000	Cass	273	57	●					●	M	13	--
Lost	11026900	Cass	71	--							M	14	--
Lower Sucker	11031300	Cass	571	48							E	8	--
Lower Trelipe	11012900	Cass	608	59			●			●	M	7	→
Man	11028200	Cass	488	28	●					●	O	11	↓
May	11048200	Cass	135	60	●						O	19	--
McCarthy	11016800	Cass	148	--							E	4	--
McKeown	11026100	Cass	164	--			●				M	16	→
Mud	11010000	Cass	1,420	--					●		--	--	--
Mule	11020000	Cass	518	44						●	M	16	→
Pleasant	11038300	Cass	1,085	55						●	M	16	↑
Ponto	11023400	Cass	379	51							O	19	↓
Portage	11020400	Cass	1,528	43				●		●	E	7	--
Portage	11047600	Cass	279	42	●		●				O	25	--
Rice	11016200	Cass	223	--			●				M	10	--
Shingobee	29004300	Hubbard	168	--							M	12	↓
Six Mile	11014600	Cass	1,297	47			●	●		●	M	9	--
Steamboat	11050400	Cass	1,761	33				●		●	M	13	→
Stony	11037100	Cass	562	41						●	O	20	↓
Swamp	11048300	Cass	600	--				●			--	--	--
Swift	11013300	Cass	351	--							M	8	--
Teepee	11031200	Cass	21	--		●					--	--	--
Ten Mile	11041300	Cass	5,025	36	●					●	M	19	↑
Thirteen	11048800	Cass	554	70							M	13	--
Three Island	11017700	Cass	287	--				●			M	12	--
Townline	11019000	Cass	666	--				●			M	7	--
Upper Trelipe	11010500	Cass	415	--							O	15	↑
Wabedo (NE Bay)	11017101	Cass	577	47			●			●	M	10	→
Wabedo (SW Bay)	11017102	Cass	622	36			●			●	M	9	↓
Webb	11031100	Cass	718	57						●	M	15	→
Woman (Broadwater Bay)	11020101	Cass	768	69			●			●	M	13	--
Woman (Main Basin)	11020102	Cass	4,754	55			●			●	M	14	↑

Table 11: Additional Characteristics of the 61 Priority Lakes in the Leech Lake River Watershed

LAKE	DNR ID	COUNTY	SURFACE AREA (acres)	% of Depths < 15 feet	Lakeshed Assess.	Sensitive Shore Study	P Mgmt Category	5% Watershed TP Reduction (lb/yr)	Fisheries Focus	Phosphorus Sensitivity	Biological Significance
Baby	*11028300*	Cass	729	55	●	●	Mixed	--	Protection	Higher	Outstanding
Barnum	*11028100*	Cass	147	63		●	Watershed	--	Protection	Highest	--
Benedict	*29004800*	Hubbard	471	42			Watershed	35	Vigilance	High	Outstanding
Big Deep	*11027700*	Cass	530	25	●	●	Upstream	--	Protection	--	--
Big Sand	*11007700*	Cass	730	86	●	●	In-Lake	--	Protection	Highest	--
Birch	*11041200*	Cass	1,256	62	●	●	Mixed	113	Protection	High	High
Blackwater	*11027400*	Cass	758	62	●	●	Mixed	--	Protection	Higher	Outstanding
Boy	*11014300*	Cass	3,647	62	●	●	Upstream	--	Protection	High	Outstanding
Child	*11026300*	Cass	283	50		●	Upstream	--	Protection	High	Outstanding
Cooper	*11016300*	Cass	133	--		●	Watershed	5	Protection	Higher	Moderate
Crappie	*29012700*	Hubbard	23	26			Monitor	--	--	--	--
Crooked	*11049400*	Cass	551	41	●		Watershed	--	Vigilance	High	--
Diamond	*11039600*	Cass	77	75			Monitor	--	--	--	--
Garfield	*29006100*	Hubbard	954	61		●	Watershed	24	Protection	Highest	Outstanding
Girl	*11017400*	Cass	414	72		●	Upstream	--	Protection	High	Outstanding
Grave	*11008600*	Cass	369	--	●		Watershed	--	Protection	Higher	--
Hart	*29006300*	Hubbard	208	100			Watershed	--	Protection	--	Outstanding
Hazel	*11029500*	Cass	15	63			Monitor	--	--	--	--
Howard	*11047200*	Cass	372	--			Watershed	9	Protection	Highest	High
Hunter	*11017000*	Cass	176	--			Watershed	--	Protection	Highest	--
Inguadona (N Bay)	*11012001*	Cass	354	52	●	●	Upstream	--	Protection	High	Outstanding
Inguadona (S Bay)	*11012002*	Cass	764	51	●	●	Upstream	--	Protection	High	Outstanding
Island	*11025700*	Cass	183	--		●	Mixed	--	Protection	Highest	--
Jack	*11040000*	Cass	141	--			Watershed	--	Protection	Highest	Moderate
Kabekona	*29007500*	Hubbard	2,435	27	●	●	Watershed	232	Protection	Higher	Outstanding
Kerr	*11026800*	Cass	80	--		●	Watershed	57	--	High	--
Kid	*11026200*	Cass	166	--			Mixed	44	Protection	High	Outstanding
Laura	*11010400*	Cass	1,248	--	●	●	In-Lake	--	Vigilance	High	Outstanding
Leech (Main Basin)	*11020301*	Cass	101,995	50	●	●	Upstream	--	Vigilance	Highest	Outstanding
Leech (Shingobee Bay)	*11020304*	Cass	319	--	●	●	Upstream	--	Vigilance	Highest	Outstanding
Leech (Kabekona Bay)	*11020302*	Cass	970	40	●	●	Upstream	--	Vigilance	Highest	Outstanding
Little Boy	*11016700*	Cass	1,423	45	●	●	Watershed	147	Protection	High	Outstanding
Little Woman	*11026500*	Cass	36	99			Upstream	--	--	--	High
Long SW Bay	*11014204*	Cass	273	--	●	●	Watershed	--	Protection	Highest	Outstanding
Long Main Basin	*11014202*	Cass	643	--	●	●	Watershed	36	Protection	Highest	Outstanding
Long	*11048000*	Cass	273	57			Watershed	16	Protection	Higher	Outstanding
Lost	*11026900*	Cass	71	--		●	Upstream	--	--	High	--
Lower Sucker	*11031300*	Cass	571	48	●		Upstream	--	Vigilance	High	--
Lower Trelipe	*11012900*	Cass	608	59	●	●	Mixed	--	Vigilance	High	--
Man	*11028200*	Cass	488	28	●	●	Mixed	--	Vigilance	Higher	Outstanding
May	*11048200*	Cass	135	60			Watershed	12	Protection	Higher	Outstanding
McCarthy	*11016800*	Cass	148	--			Watershed	--	Protection	--	Outstanding
McKeown	*11026100*	Cass	164	--			Upstream	--	Protection	High	Outstanding
Mud	*11010000*	Cass	1,420	--	●		Upstream	--	Vigilance	--	Outstanding
Mule	*11020000*	Cass	518	44	●	●	Watershed	--	Protection	Highest	--
Pleasant	*11038300*	Cass	1,085	55	●	●	Watershed	171	Protection	High	Outstanding
Ponto	*11023400*	Cass	379	51	●	●	Watershed	--	Protection	Highest	--
Portage	*11020400*	Cass	1,528	43	●	●	Watershed	83	Vigilance	Higher	--
Portage	*11047600*	Cass	279	42		●	Watershed	7	Vigilance	Highest	Outstanding
Rice	*11016200*	Cass	223	--		●	Upstream	--	Protection	High	Outstanding
Shingobee	*29004300*	Hubbard	168	--			Watershed	--	Protection	Higher	High
Six Mile	*11014600*	Cass	1,297	47	●	●	Watershed	52	Vigilance	Higher	Outstanding
Steamboat	*11050400*	Cass	1,761	33	●	●	Watershed	355	Protection	Higher	Outstanding
Stony	*11037100*	Cass	562	41	●	●	Watershed	--	Protection	Highest	--
Swamp	*11048300*	Cass	600	--		●	Monitor	--	Protection	--	Moderate
Swift	*11013300*	Cass	351	--			Mixed	--	Protection	High	Outstanding
Teepee	*11031200*	Cass	21	--			Monitor	--	--	--	--
Ten Mile	*11041300*	Cass	5,025	36	●	●	Watershed	186	Protection	Higher	Outstanding
Thirteen	*11048800*	Cass	554	70	●	●	Watershed	--	Vigilance	High	--
Three Island	*11017700*	Cass	287	--			Watershed	--	Protection	Highest	High
Townline	*11019000*	Cass	666	--	●	●	In-Lake	--	Protection	Higher	High
Upper Trelipe	*11010500*	Cass	415	--	●	●	Watershed	--	Protection	Highest	Outstanding
Wabedo (NE Bay)	*11017101*	Cass	577	47	●	●	Watershed	122	Protection	Highest	Outstanding
Wabedo (SW Bay)	*11017102*	Cass	622	36	●	●	Watershed	122	Protection	Highest	Outstanding
Webb	*11031100*	Cass	718	57	●	●	Mixed	--	Protection	Higher	--
Woman (Broadwater Bay)	*11020101*	Cass	768	69	●	●	Upstream	--	Protection	Higher	Outstanding
Woman (Main Basin)	*11020102*	Cass	4,754	55	●	●	Upstream	--	Protection	Higher	Outstanding

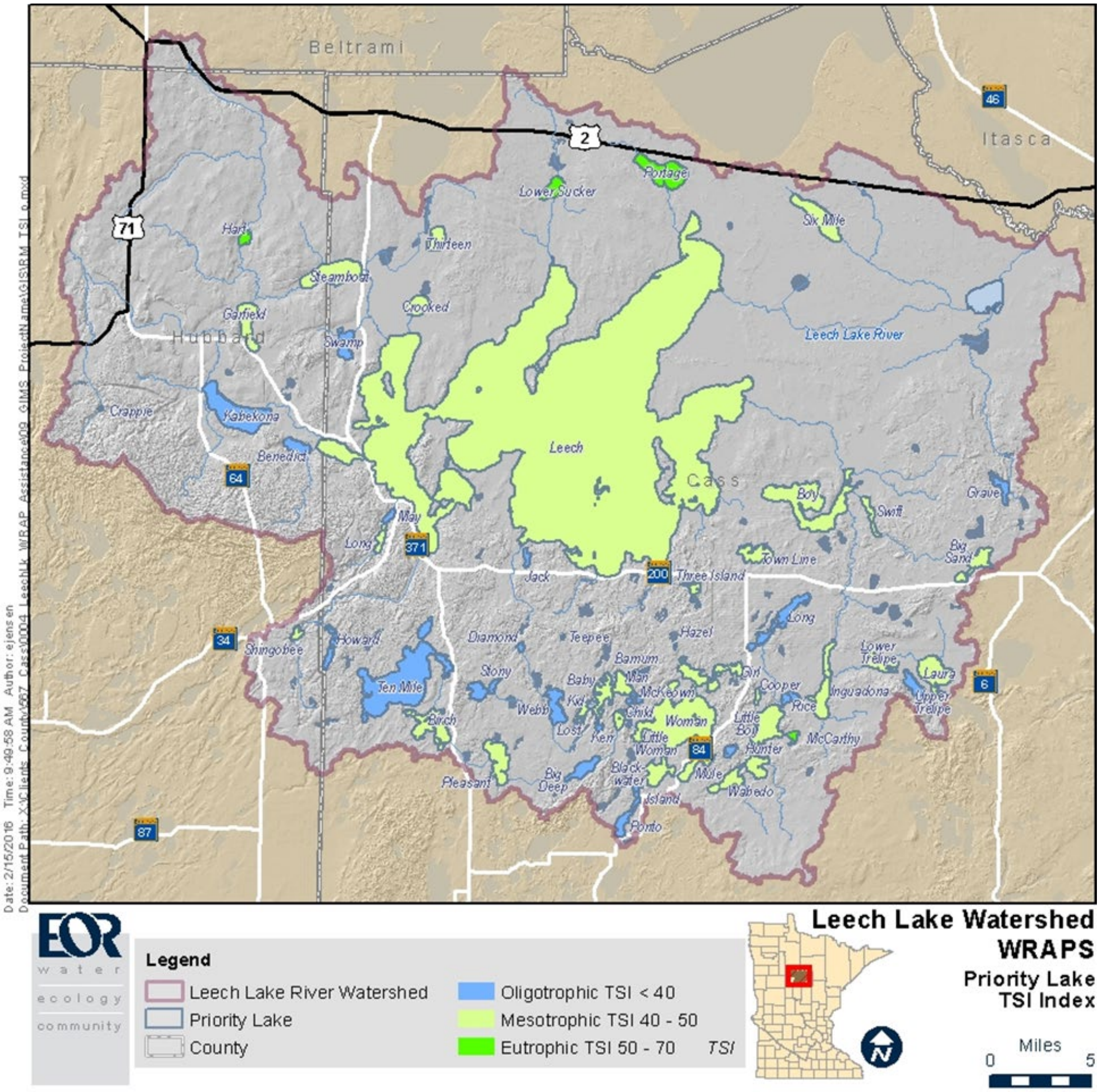
Note: -- denotes that insufficient data was available to determine

Figure 15: Leech Lake River Watershed DNR designated cisco (Tullibee) refuge, trout, and/or wild rice priority lakes



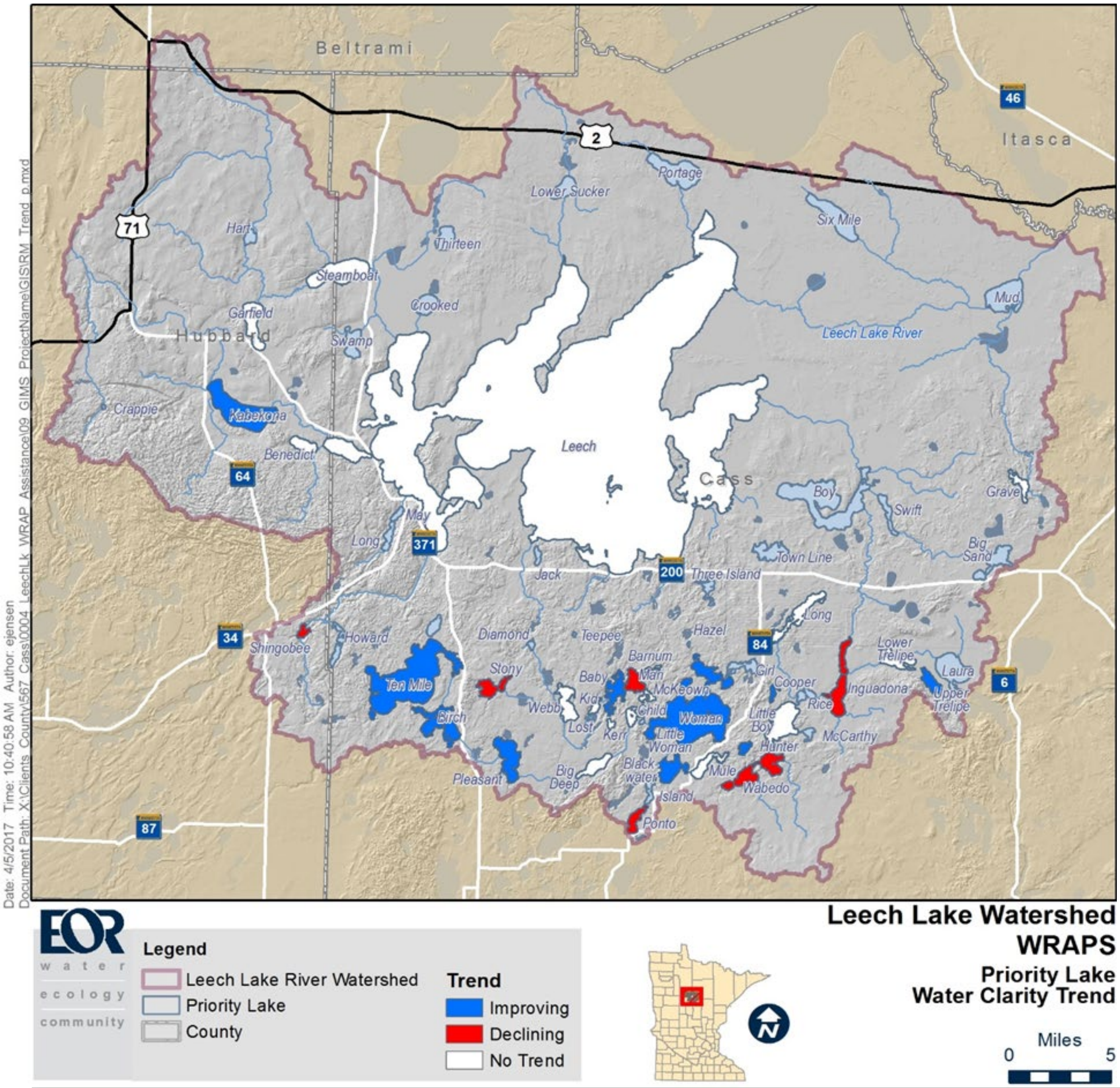
This map illustrates lakes within the Leech Lake River Watershed identified by the Minnesota DNR as Cisco Refuge Lakes under projected warmer climate scenarios. Cisco (Tullibee) is a cold water fish species that needs clean, cold and well-oxygenated water to survive. The wide distribution of ciscoes in Minnesota makes ciscoes a great indicator species to understand the potential effects of increased nutrient loading and/or climate change on Minnesota lakes.

Figure 16: Leech Lake River Watershed priority lake average trophic state



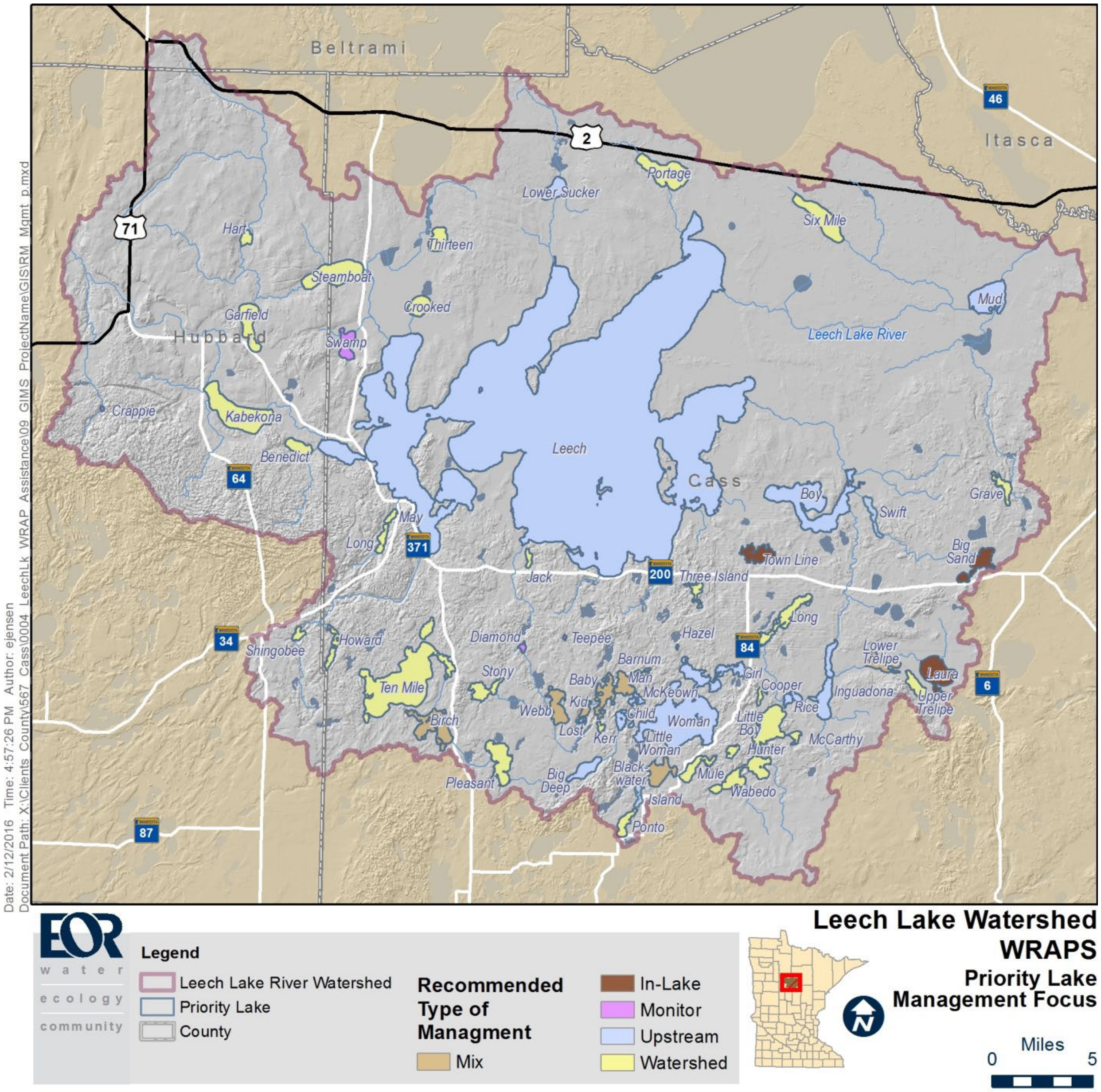
This map illustrates the Trophic State Index (TSI) for each of the priority lakes within the Leech Lake River Watershed. Carlson's trophic index scores can be used to compare lake productivity based on the relationship between in-lake total phosphorus concentrations, chlorophyll-a concentrations, and Secchi disk readings (water clarity).

Figure 17: Leech Lake River Watershed priority lake long-term trends in water clarity (MPCA Citizen Lake Monitoring Program)



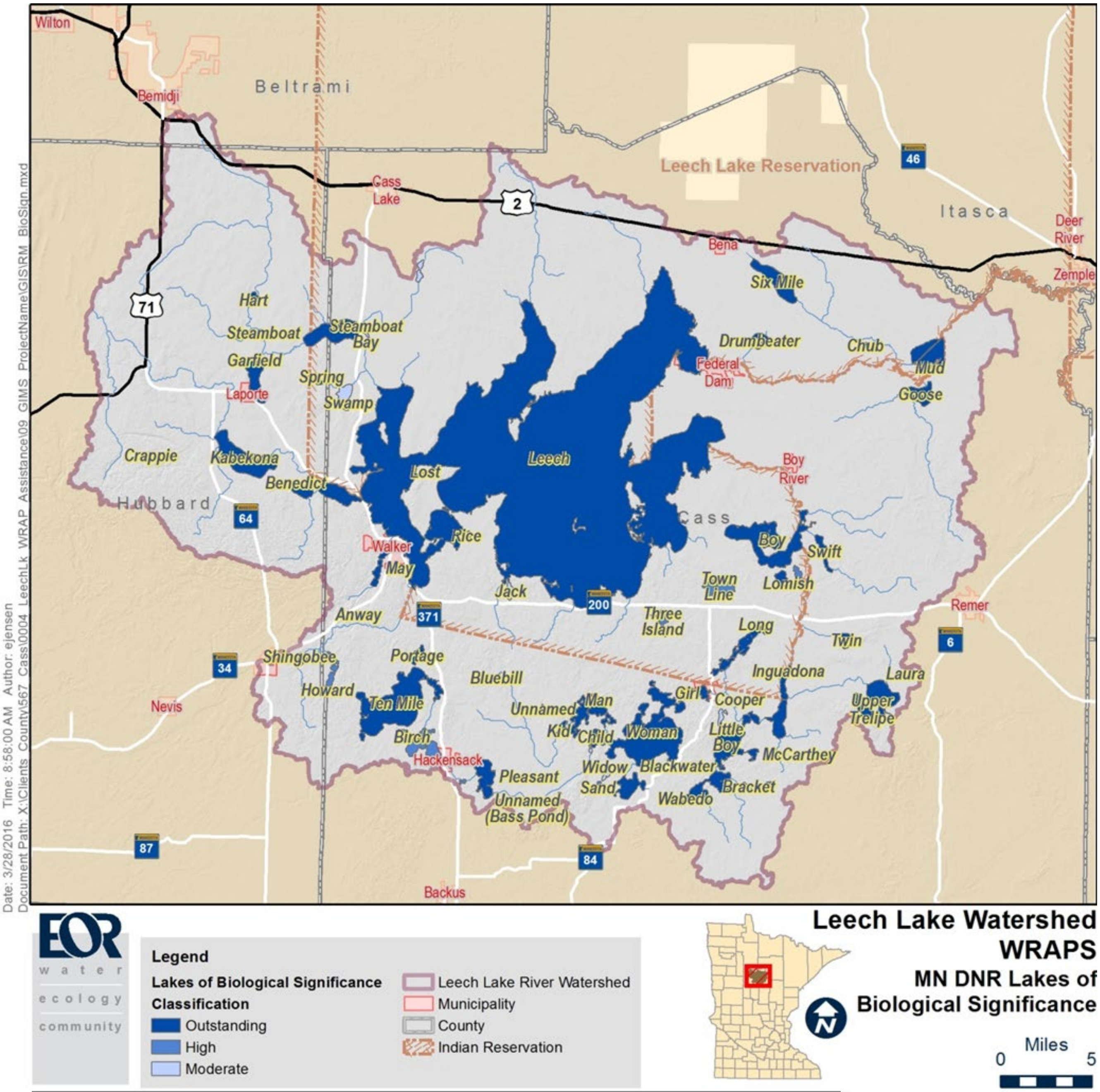
This map illustrates trends in water clarity for each of the priority lakes within the Leech Lake River Watershed based on data collected through the MPCA's citizen lake monitoring program (CLMP).

Figure 18: Leech Lake River Watershed priority lakes phosphorus load management categories



This map illustrates recommended management strategies for each of the priority lakes within the Leech Lake River Watershed based on lake and watershed characteristics.

Figure 19: Leech Lake River Watershed priority lakes of biological significance



This map illustrates lakes that were identified as biologically significant because of the presence of unique aquatic plants, fish, birds and amphibians. Outstanding lakes have all three of the following characteristics: High aquatic plant richness, high floristic quality, and a population of an endangered or threatened plant species. High lakes have 2 of those 3 characteristics, and Moderate lakes have 1 of those 3 characteristics.

Phosphorus Management Categories & Approaches

Based on lake characteristics and known source of phosphorus loading, the 61 priority lakes were further categorized (as illustrated in Figure 18 and described in Table 12) by one of the following phosphorus management strategies to guide later selection of protection strategies determined in Section 3.4:

- **Monitor:** Existing in-lake water quality is unknown or incomplete and a monitoring plan should be developed
- **In-Lake Load Management:** In-lake water quality is expected to be most strongly influenced by in-lake aquatic plant and fish population dynamics and in-lake sediment phosphorus release (internal loading)
- **Upstream Load Management:** In-lake water quality is expected to be most strongly influenced by upstream lake phosphorus loads
- **Mixed Load Management:** In-lake water quality is expected to be equally influenced by watershed phosphorus loads and upstream lake phosphorus loads
- **Watershed Load Management:** In-lake water quality is expected to be most strongly influenced by watershed phosphorus loads

In addition, Geographic Information System (GIS) technology was used to create digital maps identifying watershed flow accumulation lines and basins were created in GIS using digital elevation models for the entire LLR Watershed. They can be provided to local agencies and partners as requested to help specifically target locations through the watershed for BMPs.

Table 12: Phosphorus load management strategy for priority lakes

Phosphorus Load Management Category	Priority Lakes		Rationale	Lake Characteristics	Protection Strategies
Monitor (5 lakes)	Crappie (29-0127-00) Diamond (11-0396-00) Hazel (11-0295-00)	Swamp (11-0483-00) Teepee (11-0312-00)	Existing in-lake water quality is unknown and a monitoring plan should be developed	No TP data	Water quality monitoring
In-Lake (4 lakes)	Big Sand (11-0077-00) Laura (11-0104-00)	Town Line (11-0190-00) Three Island (11-0177-00)	In-lake water quality is expected to be most strongly influenced by in-lake aquatic plant and fish population dynamics, and/or sediment phosphorus release (internal loading)	watershed to surface area ratio < 10 AND > 80% littoral area OR maximum depth < 20 feet	In-lake aquatic plant and fish management
Upstream (13 lakes)	Big Deep (11-0277-00) Boy (11-0143-00) Child (11-0263-00) Girl (11-0174-00) Inguadona (11-0120-00) Leech (11-0203-00) Little Woman (11-0265-00)	Lost (11-0269-00) Lower Sucker (11-0313-00) McKeown (11-0261-00) Mud (11-0100-00) Rice (11-0162-00) Woman (11-0201-00)	In-lake water quality is expected to be most strongly influenced by upstream lake phosphorus loads	> 10 upstream lakes AND/OR > 1 directly upstream lake Greater upstream lake TP concentration	Protecting upstream lake water quality
Mixed (9 lakes)	Baby (11-0283-00) Birch (11-0412-00) Blackwater (11-0274-00) Island (11-0257-00)	Kid (11-0262-00) Lower Trelipe (11-0129-00) Man (11-0282-00) Swift (11-0133-00) Webb (11-0311-00)	In-lake water quality is expected to be equally influenced by watershed phosphorus loads and upstream lake phosphorus loads	< 10 total upstream lakes AND/OR Greater upstream lake TP concentration	Watershed BMPs and protecting upstream lake water quality
Watershed (30 lakes)	Barnum (11-0281-00) Benedict (29-0048-00) Cooper (11-0163-00) Crooked (11-0494-00) Garfield (29-0061-00) Grave (11-0086-00) Hart (29-0063-00) Howard (11-0472-00) Hunter (11-0170-00) Jack (11-0400-00) Kabekona (29-0075-00) Kerr (11-0268-00) Little Boy (11-0167-00) Long (11-0142-00) Long (11-0480-00)	May (11-0482-00) McCarthy (11-0168-00) Mule (11-0200-00) Pleasant (11-0383-00) Ponto (11-0234-00) Portage (11-0204-00) Portage (11-0476-00) Shingobee (29-0043-00) Six Mile (11-0146-00) Steamboat (11-0504-00) Stony (11-0371-00) Ten Mile (11-0413-00) Thirteen (11-0488-00) Upper Trelipe (11-0105-00) Wabedo (11-0171-00)	In-lake water quality is expected to be most strongly influenced by watershed phosphorus loads	All remaining lakes	Watershed BMPs

Phosphorus Load Reduction Goals

Excess phosphorus is a threat to many of Minnesota's lakes, and reducing or maintaining low phosphorus input to lakes will be critical to achieving the state's clean water goals and maintaining the high quality of lakes in the LLR Watershed.

Phosphorus pollution estimates and reduction goals by lake are needed to understand our water quality protection challenges. Reduction goals will help target and prioritize protection strategies and BMP implementation. These goals will also assist local agencies and partners in grant applications to fund implementation of lake protection strategies.

Researchers at the DNR, MPCA and BWSR developed a phosphorus pollution model that predicted annual phosphorus inputs to lakes and a sensitivity model that ranked priority lakes statewide based on their sensitivity to additional phosphorus inputs and the significance of those inputs. The goal was to identify lakes that were not resilient to additional phosphorus pollution. The most sensitive lakes (highest sensitivity) identified would most likely see substantial declines in water clarity with increasing nutrient phosphorus inputs. The sensitivity significance or the significance of water clarity changes due to eutrophication included lake size and other factors related to the importance of focusing immediate protection or restoration efforts.

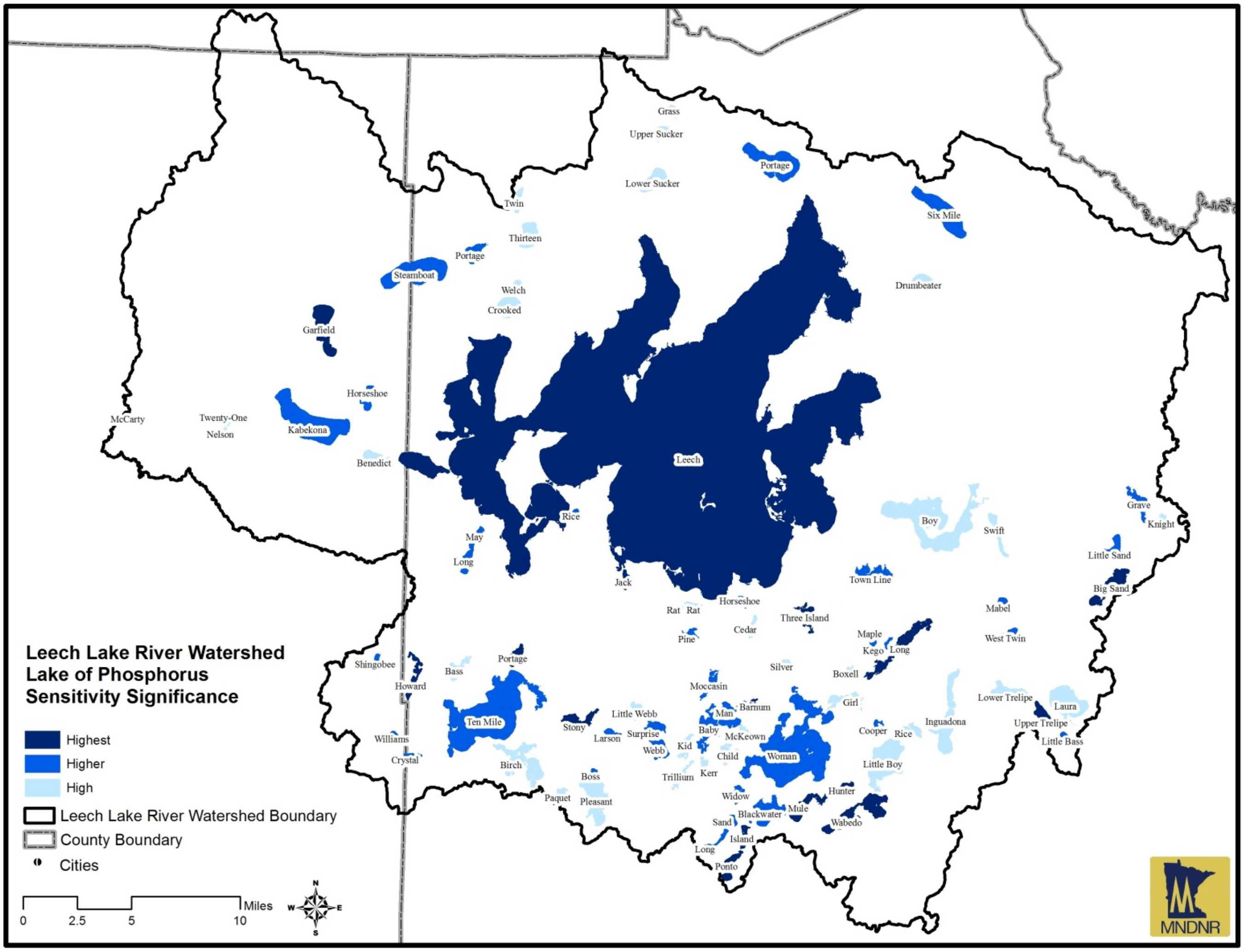
The sensitivity rankings included 2,194 lakes in Minnesota based on the latest phosphorus information. Of the lakes ranked statewide, 17 lakes in the LLR Watershed were among the top 500 lakes ranked highest for phosphorus sensitivity, including Ponto Lake, the number one lake for sensitivity to additional phosphorus loading. These lakes will be a priority focus for water quality protection efforts in the watershed due to their sensitivity to additional phosphorus loads (Figure 20).

The Team set a 5% phosphorus reduction goal for lakes of the LLR Watershed. This goal recognizes that high water quality already exists and some phosphorus pollution is occurring for lakes in the watershed. While a 5% reduction in phosphorus input for a lake appears minor, achieving this phosphorus reduction goal would produce positive lake water quality benefits. The primary goal in this watershed is to maintain the current water quality status and improve where possible. A 5% reduction goal is achievable for many of the priority lakes and provides an incentive for citizen engagement in achieving those goals.

In this high quality watershed, the primary strategy is protection by maintaining existing water quality conditions. However, in some isolated cases improvements to water quality conditions are desired and achievable. Strategies for protection include maintaining natural land cover in forests, encouraging cover crops in agricultural lands, and reducing runoff in urban areas. Vigilance to shield this watershed from improper development, loss of forest cover, and other human-induced land altering impacts, will protect water quality. The three priority lakes with declining, yet still above average, water quality will be monitored and aggressive restoration strategies implemented to reduce further declines.

The target TP reduction loads for the lakes in the LLR Watershed can be found in Appendix 5: Phosphorus Loading, Reduction, and Sensitivity. A fact sheet and more detailed methodology for the Phosphorus Sensitivity Significance model can be found here.

Figure 20: Phosphorus Sensitivity Significance ranking for lakes in the Leech Lake River Watershed



Additional Tools for Identifying Priority Areas for Water Quality Protection

The following additional tools were used by the Team along with the lake characteristics detailed in Section 3.3.2 to identify priority geographic areas for water quality protection efforts in the LLR Watershed and to inform water quality protection strategies detailed in Section 3.4.

A. HSPF Modeling

HSPF modeling was conducted by the consulting firm RESPEC to project how changes, such as those from increased development and climate changes, would impact water quality within the LLR Watershed. Because this watershed contains some of Minnesota's most pristine waters, the goal is to preserve the abundance of high quality water resources despite being faced with the same pressures that have degraded lakes and streams in other parts of the state, particularly increased population growth around lakes.

To better understand potential TP trends in lakes and streams within the LLR Watershed, stakeholders and professionals were asked to identify likely risk factors/development pressures in the watershed. The identified risk factors (increased build-out within city boundaries, increased shoreland development, loss of private forestlands, and intensification of agriculture) were modeled in a calibrated LLR HSPF model. Using five different scenarios, the HSPF model was used to complete a pollutant source assessment for the watershed and evaluate phosphorus loads to surface waters under multiple land use and climate change scenarios.

5% Watershed TP Reduction (lb/year)	The amount of phosphorus in lb/year to achieve a 5% reduction in watershed TP loads to the lake.	MPCA/DNR Lakes of Phosphorus Sensitivity Significance Analysis (see below)	None
Fisheries Focus	Suggested approaches for watershed protection and restoration of DNR managed fish lakes in Minnesota	Peter Jacobson and Michael Duval, DNR Fisheries Research Unit	**Vigilance:** Watershed disturbance < 25% and watershed protection > 75%. Sufficiently protected. Water quality supports healthy and diverse fish communities. Keep public lands protected. **Protection:** Watershed disturbance < 25% and watershed protection < 75%. Excellent candidates for protection. Water quality can be maintained in a range that supports healthy and diverse native fish communities. Disturbed lands should be limited to less than 25%.
Phosphorus Sensitivity	A ranked priority lake list based on sensitivity to additional phosphorus loading and the significance of that sensitivity.	MPCA/DNR Lakes of Phosphorus Sensitivity Significance website: https://gisdata.mn.gov/dataset/env-lakes-phosphorus-sensitivity	**Highest:** Lakes with priority scores greater than the 75th percentile. **Higher:** Lakes with priority scores from the 50 to 75th percentile. **High:** Lakes with priority scores from the 0 to 50th percentile.
Biological Significance	A list of high quality lakes based on dedicated biological sampling (unique plant or animal presence).	DNR Lakes of Biological Significance website: ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_dnr/env_lakes_of_biological_signific/metadata/lakes_of_biological_significance_criteria_20150423.pdf	**Outstanding:** High aquatic plant richness, high floristic quality, and a population of an endangered or threatened plant species. **High:** Two of the following: high aquatic plant richness, high floristic quality, or a population of an endangered or threatened plant species. **Moderate:** High aquatic plant richness, high floristic quality, or a population of an endangered or threatened plant species.

See Appendix 6: HSPF Report for the full report of phosphorus loading predictions due to land use changes modeled with and without BMPs, land use changes modeled with extra BMPs, climate change-induced precipitation changes, and a cumulative model of land use changes with BMPs and climate change.

In summary, the modeling indicated that without BMPs to mitigate the modeled land use changes projected from population growth and climate change, degradation to water quality would occur in 8% of the minor watersheds in the LLR Watershed. With implementation of BMPs to reduce runoff and hence pollutant loads, no minor watersheds would see changes in their risk classifications from the scenarios modeled. The results of the scenario modeling were predicated on restricting land use changes to "eligible land," which excludes land at low risk of conversion, such as public land and conservation easements. Much of the land in the LLR Watershed is at low risk of conversion (52% of the land is in public ownership). However, in the event that there are land sales, land ownership changes, or easement restrictions are removed, the potential impacts of land use conversion should be reexamined.

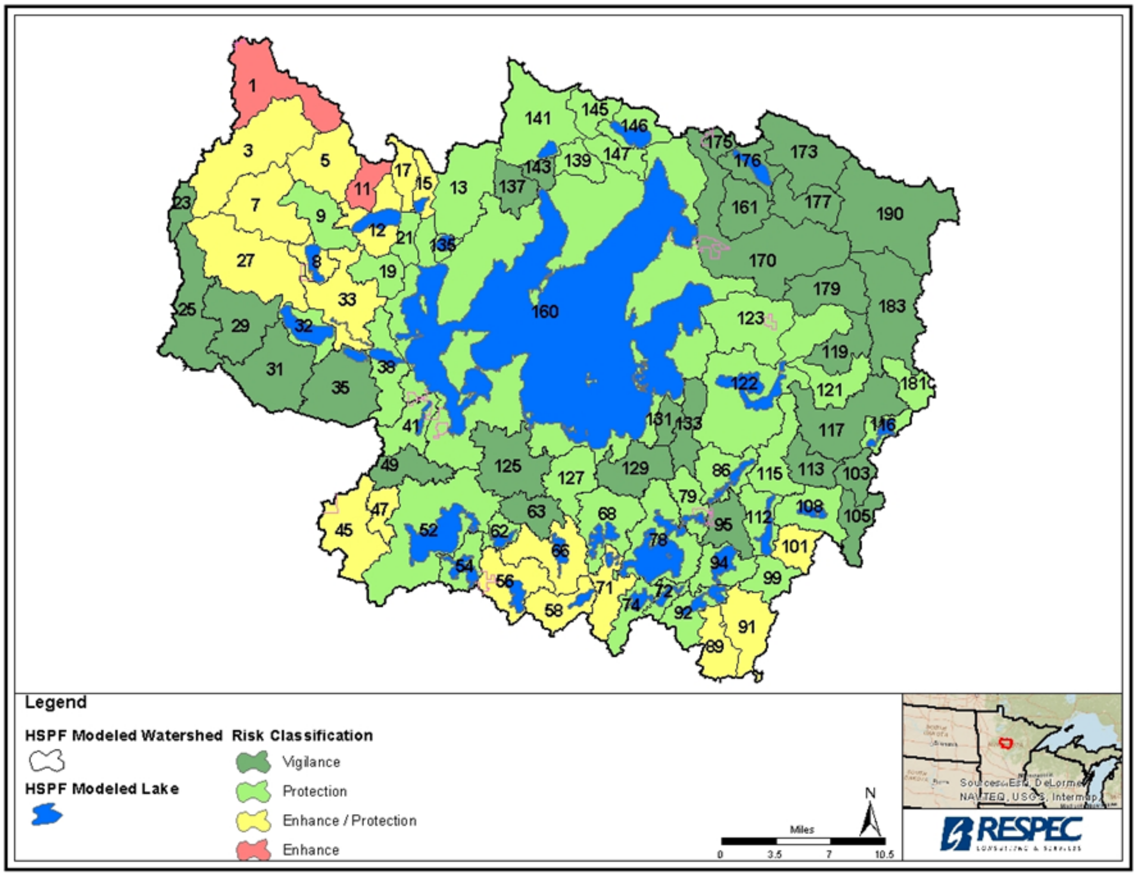
The full report makes recommendations to counties in the LLR Watershed for priorities that could be incorporated into local water plans or ordinance modifications to reduce the potential for significant degradation of water resources. These strategies are included in the strategies detailed in Section 3.4.

B. Risk Assessment and Classification

A relative risk classification system based on land disturbance was used as another tool to rank areas of the LLR Watershed that should receive the highest priority for implementation of water quality protection and improvement efforts. The assessment used two already established methodologies: 1) the risk classification system used for the development of the Crow Wing County Comprehensive Water Plan; and 2) the HSPF models for the LLR Watershed prepared by RESPEC. The risk ranking is based on a number of factors including the percentage of land that is protected by public ownership or conservation easements, the amount of disturbed land, documented water quality trends of waterbodies in minor watersheds, and various other risk factors. In Figure 21 minor watersheds (DNR catchment level 7 delineation) in the LLR Watershed have a water quality protection risk assigned in the following categories:

- **Vigilance:** Watershed with more than 50% protected lands; less than 8% land use disturbance; and no risk factors.
- **Protection:** Watershed with 40% to 65% protected lands; 8% to 30% land use disturbance; minimal risk factors; water quality that is stable or improving; and multiple high-quality resources that could be protected.
- **Enhance/Protection:** Watershed with less than 40% protected lands; moderate amount of risk factors; water quality that is stable, declining, or impaired; manageable risk factors; and one or more water resources that could be protected
- **Enhance:** Watershed with less than 40% protected lands; more than 30% land use disturbance; multiple and/or significant risk factors; and limited resources to protect.

Figure 21: Leech Lake River Subwatershed Risk Classification for Baseline Conditions and HSPF Scenarios 2, 3, 4 and 5



Values-Based Modeling to Identify Geographic Areas of High Conservation Potential

A values-based model –called Zonation—was used to identify areas of high conservation importance and hence priority areas for protection in the LLR Watershed. This model was based on fundamental conservation principles, including biodiversity and connectivity. The DNR's five-component healthy watershed conceptual framework was used to facilitate an organized process to assess and review watershed problems and solutions and identify geographic areas of highest priority for conservation efforts.

The five components for a healthy watershed are biology, hydrology, water quality, geomorphology, and connectivity. This approach recognizes that attempts to solve clean water needs are not separate from other conservation needs; each conservation activity should provide multiple benefits. For example, if protection strategies were implemented in high priority areas identified by the model, both water quality and other conservation benefits (i.e. habitat, recreation and economic stability) would be achieved.

The first step of the model was determining what conservation features are valued in the LLR Watershed. A team of natural resource professionals and interested citizens gathered and identified 26 critical conservation features based on the DNR's five healthy watershed components.

Recognizing that some conservation features are more highly valued than others are, the second step in the model set weights for the conservation features. Professionals and citizens participated in a survey (written and electronic) that asked them to compare priority conservation features on a broad scale (i.e. components of the healthy watershed) and on a finer scale (i.e. the 26 priority conservation features previously identified). The 60 survey respondents prioritized the watershed's broad conservation features in the following order: protect/improve waters of concern; protect/improve fish and wildlife habitat; reduce erosion and runoff; protect/improve lands of concern; and enhance connectivity.

In the third step, the DNR's Division of Ecological Resources team in Brainerd (Paul Radomski and Kristin Carlson) used a software tool—zonation model—to apply an optimization algorithm aggregating all the conservation features, weighting those identified by the survey, to produce a map highlighting areas of high conservation potential.

In the final and fourth step—synthesis—several meetings were held where professionals and interested citizens could review the draft map and confirm priority areas on the map or suggest modifications for further weighting based on intuitive knowledge. This synthesis step captured the knowledge and experiences of the people interested in and informed about the stresses, risks, and vulnerability of water resources within the watershed. Synthesizing the draft map with suggested modifications and running the algorithm again produced a final values-based zonation map of areas of high conservation potential. See Figure 22 for the final map identifying areas of high conservation potential.

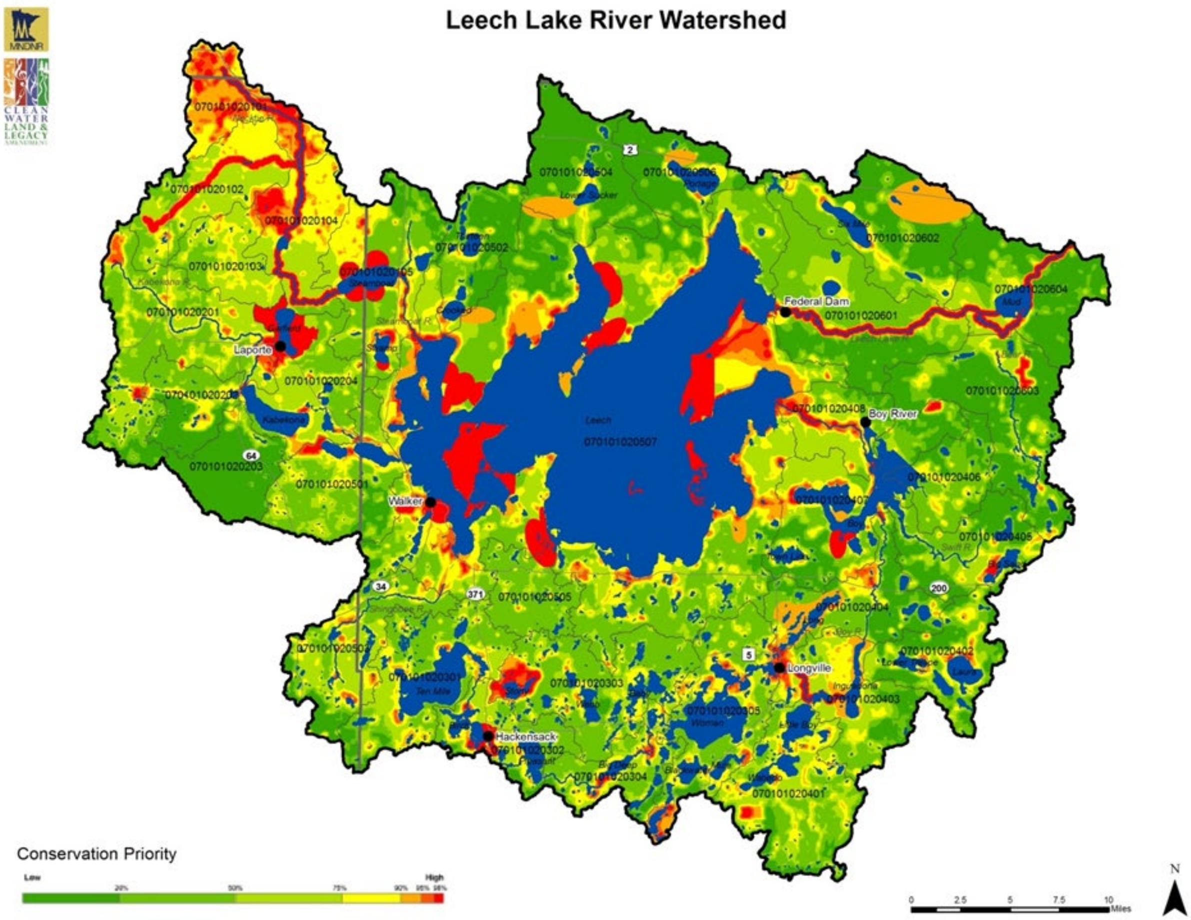
The priority maps identified several distinct high priority areas. First, high rankings were given to lands in the Necktie River and Bungashing Creek catchments in Hubbard County as land that would benefit from protection efforts. Second, the lands within and around the cities of Walker, Longville, Hackensack and Laporte were identified as priority areas for restoration and protection, including accelerating stormwater BMPs to benefit important public waters. Third, high priority rankings were associated with: lands buffering Leech Lake and the LLR; the catchment of Garfield Lake, Stony Lake, Steamboat Lake and Inguadona Lake; and lands near the Boy River.

For areas of red and orange (areas of highest conservation potential) in the Figure 22 values-based final model, the Team reviewed the maps for each of the 26 conservation features that comprised the model to determine what conservation features aggregated together in the final model for a high priority designation. This information was then useful in determining specific protection strategies.

The values-based model provided a formal, quantitative planning framework and critical citizen engagement tool that helped the Team identify priority areas of protection investments that can be integrated with other natural resource priorities to produce multiple conservation benefits.

See Appendix 7 for detailed maps of the final model results by subregion, a list of the 26 conservation features identified for the LLR Watershed around the DNR healthy watershed framework, and weighting survey.

Figure 22: Zonation-model of Conservation Priority Area in Leech Lake River Watershed



The Nature Conservancy's Multiple Benefits Model for Prioritizing Freshwater Conservation Benefits

In 2014, the North Central Conservation Roundtable (NCCR), a collaborative of natural resource agencies and non-governmental organizations (NGOs) working on conservation issues in the North Central Minnesota geography, used the values-based "zonation-modeling" to identify high priority natural resource areas and conservation priorities in a broad multi-county North Central geography, essentially most of the Mississippi River Headwaters region. The NCCR representatives identified the conservation features they desired to have modeled in the Headwaters region.

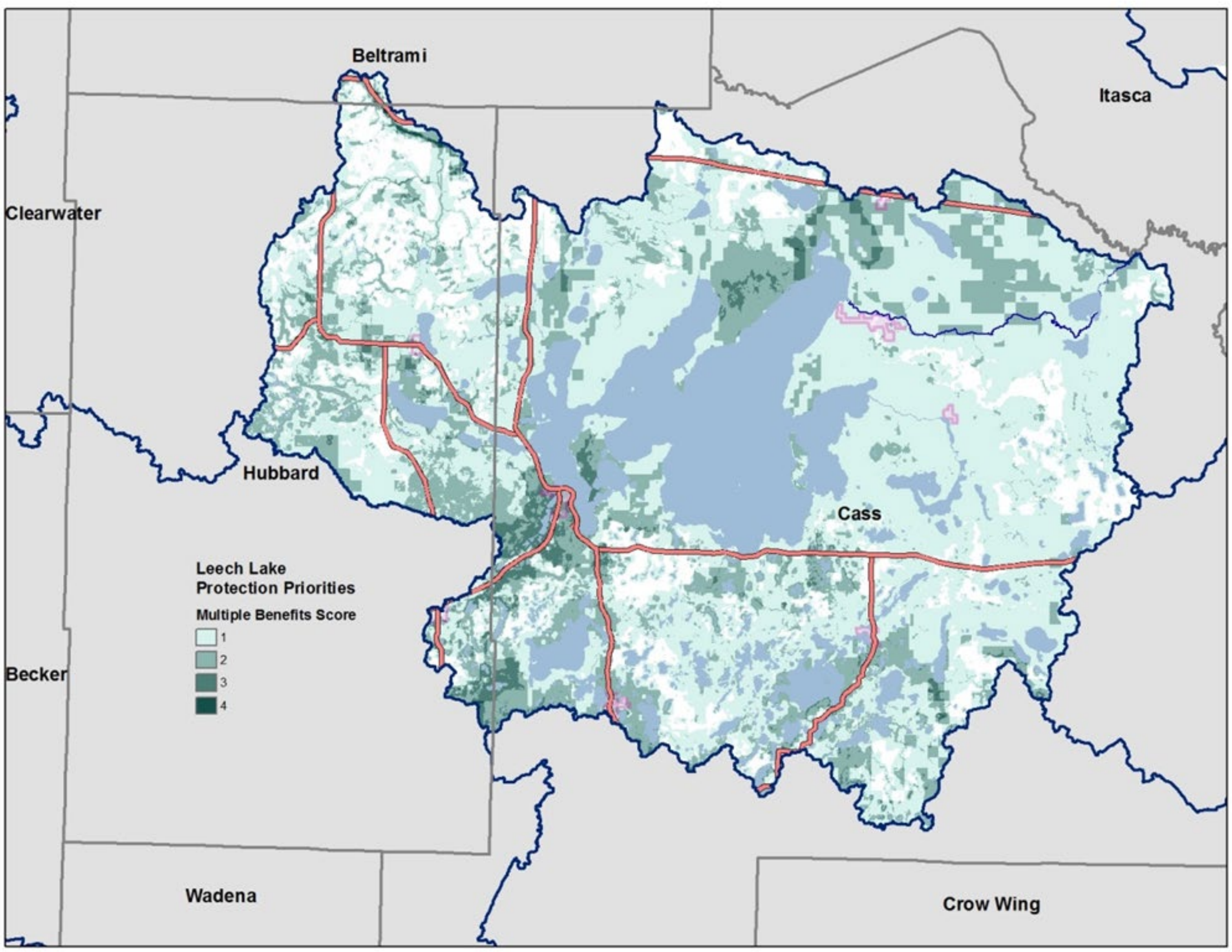
With new data layers available after the NCCR model was completed, TNC, led by Dr. Kristen Blann of their Freshwater Team, took the initiative to develop a second iteration of the zonation model for the entire Mississippi Headwaters to identify areas of high conservation potential that would have multiple conservation benefits.

The goal of TNC's Freshwater Program is to conserve the lands that protect clean water and to support high-impact conservation projects to protect clean water in Minnesota's lakes and rivers for the benefit of nature, people and the economy. As threats to clean water continue to mount, TNC sees an increasing need to identify and conserve high-priority areas for habitat and clean water benefits. Identifying where on the landscape conservation can provide multiple, overlapping benefit can help more effectively target protection and conservation efforts and more efficiently utilize limited resources.

The tweaked NCCR Zonation model for the Mississippi Headwaters was broken down into modules, each consisting of 2 to 10 input layers, based on the benefits the combined layers provided. The modules included: 1) fish and wildlife; 2) drinking water and groundwater quality; 3) flooding and erosion; and 4) groundwater quantity. In addition, a shoreland module was isolated that was straightforward and can be used as an independent layer where shoreland protection is identified as a priority.

TNC's model is intended as a tool to help TNC and its partners set programmatic direction goals as well as identify opportunities and focus areas. It is designed to be used in conjunction with information on opportunities, threats, and costs–none of which the model is designed to account for—to evaluate benefits and tradeoffs among potential conservation projects. The results of TNC's modeling was considered along with priority areas identified using the other tools discussed in Section 3.2 and 3.3 to develop strategies for water quality protection in the LLR Watershed. See Appendix 8 for a more detailed description and additional maps of the TNC multiple benefits modules.

Figure 23: TNC Multiple Benefits Scoring for Leech Lake River Watershed (darker areas correspond to areas where conservation and protection efforts will yield more multiple conservation benefits)



3.3.3 Priority Geographic Areas for Water Quality Protection

Acknowledging that a protection strategy is important for all lakes and streams within the LLR Watershed to maintain existing high quality waters, but also realizing that limited implementation funds will be available, the Team utilized all available knowledge about the water resources of the LLR Watershed, as detailed in Sections 3.2 and 3.3, to designate the following geographic areas (HUC-12s) as the highest priority for initial implementation of strategies for water quality protection (Figure 24). However, all strategies outlined in Section 3.4 will be encouraged and pursued as important and as implementation funds are available.

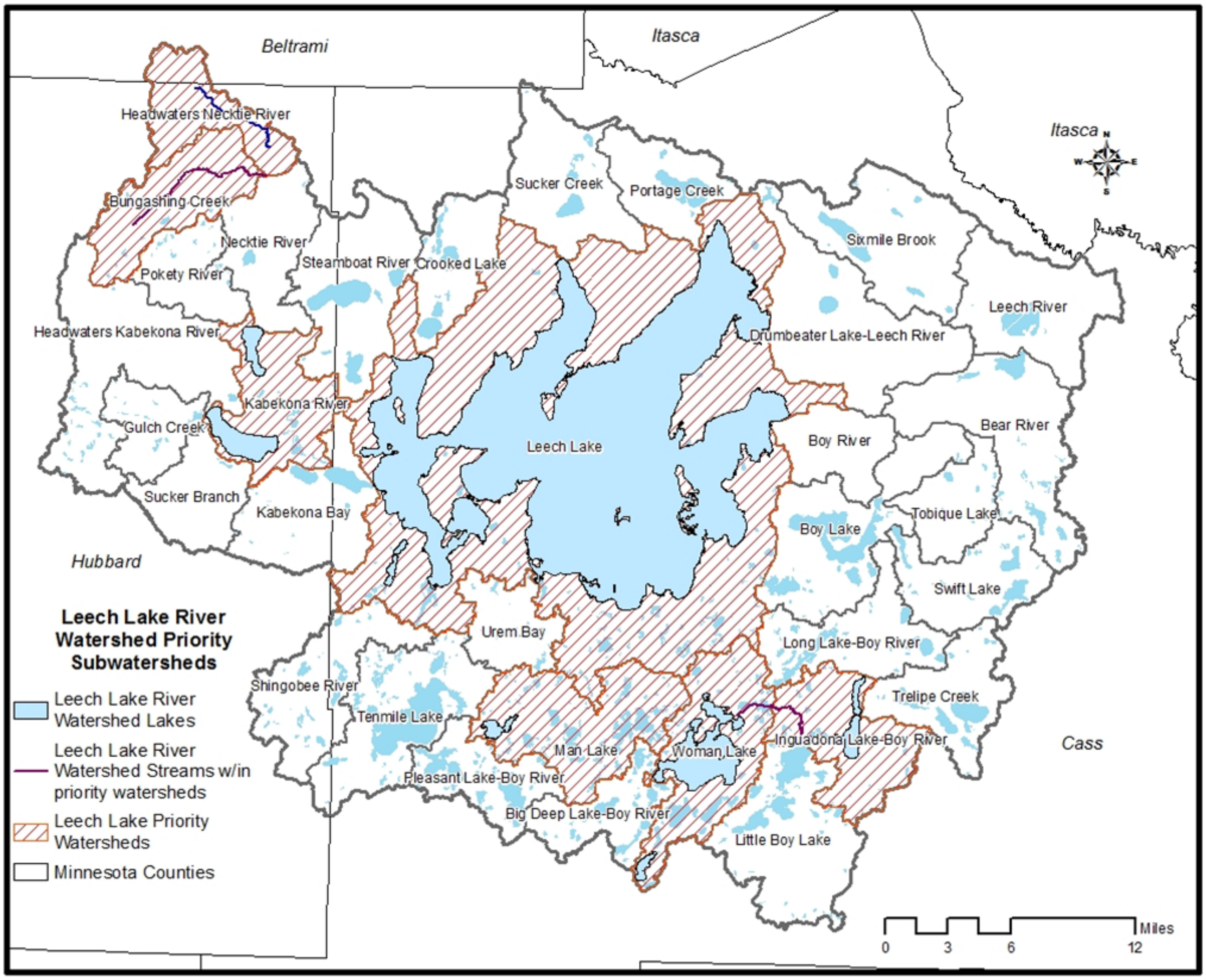
Streams:

- Headwaters of the Necktie River (HUC 070101020101); contains high value trout streams.
- Bungashing Creek (HUC 070101020102); Bungashing Creek is designated an exceptional water.
- Kabekona River (HUC 070101020204); Kabekona and Garfield lakes and adjacent lands.

Lakes:

- Man Lake (HUC 070101020303); high value chain of lakes in the Boy River Chain and Stony Lake, with documented declining water quality trend.
- Woman Lake (HUC 070101020305); high recreational value Woman Lake Chain and Ponto Lake, declining water quality trend and highest ranked lake in the state for phosphorus sensitivity significance.
- Inguadona Lake –Boy River (HUC 070101020403); declining water quality in Inguadona Lake and critical areas of Boy River between the city of Longville and Inguadona Lake.
- Leech Lake Main Basin (HUC 070101020507); Leech Lake and all bays (excluding Kabekona Bay) and adjacent high value lakes (May and Long).
- Kabekona River (HUC 070101020204); Kabekona and Garfield Lakes and the land area between the two lakesheds.

Figure 24: Priority HUC 12 Watersheds for Lake Protection in the Leech Lake River Watershed



3.4 Water Quality Protection Strategies

The Team for the LLR WRAPS recognized that while there are specific strategies for priority geographic areas (detailed in Table 14), there are general strategies for protection of water quality that are applicable across the watershed. The following general strategies, by resource management categories, should be considered by local, state, federal and tribal governments and NGOs as they develop or modify existing plans and/or ordinances for natural resource protection.

Forestry Management: A high percentage of the LLR Watershed is upland and riparian forests. "Keeping forests forested" is a critical water quality protection strategy to preserve water infiltration and reduce runoff to surface and groundwater. Strategies include:

- Permanent land conservation
- Increased private forestry management plans, especially in select tullibee-refuge lake watersheds, and promoting tax incentives for added value
- Promotion of sustainable harvesting practices

- Forest management (public and private) for climate resiliency
- Implementation of protective land use controls
- Use of selective harvesting to protect old growth forests
- Enhanced coordination between local, state, federal and tribal entities for forest management planning and implementation (e.g. storm damage, pest management, forest fire prevention)
- Promotion of reforestation/woody habitat practices to protect water quality and enhance wildlife habitat

Hydrology Management

- Completion of a culvert inventory watershed-wide, including private and township managed culverts; replace/resize culverts where needed on important stream road crossings in the watershed
- Restore channelized streams where beneficial and feasible
- Remove and modify dams to restore fish passage and stream hydrology
- Abandon improperly designed or functioning county ditches; Cass County Ditch 13 is a high priority
- Promotion of low impact/minimal impact development strategies

Land Conservation

- Identify and prioritize riparian and non-riparian lands for permanent protection (easements or acquisition), including culturally and environmentally sensitive areas (e.g. tullibee-refuge lakes and their watersheds, sensitive shorelands, and high priority wild rice lakes)
- Monitor ownership and acquire and permanently protect, if threatened, critical school trust fund lands classified for real estate
- Encourage landowners in already identified priority areas of the watershed to participate in the Wild Rice Easement Program administered by County SWCDs

Land use Controls: Vigilance and modification of local land use controls and ordinances, including:

- Establishing resource protection districts for stricter land use controls in sensitive shoreland zones in Cass County
- Consistent cross-county shoreland zoning for Steamboat Lake and Kabekona Bay of Leech Lake
- Establishing more restrictive SSTS setbacks on riparian lands
- Vigilance of new plats and stronger land use controls for second tier development in the growth corridor of Hackensack to Longville
- Requiring conservation mitigation in zoning variances and new subdivisions in shoreland zones
- Updating shoreland zoning (county and statewide)
- Establishing stricter impervious surface limitations in shoreland zones and within city limits (10%); encourage cluster developments

- Setting minimal lot sizes and providing opportunities for transfer of development rights to decrease the potential of forest fragmentation and conversion of forest land to cropland or other industrial uses
- Maintaining vigilance regarding extractive needs for the Highway 371 expansion and adopt ordinance that is written, but not yet adopted
- Also see Shoreland management/Stewardship

Livestock Management (primarily in Hubbard County)

- Stream exclusion of livestock, pasture and manure management, and rotational grazing; where possible, encourage incentives for producers

Sediment & Nutrient Management

- Road Maintenance: road (township, county, and state) and ATV trail maintenance to minimize nutrient runoff (including road salt/deicers) and erosion
- Conduct septic system compliance surveys and provide education on proper maintenance for riparian and non-riparian SSTS; provide low-interest loans and other incentive programs for non-compliant systems
- Monitor and assess runoff from campgrounds throughout the watershed
- Also see Hydrology Management strategies

Shoreland Management/Stewardship

- Maintain vegetated shorelands and vegetated littoral zones; establish and maintain 50 foot buffers on all riparian lands in compliance with state buffer law
- Promote Subsurface Sewage Treatment System (SSTS) maintenance requirements; conduct SSTS surveys on all lakes and insure compliance with current rules; provide landowner education on the operation and maintenance of SSTS
- Landowner outreach/education on shoreland stewardship, erosion and nutrient runoff

Other general protection strategies include:

- Water quality monitoring:
    - Continued monitoring of fully assessed lakes
    - Continued monitoring on lakes with no data or not enough data to establish water quality trends
    - Update trends on all lakes using recent water quality data
    - Monitor point source discharges (municipal wastewater, aggregate industries, and industrial stormwater)
    - Conduct further monitoring of streams and lakes identified as not meeting state standards but not listed on state impaired waters list or TMDLs warranted

- Better sharing of water chemistry data on lakes and streams between state agencies, local governments, and lake associations

- Insure that landowner education and outreach is an integral part of most water quality protection strategies
- Better urban stormwater management and preservation of municipal natural spaces.
- No net loss of wetlands
- Groundwater and sourcewater protection
- Protect cultural resources where prioritized

Protection Strategies Defined

The overall protection strategy for the LLR Watershed is to "maintain and improve the water quality of the watershed." In Table 14, a variety of strategies to achieve this overall goal are identified for each of the 33 HUC12s in the watershed, which are divided into three subregions. Specific actions and tools are also identified where applicable. To provide consistent interpretation of identified strategies, the strategies have been defined in the following table. These strategies fall into four categories, loosely based on the BWSR approach to water quality protection. The general categories of strategies include:

- **Regulate (R):** Local, state, federal or tribal regulations for land uses and/or other practices that can lead to degradation of water quality.
- **Build /Restore (B)**: On-the-ground actions to reduce nonpoint sources of pollutants within the watershed.
- **Conserve (C):** Permanent or temporary land conservation that limits development and/or other land disturbing practices.
- **Monitoring (M):** Water quality and biological monitoring to assess the quality of the waters of the watershed.

Some strategies fall within multiple categories of protection strategies. It is recognized that the goal of maintaining the existing high quality waters of the LLR Watershed falls under all of these strategies.

Table 13: Descriptions of Protection Strategies utilized in Table 14

Strategy	Category	Description (Applicable Implement Tools)
Erosion Control	**B**	Practices that prevent or control soil erosion from agricultural fields, shorelines, streambanks, gullies, and forest lands to reduce nutrient and sediment erosion into lakes or streams. <u>Contacts/Resources:</u> Hubbard, Cass, or Beltrami SWCDs; NRCS offices; MDA Agricultural BMP Handbook; BWSR; DNR Forestry Programs; Minnesota Forest Resources Council and Landscape Committees.

Strategy	Category	Description (Applicable Implement Tools)
Forest Management	**B/C/R**	Managing forests for proper forest health and function for water quality and habitat protection. Keeping lands forested maintains, protects and enhances infiltration rather than runoff. Activities may include: reforestation; cost share programs; urban forestry management; forest stewardship planning and incentives; tax-relief incentives; permanent land conservation (fee-title acquisition or conservation easements); working timber lands with sustainable harvesting; public and private forestry management for future climate and insect/disease resiliency. Contacts/Resources: County environmental services and land management; County SWCDs; DNR Forestry; DNR Fisheries; NRCS offices; USFS; LLBO DRM; Minnesota Forest Resource Council/North Central Landscape Plan and NGOs. See partner Forestry Management Plans: · Minnesota Forest Resource Council/North Central Landscape Plan: http://mn.gov/frc/index.html · Chippewa Plains – Pine Moraines & outwash Plains Subsection Forest Resource Management Plan - http://www.dnr.state.mn.us/forestry/subsection/cp_pmop/index.html
Forest Management (cont'd)		· Hubbard County Forest Resources Management Plan - http://www.co.hubbard.mn.us/Public%20Works/NRM/2002%20Forest%20Resources%20Management%20Plan.pdf · Chippewa National Forest Management Plan: http://www.fs.usda.gov/main/chippewa/landmanagement/planning · Leech Lake Band of Objibwe http://www.llojibwe.org/drm/forestry/forestry.html · Cass County Land Management Plan http://www.co.cass.mn.us/document_center/land/Forest_Resources_Management_Plan.pdf
Groundwater Management	**B/R**	The protection of groundwater levels, quality, use, and contribution to surface water features through ordinances, monitoring, and permitting. **Specific activities may include**: irrigation management/permitting (the process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner); capping abandoned wells; private well testing for nitrates; establishing and monitoring municipal wellhead protection zones; mapping groundwater resources and flows; completion of a geologic atlas for Cass, Hubbard, and Beltrami counties; and source water protection of drinking water supplies for downstream communities. Contacts/Resources: SWCDs; counties; municipalities; MPCA, DNR Area Hydrologist for permitting; DNR Groundwater Management Program; Minnesota Department of Agriculture (MDA) Groundwater Monitoring and Irrigation Management Program.
Hydrology Management	**B**	Protecting natural water infiltration, movement/flow and water level fluctuations through: · **Culvert Management**: Management of culvert (closed conduit to convey water generally from one side of road to another) size and position to maintain connectivity and natural water levels in lakes and streams. · **Dam Management:** Modification or removal of manmade dams, beaver dams, or improperly sized/perched culverts that are creating

Strategy	Category	Description (Applicable Implement Tools)
		impoundments, to improve connectivity and natural water levels in lakes and streams. · **Drain Water Management**: Promote conservation drainage practices when drainage applications are warranted. · **Stream Restoration/Management:** Maintenance, improvement, and/or restoration of hydrological, physical, chemical, and/or biological functions of a stream, including stream bank stabilization and channelization. Contacts/Resources**:** Depending on activity**,** contact appropriate jurisdiction i.e**.** county, DNR Area Hydrologist, DNR Fisheries, MPCA, US Forest Service (Chippewa National Forest), ACOE, LLBO DRM, and NRCS offices. For stream restoration projects: also contact Trout Unlimited.
In-Lake Management **In-Lake Management** **(cont'd)**	B	The management of fish and aquatic plant communities in the lake to maintain: low carp populations; balanced mix of predator and pan fish; sufficient native aquatic plant coverage in shallow lake sediments that are susceptible to physical disturbance; and low invasive plant species abundance. Monitor levels of chemicals used for treatment of aquatic invasive plants and animals. Activities may include: develop or revise lake association lake management plans, aquatic vegetation and fish surveys, fish stocking, and management of aquatic invasive species. Contacts/Resources: MPCA (Clean Water Partnerships); DNR Fisheries; DNR AIS Program; applicable lake associations for lake management plans; county aquatic invasive species (AIS) plans; LLBO DRM; lake management consulting firms.
Land Conservation	C	Land conservation actions that limit future development and/or uses of a property to protect conservation values and ecological function and to encourage the formation of habitat complexes and connectivity by building on existing protected land base. These may include: **Fee-title acquisition:** Fee-title to land purchased from landowner by NGO or government agency for the purpose of managing/holding the land in perpetuity to protect conservation values. **Conservation Easements**: a legal agreement between a landowner and a land trust or government agency that permanently limits uses of the land in order to protect its conservation values. It allows landowners to continue to own and use their land and/or they can sell it (with the restrictions) or pass on to heirs. **Land Conservation Programs**: e.g. Conservation Reserve Program (CRP), Reinvest in Minnesota (RIM). Contacts/Resources**:** LLAWF; TNC, Minnesota Land Trust; Trust for Public Land; MHB; DNR Fisheries and Wildlife; DNR Forestry; BWSR (RIM easements); NRCS offices; County SWCDs (Wild Rice easements); and Chippewa National Forest. Contact applicable county SWCD for initial direction.
Landowner Outreach / Education	B/C/R	Educating landowners about how their actions impact water quality and specific practices and/or programs they can do and participate in to protect or improve water quality. ***Note:*** It is recognized that most protection and restoration strategies incorporate and require landowner outreach/education to some extent.

Strategy	Category	Description (Applicable Implement Tools)
		Activities may include: shoreland stewardship, rain gardens and other stormwater management actions; septic system management; forest management/stewardship; lake management planning; and promotion of conservation and stewardship programs/incentive opportunities.
Land use Controls **Land use Controls (cont'd)**	**R**	A regulation implemented by a county, city or township that guides how land is developed and used. Zoning ordinances are the most common form of land use controls but stormwater, erosion and sediment control, building, extraction and surface water ordinances can also be used to manage activity for water body and watershed protection. Land use controls are an implementation method for a wide variety of protection and restoration strategies or practices. Land use controls are often established for a specific area or sensitive resource area (i.e. shoreland, wetlands, sensitive subwatershed). Contact/Resources: Appropriate county, city, or township land use or environmental services department; LLBO if tribal land.
Livestock Management	**B/R**	Livestock can contribute nutrients that may impair water quality from waste and grazing practices. · **Manure Management**: Proper handling and storage of livestock manure to prevent or treat runoff of nutrient- and bacteria-laden manure to lakes and streams. · **Rotational Grazing:** The strategic movement of livestock to fresh paddocks, or partitioned pasture areas, to allow vegetation in previously grazed pastures to regenerate or to protect sensitive riparian areas. · **Exclusion from Streams/Lakes:** Limiting livestock access to streams and lakes to prevent stream bank erosion and direct fecal contamination of waterbodies. · **Agro-Forestry Management:** Silviculture practices that maintain forest integrity while enhancing pasturing opportunities. Contacts/Resources: MDA, County SWCDs and NRCS offices, MPCA. MDA Resources include: o https://www.mda.state.mn.us/animals/livestock.aspx, o http://www.mda.state.mn.us/protecting/cleanwaterfund/research/agbmphandbook.aspx o http://www.mda.state.mn.us/awqcp o http://www.mda.state.mn.us/agbmploans
Riparian Buffers	**B**	Maintaining or restoring vegetated areas next to lakes or streams to protect lakes and streams from nonpoint source pollution and provide bank stabilization for aquatic and wildlife habitat.

Strategy	Category	Description (Applicable Implement Tools)
		Contacts/Resources: County SWCDs and NRCS offices, counties, DNR Area offices.
Sediment and Nutrient Management	B	Any practice that removes or reduces nutrient runoff from agricultural or disturbed (developed) lands through infiltration, filtration, or reduced volume and/or sedimentation. Includes riparian buffers, swales, and rain gardens; conservation and cover crops; vegetation management; proper management of chemicals applied to roadways; forest stewardship and forest harvest management; and water level management. Contacts/Resources: County SWCD and NRCS offices, MDA, MN Extension, MNDOT, DNR Forestry, DNR Area Hydrologist.
Shoreland Conservation and Stewardship	C	· **Shoreland Conservation**: Protection of sensitive) and critical shorelines through permanent land conservation programs; see land conservation strategy.
Shoreland Conservation and Stewardship (cont'd)	B	· **Shoreland Stewardship**: BMPs to protect water quality by curbing pollution at the source and reducing, capturing, and cleansing runoff that can carry pollutants to lakes and streams. BMPs may include: proper lawn, waste, and septic system management; reduced chemical use; maintaining native shoreland vegetation or shoreland restoration; rain gardens and reductions of impervious surfaces; protection of shoreland aquatic zones; bluff vegetation management; and proper pharmaceutical disposal. Contacts/Resources: For permanent land conservation, initial contact should be made with the LLAWF. For Shoreland Stewardship, contact: county SWCDs, county environmental services, MN Extension, DNR, and applicable lake association.
Stormwater Management	B,R	Proper urban, residential and road/highway storm water management reduces runoff volume and the contribution of sediment, nutrients, and other pollutants to receiving waters. Storm water management practices may include infiltration trenches; installation or maintenance of filtration ponds; installation of buffers, swales and rain gardens; and proper roadway design. Contacts/Resources: Municipalities, MPCA, County SWCDs, MnDOT, MHB.
Subsurface Sewage Treatment Systems (SSTS)	B,R	Monitoring, maintenance, and/or upgrading of individual onsite sewage treatment systems (septic systems) to insure correct design/placement and proper operation for effective sewage treatment. Activities may include regulatory controls, cost share programs to landowners, education, and other incentives. Contacts/Resources: Counties, LLBO DRM if tribal land, University of MN Extension, MPCA.
Water Quality Monitoring	M	In-depth and/or regular monitoring of lake or stream chemical, biological and physical characteristics, including temperature, DO, bacteria, phosphorus, water clarity, and biological communities to determine water quality conditions and changing trends, sources of pollutant loads, and responses to nutrient reduction strategies for individual or chains of connected lakes and

Strategy	Category	Description (Applicable Implement Tools)
		streams. May include local/state/federal/tribal government monitoring or MPCA citizen monitoring programs Contacts/Resources: DNR Fisheries (biological monitoring). For chemical monitoring, DNR Fisheries, county environmental services and/or SWCD, applicable lake associations, MPCA, or LLBO DRM.
Wetland Restoration & Protection	**B,R**	Practices that protect and/ or restore the hydrologic and nutrient removal function of a wetland. Contacts/Resources: County SWCD and NRCS offices, DNR Ecological and Water Resources Wetlands Program, U.S. Fish and Wildlife Service, USFS, LLBO DRM.

Table 14: Strategies and actions proposed for the Leech Lake River Watershed

HUC-12 Subwatershed: ID- Name	HUC-12 Subwatershed: Description	HUC-12 Subwatershed: Protection Ranking (see below)	Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions	Water Quality: Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
0701010201 01 Headwaters Necktie River	**Zonation Model: very high conservation potential due to DNR/fisheries at risk; very little protected lands; potentially critical School Trust fund lands adjacent to Necktie River; large amount pasture/hay land; soils have high total nitrogen, phosphorus and total suspended solids; high potential for land conversion for agriculture.**	ENHANCE	Necktie River; high quality trout stream	Hubbard Beltrami	Fish/ macroinverte brates, dissolved oxygen and hydrology	Meets Water Quality Standards	Maintain or improve existing water quality	C	Land Conservation	1) Monitor school trust fund lands classified for real estate (channelized stream shoreland and upland) and acquire if threatened; 2) prevent additional land use conversion.						x					x			x			Ongoing
								B/R	Livestock Management	Grazing monitoring; exclusion from Necktie River; producer education		x	x										x				
								B	Hydrology Management	Evaluate channelized portion of Necktie River above Hart Lake for restoration feasibility.		x				x											
								B/C/R	Forest Management	Private forest management		x				x									x		
								B,R	Stormwater Management & Land use Controls	Monitor urban development and mitigate as needed (Bemidji)				x	x		x										
0701010201 02 Bungashing Creek	**High amounts of pasture/hay lands; high total nitrogen.**	ENHANCE/ PROTECT	Bungashing Creek- Exceptional Water (trout & macro inverts)	Hubbard	Fish/ macroinverte brates, dissolved oxygen and hydrology	Meets Water Quality Standards	Maintain or improve existing water quality	B/R	Livestock Management	Livestock exclusion from Bungashing Creek, specifically above County Road 102 bridge; monitor grazing activity; producer education		x	x										x				5-10+ years
								B	Hydrology Management	Culvert redesign/maintenance for stream road crossing on Bungashing Creek at TWP 145	x	x		x		x											

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
070101020102 Bungashing Creek (cont'd)								C	Land Conservation	Monitor school trust fund 40s designated for real estate (trout stream, shoreland, and upland) and acquire if threatened.						x					x	x		x			
								B/C/R	Forest Management	Private forest management		x				x									x		
								B	Sediment and Nutrient Management Erosion Control	Along Bungashing Creek	x	x			x	x							x				
070101020103 Pokety Creek		**ENHANCE/ PROTECT**		Hubbard	Fish/ macroinvertebrates, dissolved oxygen and hydrology	Meets Water Quality Standards	Maintain or improve existing water quality	B	Hydrology Management	Improve deficient stream road crossing structures on Pokety Creek at TWP-198	x	x		x		x											5-10+ years
								B/C/R	Forest Management	Private forest management		x				x									x		
070101020104 Necktie River	**Zonation Model: High conservation potential north of Hart Lake due to ecological connections, significant school trust fund lands north and south of Hart adjacent to Necktie.**	**ENHANCE/ PROTECT**	Hart Lake (29006300) - nutrient impaired; shallow lake characteristics with excellent wild rice habitat	Hubbard	Phosphorus	Growing Season Average TP = 43.4 ppb	Maintain or reduce 5% of watershed TP load	B	Hydrology Management	Evaluate channelized portion of Necktie River above Hart Lake for feasibility of restoration		x			x	x											0-5+ years
								B/R	Livestock Management	Feedlot management; livestock exclusion from Necktie River; and producer education		x	x										x				
								R	Land use Controls	Monitor gravel pit near Hart Lake; develop extraction ordinance if needed.																	

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality																					Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	
0701010201 04 Necktie River (cont'd)								M	Water Quality Monitoring	Continued WQ monitoring of Hart Lake for nutrients & trend analysis		x			x												
								C	Land Conservation	1)Monitor priority school trust fund lands along the Necktie River and around/near Hart Lake, permanently protect if threatened; 2) riparian easements.						x					x			x			
								B/C/R	Forest Management	Private forest management		x				x									x		
0701010201 05 Steamboat River	**Zonation Model: High conservation potential around Steamboat Lake due to groundwater contamination susceptibility and sensitive shorelands.**	ENHANCE/ PROTECT	Steamboat (11050400) Swamp (11048300)	Cass Hubbard	Phosphorus	Growing Season Ave. TP: Steamboat = 19 ppb Swamp = insufficient data.	Maintain or reduce 5% of watershed TP load	C	Land Conservation	Inventory and protect sensitive shorelands on Steamboat and Swamp Lakes and large forested parcels in Steamboat lake watershed.						x					x			x	x	x	0-5+ years
								R	Land use Controls	1) Consistent shoreland zoning between Hubbard and Cass County for Steamboat Lake; 2) vigilance on extraction needs (gravel pits) for Highway 371 expansion; 3) monitor future development within Steamboat Lakeshed	x																
								B/C/R	Landowner Outreach/ Education,	Steamboat Lake riparian properties	x	x													x	x	

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
0701010201 05 Steamboat River (cont'd)									Shoreland Stewardship and SSTS Management																		
								B	Hydrology Management	Culvert redesign/maintenance at Steamboat River & CSAH5	x	x		x		x											
								M	Water Quality Monitoring	1) Continued monitoring on Swamp lake for trend analysis; 2) mass balance analysis for Steamboat Lake to determine nutrient loading					x										x		
								B	Sediment and Nutrient Management Erosion Control	Upstream Necktie River to Steamboat Lake	x	x	x	x		x											
								B,R	Wetland Protection	Steamboat Lakeshed		x				x											
								B/C/R	Forest Management	Private forest management		x				x										x	
0701010202 01 Headwaters Kabekona River	**Potlach Lands SW of City of Laporte; high conservation potential along Kabekona river, a designated trout stream.**	**ENHANCE/ PROTECT**	Kabekona River (exceptional trout sections); Kettle Lakes	Hubbard	Fish/ macroinvertebrates, dissolved oxygen and hydrology; Phosphorus	Kabekona River listed as impaired by *E. coli* bacteria. To be addressed in Livestock Management Strategy	Maintain or improve existing water quality	**M**	Water Quality Monitoring	Bacteria monitoring on Kabekona River at site of previously noted impairment		x			x											x	0-5+ years
								B/R	Livestock Management	Exclude livestock from Kabekona River to protect habitat and sediment/ nutrient loading		x	x										x				
								R	Land use Controls	Prevent forest land use conversions and expansion of extractive uses (gravel pits)	x					x											

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality																					Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	
								B,R	Stormwater and Hydrology Management	Road maintenance, culvert maintenance, and hydrology management in Kettle Lakes area (including Paul Bunyan State Forest). Implementation of BMPs as needed in extraction areas.	x			x		x											
								C	Land Conservation	Acquire easements on riparian property along trout stream portion of Kabekona River.						x					x			x	x		
0701010202 02 Gulch Creek	**High value forests west of Kabekona lake; predominantly in public ownership**	**VIGILANCE**	Gulch Creek	Hubbard	Fish/ macroinverte brates, dissolved oxygen and hydrology	Meets water quality standards	Maintain or improve existing water quality	B/C/R	Land Conservation /Forestry Management	Conservation easements and forestry management incentive programs on private forest lands in Kabekona Lake lakeshed. Forest health management on public lands.		x				x					x			x	x		Ongoing
								B	Hydrology Management	1) Culvert redesign/maintenance at Gulch Creek and NFR-14. 2) Modify dam on Gulch Creek at Kabekona WMA to allow better manipulation of water levels and allow fish passage.	x	x		x		x											
0701010202 03 Sucker Branch	**Predominantly in public ownership**	**VIGILANCE**		Hubbard	Fish/ macroinverte brates, dissolved oxygen and hydrology	Meets water quality standards	Maintain or improve existing water quality	C	Land Conservation	Conservation easements on private forest parcels in Kabekona Lake lakeshed						x					x				x		5-10+ years
								B	Hydrology Management	Identify deficient stream road crossings; repair as needed.	x			x		x		x									
0701010202 04 Kabekona River	**Area around Garfield Lake has high conservation priority including the**	**ENHANCE/ PROTECT**	Garfield Lake (29006100); Kabekona Lake (29007500)	Hubbard	Phosphorus	Growing Season Ave. TP: Garfield = 15.9 ppb Kabekona	Maintain or reduce 5% of watershed TP load	B/C/R	Land Conservation & Forestry Management	Conservation easements and forestry management incentives on privates lands (riparian and non-riparian) in Garfield and Kabekona lakesheds		x				x					x			x	x	x	5-10+ years

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
0701010202 04 Kabekona River (cont'd)	City of Laporte primarily due to areas sensitive to phosphorus loading, high total nitrogen, and sensitive shoreland on Garfield Lake. Between Kabekona and Garfield lakes is a high protection priority for TNC based on population growth projections. Kabekona is a high priority for fisheries protection.					= 11.5 ppb & D.O. > 3.0 mg/L in bottom waters		B/C/R	Shoreland Conservation & Steward-ship; SSTS Management	Garfield and Kabekona Lakes; conduct SSTS survey of Garfield Lake	x	x													x	x	
								M	Water Quality Monitoring	Monitor Garfield Lake for trend analysis		x			x											x	
								B/C/R	Landowner Outreach/Ed ucation	Garfield lake riparian properties; hold community forum		x													x	x	
								B,R	Stormwater Management	Urban management for City of Laporte with particular attention to highway runoff management; update stormwater management plan.		x		x	x												
								B,R	Groundwater Management /Wetland Protection	Lakeshed of Garfield Lake		x				x									x		
								B	Hydrology Management	Improve deficient stream road crossing on tributary to Kabekona Lake at MN-200	x	x		x		x											
								R	Land use Controls	Monitor second tier development between Kabekona and Garfield lakes	x																
								B	In-lake Management	Internal load estimation for Garfield Lake		x			x												
0701010203 01 Ten Mile Lake	Boy River Headwaters; high water quality importance for	PROTECT	Ten Mile Lake (11041300)- one of the highest water quality lakes in Minnesota	Cass Hubbard	Phosphorus; Dissolved Oxygen (Tullibee Protection)	Growing Season Ave. TP: Ten Mile = 15.6 ppb & D.O. > 3.0	Maintain or reduce 5% of watershed TP load	C	Land Conservation	1) Forest easements in the Ten Mile Lakeshed; 2) monitor priority trust fund lands classified as real estate in Ten Mile Lakeshed and		x				x					x			x		x	Ongoing

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality																				Estimated Year to Achieve Water Quality Target
ID- Name	**Description**	**Protection Ranking (see below)**				**Current Conditions**	**Goals/ Targets and Estimated % Reduction**	**Category (see key below)**	**Strategies**	**Strategy Activities/ 10-yr Milestones**	**County**	**SWCD**	**NRCS**	**Cities/Townships**	**MPCA**	**DNR**	**Other state**	**USFS**	**ACOE**	**LLBO**	**LLAWF**	**MHB**	**MDA**	**Other NGO**	**Landowners**	**Lake Association**	
	22 downstream lakes.					mg/L in bottom waters				permanently protect if threatened.																	
								B/C/R	Forest Management	Manage forests in Ten Mile Lakeshed for proper health and function; enhanced private forestry management.	x	x				x									x	x	
								B	Hydrology Management	Identify deficient culverts at stream road crossings. Repair/man-age as needed.	x	x		x		x		x									
								B/C/R	Shoreland Conservation & Stewardship; SSTS Management	Ten Mile Lakeshore Property Owners	x	x													x	x	
0701010203 01 Ten Mile Lake (cont'd)								**R**	Land use Controls	1) Vigilance over extraction needs (gravel pits) for Highway 371 expansion; 2)monitor future development	x															x	
0701010203 02 Pleasant Lake-Boy River	**Zonation Model: High conservation priority around Birch Lake/City of Hackensack (City of Hackensack) along with high groundwater susceptibility and high nitrogen and**	**PROTECT**	Pleasant Lake (11038300); Birch Lake (11041200)	Cass	Phosphorus	Growing Season Ave. TP: Pleasant = 14.9 ppb Birch = 15.3 ppb	Maintain or reduce 5% of watershed TP load	**B**	Sediment and Nutrient Management; Erosion Control	Birch and Pleasant Lakesheds	x	x		X	X	x									x	x	Ongoing
								B/C/R	Landowner Outreach/Education, Shoreland Stewardship and SSTS Management	Birch and Pleasant Lakes	x	x													x	x	
								B,R	Stormwater Management	City of Hackensack				x	x												

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
	suspended solids.							C	Land Conservation	1)Monitor school trust fund lands classified for real estate and permanently protect if threatened; 2) establish wild rice easements along Boy River; 3)riparian easements		x				x					x			x	x	x	
								R	Land use Controls	1) Vigilance over extraction needs (gravel pits) for Highway 371 expansion; 2) monitor future shoreland development.	x			x												x	
								B/C/R	Forest Management	Private forest management		x	X			x										x	
0701010203 03 Man Lake	Zonation Model: High conservation potential around Stony Lake due to groundwater contamination susceptibility; land-locked lake.	PROTECT	Baby Lake (11028300); Blueberry Lake (11037600); Barnum Lake (11028100); Kerr Lake (11026800); Kid Lake (11026200); Lost Lake (11026900); Man Lake (11028200); McKeown Lake (11026100); Stony Lake (11037100); Webb Lake (11031100)	Cass	Phosphorus	Growing Season Ave. TP: Baby = 12.7 ppb Blueberry = 30.6 ppb Barnum = 10.5 ppb Kerr = 14.1 ppb Kid = 13.1 ppb Lost = 15.7 ppb Man = 10.9 ppb McKeown = 12.1 ppb Stony = 11.0 ppb Webb = 12.6 ppb	Maintain or reduce 5% of watershed TP load	R	Land use Controls	Shoreland zones; monitor new plats and second tier development	x															x	5-10+ years
								B/C/R	Shoreland Conservation & Stewardship; SSTS Management	1) all riparian zones; 2) septic survey of properties around Stony Lake; 3) shoreland inventory on Stony Lake for recommended BMPs.	x	x													x	x	
0701010203 03 Man Lake (cont'd)								B/C/R	Landowner Education and Outreach	Specially for Stony Lake because of declining water quality	x	x														x	
								B,M	Groundwater Management & Monitoring	Monitor groundwater vulnerability areas in Stony Lakeshed and surrounding lands	x					x											
								B	Sediment and Nutrient Management ; Erosion Control	Upstream of McKeown Lake; upstream of and within lakesheds of Webb, Baby, Mann, Kidd, Kerr, Lost and Stony Lake	x	x		X	x	x	x								x	x	
								M	Water Quality Monitoring	Continued monitoring of Stony Lake to further assess declining water quality ; 2) water flow		x			x	x										x	

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
										analysis to determine areas of heaviest runoff																	
								C	Land Conservation	Riparian and forest easements		x										x					
								B/C/R	Forest Management	Private Forest Management		x					x									x	
0701010203 04 Big Deep Lake-Boy River	Zonation model: High conservation priority at south end of Big Deep Lake and surrounding lands.	VIGILANCE	Big Deep Lake (11027700); Child Lake (11026300)	Cass	Phosphorus	Growing Season Ave. TP: Big Deep = insufficient data Child = 16.5 ppb	Maintain or reduce 5% of watershed TP load	R	Land use Controls	Shoreland zones; monitor new plats and second tier development	x															x	5-10+ years
								B	Sediment and Nutrient Management; Erosion Control	Upstream of Big Deep and Child lakes		x		x		x									x	x	
								C	Land Conservation	If threatened, permanently protect school trust fund lands classified for real estate near Big Deep Lake.						x					x			x		x	
								B/C/R	Forest Management	Privately owned forest lands		x				x									x		
								M	Water Quality Monitoring	Big Deep Lake to establish trend																x	
								B/C/R	Shoreland Conservation & Stewardship; SSTS Management	Riparian zones		x			x												
0701010203 05 Woman Lake	Zonation model: high conservation potential on Broadwater Bay/Woman Lake and Girl	PROTECT	Girl Lake (11017400); Woman Lake (11020102); Blackwater Lake (11027400); Island Lake	Cass	Phosphorus	Growing Season Ave. TP: Girl = 13.5 ppb Woman = 14.4 ppb Blackwater	Maintain or reduce 5% of watershed TP load	B/C/R	Shoreland Conservation & Steward-ship; SSTS Management	1) all riparian zones; 2) septic survey and shoreline inventory of Ponto Lake properties	x	x													x	x	5-10+ years
								R	Land use Controls	Shoreland zones; monitor new plats and second tier development	x															x	

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
	Lake/Longville area		(11025700); Mule Lake (11020000); Ponto Lake (11023400)-highest phosphorus sensitivity of all MN lakes evaluated			= 14.4 ppb Island = 12.1 ppb Mule = 14.3 ppb Ponto = 8.9 ppb		C	Land Conservation	1) Large, privately owned forested lands; 2) if threatened, permanently protect school trust fund lands SE of Woman Lake; 3) riparian easements.		x				x					x			x	x	x	
								B/C/R	Forest Management	Private forest management, special emphasis on Ponto Lakeshed		x	x												x		
								B	Sediment and Nutrient Management Erosion Control	Upstream of Woman and Girl lakes; upstream and within lakeshed of Blackwater Lake; within lakesheds of Mule, Ponto, and Island Lake.	x	x	x	x	x	x									x	x	
								B/C/R	Landowner Education and Outreach	Ponto Lakeshore property owners	x	x									x					x	
								M	Water Quality Monitoring	1) Island Lake and Ponto lake to further assess declining water quality; 2) water flow analysis on Ponto Lake to determine areas of heaviest runoff.	x	x			x	x										x	
0701010204 01 Little Boy Lake	Zonation model: High conservation priority on south end of Wabedo due to groundwater contamination potential and ecological connections.		Hunter Lake (11017000); Little Boy Lake (11016700); Wabedo Lake (11017100); McCarthy Lake (11016800)	Cass	Phosphorus	Growing Season Ave. TP: Hunter = 7.5 ppb Little Boy = 18.8 ppb Wabedo = 19.4 ppb (NE Bay) & 22.4 (SW Bay) McCarthy = 74.4 ppb	Maintain or reduce 5% of watershed TP load	B	Sediment and Nutrient Management Erosion Control	Within lakesheds of Wabedo and Little Boy Lakes	x	x	x	X		x									x	x	0-5+ years
								B/C/R	Shoreland Conservation & Steward-ship; SSTS Management	Riparian zones	x	x													x	x	
								R	Land use Controls	Shoreland zones	x																
0701010204 01 Little Boy								C	Land Conservation	1) If threatened, permanently protect school trust fund lands classified real estate,		x	x			x					x			x		x	

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
Lake (cont'd)										2) private forest lands, 3) wild rice easements.																	
								B	Hydrology Management	1) repair culvert on Evergreen Rd between Kid Lake and Baby Lake; 2) repair culvert on Co Road 5 between Kerr Lake and Baby Lake; 3) improve bridge on private drive to 4399 14th Ave N.W. Baby Lake to Man Lake		x		x											x	x	
								B/R/M	Groundwater Management	Monitor vulnerability areas south of Wabedo lake.	x					x											
								M	Water Quality Monitoring	Monitor Cooper Lake for trend analysis		x			x											x	
0701010204 02 Trelipe Creek		VIGILANCE / PROTECT-ION	Laura Lake (11010400); Upper Trelipe Lake (11010500); Lower Trelipe Lake (11012900)	Cass	Phosphorus	Growing Season Ave. TP: Laura = 21.1 ppb Upper Trelipe = 11.9 ppb Lower Trelipe = 19.2 ppb	Maintain or reduce 5% of watershed TP load	B/M	In-lake Phosphorus Management	Laura Lake						x		x							x		Ongoing
								B	Sediment and Nutrient Management; Erosion Control	Upstream and within lakeshed of Lower Trelipe Lake, within lakeshed of Upper Trelipe.	x	x		x		x		x							x	x	
								B/C/R	Forest Management	Managing forests for proper health and function; private forest management		x															
								C	Land Conservation	Wild Rice easements		x													x		
0701010204 03 Inguadona Lake-Boy River		PROTECT/ ENHANCE	Cooper Lake (11016300); Rice Lake (11016200); Inguadona Lake (11012000)	Cass	Phosphorus; Dissolved Oxygen (Tullibee Protection)	Growing Season Ave. TP: Cooper = 14.9 ppb Rice = insufficient data Inguadona = 15.1 ppb	Maintain or reduce 5% of watershed TP load	R	Land use Controls	1) Evaluate septage disposal in shoreland zone of Boy River and Inguadona Lake; 2) shoreland zones	x				x											x	5-10+ years
								B	Sediment and Nutrient Management Erosion Control	Upstream of Inguadona Lake; Upstream of Rice Lake; Within the lakeshed of Cooper Lake	x			x	x	x									x	x	

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality																					Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	
0701010204 03 Inguadona Lake-Boy River (cont'd)						(N Bay) & 17.4 ppb (S Bay) & D.O. > 3.0 mg/L in bottom waters		**B/C/R**	Shoreland Conservation & Steward-ship; SSTS Management	Inguadona lakeshore, including a shoreline inventory	x	x														x	
								M	Water Quality Monitoring	1) On Boy River: Longville to Inguadona Lake for low dissolved oxygen issue; 2) continued monitoring of Inguadona Lake (in lake and inlets); 3) water flow analysis for Inguadona; 4) monitor lakes up-stream of Inguadona to assess upstream contri-butions; 5) monitor Cooper Lake for trend analysis.	x			x	x											x	
								B,R	Wetland Protection	Inguadona Lakeshed	x	x													x	x	
								B	Hydrology Management	Abandon Cass County Ditch 5 draining to Inguadona	x			x													
								B,R	Stormwater Management	City of Longville				x	x												
								C	Land Conservation	1) Wild Rice Easements along Boy River; 2) riparian easements and acquisitions.		x					x										
0701010204 04 Long Lake Boy River	**Predominately public land accept for area around Long Lake**	**PROTECT**	Long Lake (11014200)	Cass	Phosphorus; Dissolved Oxygen (Tullibee Protection)	Growing Season Ave. TP: Long = 13.2 ppb (Main Basin) & 12.2 ppb (SW Bay) & D.O. > 3.0 mg/L in bottom waters	Maintain or reduce 5% of watershed TP load	**B**	Sediment and Nutrient Management Erosion Control	Long lakeshed	x	x		x	x	x										x	Ongoing
								B/C/R	Shoreland Conservation /Stewardship & SSTS Management	Long Lake riparian owners	X	x			x										x	x	
								B/C/R	Forest Management	Manage forests for proper health and function; private forest management	x	x				x										x	

HUC-12 Subwatershed: ID- Name	HUC-12 Subwatershed: Description	HUC-12 Subwatershed: Protection Ranking (see below)	Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality: Current Conditions	Water Quality: Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
								C	Land Conservation	1) Easements on private forested lands ; 2) if threatened, permanently protect school trust fund lands along the Boy River		x				x					x			x			
0701010204 05 Swift Lake	**Predominantly in public ownership**	**VIGILANCE**	Swift Lake (11013300); Big Sand (11007700)	Cass	Phosphorus	Growing Season Ave. TP: Swift = 20.4 ppb Big Sand = 21.6 ppb	Maintain or reduce 5% of watershed TP load	C	Land Conservation	If threatened, permanently protect school trust fund lands classified as real estate and forestry						x					x			x		x	Ongoing
								B	In Lake Phosphorus Management	Big Sand Lake	x	x			x	x									x	x	
								B	Sediment and Nutrient Management Erosion Control	Swift Lake	x	x		x	x	x									x	x	
								M	Water Quality Monitoring	Big Sand and Swift lakes for trend analysis		x			x											x	
								B/C/R	Forest Management	Manage forests for proper health and function	x					x											
								B/C/R	Shoreland Conservation & Steward-ship	Swift Lake riparian owners	x	x				x										x	
0701010204 06 Tobique Lake	**Predominantly in public ownership**	**VIGILANCE**		Cass	Phosphorus	Meets water quality standards	Maintain or improve existing water quality	B	Sediment and Nutrient Management Erosion Control	Upstream of Boy Lake	x	x		X				x									Ongoing
								B/C/R	Forest Management	Manage forests for proper health and function	x																
0701010204 07 Boy Lake		**PROTECT**	Boy Lake (11014300); Townline Lake (11019000)	Cass	Phosphorus	Growing Season Ave. TP: Boy = 24.1 ppb	Maintain or reduce 5% of watershed TP load	C	Land Conservation	If threatened, permanently protect school trust fund lands in high biodiversity areas adjacent to Boy Lakes						x					x			x		x	5-10+ years

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones																	
						Townline = 14.5 ppb		B/C/R	Shoreland Conservation /Stewardship & SSTS Management	Boy Lake riparian areas	x	x				x										x	
0701010204 07 Boy Lake (cont'd)								B	In-lake Management	Townline Lake					x	x										x	
								B	Sediment and Nutrient Management Erosion Control	1) Upstream of Boy Lake; 2) along ATV trails from Boy River to Highway 200	x	x	x	x	x	x											
								M	Water Quality Monitoring	Boy and Townline Lakes for trend analysis		x			x											x	
								B/C/R	Forest Management	Manage forests for proper forest health and function.	x				x												
								R	Land use Controls	Shoreland zones; monitor new plats and second tier development	x																
0701010204 08 Boy River		**PROTECT**	Boy River Outlet to Leech Lake	Cass	Fish/ macroinverte brates, dissolved oxygen and hydrology	Meets water quality standards	Maintain or improve existing water quality	C	Land Conservation	If threatened, permanently protect school trust fund lands classified for real estate near Boy River outlet to Leech Lake						x					x			x			Ongoing
								B,R	Wetland Protection	Areas adjacent to Boy River	x	x	x			x											
								B/C/R	Forest Management	Manage forests for proper forest health and function, private forest management.	x	x				x									x		
0701010205 01 Kabekona Bay	**Largely in public ownership with private ownership around Benedict & Kabekona lakes; zonation**	**VIGILANCE (south of Benedict Lake); PROTECT (Kabekona Bay)**	Kabekona Bay of Leech Lake (11020302); Benedict Lake (29004800)	Hubbard Cass	Phosphorus; Dissolved Oxygen (Tullibee Protection)	Growing Season Ave. TP: Kabekona Bay = 13.9 ppb Benedict =	Maintain or reduce 5% of watershed TP load	C	Land Conservation	Protect sensitive shorelands on Kabekona Bay by easement or acquisition	x					x					x			x		x	0-5+ years
								B	Hydrology Management	Conduct well and spring monitoring around Benedict Lake		x			x	x										x	

HUC-12 Subwatershed ID- Name	HUC-12 Subwatershed Description	Protection Ranking (see below)	Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality Current Conditions	Water Quality Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
0701010205 01 Kabekona Bay (cont'd)	**model shows high conservation potential on the west side of Benedict Lake due to ecological connections; most of HUC is a trout stream catchment.**					9.4 ppb & D.O. > 3.0 mg/L in bottom waters D.O. Concentrations >3.0 mg/L below thermos-cline		R	Land use Controls	Consistent land use zoning for Kabekona Bay of Leech Lake between Hubbard and Cass County	x																
								B	Sediment and Nutrient Management; Erosion Control	Kabekona River upstream of Kabekona Bay; lakeshed of Benedict Lake		x	x		x	x										x	
								B/C/R	Shoreland Conservation & Steward-ship; SSTS Management	Benedict Lake		x													x		
								M	Water Quality Monitoring	Benedict Lake for trend analysis		x			x										x		
								B/C/R	Forest Management	Manage forests for proper forest health and function	x	x				x		x									
0701010205 02 Crooked Lake		VIGILANCE	Crooked Lake (11049400); Thirteen Lake (11048800)	Cass	Phosphorus	Growing Season Ave. TP: Crooked = 22.0 ppb Thirteen = 15.8 ppb	Maintain or reduce 5% of watershed TP load	C	Land Conservation	If threatened, permanently protect school trust fund lands near Crooked Lake						x					x			x			Ongoing
								B	Sediment and Nutrient Management Erosion Control	Upstream of Thirteen Lake	x	x		x				x	x						x		
								B/C/R	Forest Management	Manage forests for proper forest health and function	x					x		x									
0701010205 03 Shingobee River	**Zonation Model: High conservation potential around Shingobee Lake due to fisheries at risk, high groundwater**	**VIGILANCE (North); PROTECT/ ENHANCE (South-west)**	Shingobee Lake (29004300); Howard Lake (11047200)	Hubbard Cass	Phosphorus; Dissolved Oxygen (Tullibee Protection)	Growing Season Ave. TP: Shingobee = 17.8 ppb Howard = 8.4 ppb & D.O. > 3.0 mg/L in	Maintain or reduce 5% of watershed TP load	B/R	Livestock Management	1) Manure management during spring melt for two feedlots near the outlet for Steele Lake and creek into Island Lake; 2) rotational grazing and agro-forestry management of pasture lands; 3) encourage		x	x		x										x		0-5+ years

HUC-12 Subwatershed ID- Name	HUC-12 Subwatershed Description	HUC-12 Subwatershed Protection Ranking (see below)	Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality Current Conditions	Water Quality Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
0701010205 03 Shingobee River (cont'd)	**contamination susceptibility, and high biodiversity. There is high conservation potential throughout the HUC due to groundwater contamination susceptibility. High nitrogen, phosphorus, and suspended total solids in the pasture/hay lands in western portion of HUC.**					bottom waters				livestock producers to participate in EQUIP programs.																	
								C	Land Conservation	Encourage livestock producers to participate in the Conservation Stewardship Program (CSP) and/or Agricultural Conservation Easement Program (ACEP).			x														
								B	Stream Restoration	Restore altered vegetation along Shingobee Creek at County Road 50.		x			x	x		x									
								B	Nutrient Management	Monitor septage disposal from Akeley Wastewater Treatment Plant near Shingobee Creek.				x	x												
								B	Hydrology Management	Identify deficient culverts on stream road crossings and repair as needed.		x		x		x		x									
								M	Water Quality Monitoring	Shingobee Lake to establish trends		x													x		
								B/C/R	Forest Management	Manage forests for proper forest health and function in northern portion of subwatershed.						x											
0701010205 04 Sucker Creek	**Predominantly in public and tribal ownership**	**VIGILANCE**	Lower Sucker Lake (11031300)	Cass	Phosphorus	Growing Season Ave. TP: Lower Sucker = 27.5 ppb	Maintain or reduce 5% of watershed TP load	**B**	Sediment and Nutrient Management Erosion Control	Upstream of Lower Sucker Lake	x	x				x		x		x							Ongoing
								C	Land Conservation	If threatened, permanently protect school trust fund lands near Lower Sucker Lake						x					x			x			

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality					County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	Estimated Year to Achieve Water Quality Target
ID- Name	**Description**	**Protection Ranking (see below)**				**Current Conditions**	**Goals/ Targets and Estimated % Reduction**	**Category (see key below)**	**Strategies**	**Strategy Activities/ 10-yr Milestones**																	
								B/C/R	Forest Management	Manage forests for proper forest health and function, emphasis on northern portion of subwatershed due to 2012 storm damage.	x					x		x									
0701010205 06 Portage Creek		**VIGILANCE**	Portage Lake (11020400)	Cass	Phosphorus	Growing Season Ave. TP: Portage = 25.7 ppb	Maintain or reduce 5% of watershed TP load	**B**	Sediment and Nutrient Management Erosion Control	Lakeshed of Portage Lake	x	x						x		x							Ongoing
								C	Land Conservation	If threatened, permanently protect school trust fund lands near Portage Lake.						x					x			x			
								B/C/R	Forest Management	Manage forests for proper forest health and function, emphasis on northern portion of subwatershed due to 2012 storm damage.	x					x		x									
0701010205 07 Leech Lake (Main Basin)	**On Zonation model: High conservation potential at: 1) Agency Bay/Traders Bay/Narrows, Five Mile, Sugar, Battle Pt; Otter Tail Point; Two Points of Leech Lake--all are high biodiversity areas; 2) high biological significance around all of Leech Lake; 3) fisheries at risk on May Lake; 4) high value**	**PROTECT**	Leech Lake, Main Basin (11020301); Leech Lake, Shingobee Bay (11020304); May Lake (11048200); Long Lake (11048000) Jack (11040000); Three Island Lake (11017700)	Cass	Phosphorus	Growing Season Ave. TP: Leech, Main Basin = 17.1 ppb Leech, Shingobee Bay = 17.9 ppb May = 9.1 ppb Long = 12.8 ppb Jack = 9.7 ppb Three Island = 16.1 ppb	Maintain or reduce 5% of watershed TP load	**B,R**	Stormwater management	City of Walker: mitigate stormwater reaching the lake; increase green infrastructure and infiltration; provide city and property owner education; install BMPS i.e. rain gardens; clean out stormwater retention areas adjacent to 371. Work with MNDOT on this strategy.	x			x			X MNDOT					x					5-10+ years
0701010205 07 Leech Lake (Main Basin) (cont'd)								**B/C/R**	Forest Management	Bear Island/Leech Lake							x			x							
								C	Land Conservation	1) S Bear Island; 2) if threatened, protect school trust fund lands classified for real estate; 3) protect cultural resources.						x				x	x			x	x		

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality																					Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	
	forests south of Federal Dam and wrapping around Boy Bay; 5) school trust fund lands in high priority area on Otter Tail Point and south of Federal Dam; 6) high soil erosion risk on Ottertail peninsula.							B	Hydrology Management /Stream Restoration	1) Inventory stream road crossings; repair as identified; 2) Nelson Creek output in Uran Bay/Leech Lake	x	x				x		x									
								R	Land use Controls	Monitor Walker urban development; extraction needs for Highway 371 expansion; and shoreland zones and new plats	x			x												x	
								B/C/R	Shoreland Conservation & Stewardship; SSTS Management	All riparian areas ; septic survey of Leech Lake riparian properties	x	x														x	
								B	In-lake Management	Leech Lake	x	x							x	x						x	
								B	Sediment and Nutrient Management Erosion Control	Upstream of Leech Lake, lakesheds of Three Island, May and Long lakes.	x	x	x	x		x									x	x	
								M	Water Quality Monitoring	May and Long Lakes for trend analysis					x	x									x		
0701010206 01 Drumbeater -Leech Lake River	High conservation priority for Leech Lake River because of surrounding wetlands; high biodiversity areas around federal dam. Large portions	VIGILANCE	Drumbeater Lake (11014500)	Cass	Phosphorus	Growing Season Ave. TP: Drumbeater = 65.0 ppb	Maintain or reduce 5% of watershed TP load	B	Hydrology Management (B)	Rebuilding federal dam						x		x	x								5-10+ years
								B	Stream Restoration/ Management	Re-establish natural channel for Leech Lake River from Federal Dam to Mississippi River						x		x	x								
								B/C/R	Forest Management	Manage forests for proper forest health and function.	x					x		x									

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality																					Estimated Year to Achieve Water Quality Target
ID- Name	**Description**	**Protection Ranking (see below)**				**Current Conditions**	**Goals/ Targets and Estimated % Reduction**	**Category (see key below)**	**Strategies**	**Strategy Activities/ 10-yr Milestones**	**County**	**SWCD**	**NRCS**	**Cities/Townships**	**MPCA**	**DNR**	**Other state**	**USFS**	**ACOE**	**LLBO**	**LLAWF**	**MHB**	**MDA**	**Other NGO**	**Landowners**	**Lake Association**	
	of HUC in public ownership.							**M**	Water Quality Monitoring	Leech Lake River in relation to potential restoration of natural channel.	x					x		x									
0701010206 02 Six Mile Brook	**More than 85% of the land is in public ownership and/or tribal land. High groundwater contamination susceptibility in land area from Six Mile Lake to Mud Lake. High biodiversity areas throughout HUC.**	**VIGILANCE**	Six Mile Lake (11014600)	Cass	Phosphorus	Growing Season Ave. TP: Six Mile =19.4 ppb	Maintain or reduce 5% of watershed TP load	**B**	Sediment and Nutrient Management ; Erosion Control	Lakeshed of Six Mile Lake	x	x				x		x		x							Ongoing
								C	Land Conservation	Permanent protection of sensitive shorelands on Six Mile Lake						x					x			x			
								B/C/R	Forest Management	Manage forests for proper forest health and function.	x					x		x									
0701010206 03 Bear River	**Predominantly in public ownership**	**VIGILANCE**	Grave Lake (1108600); Goose Lake (11009600)	Cass	Phosphorus	Growing Season Ave. TP: Grave = 11.3 ppb Goose = insufficient data	Maintain or reduce 5% of watershed TP load	**B/C/R**	Forest Management	Manage forests for proper forest health and function.	x					x		x									Ongoing
0701010206 04 Leech Lake River	**Zonation Model: High groundwater contamination susceptibility and high biodiversity areas**	**VIGILANCE**	Mud Lake (11010000)	Cass	Phosphorus	Insufficient data	Maintain or reduce 5% of watershed TP load	**B**	Hydrology Management (B)	Retrofit Mud Lake Dam to enhance fish passage						x		x									5-10+ years
								C	Shoreline Conservation /Stewardship	Mud Lake	x	x								x					x		
								B/C/R	Forest Management	Manage forests for proper forest health and function.	x					x		x									

HUC-12 Subwatershed			Major Waterbodies (Lake ID) - Special Character-istics	Location and Upstream Influence Counties	Parameter (incl. non-pollutant stressors)	Water Quality																					Estimated Year to Achieve Water Quality Target
ID- Name	Description	Protection Ranking (see below)				Current Conditions	Goals/ Targets and Estimated % Reduction	Category (see key below)	Strategies	Strategy Activities/ 10-yr Milestones	County	SWCD	NRCS	Cities/Townships	MPCA	DNR	Other state	USFS	ACOE	LLBO	LLAWF	MHB	MDA	Other NGO	Landowners	Lake Association	
	throughout HUC.							B	Sediment and Nutrient Management Erosion Control	Upstream of Mud Lake	x	x		x		x		x		x							

Protection Ranking

ENHANCE - Watershed with less than 40% protected lands; more than 30% land use disturbance; multiple and/or significant risk factors; and limited resources to protect.

ENHANCE/PROTECT - Watershed with less than 40% protected lands; moderate amount of risk factors; water quality that is stable, declining, or impaired; manageable risk factors; and one or more water resources that could be protected.

PROTECT - Watershed with 40 to 65% protected lands; 8 to 30% land use disturbance; minimal risk factors; water quality that is stable or improving; and multiple high-quality resources that could be protected.

VIGILANCE - Watershed with more than 50% protected lands; less than 8% land use disturbance; and minimal risk factors.

Category Key

R = Regulate: Local, state, federal or tribal regulations for land uses and/or other practices that can lead to degradation of water quality.

B = Build/Restore: On-the-ground actions to reduce nonpoint sources of pollutants within the watershed.

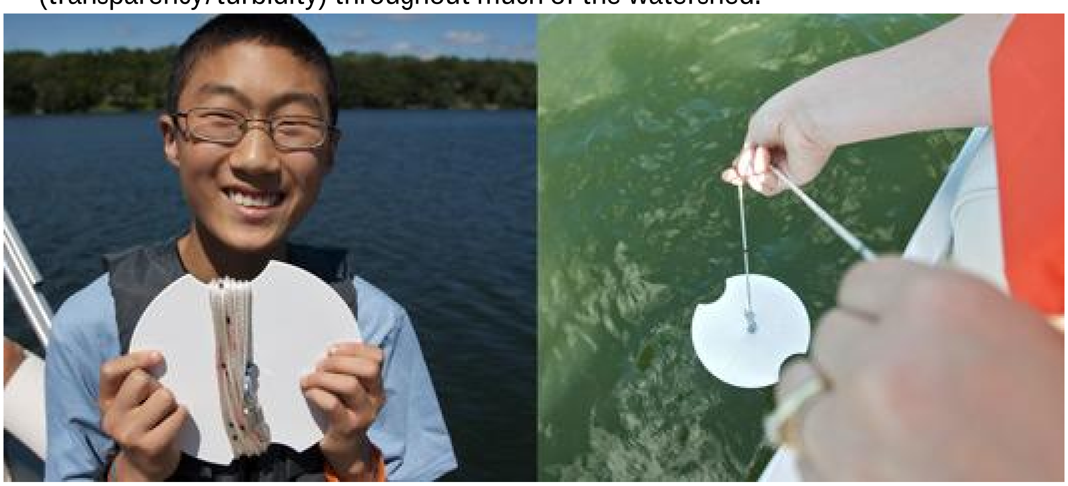
C = Conserve: Permanent or temporary land conservation that limits development and/or other land disturbing practices.

M = Monitoring: Water quality and biological monitoring to assess the quality of the waters of the watershed.

4. Monitoring Plan

Data from three monitoring programs will continue to be collected and analyzed for the LLR Watershed as part of Minnesota's Water Quality Monitoring Strategy - 2011-2021 (MPCA 2011). These monitoring programs are summarized below:

1. The IWM is the first step in the WRAPS process. Through the IWM approach, chemistry and biological data is collected throughout each major watershed once every ten years. This work is scheduled for its second iteration in the LLR Watershed in 2022. This data provides a periodic but intensive "snapshot" of water quality throughout the watershed. In addition to the monitoring conducted in association with this process, other watershed partner organizations (e.g. local, state, federal, tribal) within the watershed may have their own monitoring plan. All data collected locally should be submitted regularly to the MPCA for entry into the EQuIS database system. Based on the results of the watershed assessment/IWM process, follow up monitoring is being considered by the MPCA and watershed partners in 2016 and 2017 for the Boy River reach (S006-261) to verify DO levels and the Kabekona River reach (S006-259) to verify current *E. coli* levels.
2. The Watershed Pollutant Load Monitoring Network intensively collects pollutant samples and flow data to calculate sediment and nutrient loads on either an annual or seasonal (no-ice) basis. In the LLR Watershed, there are two subwatershed pollutant load monitoring sites. These two sites include Boy River (S006-262), Leech Lake River (S001-925).
3. The Citizen Surface Water Monitoring Program is a network of volunteers who make monthly lake and river transparency readings. Several dozen data collection locations exist within the LLR Watershed. This data provides a continuous record of one water quality parameter (transparency/turbidity) throughout much of the watershed.



In addition to the monitoring conducted in association with these processes noted above, there are other monitoring programs where data has been and will continue to be collected on surface water resources within or associated with this watershed. The programs include the following:

Sentinel Lakes Monitoring Program - Biological and chemical changes are monitored in a select sample of lakes to obtain representative data on Minnesota's most common lakes. Ten Mile Lake in Cass County is included in this monitoring program.

Ten Mile Lake - Cass County, photo courtesy of MPCA

Minnesota's Fish Contaminant Monitoring Program (MPCA 2008) - This program helps support human health and environmental protection programs within Minnesota by providing information for fish consumption, mercury cycling/trends and analysis of potential newly identified bioaccumulative pollutants.

Wetland monitoring and assessment - Wetlands are an integral part of Minnesota's water resources, and wetland monitoring information will be an essential component in the implementation of efforts to protect and restore lakes and streams.

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Leech Lake River Watershed Reports

All Leech Lake River Watershed reports referenced in this watershed report are available at the Leech Lake Watershed webpage at: https://www.pca.state.mn.us/water/watersheds/leech-lake-river

Appendix 1: Assessment status of lakes in the Leech Lake River Watershed.

Aggregated HUC-12 Subwatershed	Lake	Lake ID	Acres	Max Depth (Feet)	Aquatic Recreation Status
0701010201-01 Steamboat River	Portage	11-0490-00	360	65	FS
	Steamboat	11-0504-00	1761	93	FS
	Hart	29-0063-00	208	10.5	NS
0701010201-02 Kabekona River	Horseshoe	29-0059-00	267	15.2	FS
	Garfield	29-0061-00	954	9.1	FS
	Kabekona	29-0075-00	2435	40.5	FS
	Twenty-One	29-0130-00	33	15.7	FS
	Nelson	29-0131-00	38	5.9	FS
	Bass	29-0132-00	18	NA	FS
	McCarty	29-0224-00	12	9.8	FS
0701010205-01 Leech Lake	Three Island	11-0177-00	287	13	FS
	Leech (Main Basin)	11-0203-01	101995	150	FS
	Leech (Kabekona Bay)	11-0203-02	970	150	FS
	Leech (Ah-Gwah-Chin)	11-0203-03	65	150	IF
	Leech (Shingobee Bay)	11-0203-04	319	150	FS
	Portage	11-0204-00	1528	53	FS
	Horseshoe	11-0284-00	130	12	IF
	Pine	11-0292-00	258	25	FS
	Lower Sucker	11-0313-00	571	35	IF
	Jack	11-0400-00	141	80	FS
	Howard	11-0472-00	372	61	FS

Aggregated HUC-12 Subwatershed	Lake	Lake ID	Acres	Max Depth (Feet)	Aquatic Recreation Status
	Long	11-0480-00	273	80	FS
	May	11-0482-00	135	50	FS
	Twin	11-0484-00	162	10	FS
	Thirteen	11-0488-00	554	56	FS
	Welch	11-0493-00	190	60	FS
	Crooked	11-0494-00	551	74	FS
	Williams	29-0015-00	92	32	FS
	Shingobee	29-0043-00	168	39	FS
	Benedict	29-0048-00	471	91	FS
0701010203-01 Woman Lake	Girl	11-0174-00	414	81	FS
	Mule	11-0200-00	518	47	FS
	Broadwater Bay	11-0201-01	768	43	FS
	Woman (Main Basin)	11-0201-02	4754	60	FS
	Silver	11-0202-00	118	20	FS
	Ponto	11-0234-00	379	60	FS
	One	11-0244-00	70	35	IF
	Island	11-0257-00	183	40	FS
	Long	11-0258-00	238	37	FS
	McKeown	11-0261-00	164	37	FS
	Kid	11-0262-00	166	52	FS
	Child	11-0263-00	283	29	FS
	Kerr	11-0268-00	80	79	FS
	Lost	11-0269-00	71	26	FS
	Trillium	11-0270-00	150	48	FS
	Widow	11-0273-00	199	46	FS
	Blackwater	11-0274-00	758	67	FS
	Big Deep	11-0277-00	530	100	IF
	Sand	11-0279-00	149	54	FS
	Barnum	11-0281-00	147	29	FS

Aggregated HUC-12 Subwatershed	**Lake**	**Lake ID**	**Acres**	**Max Depth (Feet)**	**Aquatic Recreation Status**
	Man	11-0282-00	488	88	FS
	Baby	11-0283-00	729	69	FS
	Moccasin	11-0296-00	272	95	FS
	Webb	11-0311-00	718	84	FS
	Stony	11-0371-00	562	50	FS
	Larson	11-0374-00	207	58	FS
	Surprise	11-0375-00	25	73	FS
	Blueberry	11-0376-00	23	NA	IF
	Paquet	11-0381-00	134	19	FS
	Boss	11-0382-00	106	28	FS
	Pleasant	11-0383-00	1085	72	FS
	Little Webb	11-0387-00	221	37	FS
	Birch	11-0412-00	1256	45	FS
	Ten Mile	11-0413-00	5025	208	FS
	Bass	11-0474-00	274	30	FS
	Portage	11-0476-00	279	84	FS
	Crystal	11-0502-00	190	41	FS
	Diamond Pond	11-1013-00	5	NA	IF
0701010204-01 Boy River	Little Bass	11-0063-00	134	30	FS
	Big Sand	11-0077-00	730	23	FS
	Little Sand	11-0092-00	408	12	FS
	Laura	11-0104-00	1,248	5	FS
	Upper Trelipe	11-0105-00	415	69	FS
	Inguadona (N. Bay)	11-0120-01	354	76	FS
	Inguadona (S. Bay)	11-0120-02	764	76	FS
	Mabel	11-0121-00	182	14	FS
	West Twin	11-0125-00	206	5	FS
	Lower Trelipe	11-0129-00	608	32	FS
	Swift	11-0133-00	351	49	FS

Aggregated HUC-12 Subwatershed	**Lake**	**Lake ID**	**Acres**	**Max Depth (Feet)**	**Aquatic Recreation Status**
	Long (Main Basin)	11-0142-02	643	115	FS
	Long (S.W. Bay)	11-0142-04	273	115	FS
	Boy	11-0143-00	3,647	45	FS
	Rice	11-0162-00	223	30	IF
	Cooper	11-0163-00	133	70	FS
	Little Boy	11-0167-00	1423	72	FS
	McCarthy	11-0168-00	148	NA	IF
	Hunter	11-0170-00	176	48	FS
	Wabedo (N.E. Bay)	11-0171-01	577	95	FS
	Wabedo (S.W. Bay)	11-0171-02	622	95	FS
	Kego	11-0182-00	114	58	FS
	Town Line	11-0190-00	666	9	FS
0701010206-02 Bear River	Grave	11-0086-00	369	55	FS
	Knight	11-0087-00	133	10	FS
0701010206-03 Six mile Brook	Six Mile	11-0146-00	1297	68	FS
0701010206 Leech Lake River	Drumbeater	11-0145-00	398	2.6	IF

Abbreviations for Aquatic Recreation Status: **FS** = Fully Supporting; **IF** = Insufficient Information; **NS** = Non-Support. HUC 12's are listed in aggregated form to follow Leech Lake River Watershed Monitoring and Assessment Report format.

Appendix 2: MPCA and DNR Guidance Document

This document provides guidance to more systematically identify protection opportunities in Watershed Restoration and Protection Strategy (WRAPS) projects following priorities outlined in Minnesota's the Nonpoint Priority Funding Plan (NPFP). The Clean Water Accountability Act (MS 114D.24, Subd 1) and the NPFP require WRAPS to contain clear watershed protection strategies and to identify and prioritize waters at-risk.

Background

Protecting healthy watersheds and water bodies is a cost-effective strategy to ensure that the economic and ecosystem services provided by healthy waters remain intact. Preventing impairments in healthy watersheds ensures that water bodies continue to provide economic benefits to society and prevent expensive replacement and restoration costs. For example, future costs associated with the loss of natural intact systems and services can include significant expenses to construct new infrastructure to manage and treat more stormwater and drinking water or to treat wastewater. Studies from Maine and Minnesota show that home values declined by tens of thousands of dollars with declining water quality. Likewise we know that lakes and wetlands effectively trap many pollutants in their sediments. Once these systems become impaired, the internal pollutant loads become the legacy of historical practices thereby increasing the cost and complexity of restoration efforts. Finally, expenditures for protection activities help ensure that Minnesota's multi-billion dollar tourism industry will continue to thrive.

The state's environmental agencies use a watershed approach to deliver recommendations on how to protect and/or restore the quality of surface waters. The goal of the watershed approach is ambitious. The organization of protection strategies is designed to reflect the resource conditions and protection needs of individual waters while contributing to the overall health of the watershed's surface water resources. That effort includes working with local communities/resource experts to collect and organize water quality information, evaluate water quality risks (stressor ID and hydrologic modeling), develop protection and restoration goals (WRAPS), and implement prioritized and targeted implementation activities (e.g. Targeted Watersheds, 1W1P).

Minnesota's investment in water quality/water resource monitoring provides a strong foundation for organizing and delivering watershed-based strategies. Although Minnesota's surface water resources are extensive, so is the information base available to draw from. For example, the water quality assessment data that provides the foundation for the tools described in this report is currently available on over 2000 of the state's larger lakes where public use is focused. The goal of this guidance is to outline how to consolidate and organize that information to inform protection strategy development.

Given the high projected costs of restoring waters that have become impaired, it is prudent for the agencies to develop and deliver guidance on where to focus and how to be efficient with protection investments so that the number of impaired waters that need to be addressed does not continue to expand. This guidance is intended to provide state agencies and their partners with a consistent method and rationale for how to identify water bodies at risk, set reasonable goals for protection, incorporate locally held water quality values and considerations, and provide recommendations for specific protection methods that will be pursued during implementation (1W1P) phases.

The approach taken includes five discrete steps that are meant to be applied in order to any given WRAPS project. The following discussion outlines how this 5-step approach would be applied to lakes; additional guidance needs to be developed related to river/stream and wetland protection needs. The authors recognize that most of these process steps may be new to WRAPS project teams and will benefit greatly from the comments and feedback from agency staff and local partners as they begin to incorporate the guidance into their projects.

Steps 1 and 2 deal primarily with the presentation and analysis of available historical water quality data (total phosphorus, chlorophyll-a, and Secchi transparency) that are then used to examine trends and to set water quality goals for unimpaired lakes.

Step 3 establishes a score for each lake based on risk factors (proximity to the impairment threshold, long term trend data, sensitivity of the lake to future phosphorus inputs, and other factors) to produce a prioritized list of lakes for each watershed. It is the result of Step 3 that will be provided to watershed project teams during the assessment phase of each WRAPS project.

Step 4 brings additional information to the WRAPS protection strategy development re: the perceived value of individual aquatic resources for consideration alongside of the priotization-based information from Step 3. The Nonpoint Priority Funding Plan (NPFP) acknowledges that values are a part of the decision making process and specifically calls out recreation, aesthetic, and economic values as important considerations. Local partners, citizens and other stakeholders provide key data layers and input during this step.

Step 5 uses the WQ data and values information collected in the first four steps to refine and present: 1) targeted protection strategies that will be particularly effective in a given watershed; 2) critical areas where they those strategies could be targeted; and 3) key linkages with other water quality/natural resource planning goals.

Finally, this guidance acknowledges that several similar water quality protection and risk management approaches have been or are being developed and some watersheds may already have tools in place that serve to identify and prioritize watershed protection efforts. This guidance is not intended to replace those systems but is offered as a model where it is needed to advance the state of water quality protection science in Minnesota.

Step 1: Summary of Current Water Quality Status

Approach and Rationale: Communities and organizations making decisions about where to focus water quality protection efforts need access to the most recent water quality data available and be able to relate it to thresholds used to determine impairment or support of recreation uses. For lakes, MPCA has data with various ranges of coverage and different levels of certainty. The results range from water clarity estimates derived from remote sensing (satellite) data that are available for many of the state's lakes to waters that have been officially assessed, a much smaller number. It is appropriate for a WRAPS to determine which of these data sources are needed to convey an adequate assessment of the status of unimpaired lakes in a particular watershed.

Data Sources: The MPCA uses a four-tiered approach to monitoring water quality:

- Monitoring by MPCA staff;
- Monitoring by local partners such as counties, watershed districts and non-profit organizations;
- Remote sensing such as satellite imagery; and
- Volunteer citizen monitoring support

Prior to the start of a WRAPS project, staff in the Environmental Analysis and Outcomes (EAO) Division query all water quality data available in EQuIS (Minnesota's water quality data warehouse). For the summary of lakes status, the most recent 10 years of data for total phosphorus, corrected chlorophyll-a, and Secchi transparency is utilized. Analysis (both seasonal averages and long term averages) is completed using Access queries to summarize June to September data that meets the requirements for assessments (approved methods of analysis). Data on watershed area, lake morphometry, etc. are provided by CORE_WU data structures at MPCA; portions of these tables are populated by updates from DNR GIS layers. Assessment determinations are provided by the Assessment Database (soon to be WALIS). All are consolidated into the Lake TSI and Lake Year TSI tables annually. Based on the results of the EQuIS review, and prior to the start of the assessment process, EAO develops a list of lakes by watershed that are eligible for Surface Water Assessment Grants (SWAGs). SWAGs enlist local partners during the first two years of the WRAPS project to collect sufficient data to be able to conduct assessments on those lakes that lack a complete data set.

For lakes with only remote sensing data available, MPCA relies on the GIS coverage provided by the University of Minnesota Remote Sensing Laboratory with satellite inferred Secchi transparency. Due to limitations of satellite-inferred transparency based measurements (sufficient depth, bog stained water, etc.), lakes relying solely on remote sensing or Secchi transparency should be considered for additional water quality monitoring, if they are considered to be of special interest or concern by the local partner group. Additional monitoring may be accomplished through the SWAG or through the WRAPS contract itself. Typically, WRAPS project staff will consult with project partners at least one year prior to the start of a new WRAPS project to evaluate any special needs for lake monitoring.

Presentation Formats: The EAO Division will provide data to the WRAPS project manager in a tabular format (excel). The data can be sorted to display visually the proximity to the applicable water quality standard. It has historically been provided in an appendix in watershed reports. Specific guidance has not been developed for which data sources need to be incorporated into the body of the WRAPS or how that data should be displayed. Decisions about how to summarize results on the status of unimpaired lakes should be informed by the number and importance of unimpaired lakes in the watershed's aquatic resource base, the level of priority that local partners place on lake protection actions, and the data presentation framework of the rest of the WRAPS document. An example table presentation format is included for reference but alternate formats (e.g., map based) are acceptable.

Links to Other Steps: Step 1 provides data used in Step 2 and Step 3. Step 1 also relates directly to *Section 2.1 Condition Status* in the WRAPS template (copied below). It is important to note that a key purpose of step 1 is to convey where unimpaired waters fall on the continuum from highest quality to waters at the water quality impairment threshold. If there are clear patterns in lake water quality across the watershed that reflect underlying landscape conditions and/or land-use practices, displaying the data in a way that helps highlight the different areas is encouraged.

Step 1: Example – assessed lakes

Name	DNR ID	DEPTH	Lake acres	Water shed acres	Mean TP (ug/L)
Big Trout	18031500	Deep	1,363	8,150	11
Sylvan	11024600	Deep	113	3,237	13
Ada	11025000	Deep	963	8,201	13
Hen	18027000	Deep	129	251,756	13
Pig	18035400	Deep	213	465	15
Bertha	18035500	Deep	353	1,880	15
Roosevelt	11004300	Deep	1,520	26,349	15
Cross Lake Reservoir	18031200	Deep	1,813	350,769	15
Whitefish	18031000	Deep	7,969	248,558	16
Leavitt	11003700	Deep	122	8,105	19
Pine Mountain	11041100	Deep	1,612	28,249	20
Upper Hay	18041200	Deep	596	14,799	31
Island	11036000	Shallow	101	19,904	32
Norway	11030700	Shallow	515	95,111	34

TP Standard < 30 ug/L

14

[Per 114D.26, Subd. 1, (1) WRAPS shall "**identify impaired waters and waters in need of protection.**" This can mostly be done in tabular form covering the full range of conventional parameters used in assessment. However, in the narrative it is important to introduce the point that the waters that are not listed as impaired will be subject to protection efforts. More on protection considerations can be covered in section 2.5.]

Additional Information: This data can be updated as needs arise. Annual updates are planned for programmatic purposes. MPCA EAO compiles and provides this data.

Author: Pam Anderson
Recommendations to refine/enhance this guidance: Reed Larson/Terry McDill
Date: August 31, 2015

Step 2: Developing a Target for Lakes in Need of Protection

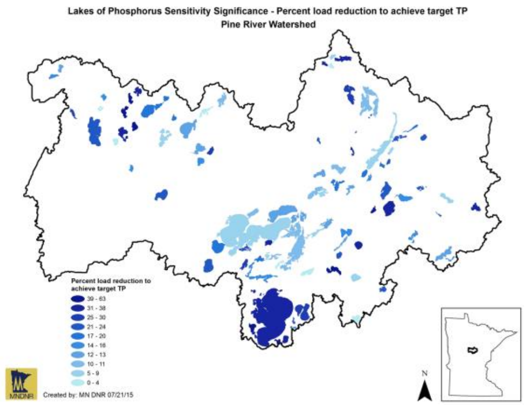
Approach and Rationale: Communities and organizations making decisions about where to focus water quality protection efforts should be provided with targets or goals to help guide their efforts. Protection efforts are designed to help ensure that the quality of highly valued waters does not degrade over time and/or that reasonable targets may be set for improvements in unimpaired waters. Because we know that lakes may exhibit time lags before pollutant inputs are fully expressed, setting goals also helps offset uncertainty in our assessment measurements. Finally, setting a protection goal helps local managers match the type of practice or approach they choose to implement with the scale of protection needed.

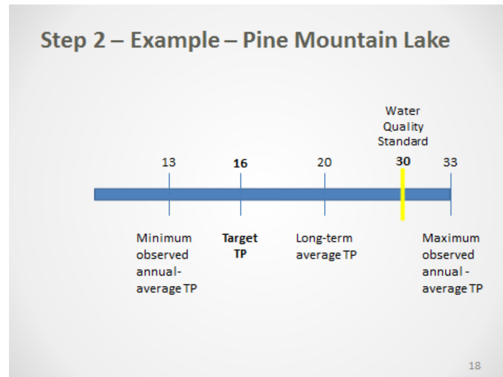
Because of the large number and wide diversity of lake types in Minnesota, our goal is to develop a target/goal that is specific to each lake. As a result, the exercise is limited to lakes with at least 8 samples for total phosphorus (equivalent to our data minimums for assessment) and the target is set based on the standard deviation of the available data. The "target TP" is set at a value below the long-term mean, with the protection goal being defined as the pounds of phosphorus reduction necessary to reach the "target TP".

Data Sources: All relevant water quality data available in EQuIS (Minnesota's water quality data warehouse) is used as input for Step 2. For this analysis, the entire period of record available for a given lake is used (2 years of data or greater), the period of record is not limited to the last 10 years. The long-term average TP value that is generated is used in a statistical model* to determine the lake's current loading rates of phosphorus. Then the standard deviation of the long-term mean TP is calculated and used to determine the target TP (Mean TP – SD of TP = Target TP) . The model is then run again with the target TP to determine the reduction in phosphorus needed to meet the target. For example, in the Pine Mountain Lake example below, the long-term measured TP had an average of 20, a standard deviation was 4, so that the target TP was set at 16.

Caveats: There are important qualifiers associated with how the data is processed and amount of input data used. The load reduction estimates have wide confidence intervals. All lake target TPs are calculated the same way (i.e. they are not customized/calibrated individually). In addition, analysis is run on lakes with as little as 2 years of data. IT IS IMPORTANT TO REVIEW the targets to make sure that they are reasonable and in line with other available information on a particular lake's status and trends before the results are finalized in a WRAPS report. WRAPS project staff should consult with EAO assessment staff with any questions or concerns about water quality targets prior to finalizing.

Presentation Formats: Data is provided in a tabular format (excel) but it is likely that graphical representations of the results will be easier for the reader to interpret. Two examples are provided below:





Links to Other Steps: Step 2 uses data from Step 1 in the calculations. It is not used in any subsequent steps. The goal of Step 2 is to provide an actionable target that is similar to the TMDL goal for waters that need to be restored. This step does not have the quantitative rigor that is required of a TMDL and it is important to convey the output from Step 2 in that context.

Additional Information: This data can be updated as needs arise. Annual updates are planned for programmatic purposes. MPCA EAO compiles and DNR analyzes this data.

Author: Pam Anderson
Recommendations to refine/enhance this guidance: Reed Larson/Terry McDill
Date: August 31, 2015

*This work is currently completed by DNR EWR.

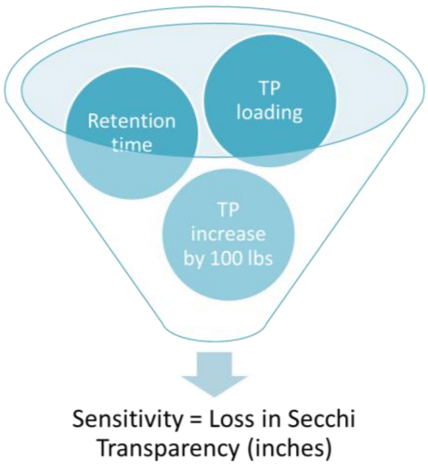
Step 3: Identifying Unimpaired Waters at Risk

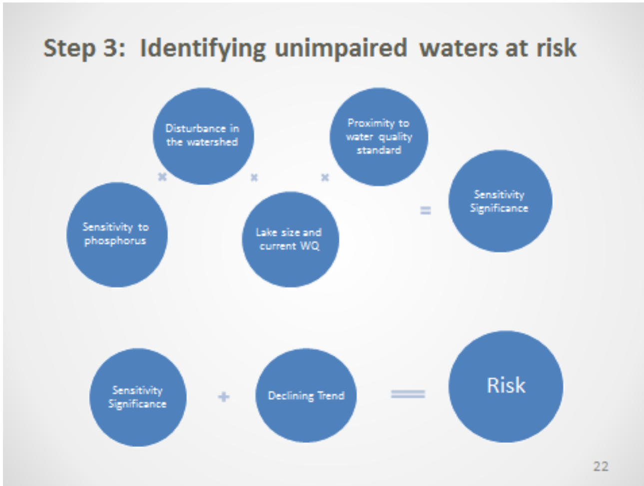
Approach and Rationale: Communities and organizations making decisions about where to focus water quality protection efforts need information on which unimpaired waters are at greatest risk for degradation to help focus protection actions. In addition, Minnesota's Nonpoint Priority Funding Plan (NPFP) identifies unimpaired waters at greatest risk as a key State consideration on where to focus Clean Water implementation funding. This step is designed to provide this key NPFP criterion for lakes.

If lakes are to be compared/ranked re: their risk of water quality degradation, that process should be based on our scientific understanding of water quality impacts and the best available data. The exercise was limited to lakes with 8+ samples for total phosphorus (equivalent to our data minimums for assessment). The developed process involves three related steps that are explained and outlined diagrammatically below:

A) Determine each lake's sensitivity to a fixed amount of increase in phosphorus loading and the resulting loss in clarity. The mass balance limnological equation that is used includes an estimate of the lake's retention time
B) An index is calculated which adjusts the lake sensitivity value from Step A which incorporates
    1) its proximity to the water quality standard
    2) the percent disturbed land use (row crop and urban) in the watershed
    3) and lake size and current phosphorus levels
C) For lakes with a declining trend in clarity, a further adjustment is made to account for this additional risk factor.

The product of steps A – C above is a score that represents the risk of degradation from additional phosphorus loading for each lake. All lakes across the state with scores are then pooled, ordered from highest to lowest score, and broken into 3 priority categories: A, B, and C. These categories are general groups; the top 25% are A, the next 25% are B and the bottom half are in category C.



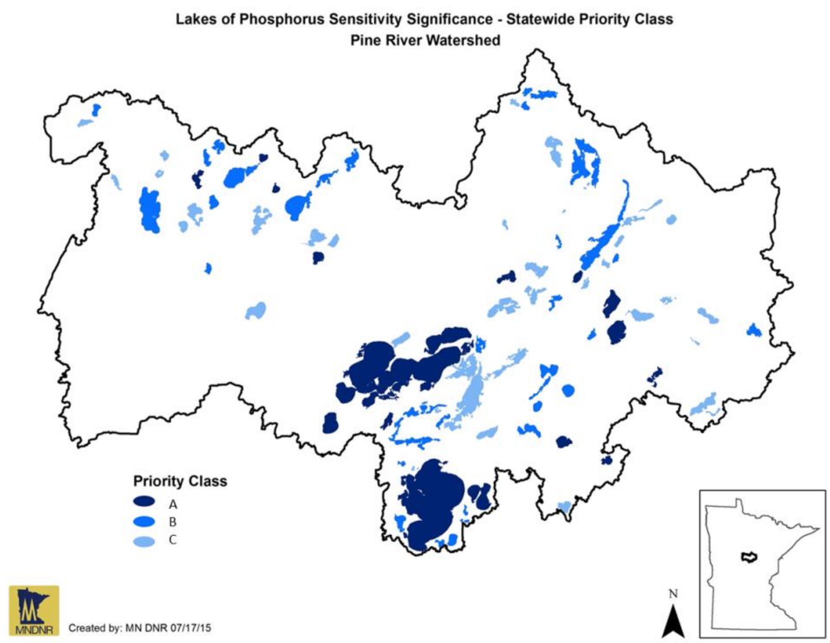


Data Sources: All relevant water quality data available in EQuIS (Minnesota's water quality data warehouse) was used to develop the risk assessment calculations outlined. For this analysis, the entire period of record is used (2 years of data or greater), not just the most recent 10 years of data. The calculated long-term average TP is used in a mass balance limnological equation to predict loading and resulting loss of clarity due to increase of 100 lbs of phosphorus. Results from the MPCA lake trend analysis (seasonal Kendall-Mann trend, calculated in R) were added to the result of the sensitivity significance equation. Watershed areas were derived by the MN DNR lake catchment layer and the percent disturbed land use was derived by determining the percent row crop and urban land use based on the 2011 National Land Cover Dataset.

Presentation Formats: Data are provided for all HUC 8 watersheds by the EAO staff in a tabular format (excel); an example is shown below. The number of lakes evaluated to determine their degradation risk from additional phosphorus loading will be updated annually as new assessment results are added to EQuIS; the EAO staff will be responsible for removing lakes that are officially designated as impaired. It may be desirable in the WRAPS to display this data graphically to help emphasize the watershed-scale patterns at risk (see example below).

Name	DNR ID	DEPTH	acres	Water shed acres	Proportion Disturbed Land Use	Mean TP (ug/L)	Secchi Trend	Priority Category
Pig	18035400	Deep	213	465	0.06	15	Decreasing	A
Bertha	18035500	Deep	353	1,880	0.14	15	Decreasing	A
Whitefish	18031000	Deep	7,969	248,558	0.12	16	Decreasing	A
Big Trout	18031500	Deep	1,363	8,150	0.07	11	None	A
Upper Hay	18041200	Deep	596	14,799	0.24	31	None	A

Sylvan	11024600	Deep	113	3,237	0.26	13	None	A
Ada	11025000	Deep	963	8,201	0.05	13	Increasing	B
Pine Mountain	11041100	Deep	1,612	28,249	0.06	20	None	B
Roosevelt	11004300	Deep	1,520	26,349	0.04	15	Increasing	B
Cross Lake Reservoir	18031200	Deep	1,813	350,769	0.10	15	None	C
Norway	11030700	Shallow	515	95,111	0.09	34	None	C
Island	11036000	Shallow	101	19,904	0.06	32	None	C
Leavitt	11003700	Deep	122	8,105	0.02	19	None	C
Hen	18027000	Deep	129	251,756	0.12	13	None	C



Caveats: Analysis is run on lakes with as little as 2 years of data. As a result, the generated priority rankings may have wide confidence intervals. IT IS IMPORTANT TO REVIEW the generated priority ranks to make sure that they are reasonable and in line with other available information on a particular lake's status and trends before the results are finalized in a WRAPS report. It is also important to remember that the sensitivity approach makes one "value" judgement. One of the multipliers adjusts sensitivity based on lake size; larger lakes are given a higher significance. This "value" adjustment was incorporated based on our work with local partners and their perspective that large lakes, in general, should be given a higher priority for water resource management actions. This analysis, based on available data and the results of 3 calculations (mass balance limnological equation, sensitivity significance, and trend), produces an objective assessment - delivered as either an “A”, “B”, or “C” priority ranking – of a lake’s risk to degradation from increased phosphorus inputs. Other qualitative values, such as economic or recreational considerations, or the anticipated conversion of land, should be considered in Step 4.

Links to Other Steps: Step 3 uses data from Step 1 in the calculations. Note, there is no comparable process to Step 3 for waters/lakes that are identified as impaired. The NPFP identifies *Restore those impaired waters that are closest to meeting state water quality standards* as a state priority for Clean Water implementation funding. Step 3 is designed to identify unimpaired waters that are at highest risk. Additional analysis would be required to evaluate and rank “impaired waters that are closest to meeting state water quality standards.”

Additional Information: This data can be updated as needs arise. Annual updates are planned for programmatic purposes. MPCA EAO compiles and DNR analyzes this data.

Author: Pam Anderson
Recommendations to refine/enhance this guidance: Reed Larson/Terry McDill
Date: August 31, 2015

*This work is completed by DNR EWR.

Step 4: Information on Lakes and Rivers that have Important Recreational, Aesthetic, or Economic Value and/or that Contribute to the Watershed's Health

Approach and Rationale: Communities and organizations making decisions about where to focus water quality protection efforts will use the results of Step 3 as a starting point. Step 4 is intended to bring additional information re: the perceived value of individual aquatic resources for consideration alongside of the WQ risk-based information from Step 3. The Nonpoint Priority Funding Plan (NPFP) acknowledges that values are a part of the decision making process and specifically calls out recreation, aesthetic, and economic values as important considerations in addition to "waters that contribute to the watershed's health." The goal of Step 4 then is to organize and deliver information or data sets about the various values of individual water resources for use in augmenting the WQ trend and risk information from Step 3.

Data Sources: The list of WQ-values information sources that can be incorporated can be extensive and will vary based on basin and ecoregion, as well as watershed-specific geographic, geologic and hydrologic considerations. Several references are available that can assist in the identification of lakes, rivers, streams, and/or wetlands in the watershed that can be considered "high value". The list of data sources can generally be divided into "Resource Agency Information" lists or data sets and "Local Partner Lists or Data Sources." Decisions on which lists or resources to assemble and incorporate during the WRAPS process will be based on the numbers and types of water resources present in a watershed, the overall condition of the aquatic resources, and the specific goals and objectives of the partners participating in the process. It should also be noted that some of this information may already exist in local water plans or 1W1P implementation plans. The WRAPS project team should determine if the compilation of this material is needed in the WRAPS document or if it already exists among local planning resources and should simply be referenced in the WRAPS document, so as not to duplicate existing efforts. Following is a partial list of some of the resources that likely will be drawn from:

Resource Agency Information

- Drinking water source protection areas
- Locations of high-value aquatic communities (e.g., DNR's list of Lakes of Biological Significance)
- Lakes with public access or DNR water trails
- Recreation or tourism data and statistics
- Stormwater pollution prevention plans (SWPPPs)

Local Partner Lists or Data Sources

- Priority waters identified in conservation plans or water plans completed by environmental or local partner groups
- Locally available economic or tourism data related to lake or surface water recreation
- Local parks or open space long range plans
- Land use or zoning maps and information showing future growth plans/patterns
- Local conservation Design or Low Impact Development (LID) ordinance language

The WRAPS project team works with local partners and other stakeholders to incorporate appropriate WQ-values data sets into the WRAPS. This may involve simply reference existing documents or plans or reproducing material from those publications directly into the WRAPS document. It is not required that the various types of WQ-values data sets be ranked or prioritized. The goal is that high value waters information is identified and easily accessible for future implementation planning.

Development of more detailed Step 4 guidance on data sources is intended to be iterative and adaptive. Feedback from WRAPS project teams will be used to improve future guidance on how to best organize and present Step 4 results to enhance the usability of the information for local decision-makers.

Presentation Formats: A specific format for displaying or delivering information on “high value” waters will be developed during current and future WRAPS projects. Several recent WRAPS can be reviewed for examples of presentation formats that have already been developed. It is recommended that information from multiple sources, to the extent feasible, be consolidated and organized and inserted in the appropriate WRAPS template sections. For WRAPS that have included conservation planning using the Zonation process as part of their planning effort, a Zonation Map product that incorporates GIS layers of high value aquatic resources may be available for presentation purposes.

We anticipate that future WRAPS template versions will contain formatting specifically designed to incorporate WQ-values protection data. In highly complex or urban watersheds, the sheer number of data sets or information that could be included will be too great to attempt to include, other than through summaries or reference. WRAPS project teams must determine the right mix of data to attempt to summarize or include in this step. Following is an example of a table format that has been used for WRAPS projects.

Priority Ranking	HUC 12	Fisheries Area	Lakes Surveyed by DNR Fisheries: Lake Name (Identification Number)	High Value & Sensitive Water Resources	DNR Land Resources	Areas of Biodiversity & Significance	Current or Future Changes, Pressures & Risks to Condition & Quality
1	Mantrap Lake	Park Rapids	Bad Axe (29020800), Mantrap (29015100), Petit (29014700)	Mantrap Lake	Paul Bunyan State Forest	* Tullibee in Buck, Bad Axe, Mantrap * Musky in Mantrap, Bad Axe *Wild Rice in Mantrap & Sand Creek	*Shoreline Development - 5% Increase projected *Currently under 75% Upland Protected from land use conversion – 47% protected including all upstream catchments
1	Big Sand Lake	Park Rapids	Big Sand (29018500), Emma (29018600), Loon (29019000), Lower Bottle (29018000), Stocking (29017200), Upper Bottle (29014800)	Big Sand Lake	Bottle Lake AMA	* Tullibee in Big Sand, Emma, Upper and Lower Bottle *Wild Rice in Upper & Lower Bottle	*Shoreline Development - 7% increase projected *Currently under 75% Upland Protected from land use conversion – 48% protected including all upstream catchments
1	Lake of the Valley	Bemidji Detroit Lakes	Bad Medicine (3008500), Cox (15006900), Glanders (15007000), Long Lost (15006800)	Bad Medicine Lake	Bad Medicine Lake AMA, Gardner Lake WMA, White Earth State Forest	* Tullibee and Rainbow Trout in Bad Medicine Lake * Wild rice	*Shoreline Development - <1% increase projected *Currently Over 75% Upland Protected from land use conversion

Links to Other Steps: Step 4 is intended to build on the first three steps of the protection framework by providing important but independent information into the process of building a WRAPS protection strategy. Local governments and other groups, in the process of identifying protection and restoration priorities, are likely to include a variety of aquatic resource values in their decision process. In addition to guiding protection planning efforts, information gathered in Step 4 should have direct relevance for local efforts to rank their *restoration* priorities. For example, "high value" waters that are good candidates for restoration to an unimpaired status may benefit from the Step 4 analysis outlined above.

Additional Information: Local government and citizen partners will have additional information about water resource values that are typically captured in existing local water plans. It is envisioned that local water plan information should not be duplicated in the WRAPS document but be brought forward during the 1W1P implementation planning phase and updated based on the results of the WRAPS protection strategy recommendations.

Author: David Wright
Recommendations to refine/enhance this guidance: Reed Larson/Terry McDill
Date: August 31, 2015

Step 5: Recommend Implementation Strategies Tailored to Watershed-Specific Conditions and Stressors

Approach and Rationale: There is a strong interest to ensure that water quality restoration and protection actions implemented using Clean Water funds are being spent as effectively as possible; as stated in the Clean Water Accountability Act (MS 114D.26), *To ensure effectiveness and accountability in meeting the goals of this chapter.* Communities and organizations making decisions about where to focus water quality protection and what methods to use will benefit from insights the WRAPS process provides. The goal of Step #5 is to use the WQ data and values information collected in the first four steps to refine and deliver:

- targeted protection strategies that will be particularly effective in the watershed
- critical areas where they could be targeted
- and key linkages with other water quality/natural resource planning goals.

The vision is to capture the learning that has occurred during four or more years of assessment efforts, modeling runs, stressor ID studies, and strategy development discussions to identify high-leverage options that local implementers should consider. Unlike restoration strategies where the implementation table reflects a tight, one-to-one linkage between a specific set of strategies and a specific impairment, the organization of protection strategies can be more flexible and designed to reflect the resource conditions and protection needs in the watershed as a whole.

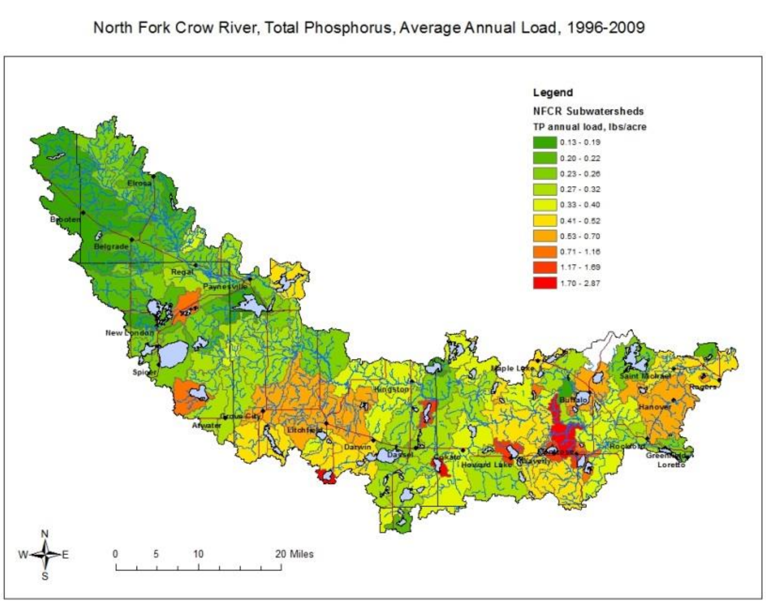
Data Sources: Data and information relevant for the targeting of watershed protection efforts is collected in Steps 1 to 4 above. Step 5 is meant to provide the final data analysis effort to select high-leverage protection implementation approaches for a watershed. It is expected that as this section is drafted in existing and future WRAPS, a generalized approach that works best for WRAPS will emerge. Much of Step 5 is based on applying what we have learned about water quality trends and risks to individual water bodies in the context of land use activities occurring around them. This Step will rely heavily on the use of GIS data sets and land use information that is available to the WRAPS project team. It is not meant to replace the more detailed implementation work that follows but to identify protection approaches and opportunities based on the best data available at the time of the WRAPS project.

The suite of protection strategies that implementers can draw from is not long or complex, and the range of protection needs is not extensive, so consistent patterns should be expected. It is further expected that regional patterns will emerge based on ecoregion, hydrological changes, or limnological factors that are common to a watershed or set of watersheds. The following list is not exhaustive but provides examples of the types of data resources that can be used for Step 5 analysis:

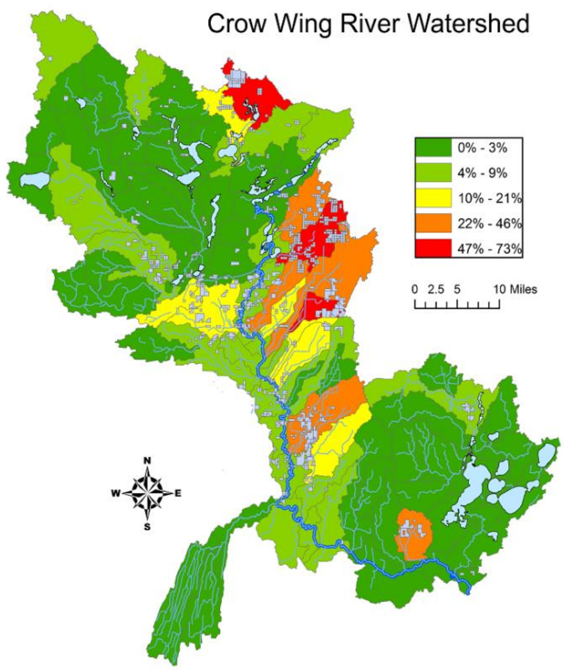
- Stressors listed in stream/river and lake stressor ID reports that are applicable in areas where protection is the priority
- Sub-watershed scale stress assessments from HSPF modeling runs
- Recommendations from other water quality or natural resource planning efforts that provide spatially explicit guidance at an appropriate scale
- Evaluation of zoning practices or land use standards that identify gaps and/or opportunities for enhancement
- DNR % Perennial Cover Index
- Impervious surface maps or remote sensed data layers
- DNR’s Habitat Framework for Lakes (Shoreline and Watershed Disturbance data)
- Local knowledge of emerging land-use activities that will require a new protection focus
- Areas with multiple conservation opportunities, e.g., as identified on zonation maps

The WRAPS project teams will need to determine when it makes sense to simply reference existing documents or plans vs. reproducing material from those publications directly into the WRAPS. It is not envisioned that an effort should be made to rank or prioritize among the various information sources. The goal is to make sure that high-leverage protection opportunities identified during the WRAPS process are presented and easily accessible to guide water quality protection implementation efforts.

These data sets, used in combination with what was learned in the risk prioritization efforts of Steps 1 through 3, and the values considerations from Step 4, should point to opportunities for high-leverage protection approaches in the watershed. Project teams should include in their analysis a rationale for the use of specific data sets in this step to guide future decision-making processes.



As an example, the HSPF subwatershed modeling example provided here allows for a quick visual comparison that can be used to generally identify watershed areas of special concern for specific water bodies. Project teams and local partners can work with MPCA HSPF modelers to evaluate at the watershed scale: 1) the efficacy of different kinds or adoption rates of protection BMPs, and 2) effects of proposed or hypothetical land use changes.



Modeled % Increase in Phosphorus Load Due to Forest Conversion

In another watershed, an HSPF scenario was run as a prediction tool for a future development scenario. The model run shows the impact of 50% of Potlatch lands being converted from forest to agriculture in the Crow Wing watershed. In the sub-watersheds where conversion was modeled, the range of average annual increase of phosphorus loading to receiving water was 0.26-0.38 lbs per acre of land converted.

In another WRAPS project, the Vermillion River WRAPS (Scott & Dakota Counties), the Vermillion River Watershed Joint Powers Organization (VRWJPO) helped develop protection strategies for unimpaired water bodies:

- The JPO is using LIDAR to map priority areas in the watershed lacking shade cover for the streams
- The JPO will target landowners in prioritized reaches to restore shoreline areas with woody cover to reduce stream temperatures
- Other model outputs were used to identify additional protection activities necessary to increase in stream aeration
- The JPO will also update local rules and water plan language to increase protections for coldwater species

Development of more detailed Step 5 guidance is intended to be iterative and adaptive. Actual WRAPS project feedback will be used to improve future guidance on how to best organize, analyze, and present Step 4 results to enhance the usability of the information for local decision-makers.

Presentation Formats: Specific formats for displaying or delivering information on tailored implementation strategies will be developed in current and future WRAPS projects. The option of organizing recommendations at one or more scales should be considered as part of this effort. The following scales are provided as examples:

HUC 8 Scale Guidance – identify major categories for protections actions that are particularly relevant for the watershed along with a table that highlights types of landscapes/activities where they would be appropriate (examples include: 1) manage nutrients and potential pollutants wisely; 2) retain/enhance watershed storage to replicate natural runoff rates and volumes to the extent possible; 3) govern land-use changes and activities in sensitive areas; and 4) enhance bridge and culvert design to improve stream connectivity and sediment transport)

Sub-watershed Scale Guidance – a version of what is described above but organize information so that subwatersheds with similar type of stressors are grouped and protection strategies are developed for each subwatershed grouping.

Prioritized Conservation Area Scale Guidance - For WRAPS that have included the conservation planning using Zonation process as part of their planning effort, protection strategy advice would be developed for the areas highlighted on the Zonation Map product.

Links to Other Steps: Step 5 output is directly linked to the WRAPS Strategies and Actions Table that is included in every WRAPS. MPCA’s current WRAPS template provides specific guidance on that table’s content and format. On the protection side, a separate, shorter table that is specifically tailored to reflect the protection needs of individual water bodies may be considered. WRAPS project teams are encouraged to consider different formatting options for displaying protection strategies based on their needs.

Additional Information: Local implementers will have access to many tools designed to help optimize where individual practices are located and new tools continue to come on-line. The strategies provided in Step 5 are not meant replace or replicate those fine-scale targeting efforts. The strategies offered in Step 5 are intended to offer watershed-scale insights into how to be effective in selecting protection strategies. What is provided in the WRAPS should be designed to inform, not replace, local targeting efforts.

Author: Dave Wright
Recommendations to refine/enhance this guidance: Reed Larson/Terry McDill
Date: August 31, 2015

The "P" in WRAPS – Protection Guidance

The MPCA and DNR recently drafted guidance to help local communities identify water quality protection needs.

Why protection guidance?

Restoring impaired waters is very expensive, while protecting a lake or stream that's in good shape is far more cost-effective. If protection dollars can be directed towards waters that are "at risk" of becoming impaired, the state can prevent the number of impaired waters from expanding, saving considerable money on restoration in the future. The MN Nonpoint Priority Funding Plan (NPFP) identifies protection as one of three high level priorities:

> *"Protect those high-quality unimpaired waters at greatest risk of becoming impaired."*

The guidance was developed so that state and local partners have a consistent method for deciding where to target protection efforts and which protection approaches are best for individual waters. The process will identify healthy lakes and rivers that are at the highest risk of becoming impaired, and offer targeted protection approaches based on the best available science.

Protection priorities and strategy recommendations will be put in Watershed Restoration and Protection Strategy (WRAPS) documents for major watersheds so that it is readily available to inform implementation plans.

How does it work?

The approach includes five discrete steps that happen during WRAPS development. This approach is for lakes; additional guidance will be developed for river/stream and wetland protection priorities. Because many of these process steps are new, feedback from WRAPS project teams will be used to refine and enhance the guidance as state and local partners begin incorporating this approach.

<u>Step 1 – Summarize current water quality</u>

Step one is a summary of existing information for non-impaired waters to create a comprehensive picture of good-quality waters in each watershed. Within each watershed, lakes are ranked by water quality.

Step 1: Example – assessed lakes

Name	DNR ID	DEPTH	Lake acres	Water shed acres	Mean TP (ug/L)
Big Trout	18031500	Deep	1,363	8,150	11
Sylvan	11024600	Deep	113	3,237	13
Ada	11025000	Deep	963	8,201	13
Hen	18027000	Deep	129	251,756	13
Pig	18035400	Deep	213	465	15
Bertha	18035500	Deep	353	1,880	15
Roosevelt	11004300	Deep	1,520	26,349	15
Cross Lake Reservoir	18031200	Deep	1,813	350,769	15
Whitefish	18031000	Deep	7,969	248,558	16
Leavitt	11003700	Deep	122	8,105	19
Pine Mountain	11041100	Deep	1,612	28,249	20
Upper Hay	18041200	Deep	596	14,799	31
Island	11036000	Shallow	101	19,904	32
Norway	11030700	Shallow	515	95,111	34

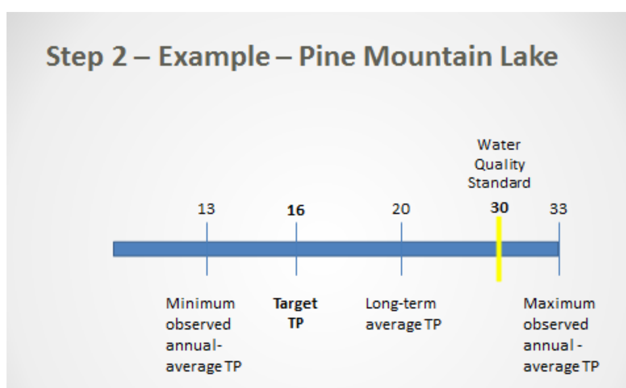
TP Standard < 30 ug/L

14

<u>Step 2 – Set a water quality protection target and a pollution reduction goal</u>

Step two identifies an individualized total phosphorus goal for lakes with enough data. The "target TP" is set below the long term mean, providing a reasonable goal for reducing phosphorus. The target is intended to be similar to Total Maximum Daily Load goals for restoration. Local partner review of the targets is important to ensure that the data analysis provides an accurate depiction of actual conditions.

The purpose of identifying the target and associated phosphorus reduction goal is to prevent clean waters from degrading over time. It will also help local partners select the right implementation options for improving their most highly-valued waters.



Step 3 – Identify unimpaired waters at greatest risk.
Step three evaluates the risk that a clean lake will become impaired in the future. Each lake with enough data gets an individualized score based its sensitivity to increases in phosphorus, along with other factors like how close the lake is to being impaired; land use in the watershed, and water quality trends for that lake.

Lakes are then assigned to prioritized groups relative to other lakes in the major watershed (“A”, “B”, and “C”’… with “A” having the highest risk). Local review is important to compare risk levels and priorities with local knowledge about each lake and the watershed.

Steps one, two, and three are processed centrally and the results are provided to watershed project teams during the assessment phase of each WRAPS project.

Step 3: Example – Pine River Watershed

Name	DNR ID	DEPTH	acres	Water shed acres	% Disturbed Land Use	Mean TP (ug/L)	Secchi Trend	Priority Category
Pig	18035400	Deep	213	465	6	15	Decreasing	A
Bertha	18035500	Deep	353	1,880	14	15	Decreasing	A
Whitefish	18031000	Deep	7,969	248,558	12	16	Decreasing	A
Big Trout	18031500	Deep	1,363	8,150	7	11	None	A
Upper Hay	18041200	Deep	596	14,799	24	31	None	A
Sylvan	11024600	Deep	113	3,237	26	13	None	A
Ada	11025000	Deep	963	8,201	5	13	Increasing	B
Pine Mountain	11041100	Deep	1,612	28,249	6	20	None	B
Roosevelt	11004300	Deep	1,520	26,349	4	15	Increasing	B
Cross Lake Reservoir	18031200	Deep	1,813	350,769	10	15	None	C
Norway	11030700	Shallow	515	95,111	9	34	None	C
Island	11036000	Shallow	101	19,904	6	32	None	C
Leavitt	11003700	Deep	122	8,105	2	19	None	C
Hen	18027000	Deep	129	251,756	12	13	None	C

26

Step 4 – Identify high-value waters as well as lakes and rivers that contribute to a watershed’s health.
The Nonpoint Priority Funding Plan acknowledges that values are a key part of the decision-making process. The plan specifically calls out recreation, aesthetic, and economic values as important considerations. Local partners, citizens, and other stakeholders provide key data, information, and input during this step.

Examples of values data include drinking water protection and groundwater sensitivity maps, biologically significant lakes, lakes with public access, waters identified in conservation plans and/or demographic, economic, and tourism data.

Step 5 – Recommend implementation strategies
Step five uses the water quality risk information and values data from previous steps to identify protection strategies that are most appropriate based on the best available science as well as knowledge of local demographics and economic factors.

The partners that participated in WRAPS will have spent a number of years assessing, analyzing, and interpreting the watershed’s water quality. Their insights and recommendations on implementation strategies that will be most effective to achieving protection goals are captured in this final step.

Products of Step five include:

1) targeted protection strategies that are most effective in a given watershed;
2) critical areas where they those strategies should be targeted; and
3) key linkages with other water quality/natural resource planning goals

See example of local impervious surface zoning map based on development of lake phosphorus goals.

Appendix 3: Leech Lake River HUC 10 & HUC 12 Units

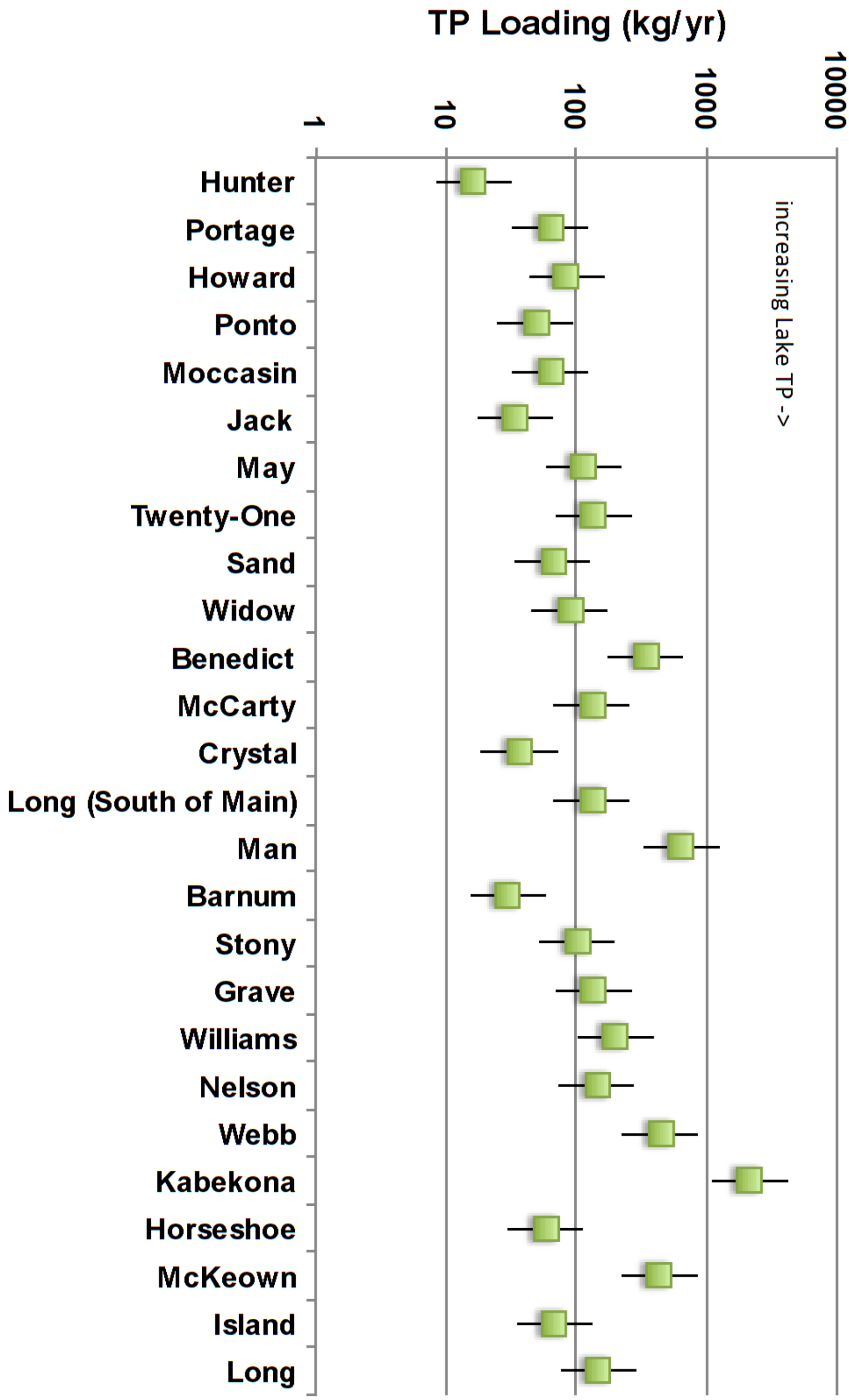
HUC 10 Name	HUC 12	HUC 12 Name
Steamboat River	070101020101	Headwaters Necktie River
	070101020102	Bungashing Creek
	070101020103	Pokety River
	070101020104	Necktie River
	070101020105	Steamboat River
Kabekona River	070101020201	Headwaters Kabekona River
	070101020202	Gulch Creek
	070101020203	Sucker Branch
	070101020204	Kabekona River
Woman Lake	070101020301	Tenmile Lake
	070101020302	Pleasant Lake-Boy River
	070101020303	Man Lake
	070101020304	Big Deep Lake-Boy River
	070101020305	Woman Lake
Boy River	070101020401	Little Boy Lake
	070101020402	Trelipe Creek
	070101020403	Inguadona Lake-Boy River
	070101020404	Long Lake-Boy River
	070101020405	Swift Lake
	070101020406	Tobique Lake
	070101020407	Boy Lake
	070101020408	Boy River
Leech Lake	070101020501	Kabekona Bay
	070101020502	Crooked Lake
	070101020503	Shingobee River
	070101020504	Sucker Creek
	070101020505	Urem Bay
	070101020506	Portage Creek
	070101020507	Leech Lake
Leech River	070101020601	Drumbeater Lake-Leech River
	070101020602	Sixmile Brook
	070101020603	Bear River
	070101020604	Leech River

Appendix 4: Lake Characteristic description, data source and categories

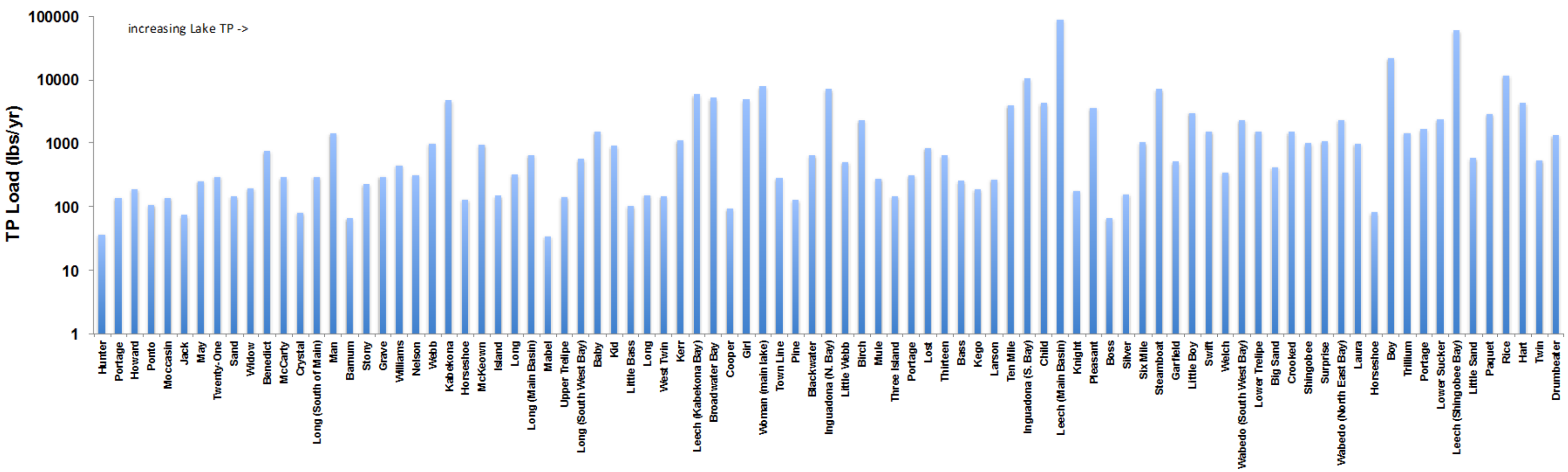
Parameter	Description	Data Source	Categories
Surface Area (ac)	The surface area of each individual lake in acres	MPCA Assessment	None
% of Depths < 15 feet	The percent of lake depths that are less than 15 feet – the depth at which aquatic plants are expected to grow	DNR	None
Tullibee	Tullibee (cisco or lake herring) are the primary forage fish for trophy walleye, northern pike, muskellunge, and lake trout. They require cold, well-oxygenated water of deep, high water quality lakes. Tullibee refuge lakes are a subset of tullibee lakes that need extra protection to insure future water quality supports tullibee populations.	The DNR Fisheries Research Unit, in conjunction with the University of Minnesota, has identified tullibee refuge lakes in Minnesota that are deep and clear enough to sustain tullibees even after climate warming occurs. These lakes need priority protection.	l indicates that the lake contains tullibee and is deep and clear enough to sustain tullibees even after climate warming
Trout	DNR designated trout lake	Minnesota Rules 6264.0050	l indicates that the lake is a DNR designated trout lake
Wild Rice	DNR designated wild rice lake	Minnesota DNR statewide inventory of wild rice waters (2008-02-15)	l indicates that the lake is a DNR designated wild rice lake
Leech Lake Band of Ojibwe Reservation	Lakes that are located in the Leech Lake Indian Reservation	Reservation boundary downloaded from MnDOT http://www.dot.state.mn.us/maps/gdma/gis-data.html or of indicated importance as identified by the Leech Lake Band of Objibwe.	l indicates that the lake is located within the boundaries of the Leech Lake Band of Ojibwe Reservation
Riparian Focus	Riparian management focus in the Chippewa National Forest, U.S. Forest Service.	Chippewa National Forest Riparian Area Health and Function Assessment *Current Conditions and Future Restoration Opportunities*	l indicates that some portion of the lake shoreline was identified as a riparian management focus area by the U.S Forest Service
In HSPF	Lakes that were explicitly modeled in the Leech Lake River Watershed HSPF model	HSPF model supporting documentation (RESPEC)	l indicates that the lake was explicitly modeled in HSPF for water quantity (lake level, volume) and quality.
Trophic Status	The trophic status is a characteristic of the frequency and severity of algae blooms.	MPCA Assessment	**Oligotrophic (O; light blue shading)** = rare or no algae blooms **Mesotrophic (M; light green shading)** = occasional algae blooms **Eutrophic (E; dark green shading)** = frequent algae blooms Blank = insufficient data to determine trophic status

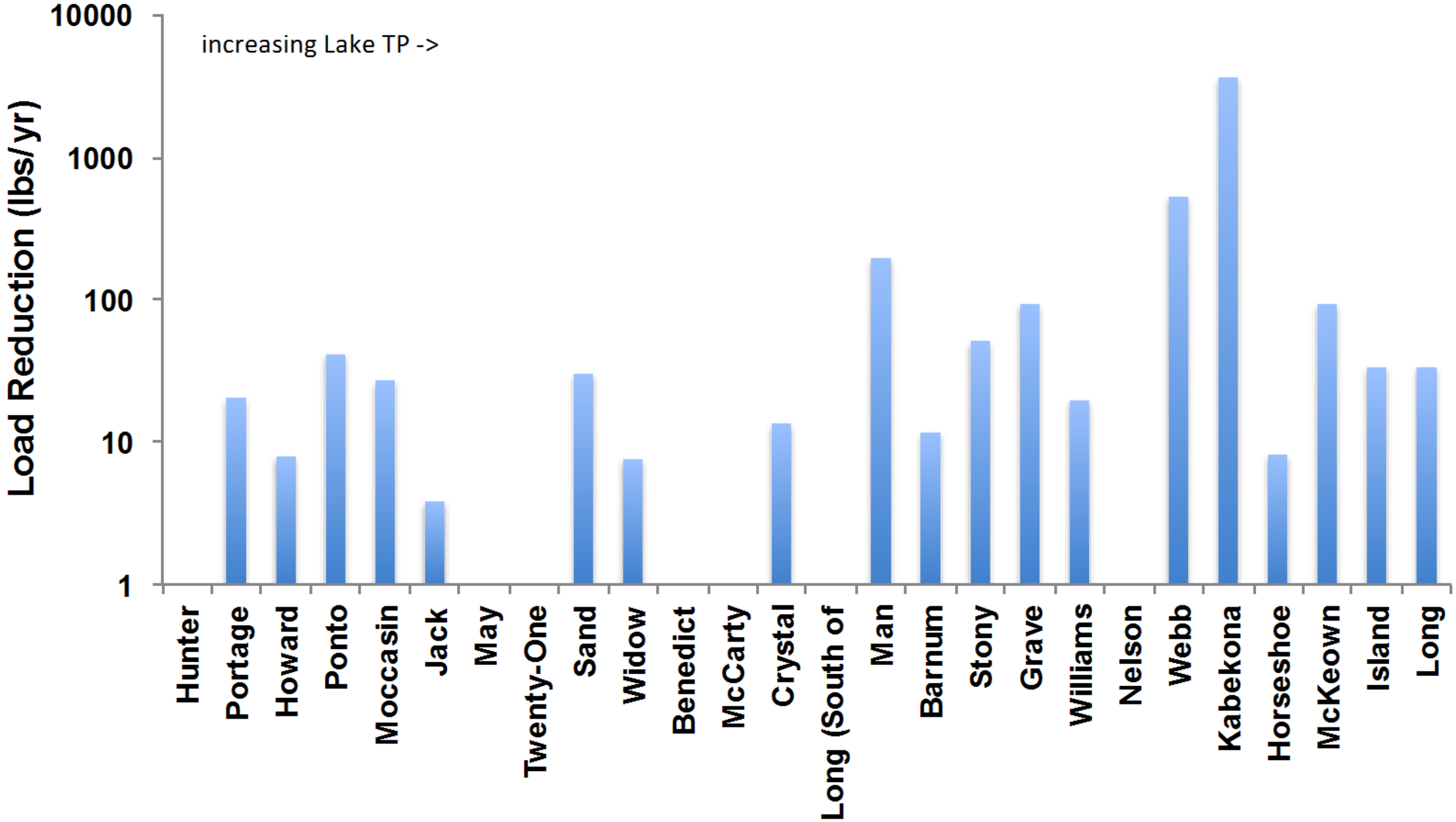
Parameter	Description	Data Source	Categories
Water Clarity Trend	Long-term trend of lake water transparency	MPCA Citizen Lake Monitoring Program (CLMP) trend analysis	**Up Arrow**: improving trend **Right Arrow**: no evidence of trend **Down Arrow**: declining trend **No Arrow**: insufficient data for trend analysis
Lakeshed Assessment	Lakeshed Assessment (Assess.) Report that summarizes lake water quality and lakeshed data but does not provide monitoring and BMPs recommendations	RMB Environmental Laboratories: Cass County Lake Water Quality (www.co.cass.mn.us/esd/water_quality.html) Crow Wing County Large Lake Assessments (crowing.us/index.aspx?NID=705)	I indicates that a Lakeshed Assessment Report is available for this lake
Sensitive Shoreland Study	Sensitive shoreline areas that provide unique or critical ecological habitat have been identified using DNR sensitive lakeshore protocols: field surveys to assess habitat quality and use by high priority animal species, an ecological model that objectively incorporates various field assessments into a sensitivity index, and the compilation and delivery of information on sensitive lakeshores to various land and resource managers.	DNR Sensitive Lakeshore Identification website: http://www.dnr.state.mn.us/eco/sli/index.html	I indicates that sensitive shorelines have been identified for this lake
Phosphorus Manage-ment Category	Phosphorus management (P Mgmt.) category is the phosphorus load source expected to drive in-lake water quality based on certain lake characteristics. These categories were used to guide selection of protection strategies.	This WRAPS study (EOR).	**Monitor (white shading)**: Existing in-lake water quality is unknown and a monitoring plan should be developed. **In-Lake (blue shading)**: In-lake water quality is expected to be most strongly influenced by in-lake aquatic plant and fish population dynamics and in-lake sediment phosphorus release (internal loading) **Upstream (orange shading)**: In-lake water quality is expected to be most strongly influenced by upstream lake phosphorus loads **Mixed (purple shading)**: In-lake water quality is expected to be equally influenced by watershed phosphorus loads and upstream lake phosphorus loads **Watershed (green shading)**: In-lake water quality is expected to be most strongly influenced by watershed phosphorus loads

Appendix 5: Phosphorus Loading, Reduction, and Sensitivity

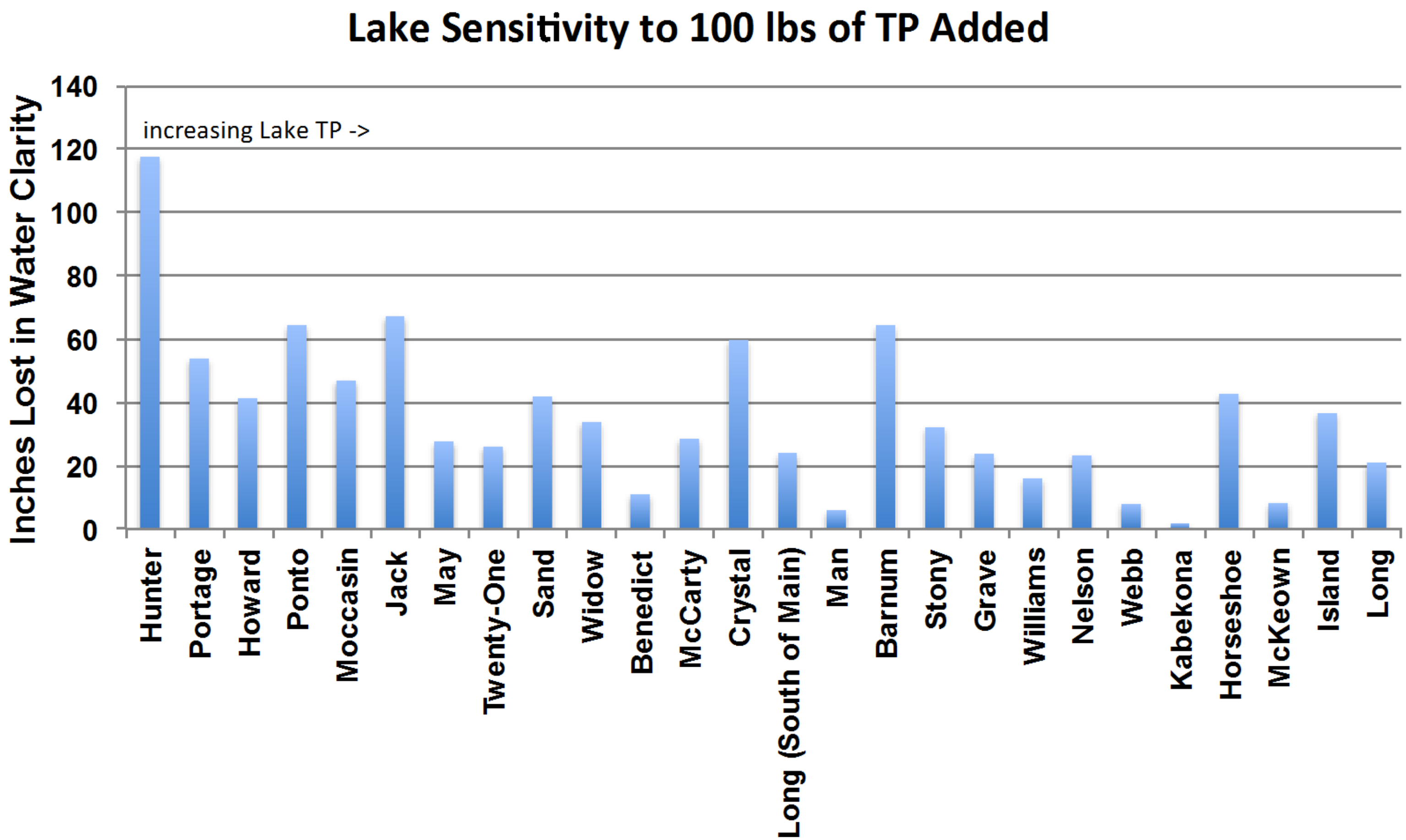


TP Loading (kg/yr)
1
10
100
1000
10000
increasing Lake TP ->
Hunter
Portage
Howard
Ponto
Moccasin
Jack
May
Twenty-One
Sand
Widow
Benedict
McCarty
Crystal
Long (South of Main)
Man
Barnum
Stony
Grave
Williams
Nelson
Webb
Kabekona
Horseshoe
McKeown
Island
Long


TP Load (lbs/yr)
100000
10000
1000
100
10
1
increasing Lake TP ->
Hunter
Portage
Howard
Ponto
Moccasin
Jack
May
Twenty-One
Sand
Widow
Benedict
McCarty
Crystal
Long (South of Main)
Man
Barnum
Stony
Grave
Williams
Nelson
Webb
Kabekona
Horseshoe
McKeown
Island
Long
Long (Main Basin)
Mabel
Upper Trelipe
Long (South West Bay)
Baby
Kid
Little Bass
Long
West Twin
Kerr
Leech (Kabekona Bay)
Broadwater Bay
Cooper
Girl
Woman (main lake)
Town Line
Pine
Blackwater
Inguadona (N. Bay)
Little Webb
Birch
Mule
Three Island
Portage
Lost
Thirteen
Bass
Kego
Larson
Ten Mile
Inguadona (S. Bay)
Child
Leech (Main Basin)
Knight
Pleasant
Boss
Silver
Six Mile
Steamboat
Garfield
Little Boy
Swift
Welch
Wabedo (South West Bay)
Lower Trelipe
Big Sand
Crooked
Shingobee
Surprise
Wabedo (North East Bay)
Laura
Horseshoe
Boy
Trillium
Portage
Lower Sucker
Leech (Shingobee Bay)
Little Sand
Paquet
Rice
Hart
Twin
Drumbeater



increasing Lake TP ->
Load Reduction (lbs/yr)
10000
1000
100
10
1
Hunter
Portage
Howard
Ponto
Moccasin
Jack
May
Twenty-One
Sand
Widow
Benedict
McCarty
Crystal
Long (South of
Man
Barnum
Stony
Grave
Williams
Nelson
Webb
Kabekona
Horseshoe
McKeown
Island
Long


Lake Sensitivity to 100 lbs of TP Added
Inches Lost in Water Clarity
increasing Lake TP ->
0
20
40
60
80
100
120
140
Hunter
Portage
Howard
Ponto
Moccasin
Jack
May
Twenty-One
Sand
Widow
Benedict
McCarty
Crystal
Long (South of Main)
Man
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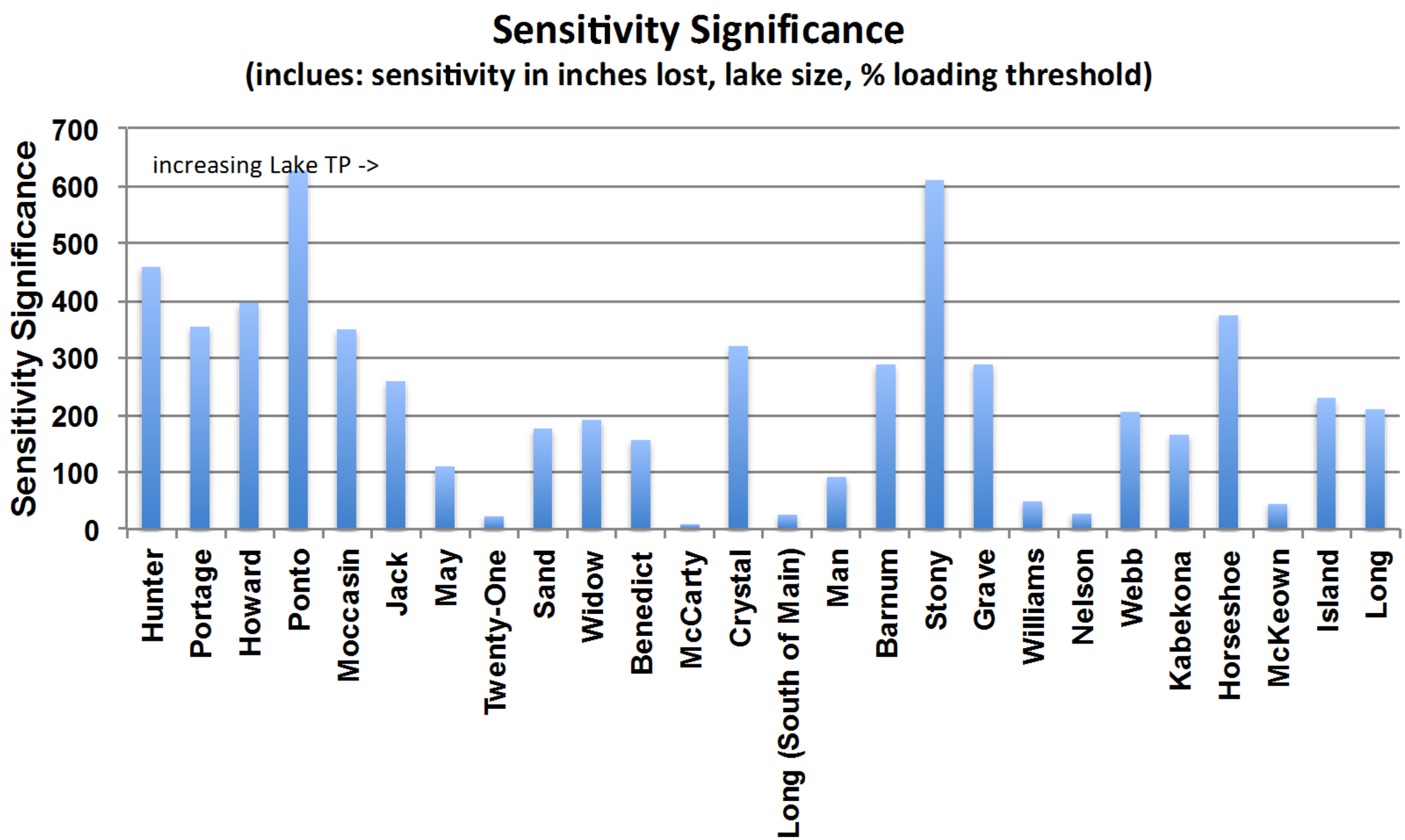
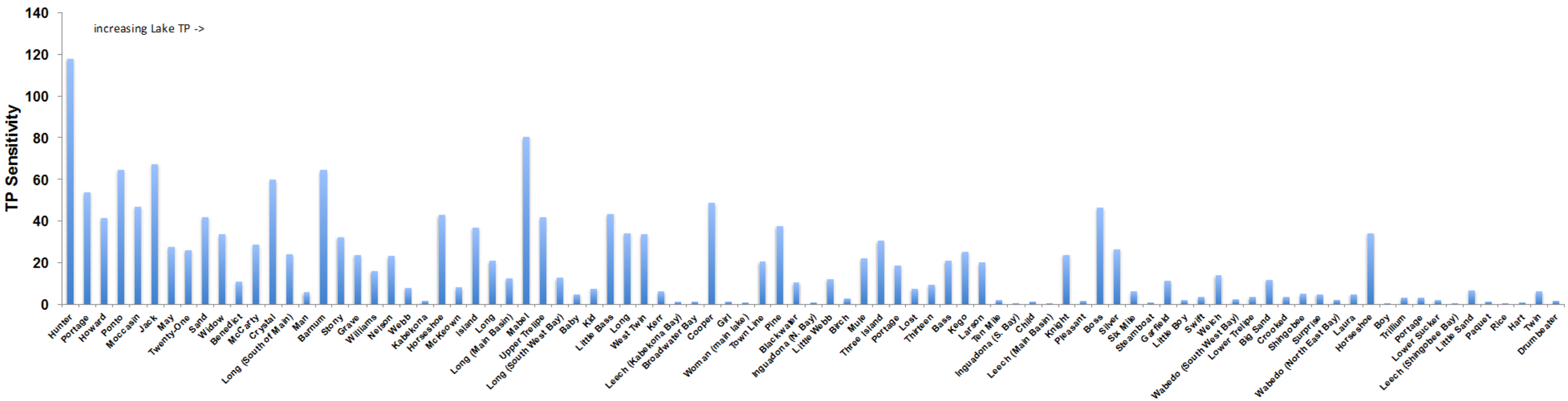
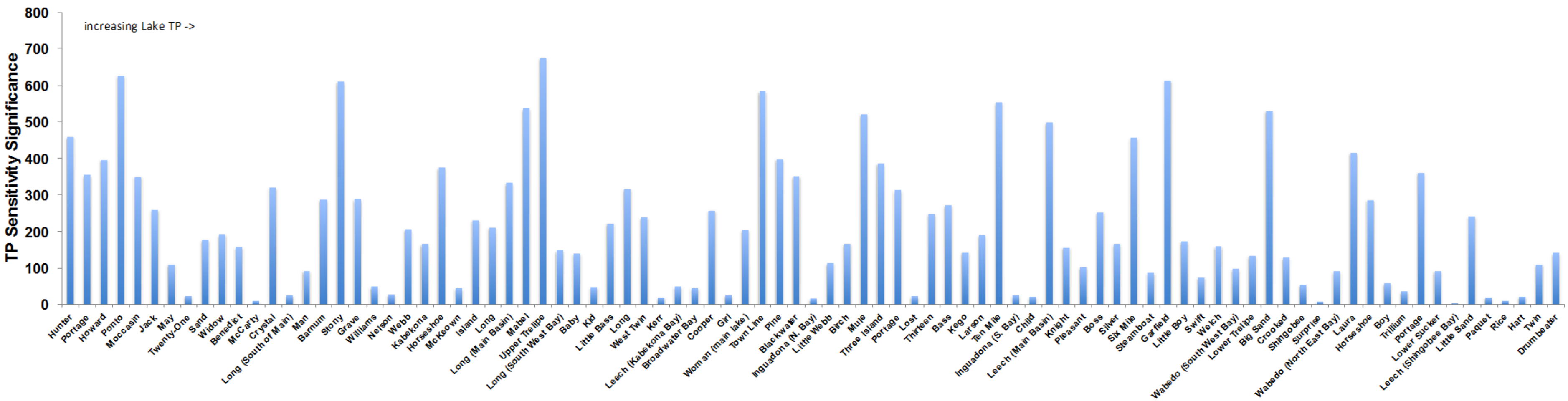
Grave
Williams
Nelson
Webb
Kabekona
Horseshoe
McKeown
Island
Long



Sensitivity Significance
(inclues: sensitivity in inches lost, lake size, % loading threshold)
Sensitivity Significance
0
100
200
300
400
500
600
700
increasing Lake TP ->
Hunter
Portage
Howard
Ponto
Moccasin
Jack
May
Twenty-One
Sand
Widow
Benedict
McCarty
Crystal
Long (South of Main)
Man
Barnum
Stony
Grave
Williams
Nelson
Webb
Kabekona
Horseshoe
McKeown
Island
Long



TP Sensitivity
140
120
100
80
60
40
20
0
increasing Lake TP ->
Hunter
Portage
Howard
Ponto
Moccasin
Jack
May
Twenty-One
Sand
Widow
Benedict
McCarty
Crystal
Long (South of Main)
Man
Barnum
Stony
Grave
Williams
Nelson
Webb
Kabekona
Horseshoe
McKeown
Island
Long
Long (Main Basin)
Mabel
Upper Trelipe
Long (South West Bay)
Baby
Kid
Little Bass
Long
West Twin
Kerr
Leech (Kabekona Bay)
Broadwater Bay
Cooper
Girl
Woman (main lake)
Town Line
Pine
Blackwater
Inguadona (N. Bay)
Little Webb
Birch
Mule
Three Island
Portage
Lost
Thirteen
Bass
Kego
Larson
Ten Mile
Inguadona (S. Bay)
Child
Leech (Main Basin)
Knight
Pleasant
Boss
Silver
Six Mile
Steamboat
Garfield
Little Boy
Swift
Welch
Wabedo (South West Bay)
Lower Trelipe
Big Sand
Crooked
Shingobee
Surprise
Wabedo (North East Bay)
Laura
Horseshoe
Boy
Trillium
Portage
Lower Sucker
Leech (Shingobee Bay)
Little Sand
Paquet
Rice
Hart
Twin
Drumbeater


TP Sensitivity Significance
increasing Lake TP ->
0
100
200
300
400
500
600
700
800
Hunter
Portage
Howard
Ponto
Moccasin
Jack
May
Twenty-One
Sand
Widow
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McCarty
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Grave
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Nelson
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Baby
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Little Bass
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Inguadona (N. Bay)
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Birch
Mule
Three Island
Portage
Lost
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Bass
Kego
Larson
Ten Mile
Inguadona (S. Bay)
Child
Leech (Main Basin)
Knight
Pleasant
Boss
Silver
Six Mile
Steamboat
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Welch
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Big Sand
Crooked
Shingobee
Surprise
Wabedo (North East Bay)
Laura
Horseshoe
Boy
Trillium
Portage
Lower Sucker
Leech (Shingobee Bay)
Little Sand
Paquet
Rice
Hart
Twin
Drumbeater

Appendix 6: HSPF Report

RESPEC

External Memorandum

To: Mr. John Ringle
Cass County Environmental Services
303 Minnesota Avenue West
Walker, MN 56484

cc: Phil Votruba, Minnesota Pollution Control Agency
MPCA Brainerd Office
7678 College Road, Suite 105
Baxter, MN 56425

Project Central File 2245 — Category A

From: Ms. Emily L. Javens, P.E.
RESPEC
1935 West County Road B2, Suite 320
Roseville, MN 55113

Date: March 9, 2015

Subject: Leech Lake River Watershed Prioritization

Developing the Watershed Restoration and Protection Strategies (WRAPS) for the Leech Lake River Watershed is underway by the Minnesota Pollution Control Agency (MPCA), Cass County Environmental Services, the Leech Lake Area Watershed Foundation, and other local partners. RESPEC is responsible for the task related to integration of HSPF products with local water plans. This memorandum summarizes the work we have completed for this component of the Leech Lake River Watershed WRAPS project.

BACKGROUND

Prioritizing areas for implementation efforts of water quality projects in the Leech Lake River Watershed requires an understanding of the existing conditions and of how projected changes, such as those from increased development and changing climate, may affect water quality in this watershed. The Leech Lake River Watershed contains some of the most pristine lakes in the state; currently all lakes and all but one stretch of the Leech Lake River meet Minnesota's surface water quality standards. The Leech Lake River Watershed contains half of Minnesota's naturally reproducing Musky (*Esox masquinongy*) lakes and the largest number of breeding eagle pairs in the lower 48 states [MPCA, 2014]. A goal of counties in the Leech Lake River Watershed (Beltrami, Cass, and Hubbard Counties) is to preserve the abundance of high-quality water resources despite being faced with the same pressures that have degraded lakes and streams in other parts of the state. These pressures include increased development from population growth. Cass County and Hubbard County have needed to place additional emphasis on addressing challenges related to population growth and increased development pressure around surface water resources [Cass County Environmental Services, 2014, and Hubbard Soil and Water Conservation District, 2012]. Beltrami County only represents 0.35 percent of the total land area in the Leech Lake River Watershed; it was assumed the development pressures in this small portion of the watershed were not significantly different from those experienced by Cass and Hubbard Counties.

To address the development pressure, Crow Wing County updated its water plan in 2013 to include a risk classification system. This system ranks the areas in each watershed that should receive the highest priority for implementation of water quality protection and improvement efforts using a decision-point flow chart

Upon review of this methodology and discussions with project team members, it was determined that RESPEC would be able to enhance this analysis by using the results of the Scenario Analysis previously completed for this project. This memorandum discusses the results of this analysis as well as the recommendations for integrating watershed protection and restoration strategies into the Cass and Hubbard County local water plans.

PRIORITIZATION METHODS

The methods used for this task incorporated two already established methodologies: (1) the risk classification used for the development of the Crow Wing County Comprehensive Water Plan and (2) the HSPF scenarios that RESPEC modeled as part of a previous project task. Some customization was required to meet the needs of the project. Therefore, only a summary of these two methods is provided here along with explanation of the customization needed to apply these methods for this analysis. Details of the risk classification methodology can be found in the Crow Wing County Comprehensive Water Plan. Details of the HSPF scenario methodology can be found in the RESPEC technical report titled “Leech Lake River Watershed Pollutant Source Assessment and Evaluation of Resource Management and Precipitation Scenarios” submitted to the Crow Wing County Soil and Water Conservation District (SWCD) in May 2014.

RISK CLASSIFICATION

Crow Wing County’s 2013 Comprehensive Water Plan included a risk classification system that ranks the areas in each watershed that should receive the highest priority for implementation of water quality improvement projects. The risk ranking is based on many factors, including the percentage of land that is protected by public ownership or conservation easements, the amount of land that is disturbed, the documented water quality trends of the waterbodies in each minor watershed, and various risk factors [Crow Wing County, 2004]. RESPEC extended this classification analysis to the Leech Lake River Watershed, making it possible for Cass, Hubbard, and Beltrami Counties to consider management of resources in a similar way.

During approximately the same period of time, RESPEC was contracted by MPCA to develop a calibrated hydrological model of the Leech Lake River Watershed that was capable of analyzing the impacts development and increased rainfall events would have on the water resources in the county.

The work completed as part of this Leech Lake River Watershed Prioritization project integrated the work previously completed by RESPEC with the risk classification methods established by Crow Wing County. Combining both methods will enable adjacent counties to evaluate the area on a watershed scale and not just a county-based evaluation system.

Risk Classification Methods

The classification system created by Crow Wing County considers variables that are indicators of preservation and/or degradation of water resources. Those indicators include:

- **Protected land use**: The percent of land in a watershed that is protected by public ownership, conservation easements, and lakes, rivers, and wetlands
- **Disturbed land cover**: The percent of land in a watershed that is disturbed by development, cultivation, pasture, and grassland
- **Water quality trends**: A factor given to the watershed based on whether or not the water resources show a pattern of declining water quality
- **Risk factors**: Threats such as agriculture as measured by the number of animal units, development, ditching and draining, presence of aquatic invasive species, and extractive uses (mining).

The risk classification system follows the flow chart in Figure 1 and results in four different categories, color coded with two shades of green and one shade each of yellow and red as follows:

- **Vigilance**: Watershed with more than 50 percent protected lands; less than 8 percent land use disturbance; and no risk factors
- **Protection:** Watershed with 40 percent to 65 percent protected lands; 8 percent to 30 percent land use disturbance; minimal risk factors; water quality that is stable or improving; and multiple high-quality resources that could be protected
- **Enhance/Protection:** Watershed with less than 40 percent protected lands; moderate amount of risk factors; water quality that is stable, declining, or impaired; manageable risk factors; and one or more water resources that could be protected
- **Enhance:** Watershed with less than 40 percent protected lands; more than 30 percent land use disturbance; multiple and/or significant risk factors; and limited resources to protect.

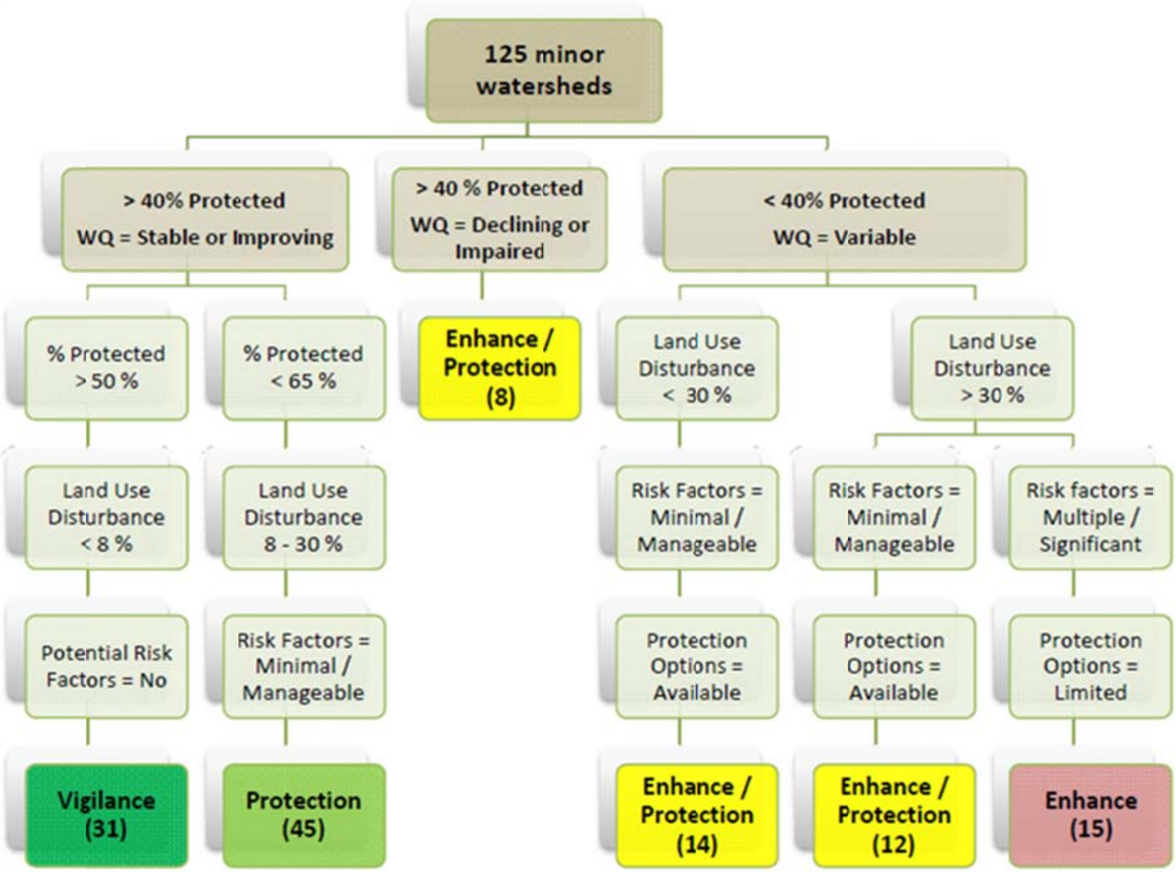

Figure 1. Risk Classification Flow Chart—Crow Wing County

RESPEC extended the risk classification approach completed in Crow Wing County into the Leech Lake River Watershed using the following steps:

1) **Determined the percentage of protected land in each minor watershed.** The watersheds that were delineated during the creation of the HSPF model were used to determine total areas. The total amount of protected land was calculated by summing the following areas:

   a. Publicly owned land—defined in the ownership code of each county's parcel data

   b. Lakes—Department of Natural Resources (DNR) public waters basins (DNR Quick Layers Geospatial Data Resource Site [GDRS])

   c. Rivers—25-foot buffer of stream centerline from Minnesota DNR public watercourses Geographic Information Systems (GIS) Layers (DNR Quick Layers GDRS)

   d. Conservation easements— Reinvest in Minnesota (RIM) and other state-funded conservation easements (DNR Quick Layers GDRS)

   e. Wetlands on private property—National Wetlands Inventory (DNR Quick Layers GDRS)

2) **Determined the water quality trends of each minor watershed.** Hubbard County and Cass County recently completed Large Lake Assessments to identify water quality trends as a result of increased development pressure [Cass County Environmental Services and Minnesota Board of Soil and Water Resources, 2012]. Total phosphorus (TP) data was evaluated to determine water quality trends. Mean trophic status index (TSI) was used to evaluate the relative health of the lake when there was not the level of TP data required to identify trends.

   Trends for TP were determined on several lakes in Hubbard County. Of these lakes, only Kabekona Lake was located in the Leech Lake River Watershed. There was not enough historical data to complete trend analysis for TP or chlorophyll *a* on any of the evaluated Cass County lakes.

   Mean TSI data was available in the Large Lake Assessment reports for lakes in Cass County and Hubbard County [Cass County Environmental Services and Minnesota Board of Soil and Water Resources, 2012, and Hubbard Soil and Water Conservation District and Minnesota Board of Soil and Water Resources, 2012]. Lakes with a mean TSI greater than 50 were identified as eutrophic. An additional review of the Large Lake Assessment reports was conducted to identify impaired lakes and lakes with aquatic invasive species. Subwatersheds that contained lakes that were classified as eutrophic, impaired, or contained invasive species were given a lower classification if the amount of protected land or disturbed land was close to the boundary between two different risk classifications.

   Kabekona Lake, Mann Lake, Ten Mile Lake, and Long Lake were identified as Cisco refuge lakes. Mann Lake was already identified as a vigilant subwatershed; therefore, a change in risk classification wasn't needed for this subwatershed. Kabekona Lake, Ten Mile Lake, and Long Lake were all identified as protection watersheds. These types of watersheds with low disturbance and high-quality fisheries are high-priority areas for implementation of protection strategies.

3) **Determined the percentage of land considered to be disturbed in each minor watershed.** The watersheds that were delineated during the creation of the HSPF model were used to determine total land areas and the total amount of disturbed land was calculated by summing the following areas that were taken from the National Land Cover Dataset (NLCD):

   a. Developed—defined by NLCD Codes 21, 22, 23, 24
   b. Cultivated—defined by NLCD Code 82
   c. Pasture/Hay—defined by NLCD Code 81
   d. Grassland—defined by NLCD Code 71

4) **Determined if risk factors were present in each minor watershed.** The total number of feedlot animal units per subwatershed and the percent of subwatershed as impervious land use were added as potential risk factors. These factors were used to place subwatersheds that were on the line between two risk classifications into an appropriate class. For example, if a subwatershed was on the border of being classified as either protection or enhance/protection, we looked at the presence of feedlots or impervious area greater than 10 percent of the subwatershed as a risk factor that would

suggest a downgrade to the lower risk classification. The absence of these factors was used to provide added evidence to keep a subwatershed at a higher risk classification.

5) **Classified each minor watershed by following the flow chart in Figure 1.**

HSPF Scenario Methods

To better understand potential trends in lake and stream TP concentrations in the Leech Lake River Watershed moving forward, stakeholders with interest in the Leech Lake River Watershed agreed upon likely risk factors/developmental pressures in the Leech Lake River Watershed. These risk factors (increased build-out within city boundaries, increased shoreland development, loss of private forest, and intensification of agriculture) were modeled in the calibrated Leech Lake River HSPF model. The HSPF model was used to complete a pollutant source assessment for the Leech Lake River Watershed and evaluate phosphorus loads to surface waters under multiple land use and climate change scenarios; a review of all scenarios is provided below.

Scenario 1: Land Use Changes Without BMPs

Scenario 1 analyzed the impacts that predicted land use changes would have on phosphorus loads delivered to the water resources if the changes occurred and no best management practices (BMPs) were implemented to mitigate the changes. The land use changes included:

- **Intensification of agriculture.** Fifteen percent of private forest land was converted to agriculture that consisted of a mix of pasture/hay and cultivated crops. In the original and new agricultural areas, more intense use of the land was simulated by lower rates of infiltration, interception, and evapotranspiration, in addition to a 50 percent increase of animal units on existing feedlots.
- **Shoreland development.** Shoreland development was simulated on all areas within 500 feet of lakes.
- **City growth.** All land within city boundaries was converted to developed lands with a 13 percent effective impervious area, which is the level of imperviousness from existing developed areas within cities in the Leech Lake River Watershed.
- **Highway 371 expansion.** Highway 371 was expanded from a two-lane to a four-lane corridor throughout the watershed.

Scenario 2: Land Use Changes With BMPs

Scenario 2 analyzed projected watershed phosphorus loads if watershed BMPs were used to mitigate the changes. The land use changes with BMPs scenario was used as a starting point and the following model inputs and parameters were used to simulate the effects of watershed BMPs.

- **Intensification of agriculture.** Better farming practices, such as rotational grazing, low-density feedlot operations, and low-till agriculture, were simulated by returning infiltration, interception, evapotranspiration rates, and feedlot animal units back to existing conditions. Furthermore, the future role of conservation easements in preserving valuable forests was simulated by not converting 15 percent of private forest to agriculture.

- **Shoreland development, city growth, and Highway 371 expansion.** The first 1.1 inches of stormwater runoff from all impervious surfaces were captured and retained by increasing the retention storage parameter by 1.1 inches. This volume is based on Minnesota's Minimal Impact Design Standards (MIDS) work group performance goal for new development.

Scenario 3: Land Use Changes With Extra BMPs

This scenario is similar to Scenario 2 but simulates additional BMPs. In addition to the simulated practices described under the first land use changes with BMPs scenario (Scenario 2), the following model inputs and parameters were used to simulate the effects of watershed BMPs:

- **50-foot shoreline buffers.** Watershed phosphorus loads from newly developed areas around the lakes were reduced by 68 percent, which assumes a high-quality, 50-foot shoreline buffer [Nieber et al., 2011].
- **Preservation of natural areas within city limits.** In Scenario 1, development was allowed to occur on all lands within city boundaries, which includes wetlands. For Scenario 3, land developed within city boundaries adhered to the following guidelines that placed a greater emphasis on preserving natural areas:
    - All wetlands within city boundaries were preserved.
    - Seventy-five percent of natural areas within city boundaries were preserved. These natural areas include forests, grassland, and all wetlands.
    - For the remaining 25 percent of areas within city boundaries, cluster development was simulated. The effective impervious area was lowered from 13 percent (in Scenarios 1 and 2) to 10 percent of the entire city boundary, and the remaining 15 percent was simulated as developed pervious areas (such as lawns). Cluster development typically has lower levels of impervious surfaces than traditional development [Center for Watershed Protection, 2000].

Scenario 4: Climate Change-Induced Precipitation Changes

In addition to anticipated land use changes, climate change is expected to affect many factors that influence water quality, including air temperature, precipitation, and land cover. Projected changes to precipitation patterns were simulated in the Leech Lake River Watershed to evaluate the impact to water quality of this one aspect of climate change. The climate change-induced precipitation changes (Scenario 4) led to a 20 percent increase in TP loads across the Leech Lake River Watershed.

The following predictions for the Leech Lake River Watershed were used as the basis of the precipitation change scenario:

- Precipitation increase of 1.4–1.7 inches per year.

- An increase of 0.4–1.1 days of heavy precipitation per year. Heavy precipitation is defined as the top 2 percent of all days with precipitation.
- 0–4 fewer dry days per year. Dry days are defined as days with less than 0.1 inch of precipitation.
- An increase of 0–0.2 inch of precipitation during the wettest 5-day period.

Scenario 5: Land Use Changes, Climate Change, and Extra BMPs

Scenario 5 represents a cumulative scenario where the land use changes of Scenario 1 were combined with the extra BMPs implemented in Scenario 3 and takes into account the climate changes modeled in Scenario 4.

Combined HSPF Scenario and Risk Classification Methods

The water quality predictions derived from each HSPF modeled scenario were incorporated into the risk assessment by replacing the trend data used for the water quality indicator component used originally with the TP load (pounds/acre/year) reaching the stream/lake in each modeled sub-watershed under each scenario. An increase in TP load greater than 100 percent from the existing baseline conditions (Figure 2) was used to identify sub-watersheds where a downgraded risk classification was likely.

RESULTS

HSPF Scenario Results—Land Use Changes

The land use changes without BMPs scenario (Scenario 1) led to an 8 percent increase in runoff volume from 365,570 acre-feet per year to 393,882 acre-feet per year and a 41 percent increase in TP loads from 74,818 pounds per year to 105,322 pounds per year relative to baseline conditions for the Leech Lake River Watershed (Figure 3). The first land use changes with BMPs scenario (Scenario 2) mitigated the increase in loads such that there was a 2 percent increase in runoff from 365,570 acre-feet per year to 371,594 acre-feet per year and a 12 percent increase in phosphorus runoff from 74,818 pounds per year to 83,636 pounds per year (Figure 4). In both Scenarios 1 and 2, the phosphorus load increases occurred primarily in the subwatersheds that intersected lakes because these are the areas where the greatest amount of land use changes occurred. The second land use changes with BMPs scenario (Scenario 3) further mitigated the increase in loads such that, when comparing the baseline to the second land use changes with BMPs scenario (Scenarios 0 and 3), the phosphorus loads increased only 4 percent from 74,818 pounds per year to 75,824 pounds per year (Figure 5).

HSPF Scenario Results—Climate Change

The climate change-induced precipitation changes led to an 18 percent increase in watershed runoff volume and TP loads across the Leech Lake River Watershed (Figure 6). The percent increase in runoff was higher than the percent increase in volume of precipitation (18 versus 6) because the precipitation increase was achieved partly through the addition of extreme

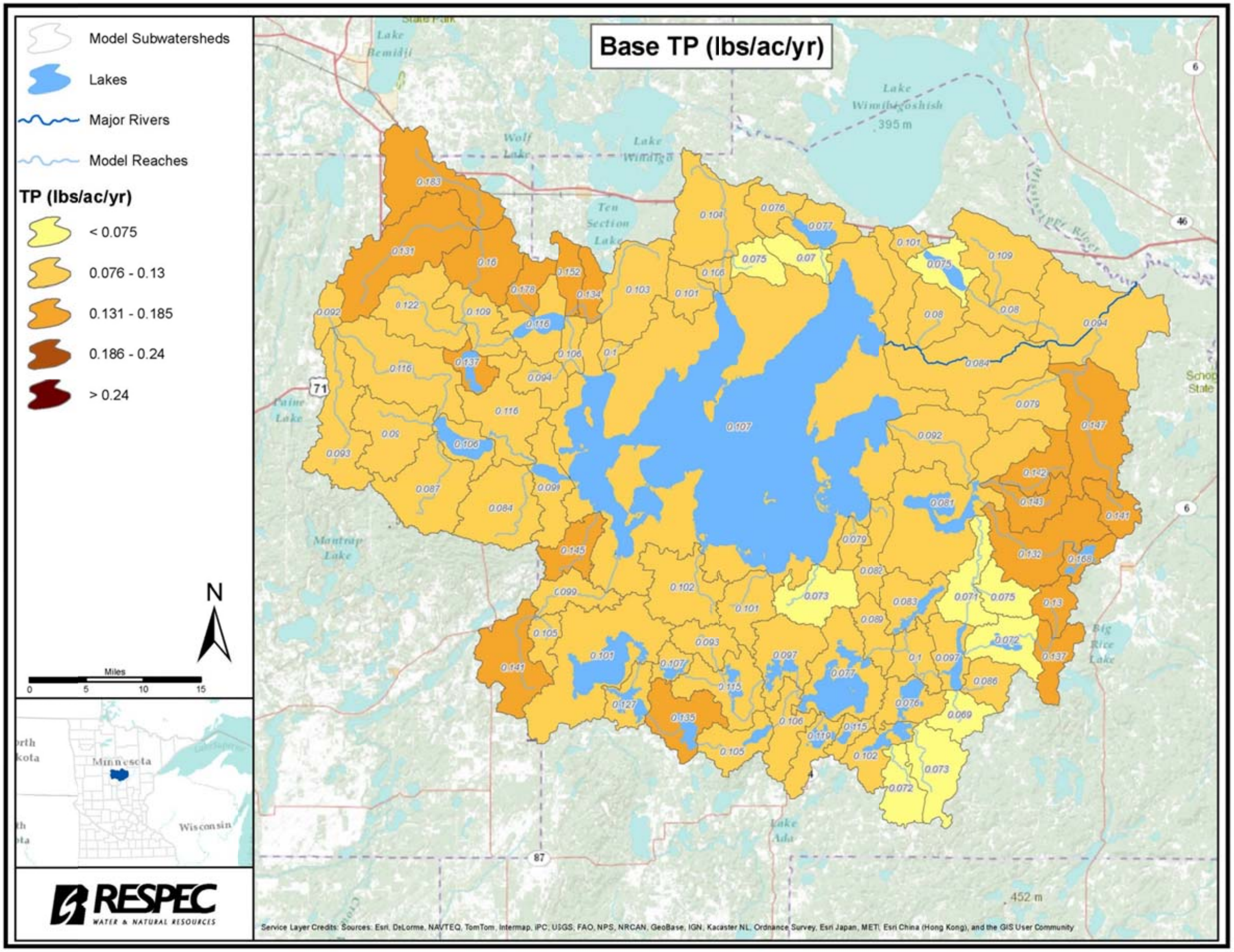

Figure 2. Baseline Phosphorus Loading.

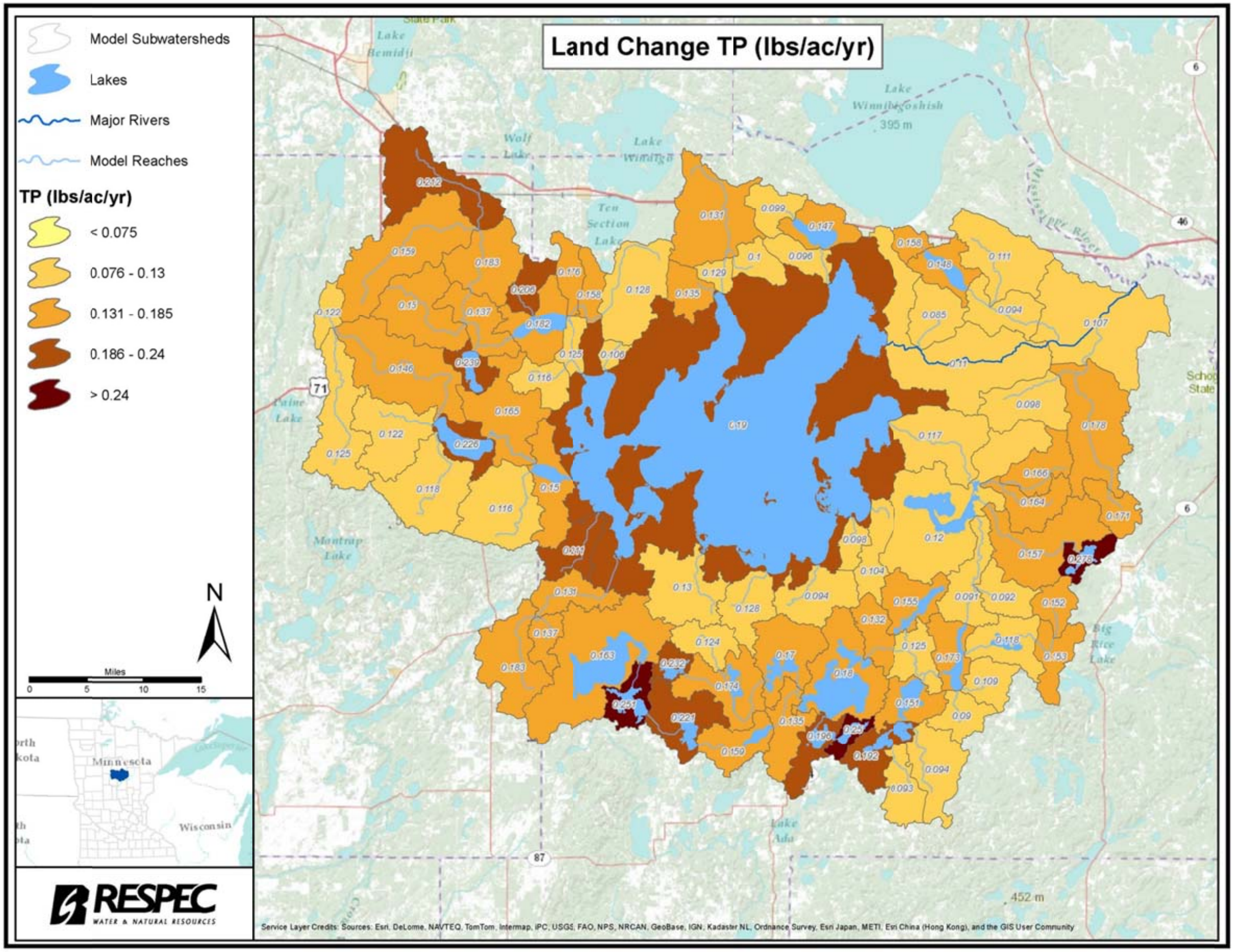

Figure 3. Scenario 1 Phosphorus Loading.

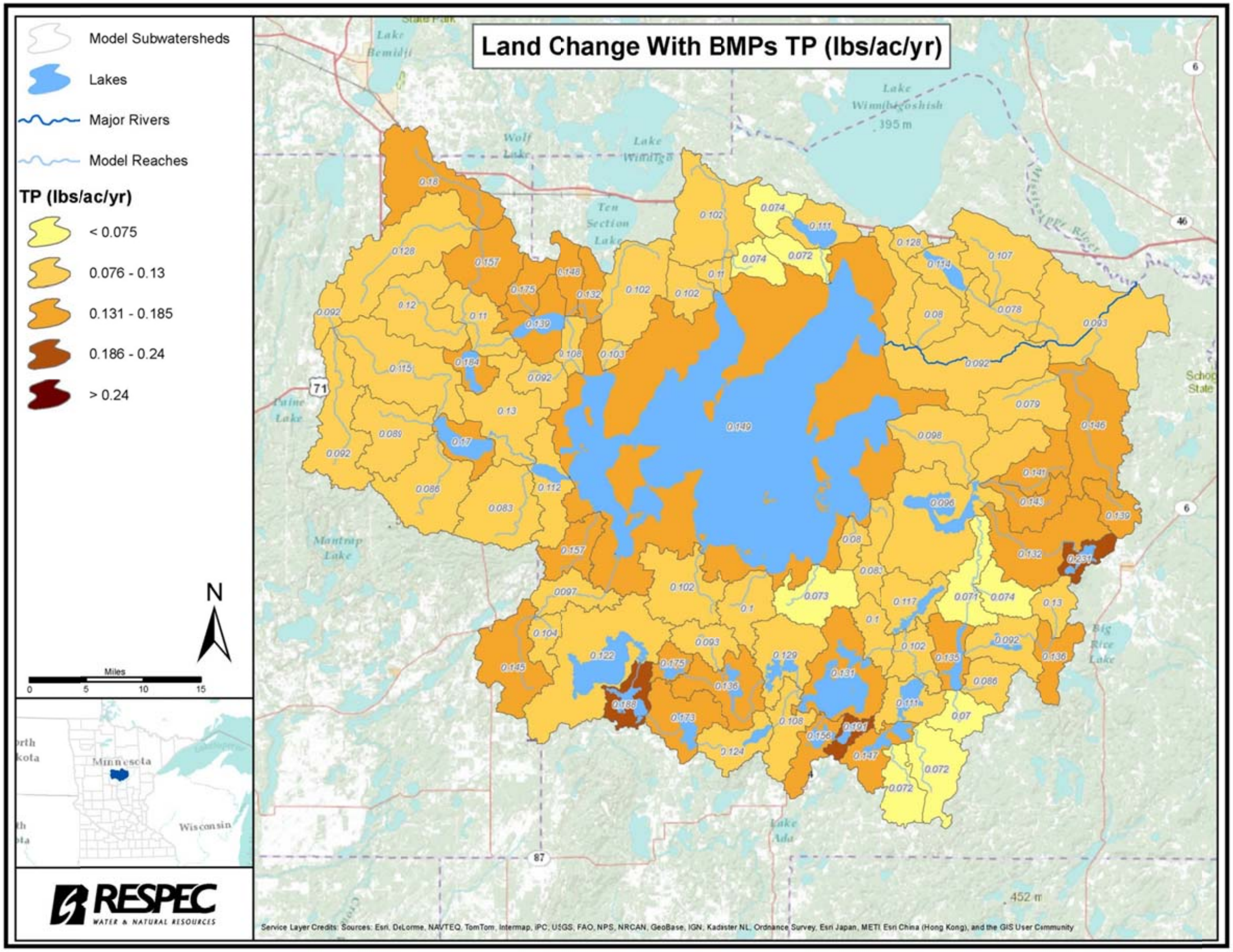

Figure 4. Scenario 2 Phosphorus Loading.

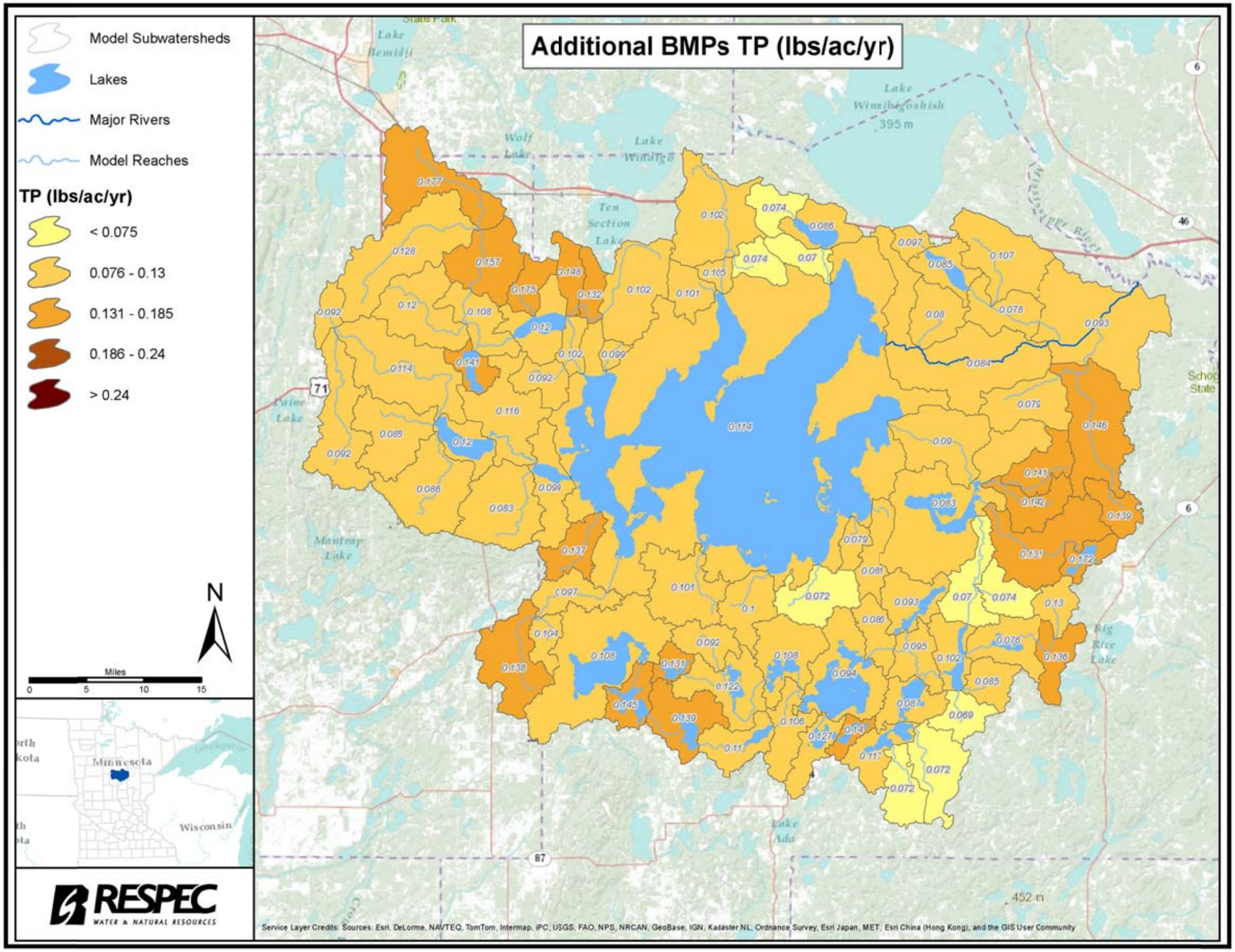

Figure 5. Scenario 3 Phosphorus Loading.

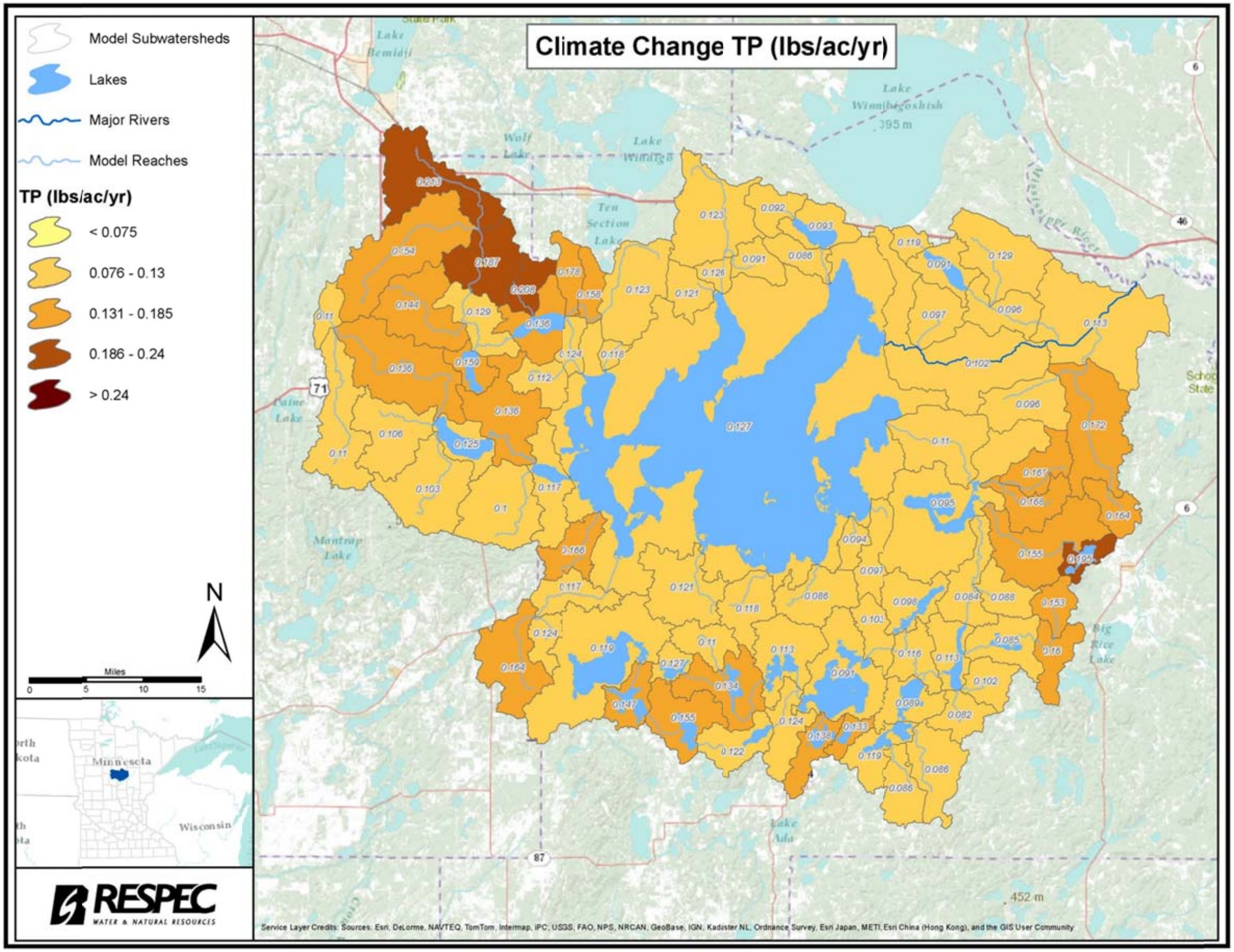

Figure 6. Scenario 4 Phosphorus Loading.

precipitation events. A greater amount of runoff is generated from extreme events relative to precipitation volume than is generated in more moderate events.

Table 1. Top Ten Subwatersheds With the Greatest Percent Change in Simulated TP Loads Under Modeled Scenarios 1, 2 and 3

Subwatershed	Scenario 1 TP Load (lbs/acre-year change)	Scenario 2 TP Load (lbs/acre-year change)	Scenario 3 TP Load (lbs/acre-year change)	Waterbody Name
72	0.135	0.077	0.025	Mule Lake
62	0.125	0.068	0.023	Stony lake
54	0.124	0.061	0.018	Birch Lake
32	0.120	0.064	0.013	Kabekona Lake
116	0.110	0.063	0.004	Big Sand Lake
78	0.103	0.054	0.017	Woman Lake
8	0.102	0.047	0.004	Garfield Lake
92	0.090	0.045	0.015	Wabedo Lake
56	0.086	0.038	0.004	Pleasant Lake
160	0.083	0.041	0.007	Leech Lake

HSPF Scenario Results—Cumulative Scenario

The BMPs in the land use change scenarios were not able to mitigate the projected increases in volumes or phosphorus loads when combined with the precipitation change scenarios; the cumulative scenario led to a 19 percent increase in runoff volumes and a 19 percent increase in phosphorus loads relative to baseline conditions (Figure 7). The BMPs in the land use change scenarios were targeted at mitigating the projected phosphorus load increases caused by intensification of agriculture, shoreland development, and city growth. The BMPs were not targeted at mitigating the runoff changes resulting from changes in precipitation patterns.

Risk Classification Results

Figure 8 shows the risk classification for the entire Leech Lake River Watershed based on current land use practices. Sixty-three of the 83 modeled subwatersheds fall under the vigilance or protection classifications, while only two subwatersheds are within the enhance classification.

Figure 9 shows the recalculation of the risk classification if the water quality trend component is replaced with the HSPF predictions of Scenario 1 (land use changes without BMPs). Once reclassified, Scenario 1 shows seven minor watersheds receiving a downgraded status. Scenarios 2 through 5 show no downgraded statuses based on a 100 percent change in TP load threshold.

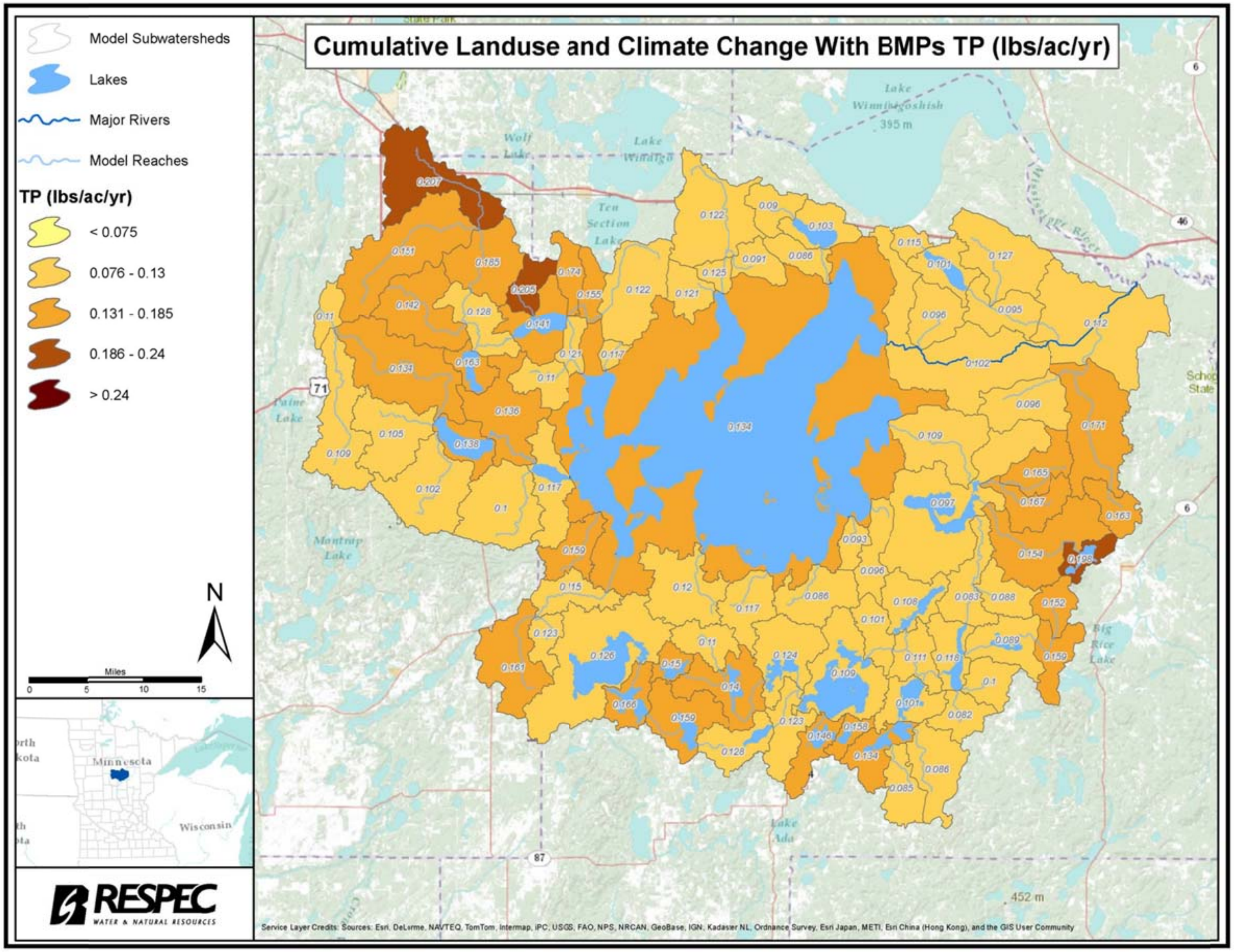

Figure 7. Scenario 5 Phosphorus Loading.

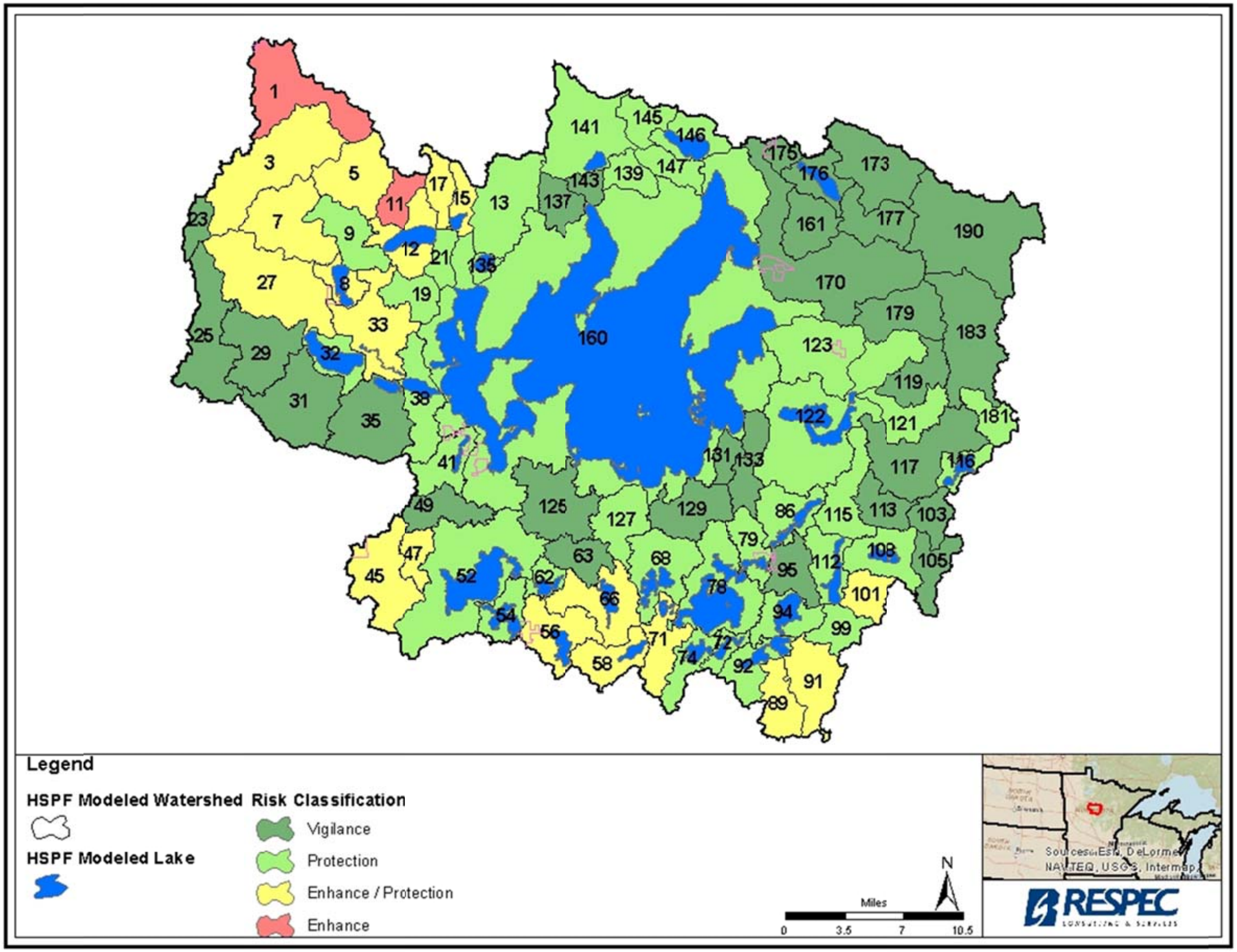

Figure 8. Subwatershed Risk Classifications for Baseline Conditions and Scenarios 2, 3, 4, and 5.

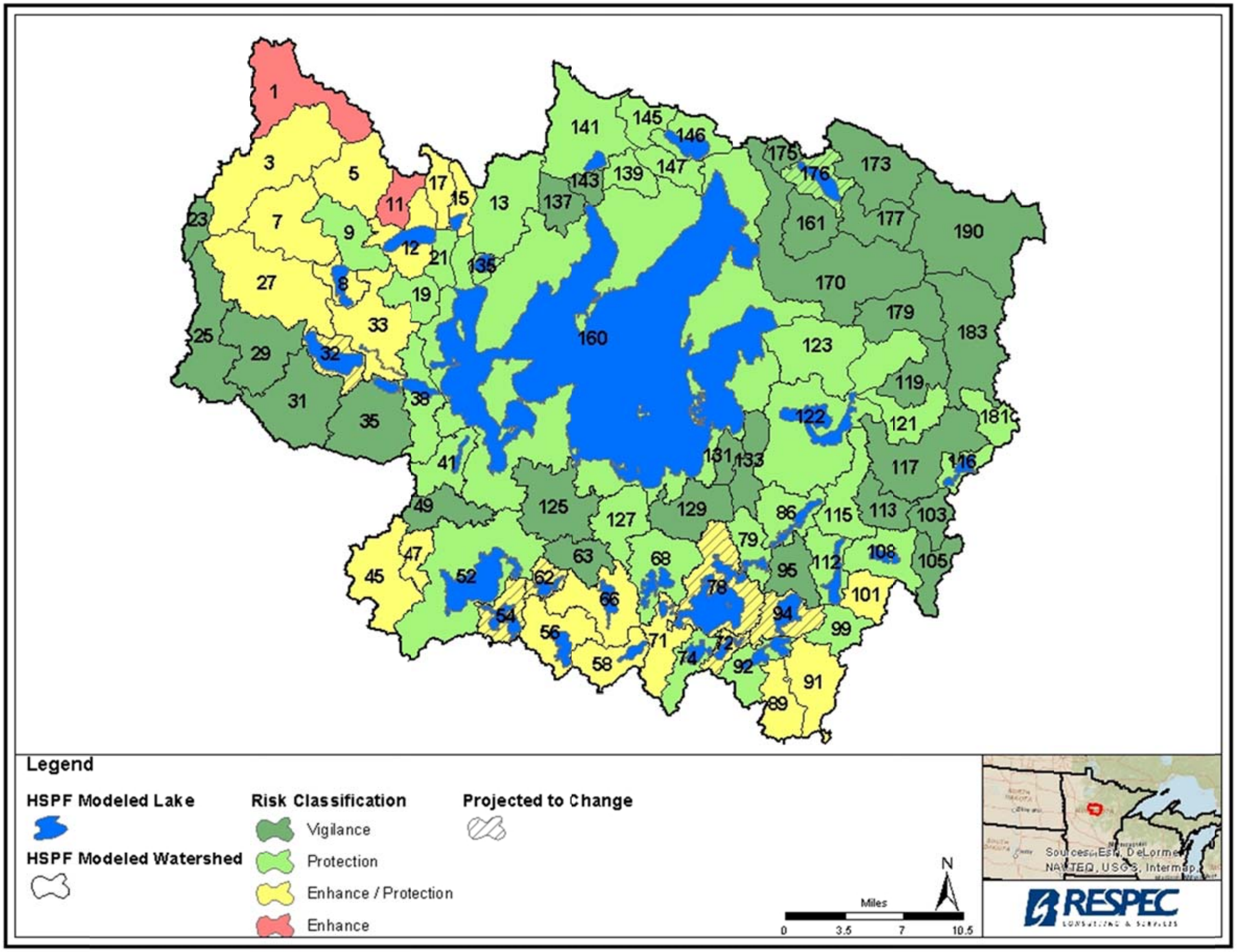

Figure 9. Subwatershed Risk Classifications for Baseline Conditions and Scenario 1.

DISCUSSION

High-quality lakes and streams such as those in the Leech Lake River Watershed may be able to tolerate occasional disturbances as long as key components of the lake system, such asriparian vegetation, macrophytes, and wetlands, are maintained and intact [Carpenter and Cottingham, 1997]. However, increases in the intensity and duration of disturbances within a waterbody's catchment or within the waterbody itself can begin to affect a waterbody's capacity to maintain these processes.

The HSPF model indicates that if all of the projected land use changes modeled in Scenario 1 occur without the implementation of BMPs to mitigate the impacts, then degradation to water resources will occur in approximately 8 percent of minor watersheds in the Leech Lake River Watershed. Implementation of the BMPs modeled in Scenario 2 (better agricultural practices and 1.1-inch retention of runoff) mitigated the increase in loads such that no watershed was projected to change its risk classification. Lakes that are on the border of becoming eutrophic (like Lower Trelipe and Little Boy Lake) may make the transition from a mesotrophic status to a eutrophic status under Scenario 2. However, if the additional BMPs modeled under Scenario 3 (50-foot shoreline buffer requirement on new development, MIDS, and natural area preservation standards) were implemented, loads increased only slightly when compared to the baseline condition and will not result in a downgraded status in any of the watersheds when evaluated by Crow Wing County's risk classification system.

Additionally, to a great degree the results of the scenario models are predicated on restricting land use changes to "eligible land," which excludes land at low risk for conversion, such as public land and land held in conservation easements. Much of the land in the Leech Lake River Watershed is at low risk of conversion. However, in the event that there are land sales, land ownership changes, or easement restrictions are removed, the potential impacts of land use conversion should be reexamined.

Combining Crow Wing County's risk classification methods with the HSPF scenario results provides valuable information for consideration by local officials when water planning efforts are underway. This analysis gives the counties an opportunity to work together with common analysis tools to manage the watershed as one unit, rather than each county stopping their work at the county line.

Integration With Comprehensive Local Water Plans

Cass County initiated the process to update its comprehensive local water plan in mid-2014. In order to facilitate the public engagement process for determining local water plan priority concerns, RESPEC facilitated a stakeholder meeting in November 2014. Stakeholders in attendance included Cass County, Hubbard County SWCD, the Leech Lake Area Watershed Foundation, Minnesota DNR, Leech Lake Band of Ojibwe, U.S. Forest Service, Minnesota Board of Water and Soil Resources, and others. The priorities in the current water plan were reviewed, progress was noted, and updates on current efforts were provided. Significant emphasis was placed on the implementation of the WRAPS programs throughout the various watersheds in the county as well as the new One Watershed, One Plan legislation recently passed. The stakeholders recommended that the updated Cass County Comprehensive Water Plan be based on the watershed approach and leverage the work completed through the WRAPS process throughout the county. The WRAPS progress and components for the watersheds in the county vary. The Crow Wing Watershed WRAPS was completed in 2014 and does not include either HSPF scenarios or zonation prioritization methodologies that help target implementation efforts. The Pine River Watershed and Leech Lake Watershed WRAPS programs occurred nearly simultaneously and will be completed in 2015. Both of these WRAPS included HSPF scenarios and zonation prioritization methodology. The Mississippi Headwaters WRAPS will contain these elements as well but will not be completed until 2016 or early 2017. Because of the varying timeframes and elements included in the WRAPS, the stakeholders recommended that Cass County incorporate the WRAPS products and look to fill gaps when possible.

The stakeholders also recommended that the water plan "nest" regulatory, educational, and implementation strategies within the objectives, goals, and actions for each watershed in the county rather than having these be discrete categories. For instance, the regulatory approach for one watershed might contain strict zoning controls on forest conversion, while others emphasize buffers in shoreland areas depending on the lands that either are or have the potential to increase pollutant loading.

Finally, while the stakeholders supported the WRAPS and One Watershed, One Plan approach, they voiced concerns that there were resources of concern that were not addressed by these approaches. Specifically, they were concerned about the impacts of climate and temperature change on coldwater regime lakes, the loss of critical habitat on the health of the ecosystem, groundwater vulnerability and availability, and groundwater/surface water interaction. The stakeholders recommended that these concerns (which are not examined in the WRAPS program) be addressed in the county water plan.

Hubbard County will be updating its comprehensive local water plan in 2015. The results of this analysis will be shared with Hubbard County in order to inform their update process.

Recommendations

The following BMPs are recommended to identify priorities in the comprehensive county water plan and for adoption by the county board in zoning ordinances in order to reduce the potential for significant degradation to water resources in the Leech Lake River Watershed:

- Incentivize improved farming practices, such as rotational grazing, low-density feedlot operations, and low-till agriculture
- Require the retention of 1.1 inches of surface runoff from all impervious surfaces
- Require 50-foot shoreline buffers for new development that occurs within 500 feet of lakes
- Preserve all wetlands and 75 percent of the natural areas within city boundaries
- Decrease the potential of forest fragmentation and conversion of forest land through setting minimal lot sizes and providing opportunities for transfer of development rights
- Decrease the effective impervious area within city limits to 10 percent, particularly through the use of cluster development in areas where natural areas are developed.

Moving forward, counties within the watershed can use the results of this work when considering the next revisions of their water plans and potential land use ordinance changes.

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LEECH LAKE RIVER WATERSHED POLLUTANT SOURCE ASSESSMENT AND EVALUATION OF RESOURCE MANAGEMENT AND PRECIPITATION SCENARIOS

Topical Report RSI-2436

prepared for

Cass County Environmental Services
303 Minnesota Avenue W
Walker, Minnesota 56484

May 2014

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Topical Report RSI-2436

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May 2014

EXECUTIVE SUMMARY

Development of the Watershed Restoration and Protection Strategies (WRAPS) for the Leech Lake River Watershed is underway by the Minnesota Pollution Control Agency (MPCA), Cass County Environmental Services, and other local partners. A hydrologic and water-quality model of the Leech Lake River Watershed was developed with HSPF for the MPCA [Kenner, 2013][1]. The HSPF model application was used to complete a pollutant source assessment for the Leech Lake River Watershed and evaluate phosphorus loads to surface waters under multiple resource management scenarios.

Average simulated phosphorus concentrations in watershed runoff are fairly low throughout the watershed, with higher rates in the northwestern portion of the watershed where agricultural practices are more intensive. Spatial patterns of nitrogen and sediment concentrations are similar. The largest source category of nutrient loading is deciduous forests, which make up approximately 49 percent of the watershed area, followed by wetlands and agriculture, which make up 27 percent and 5 percent of the watershed, respectively. The highest phosphorus, nitrogen, and sediment unit-area loading rates are from feedlots, agriculture, and developed land uses.

The following five scenarios were modeled:

- **Land change without best management practices (BMPs) (Scenario 1).** This scenario was developed to answer the question, How would the projected watershed threats affect watershed phosphorus loads if watershed BMPs were not used to mitigate the changes? The scenario incorporated shoreland development, city growth, and expansion of Highway 371.
- **Land change with BMPs (A) (Scenario 2).** This scenario was developed to answer the question, How would the projected watershed threats affect watershed phosphorus loads if watershed BMPs were used to mitigate the changes? The scenario incorporated capturing and retaining 1.1 inches of runoff from impervious surfaces.
- **Land change with BMPs (B) (Scenario 3).** This scenario is similar to the previous one but simulates additional BMPs. The scenario incorporated shoreline buffers around lakes in developed areas, wetland preservation, preservation of 75 percent of natural areas within city boundaries, and cluster development.
- **Climate change-induced precipitation changes (Scenario 4).** Climate change is expected to affect many factors that influence water quality, including air temperature,

[1] **Kenner, S. J., 2013.** *Model Development for Mississippi River Headwaters (07010101), Leech Lake River (07010102), and Pine River Watersheds (07010105),* Letter RSI(RCO)-2046/6-13/40, prepared by RESPEC, Rapid City, SD, for the Minnesota Pollution Control Agency, St. Paul, MN, June 20.

precipitation, and land cover. Projected changes to precipitation patterns were simulated in the Leech Lake River Watershed to evaluate the impact to water quality of this one aspect of climate change.

- **Cumulative scenario (Scenario 5).** A cumulative scenario was simulated by using a combination of the land change with BMPs (B) and the climate change-induced precipitation scenario.

In developed areas, the load reductions achieved through capturing and retaining 1.1 inches of runoff from all impervious surfaces were not enough to mitigate the projected increases in load from new development, which consists of over 85 percent pervious areas. When shoreline buffers were added to lakes and 75 percent of natural areas was preserved within city boundaries, the load increase in the land change scenario relative to baseline conditions was minimal.

These results apply to the specific scenarios in this project. If development were to proceed differently than what is presented here, the overall pattern of the predictions would apply. For example, development might occur outside of city boundaries, in areas within townships that are adjacent to highways. If this land change were to occur without BMPs, phosphorus loads would be expected to increase by similar percentages as those presented in Scenario 1 relative to the baseline. The BMPs modeled in Scenarios 2 and 3 would be expected to mitigate the increase in loads by similar percentages.

The changes in precipitation predicted to result from climate change resulted in a 20 percent increase in runoff volumes and phosphorus loads. These increases were not mitigated by the BMPs modeled in these scenarios.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Development of the Watershed Restoration and Protection Strategies (WRAPS) for the Leech Lake River Watershed is underway by the Minnesota Pollution Control Agency (MPCA), Cass County Environmental Services, and other local partners. A hydrologic and water-quality model of the Leech Lake River Watershed was developed with HSPF for the MPCA [Kenner, 2013a]. The HSPF model application was used to complete a pollutant source assessment for the Leech Lake River Watershed and evaluate phosphorus loads to surface waters under multiple resource management scenarios.

HSPF is a continuous simulation model that typically produces data on a daily basis using an hourly time step. The model application was developed for the Leech Lake River Watershed to simulate the time period from January 1, 1995, to December 31, 2009, and it incorporates both point- and nonpoint-source loads. The fully functioning, calibrated, and validated HSPF model application for the Leech Lake River Watershed simulates hydrology and water quality at a management-unit level. This model development was completed by RESPEC through their Master Services Contract with the MPCA.

2.0 POLLUTANT SOURCE ASSESSMENT

2.1 METHODS

The HSPF watershed modeling system is a comprehensive package for simulating watershed hydrology and water quality for both conventional and toxic organic pollutants. HSPF is capable of simulating the hydrologic and associated water-quality processes on pervious and impervious land surfaces, in streams, and in well-mixed impoundments. HSPF incorporates the watershed-scale Agricultural Runoff Management (ARM) and nonpoint-source models into a basin-scale analysis framework that includes fate and transport in one-dimensional stream channels. It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment/chemical interactions. The result of this coupled simulation is a continuous record of the runoff flow rate and sediment, nutrient, and other water-quality constituent concentrations at any point in a watershed [Bicknell et al., 2001].

HSPF is used to assess the effects of land-use change, reservoir operations, point-source or nonpoint-source treatment alternatives, and flow diversions. The model contains hundreds of process algorithms developed from theory, laboratory experiments, and empirical relations from instrumented watersheds. The model simulates processes such as evapotranspiration; interception of precipitation; snow accumulation and melt; surface runoff; interflow; base flow; soil moisture storage; groundwater recharge; nutrient speciation; biochemical oxygen demand; heat transfer; sediment (sand, silt, and clay) detachment and transport; sediment routing by particle size; channel and reservoir routing; algae growth and die-off; bacterial die-off and decay; and build-up, wash-off, routing, and first-order decay of water-quality constituents. Continuous rainfall and other meteorological records are input at an hourly time step into the model algorithms to compute streamflow, pollutant concentrations, and loading time series. Hydrographs and pollutographs can then be created, and frequency and duration analyses can be performed for any output time series.

An HSPF model application for the Leech Lake River Watershed was developed for the MPCA in 2013 as part of a larger effort to develop model applications for the Pine River Watershed and the Mississippi River Headwaters Watershed in addition to the Leech Lake River Watershed. Details about the model construction and hydrology calibration can be found in Kenner [2013a; 2013b]. The water-quality calibration of the Leech Lake River Watershed model application was completed as part of a current project to complete the calibration for eight major watersheds in the Upper Mississippi River Basin; the memorandum documenting this process will be available upon completion of the full project in May 2015. The model application simulates hydrology and water quality from January 1, 1995, through December 31, 2009; results are reported for the years 1996 through 2009.

Total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) pollutant loads generated from the land surface were summed by source and by model subwatershed. The source categories are based primarily on land use and land cover (Figure 2-1) and consist of the following land classifications that were defined in the HSPF model application [Kenner, 2013a]:

- Old deciduous forest
- Old evergreen forest
- Young forest
- Grassland
- Agriculture (pasture/hay and cultivated crops)
- Feedlot
- Wetland
- Developed
- Septics

2.2 RESULTS

2.2.1 Loads by Subwatershed

Average simulated phosphorus concentrations in watershed runoff are fairly low throughout the watershed, with higher rates in the northwestern portion of the watershed where agricultural practices are more intensive (Figure 2-2). Spatial patterns of nitrogen and sediment concentrations are similar (Figure 2-3 and Figure 2-4). Subwatershed loading rates for phosphorus, nitrogen, and sediment are provided in Appendix A.

2.2.2 Loads by Source Category

The largest source category of nutrient loading is deciduous forests, which make up approximately 49 percent of the watershed area, followed by wetlands and agriculture, which make up 27 percent and 5 percent of the watershed, respectively (Table 2-1, Figure 2-1). The highest phosphorus, nitrogen, and sediment unit-area loading rates are from feedlots, agriculture, and developed land uses.

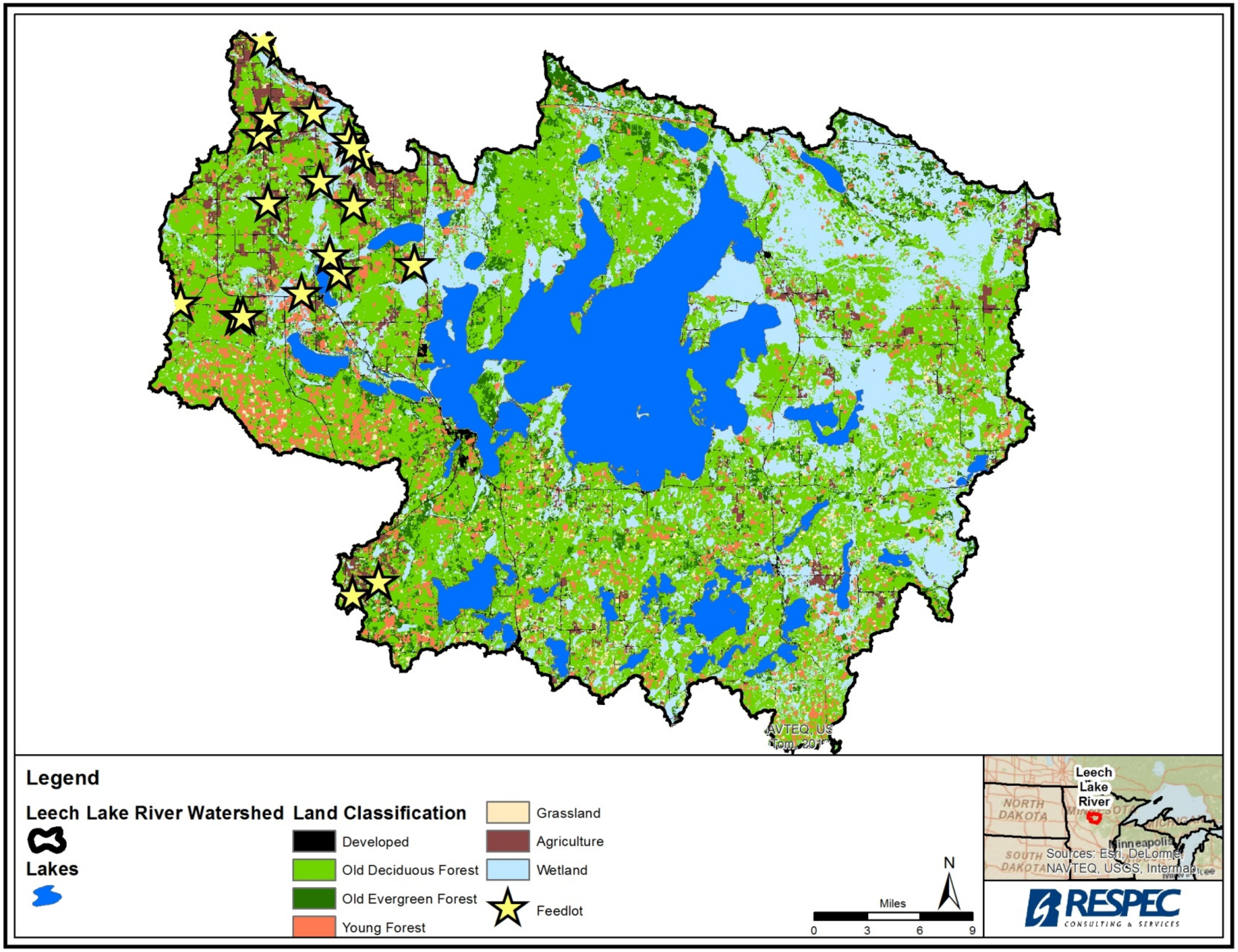

Figure 2-1. Land Classification.

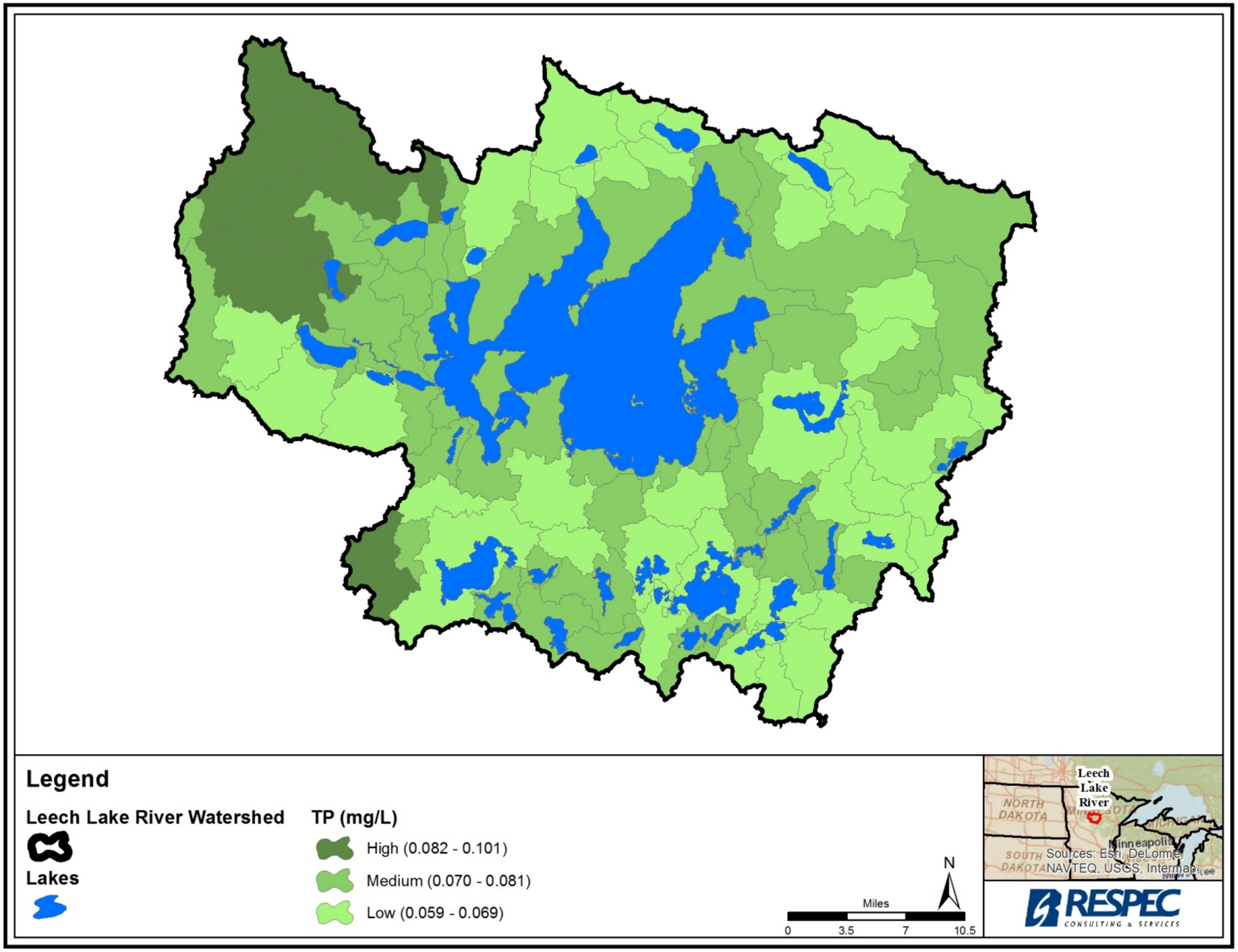

Figure 2-2. Average Simulated Total Phosphorus Concentration by Subwatershed, 1996–2009.

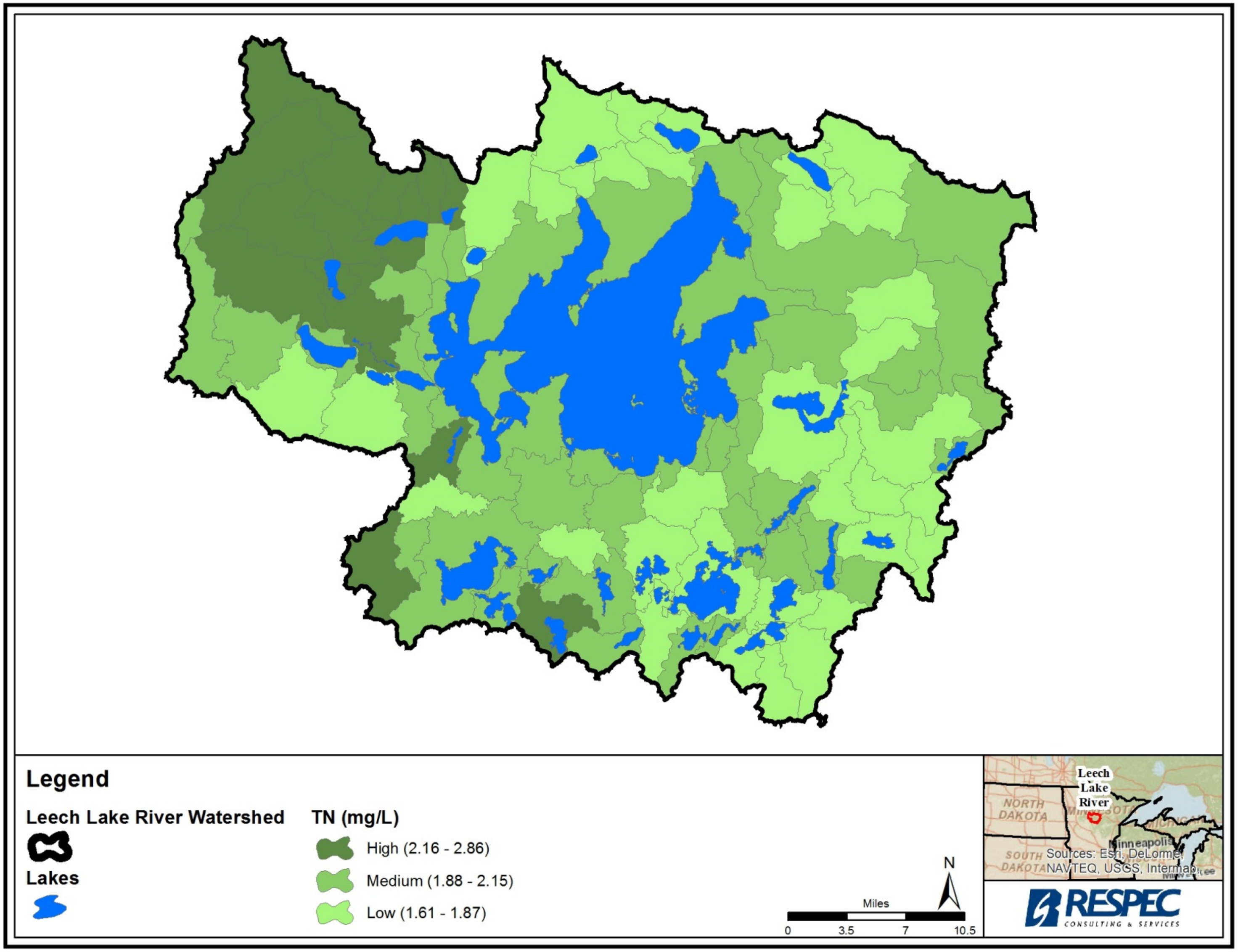

Figure 2-3. Average Simulated Total Nitrogen Concentration by Subwatershed, 1996–2009.

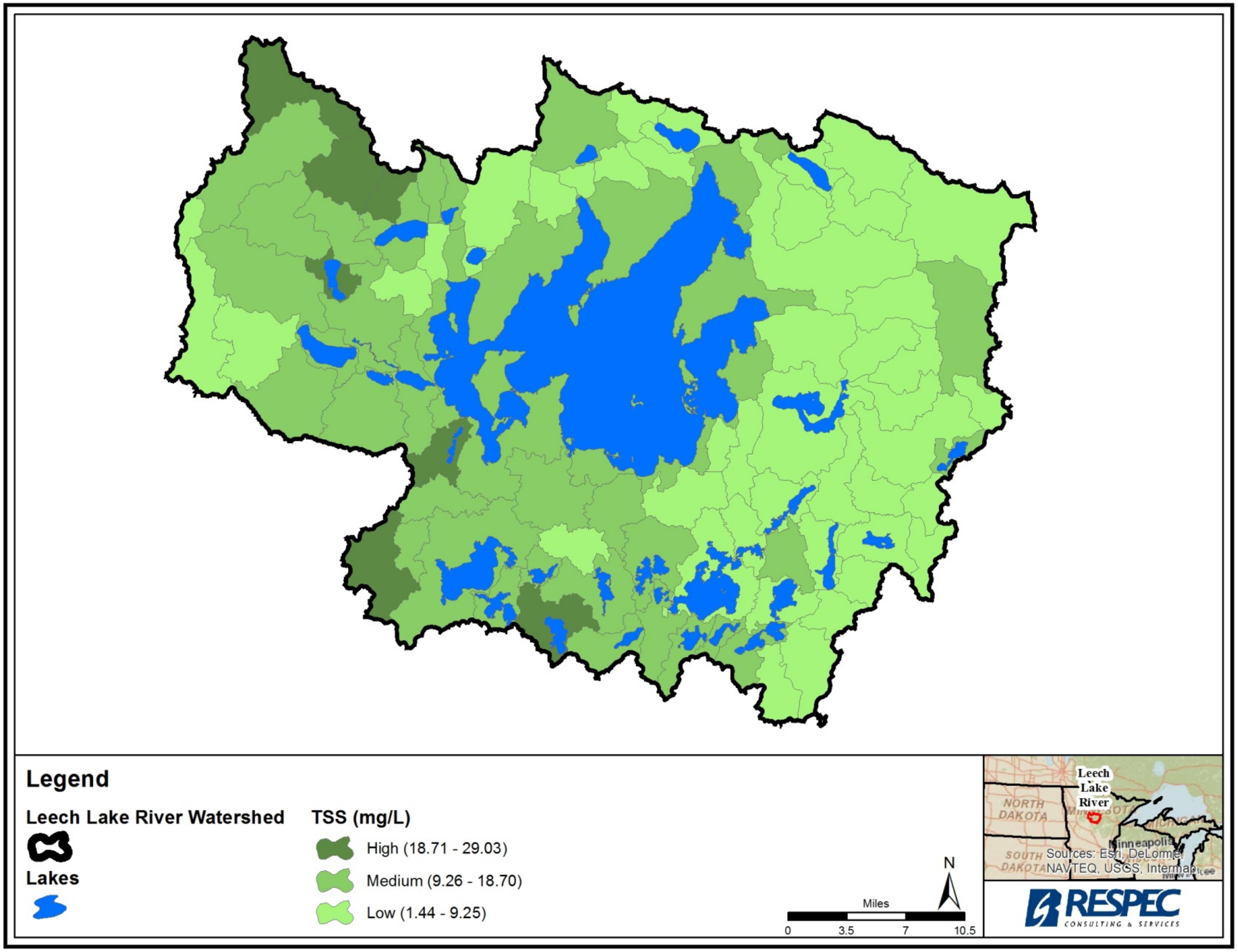

Figure 2-4. Average Simulated Total Suspended Solids Concentration by Subwatershed, 1996–2009.

Table 2-1. Average Annual Pollutant Loads and Flow Rates by Land Classification, 1996–2009

Source Category	Area (ac)	Percent Area (%)	Total Phosphorus			Total Nitrogen			Total Suspended Solids			Flow		
			Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Percent Watershed Load (%)	Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Percent Watershed Load (%)	Unit-Area Load (ton/ac-yr)	Annual Load (ton/yr)	Percent Watershed Load (%)	Unit-Area Rate (in/yr)	Rate (ac-ft/yr)	Percent Watershed Flow (%)
Old deciduous forest	343,875	49	0.08	29,146	41	2.3	806,855	41	0.004	1,295	25	5.5	1.6×10^5	43
Old evergreen forest	50,454	7	0.06	3,202	4	1.8	93,166	5	0.004	186	4	5.0	2.1×10^4	6
Young forest	49,641	7	0.08	3,966	6	2.3	116,354	6	0.007	368	7	6.3	2.6×10^4	7
Grassland	22,818	3	0.08	1,831	3	2.6	59,106	3	0.023	518	10	8.0	1.5×10^4	4
Agriculture	32,947	5	0.29	9,583	13	8.4	278,388	14	0.043	1,405	27	7.8	2.2×10^4	6
Feedlot	9	< 1	0.51	5	< 1	17.6	167	< 1	0.179	2	< 1	9.1	7.2×10^0	< 1
Wetland	194,317	27	0.09	18,152	25	2.4	473,086	24	0.001	157	3	6.1	9.9×10^4	27
Developed	14,852	2	0.31	4,538	6	10.1	149,340	7	0.091	1,352	26	10.0	1.2×10^4	3
Septics	NA	NA	NA	1,044	1	NA	15,159	1	NA	0	< 1	NA	1.2×10^4	3

NA = not applicable.

3.0 EVALUATION OF RESOURCE MANAGEMENT AND PRECIPITATION SCENARIOS

Five model scenarios were developed to evaluate the hydrologic and water-quality impacts of resource management options or changes in the watershed. The scenario results will inform the implementation strategies selected for the Leech Lake River WRAPS. Concerns about and threats to the watershed's surface water resources were identified at stakeholder meetings and were narrowed down to the following based on those that can be appropriately evaluated with the HSPF model:

- Surface water protection
- Protection of forests
- Intensification of agriculture
- Lakeshore development
- Population growth in cities
- Climate change

The details of the scenarios were determined though input from the WRAPS stakeholder group.

3.1 METHODS

3.1.1 Land Change Without Best Management Practices (Scenario 1)

This scenario was developed to answer the question, How would the projected watershed threats affect watershed phosphorus loads if watershed best management practices (BMPs) <u>were not</u> used to mitigate the changes? The threats were translated into model inputs and parameters according to the following:

- **Shoreland development.** Shoreland development was simulated on all areas within 500 feet of lakes in the MPCA's Assessed Lakes 2010 GIS data. Land under conservation easements and county, state, and federal public lands were considered not to be eligible for development. The median existing effective impervious area[2] of subwatersheds in the Leech Lake River Watershed is 11 percent. The effective impervious area of newly developed land was increased to 15 percent to reflect the larger scale homes with higher amounts of impervious surfaces that are common in new shoreland development.

[2] Effective impervious area represents the level of impervious surfaces that are directly connected to a local hydraulic conveyance system (e.g., gutter, storm sewer, stream, or river). Effective impervious area is estimated from mapped percent imperviousness based on an equation in Sutherland [1995].

- **City growth.** All land within city boundaries was converted to developed with a 13 percent effective impervious area, which is the level of imperviousness from existing developed areas within cities in the Leech Lake River Watershed.
- **Highway 371 expansion.** Highway 371 up to Walker (the Y-junction at Highways 371 and 200) was expanded from a 2-lane to a 4-lane corridor by adding a 35-foot buffer on each side of the highway and assigning a 75 percent effective impervious area. This level of imperviousness corresponds to the highly developed land class in the National Land Cover Database.

3.1.2 Land Change With Best Management Practices (A) (Scenario 2)

This scenario was developed to answer the question, How would the projected watershed threats affect watershed phosphorus loads if watershed BMPs were used to mitigate the changes? The land change with BMPs scenario was used as a starting point and the following model inputs and parameters were used to simulate the effects of watershed BMPs:

- **Shoreland development, city growth, and Highway 371 expansion.** 1.1 inches of runoff from all impervious surfaces were captured and retained by increasing the retention storage parameter by 1.1 inches. This volume is based on Minnesota's Minimal Impact Design Standards (MIDS) work group performance goal for new development.

3.1.3 Land Change With Best Management Practices (B) (Scenario 3)

This scenario is similar to the previous one but simulates additional BMPs. In addition to the simulated practices described under the first land change with BMPs scenario (Scenario 2), the following model inputs and parameters were used to simulate the effects of watershed BMPs:

- **Shoreline buffers.** Watershed phosphorus loads from newly developed areas around the lakes were reduced by 68 percent, which assumes a high quality, 50-foot shoreline buffer [Nieber et al., 2011].
- **City growth.** In the land change without BMPs scenario (Scenario 1), development was allowed to occur on all lands within city boundaries, which includes wetlands. For Scenario 3, land developed within city boundaries followed the following guidelines:
  - All wetlands within city boundaries were preserved.
  - Seventy-five percent of natural areas within city boundaries was preserved. These natural areas include forests, grassland, and all wetlands.
  - For the remaining 25 percent of areas within city boundaries, cluster development was simulated. The effective impervious area was lowered from 13 percent (in Scenarios 1 and 2) to 10 percent of the entire city boundary, and the remaining 15 percent was simulated as developed pervious areas (such as lawns). Cluster development typically has lower levels of impervious surfaces than traditional development [Center for Watershed Protection, 2000].

3.1.4 Climate Change-Induced Precipitation Changes (Scenario 4)

Climate change is expected to affect many factors that influence water quality, including air temperature, precipitation, and land cover. Projected changes to precipitation patterns were simulated in the Leech Lake River Watershed to evaluate the impact to water quality of this one aspect of climate change. The National Climate Assessment and Development Advisory Committee (NCADAC) released their draft climate report in 2013, which summarizes climate observations and research from across the country and analyzes the impacts on seven selected sectors, one of which is water. Predictions from Chapter 18. Midwest [Pryor et al., 2013] of the NCADAC report were used to manipulate the hourly precipitation data in the model. Projected changes based on Global Climate Model output for the middle of this century (2041–2070) relative to the end of the last century (1971–2000) are summarized in Figure 18.7 of their report. The following predictions for the Leech Lake River Watershed were used as the basis of the precipitation change scenario:

- Precipitation increase of 1.4–1.7 inches per year.
- An increase of 0.4–1.1 days of heavy precipitation per year. Heavy precipitation is defined as the top 2 percent of all days with precipitation.
- 0–4 fewer dry days per year. Dry days are defined as days with less than 0.1 inch of precipitation.
- An increase of 0–0.2 inch of precipitation during the wettest 5-day period.

The Climate Assessment Tool within BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) Version 4 was used to facilitate the manipulation of precipitation data. Extreme storm events were added to yield a 4 percent increase in annual volume. This is done in the Climate Assessment Tool by specifying event parameters; the tool searches the precipitation record to find events that meet the specifications and then duplicates these storms randomly in the precipitation record. Extreme events were classified as having a total volume greater than 1.7 inches and a total duration above 24 hours, allowing gaps up to 6 hours. In addition to the 4 percent increase from extreme events, a 2 percent increase was applied to every record in the original hourly precipitation record to yield a total volume increase of 6 percent at each of the six precipitation time series across the watershed. Most of the NCADAC predictions were met by the simulated changes in precipitation with a few of the summary statistics falling outside of the preferred ranges (Table 3-1).

3.1.5 Cumulative Scenario (Scenario 5)

A cumulative scenario was simulated using a combination of the second land change with BMPs scenario (Scenario 3) and the climate change-induced precipitation scenario (Scenario 4).

Table 3-1. Summary of Simulated Precipitation Changes

Precipitation Time-Series I.D.	Precipitation Increase (in/year)	Increase in Days of Heavy Precipitation (day/year)	Precipitation Increase in the Wettest 5 Days (in/year)
Target:	*1.4–1.7*	*0.4–1.1*	*0–0.2*
310	1.4	0.3	0.1
710	1.4	0.5	0.2
910	1.5	0.5	0.2
1110	1.4	0.7	0.1
1310	1.5	0.4	0.1
2110	1.5	0.5	0.9
2310	1.5	0.7	0.6
2510	1.5	0.3	1.4
2710	1.4	0.3	0.1
2910	1.4	0.4	0.1
3510	1.6	0.6	0.1
3710	1.4	0.5	0.1
3910	1.5	0.3	0.2

3.2 RESULTS

3.2.1 Land Change Scenarios

The land change without BMPs scenario (Scenario 1) led to a 3 percent increase in runoff volume and a 19 percent increase in phosphorus runoff relative to baseline conditions (Figure 3-1, Table 3-2). The first land change with BMPs scenario (Scenario 2) mitigated the increase in loads but only slightly. The second land change with BMPs scenario (Scenario 3) further mitigated the increase in loads such that, when comparing the baseline to the second land change with BMPs scenario (Scenarios 0 and 3), the phosphorus loads increased only 1 percent (Table 3-2).

The majority of the increase in phosphorus loads was because of the increase in developed areas (Figure 3-2). The phosphorus load increases occurred primarily in the subwatersheds that intersect existing city boundaries and lakes (Figure 3-3) because these are the areas where most of the land change occurred.

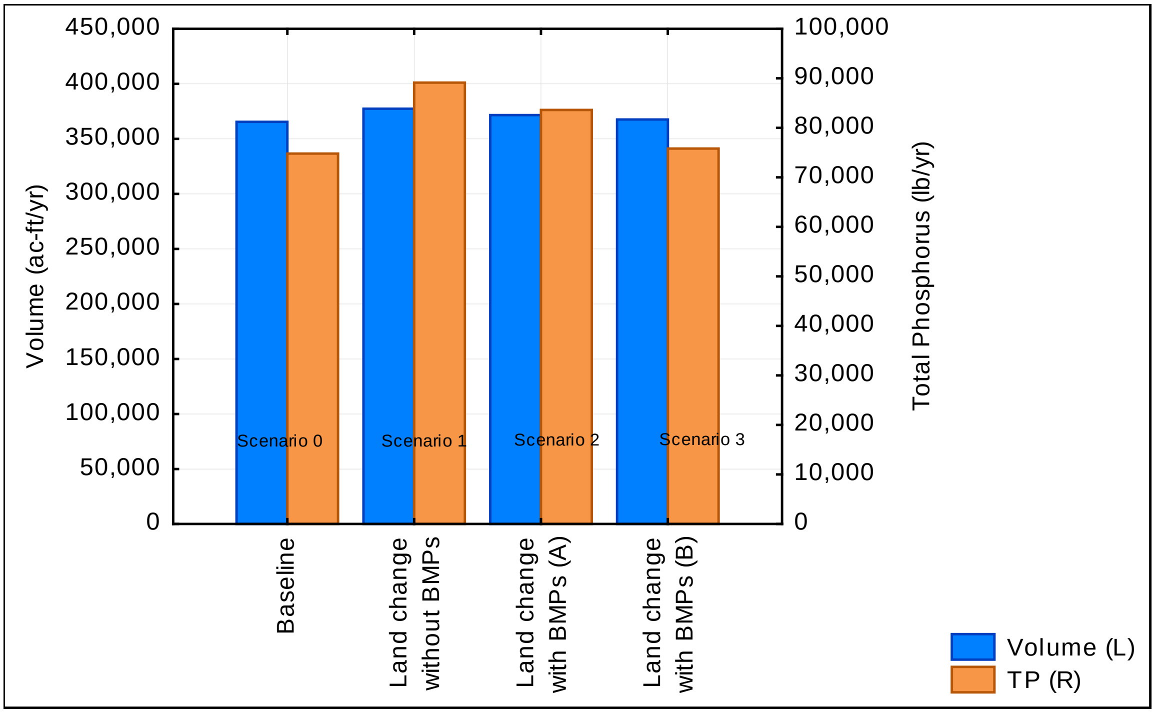

Figure 3-1. Watershed Runoff Volumes and Phosphorus Loads From Baseline and Land Change Scenarios.

Table 3-2. Leech Lake River Watershed Runoff Volume and Phosphorus Load Changes

Scenario	Percent Change Runoff Volume (%)	Percent Change TP Runoff (%)
0 to 1	3	19
1 to 2	–2	–6
2 to 3	–1	–9
0 to 3	1	1
0 to 4	18	18
0 to 5	19	19

3.2.2 Climate Change-Induced Precipitation Changes (Scenario 4)

The climate change-induced precipitation changes led to an 18 percent increase in watershed runoff volume and total phosphorus loads across the Leech Lake River Watershed (Figure 3-4,

Table 3-2). The percent increase in runoff is higher than the percent increase in volume of precipitation (18 versus 6) because the precipitation increase was achieved partly through the addition of extreme precipitation events. A greater amount of runoff is generated from extreme events relative to precipitation volume than is generated in more moderate events.

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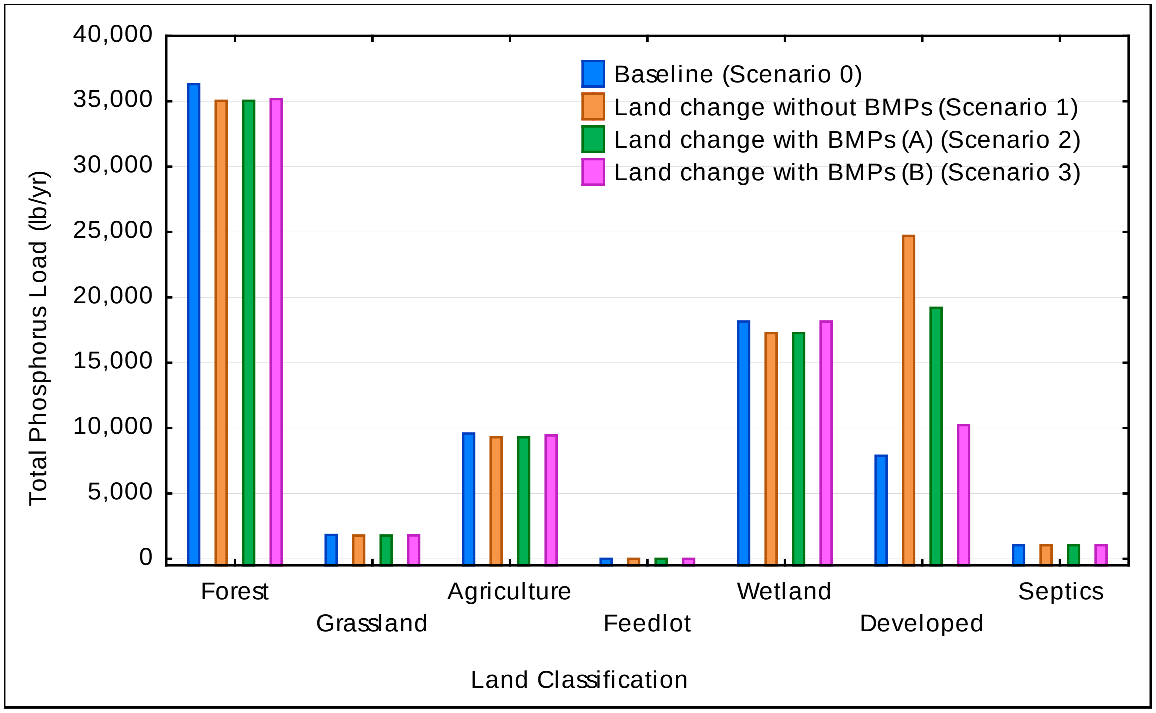

Figure 3-2. Watershed Runoff Volumes and Phosphorus Loads by Land Classification From Baseline and Land Change Scenarios.

3.2.3 Cumulative Scenario

The BMPs in the land change scenarios were not able to mitigate the projected increases in volumes or phosphorus loads from the precipitation change scenarios; the cumulative scenario led to a 19 percent increase in runoff volumes and a 19 percent increase in phosphorus loads relative to baseline conditions (Table 3-2). The BMPs in the land change scenarios were targeted at mitigating the projected load increases caused by shoreland development and the city growth. The BMPs were not targeted at mitigating the runoff changes resulting from changes in precipitation patterns.

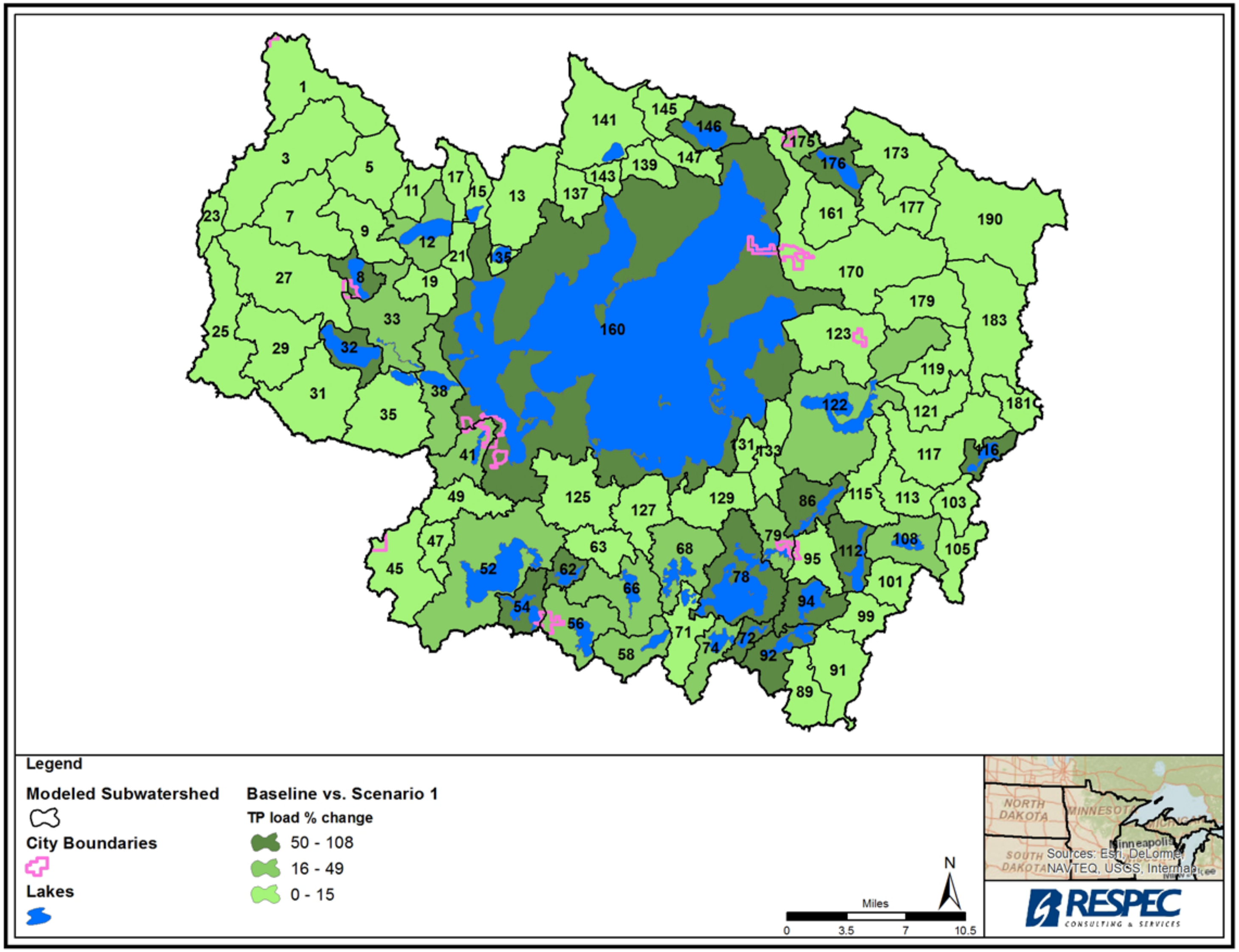

Figure 3-3. Percent Change in Phosphorus Loads by Subwatershed From Land Change Without Best Management Practices Scenario Relative to Baseline Conditions (Scenarios 1 and 0).

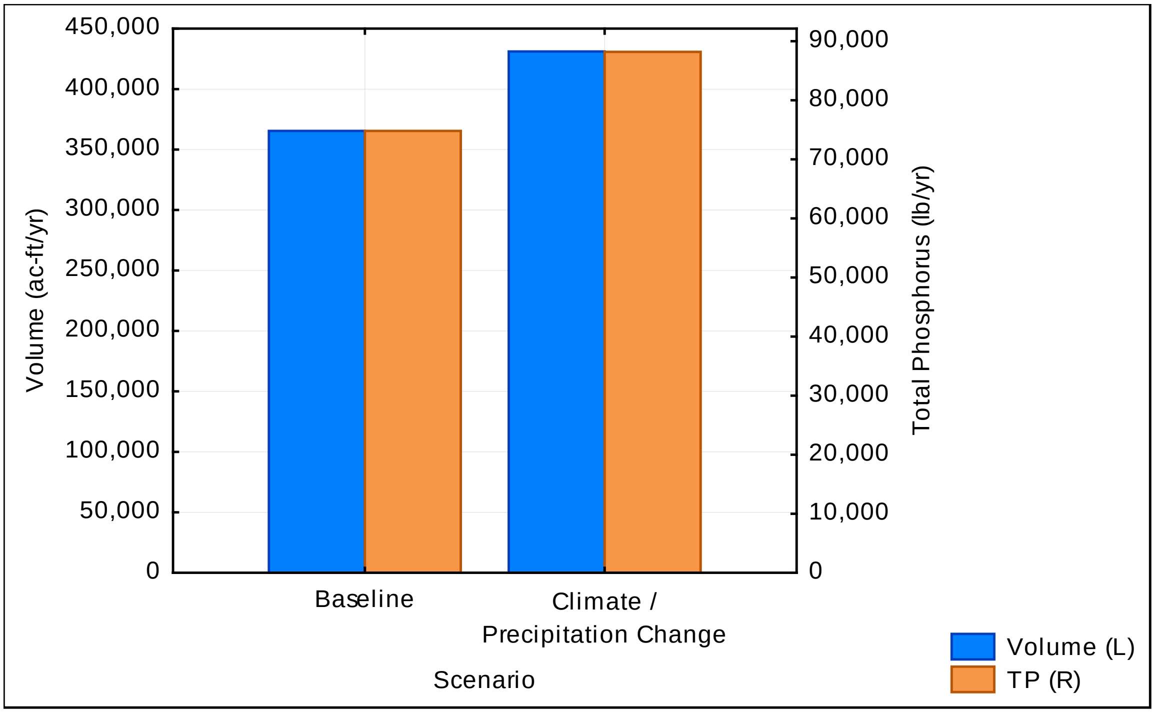

Figure 3-4. Watershed Runoff Volumes and Phosphorus Loads From Baseline and Climate Change Scenarios.

3.3 CONCLUSIONS

In developed areas, the load reductions achieved through capturing and retaining 1.1 inches of runoff from all impervious surfaces were not enough to mitigate the projected increases in load from new development, which consists of over 85 percent pervious areas. When shoreline buffers were added to lakes and 75 percent of natural areas was preserved within city boundaries, the load increase in the land change scenario relative to baseline conditions was minimal.

These results apply to the specific scenarios in this project. If development were to proceed differently than what is presented here, the overall pattern of the predictions would apply. For example, development might occur outside of city boundaries, in areas within townships that are adjacent to highways. If this land change were to occur without BMPs, phosphorus loads would be expected to increase by similar percentages as those presented in Scenario 1 relative to the baseline. The BMPs modeled in Scenarios 2 and 3 would be expected to mitigate the increase in loads by similar percentages.

The changes in precipitation predicted to result from climate change resulted in an 18 percent increase in runoff volumes and phosphorus loads. These increases were not mitigated by the BMPs modeled in these scenarios.

4.0 REFERENCES

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APPENDIX A

POLLUTANT LOADING TABLES

APPENDIX A
POLLUTANT LOADING TABLES

Subwatershed loading rates for phosphorus, nitrogen, and sediment are provided in Table A-1. Figure A-1 contains the key of the subwatershed locations.

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 1 of 4)

Subwatershed	Area (ac)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (ton/ac-yr)	Annual Load (ton/yr)	Unit-Area Rate (in/yr)	Rate (ac-ft/yr)
1	14,018	0.168	2,348	4.8	67,265	0.025	348	7.6	8,828
3	18,266	0.126	2,292	3.6	65,264	0.010	179	6.0	9,166
5	9,550	0.154	1,471	4.3	41,191	0.022	214	7.4	5,870
7	11,541	0.118	1,364	3.3	38,599	0.008	97	5.9	5,684
8	2,409	0.122	293	3.5	8,485	0.016	39	6.3	1,269
9	6,797	0.106	720	3.0	20,272	0.010	68	6.0	3,372
11	3,792	0.172	650	4.8	18,366	0.024	92	7.5	2,364
12	5,963	0.111	664	3.2	19,002	0.010	62	6.1	3,024
13	12,105	0.102	1,228	2.7	33,221	0.006	76	6.7	6,717
15	2,852	0.128	366	3.6	10,194	0.012	34	7.1	1,690
17	3,867	0.142	549	4.0	15,360	0.014	56	7.2	2,316
19	4,554	0.091	416	2.5	11,504	0.005	23	5.8	2,193
21	2,816	0.097	275	2.7	7,586	0.006	16	6.0	1,404
23	2,807	0.091	256	2.5	7,096	0.004	10	5.6	1,313
25	12,749	0.091	1,155	2.5	32,369	0.004	53	5.7	6,052
27	17,539	0.110	1,928	3.1	54,539	0.007	126	5.9	8,680
29	10,603	0.087	926	2.4	25,908	0.004	39	5.7	5,040
31	13,122	0.084	1,103	2.4	31,463	0.007	93	5.9	6,481
32	2,623	0.097	256	2.8	7,267	0.010	26	6.2	1,358
33	11,688	0.109	1,275	3.1	36,180	0.011	123	6.1	5,934
35	12,090	0.082	997	2.3	28,380	0.007	85	5.8	5,860
38	7,192	0.092	664	2.6	18,924	0.007	52	5.8	3,448
41	5,324	0.115	612	3.5	18,513	0.018	95	6.8	3,017

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 2 of 4)

Subwatershed	Area (ac)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (ton/ac-yr)	Annual Load (ton/yr)	Unit-Area Rate (in/yr)	Rate (ac-ft/yr)
45	11,186	0.132	1,478	3.8	42,803	0.021	233	7.0	6,503
47	3,312	0.103	340	2.9	9,591	0.010	32	6.4	1,776
49	5,656	0.094	531	2.7	15,271	0.010	54	6.4	3,038
52	20,342	0.097	1,963	2.8	56,021	0.009	178	6.3	10,706
54	3,688	0.112	412	3.2	11,902	0.014	53	6.8	2,077
56	7,462	0.120	894	3.5	25,886	0.018	132	6.8	4,219
58	5,735	0.102	584	2.8	16,302	0.011	62	6.5	3,112
62	1,911	0.104	199	2.9	5,607	0.009	17	6.5	1,038
63	4,953	0.092	456	2.6	12,708	0.006	27	6.4	2,625
66	8,819	0.110	972	3.1	27,339	0.014	122	6.6	4,844
68	8,286	0.095	785	2.6	21,647	0.008	67	6.3	4,339
71	5,923	0.102	604	2.8	16,592	0.009	55	6.6	3,265
72	1,773	0.107	190	3.0	5,338	0.012	22	6.6	973
74	4,063	0.110	447	3.1	12,463	0.012	47	6.6	2,228
78	8,507	0.072	616	2.0	16,896	0.003	26	5.0	3,521
79	4,355	0.079	345	2.2	9,737	0.005	20	5.0	1,821
86	5,682	0.077	440	2.1	12,190	0.004	21	4.9	2,344
89	5,822	0.071	412	2.0	11,366	0.003	17	4.9	2,394
91	8,742	0.071	623	1.9	16,995	0.003	24	5.1	3,715
92	4,737	0.100	472	2.7	12,888	0.009	44	6.5	2,580
94	4,212	0.072	302	2.0	8,234	0.003	11	4.9	1,708
95	5,331	0.087	465	2.5	13,190	0.006	31	5.2	2,317
99	4,399	0.069	302	1.9	8,185	0.002	9	5.1	1,877

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 3 of 4)

Subwatershed	Area (ac)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (ton/ac-yr)	Annual Load (ton/yr)	Unit-Area Rate (in/yr)	Rate (ac-ft/yr)
101	4,449	0.083	369	2.3	10,208	0.004	20	5.2	1,934
103	3,872	0.129	500	3.5	13,679	0.006	24	8.8	2,825
105	5,404	0.134	724	3.6	19,697	0.006	31	8.8	3,956
108	6,491	0.071	459	1.9	12,403	0.002	12	4.9	2,650
112	4,228	0.091	385	2.6	10,782	0.005	20	5.3	1,858
113	4,757	0.073	348	2.0	9,461	0.002	11	4.9	1,936
115	7,201	0.070	500	1.9	13,592	0.002	14	4.8	2,903
116	2,474	0.157	389	4.4	10,910	0.013	31	9.1	1,873
117	14,054	0.131	1,834	3.6	50,409	0.006	90	8.7	10,133
119	5,757	0.139	802	3.8	22,120	0.008	44	8.7	4,190
121	5,909	0.141	835	3.9	22,813	0.007	40	8.8	4,341
122	23,686	0.077	1,830	2.1	49,696	0.003	61	5.0	9,802
123	11,950	0.087	1,041	2.4	28,388	0.004	52	5.3	5,313
125	11,003	0.100	1,095	2.8	30,931	0.009	98	6.5	5,994
127	6,779	0.099	669	2.7	18,480	0.009	59	6.3	3,567
129	7,797	0.072	561	2.0	15,275	0.002	15	4.8	3,140
131	2,534	0.078	198	2.1	5,372	0.002	6	4.9	1,033
133	5,462	0.080	435	2.2	11,984	0.003	16	5.0	2,262
135	810	0.099	80	2.6	2,096	0.002	2	6.7	452
137	4,371	0.100	436	2.7	11,828	0.007	30	6.5	2,374
139	3,672	0.073	269	2.0	7,335	0.003	10	5.0	1,517
141	14,644	0.100	1,461	2.7	40,040	0.007	107	6.6	8,088
143	2,041	0.104	212	2.8	5,694	0.006	13	6.8	1,159

Table A-1. Average Annual Pollutant Loads and Flow Rates by Subwatershed, 1996–2009 (Page 4 of 4)

Subwatershed	Area (ac)	Total Phosphorus		Total Nitrogen		Total Suspended Solids		Flow	
		Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (lb/ac-yr)	Annual Load (lb/yr)	Unit-Area Load (ton/ac-yr)	Annual Load (ton/yr)	Unit-Area Rate (in/yr)	Rate (ac-ft/yr)
145	4,274	0.071	302	2.0	8,451	0.004	16	5.0	1,767
146	4,317	0.073	314	2.0	8,676	0.003	14	5.1	1,827
147	3,828	0.069	265	1.9	7,251	0.002	9	4.9	1,565
160	90,016	0.101	9,115	2.8	254,782	0.007	645	6.4	47,681
161	6,381	0.080	508	2.1	13,137	0.001	6	5.5	2,914
170	25,695	0.081	2,085	2.2	56,668	0.003	83	5.1	10,930
173	11,814	0.104	1,234	2.8	32,833	0.004	53	7.1	6,951
175	2,160	0.086	185	2.4	5,191	0.006	14	5.6	1,006
176	4,029	0.073	294	2.0	7,937	0.002	9	5.1	1,711
177	6,621	0.076	502	2.1	13,614	0.003	19	5.1	2,835
179	8,486	0.078	662	2.1	17,977	0.004	31	5.1	3,628
181	4,193	0.137	575	3.8	15,932	0.008	34	8.8	3,081
183	15,668	0.145	2,269	4.0	62,582	0.011	167	8.8	11,472
190	22,925	0.091	2,092	2.5	57,298	0.003	73	5.6	10,705

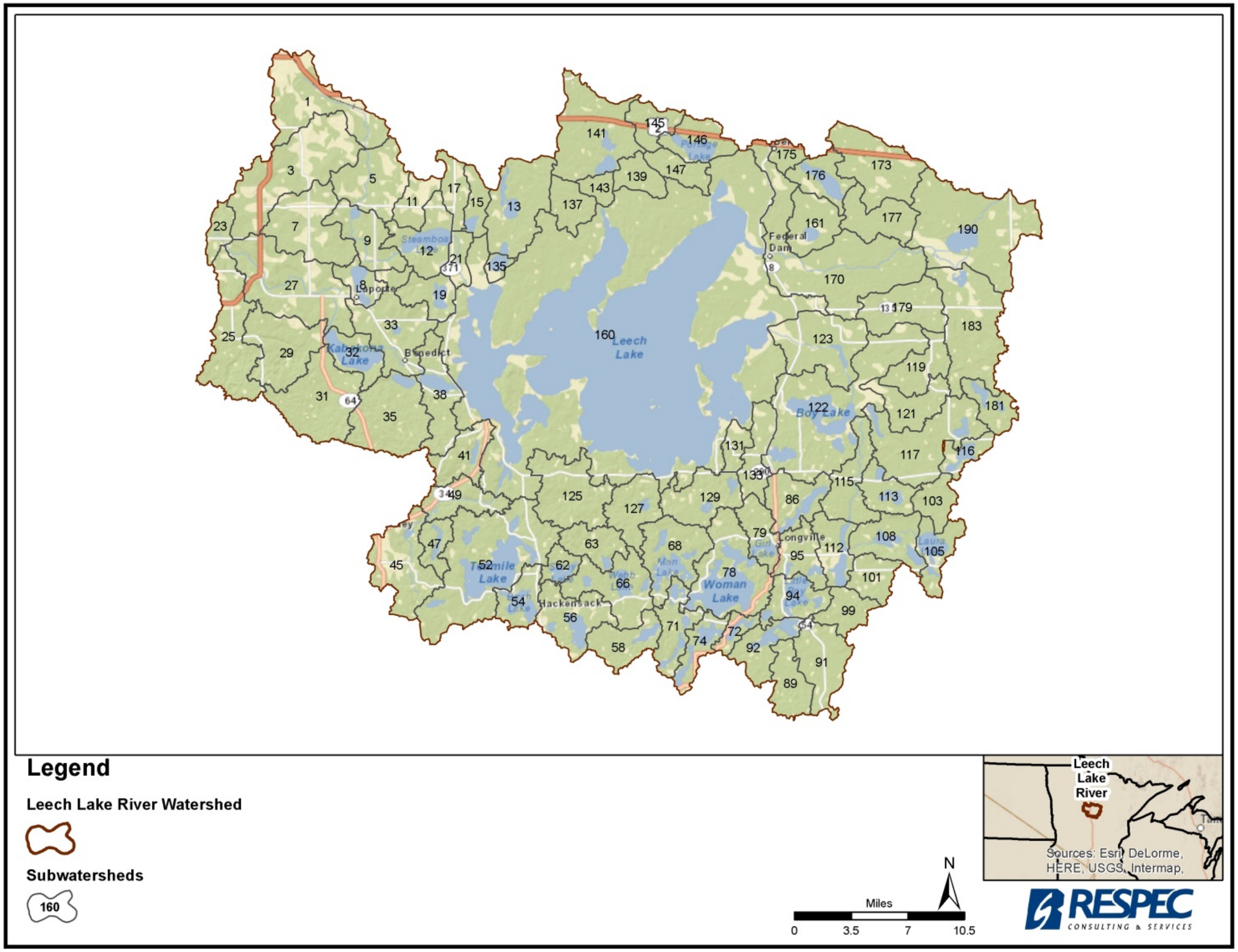
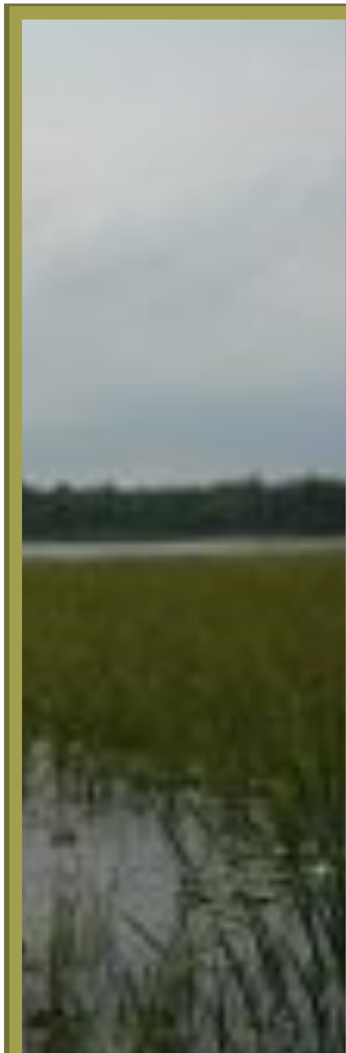


Figure A-1. Subwatershed Key.

Appendix 7: Zonation Modeling Maps and Descriptions

Systematic Conservation Planning

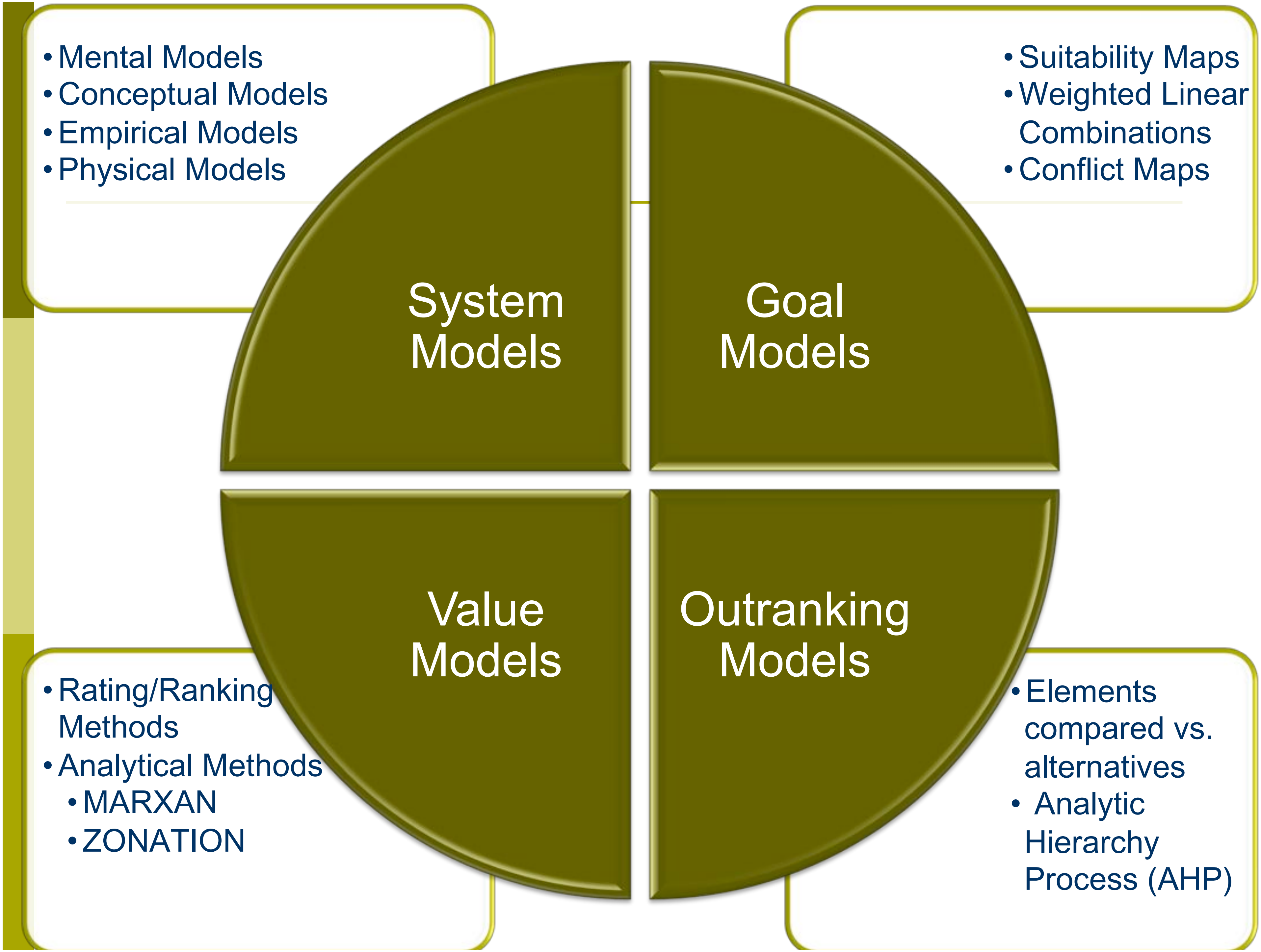
Paul Radomski and Kristin Carlson



6 Common Mistakes in Conservation Planning

- Not acknowledging conservation plans are prioritizations
- Trying to solve an ill-defined problem
- Arbitrariness
- Hidden value judgments
- *Not prioritizing actions*
- *Not acknowledging risk of failure*

Source: Game et al. 2013. Conservation Biology



• Mental Models
• Conceptual Models
• Empirical Models
• Physical Models
• Suitability Maps
• Weighted Linear Combinations
• Conflict Maps
System Models
Goal Models
Value Models
Outranking Models
• Rating/Ranking Methods
• Analytical Methods
• MARXAN
• ZONATION
• Elements compared vs. alternatives
• Analytic Hierarchy Process (AHP)

Using Zonation in Conservation Priority Setting

1. Formulate the Objective

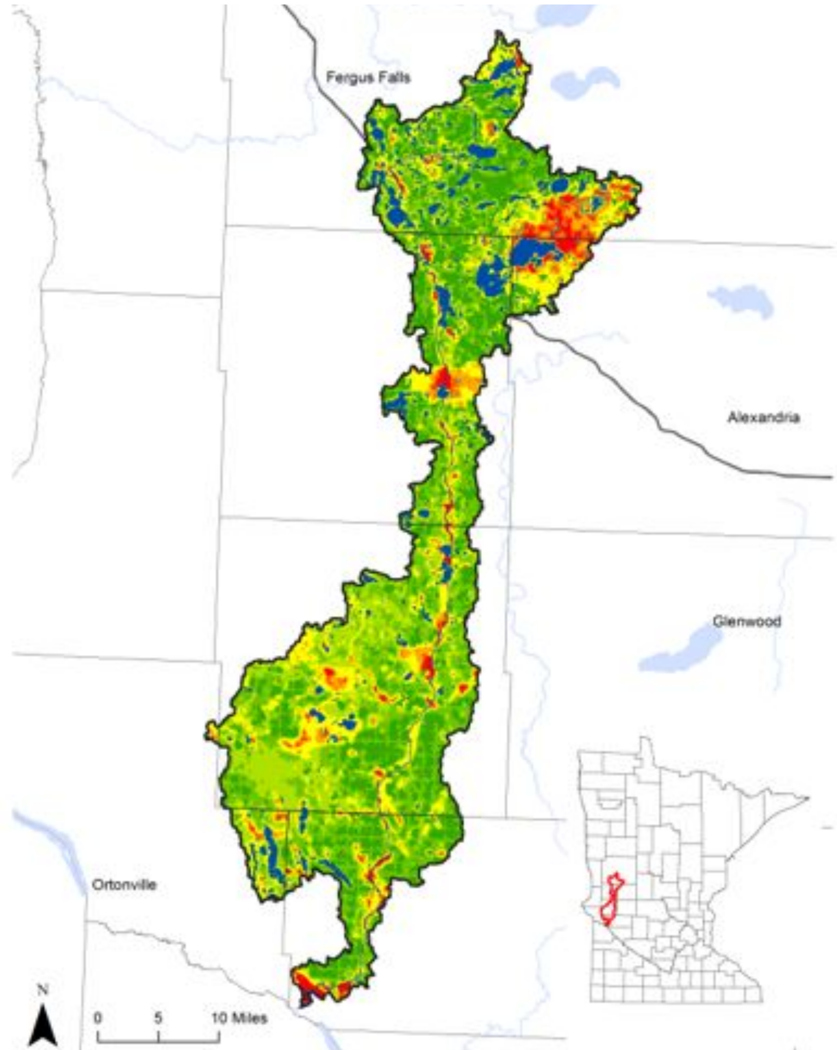
- What conservation features are valued?
- How are the conservation features aggregated?
- How to account for connectivity of features?

2. Set weights on each conservation feature

- Should reflect social valuation
- Analytic Hierarchy Process

3. Apply the optimization algorithm

4. Synthesis



Systematic Conservation Planning

- Identify areas that optimize benefits by accounting for economic and environmental values.
- Reduce interference between competing land uses (habitat, rare features, agriculture, watershed services, etc.).
- Integrate multiple benefits at a scale appropriate for land management decisions.
- Use in a public consultation process.

Zonation

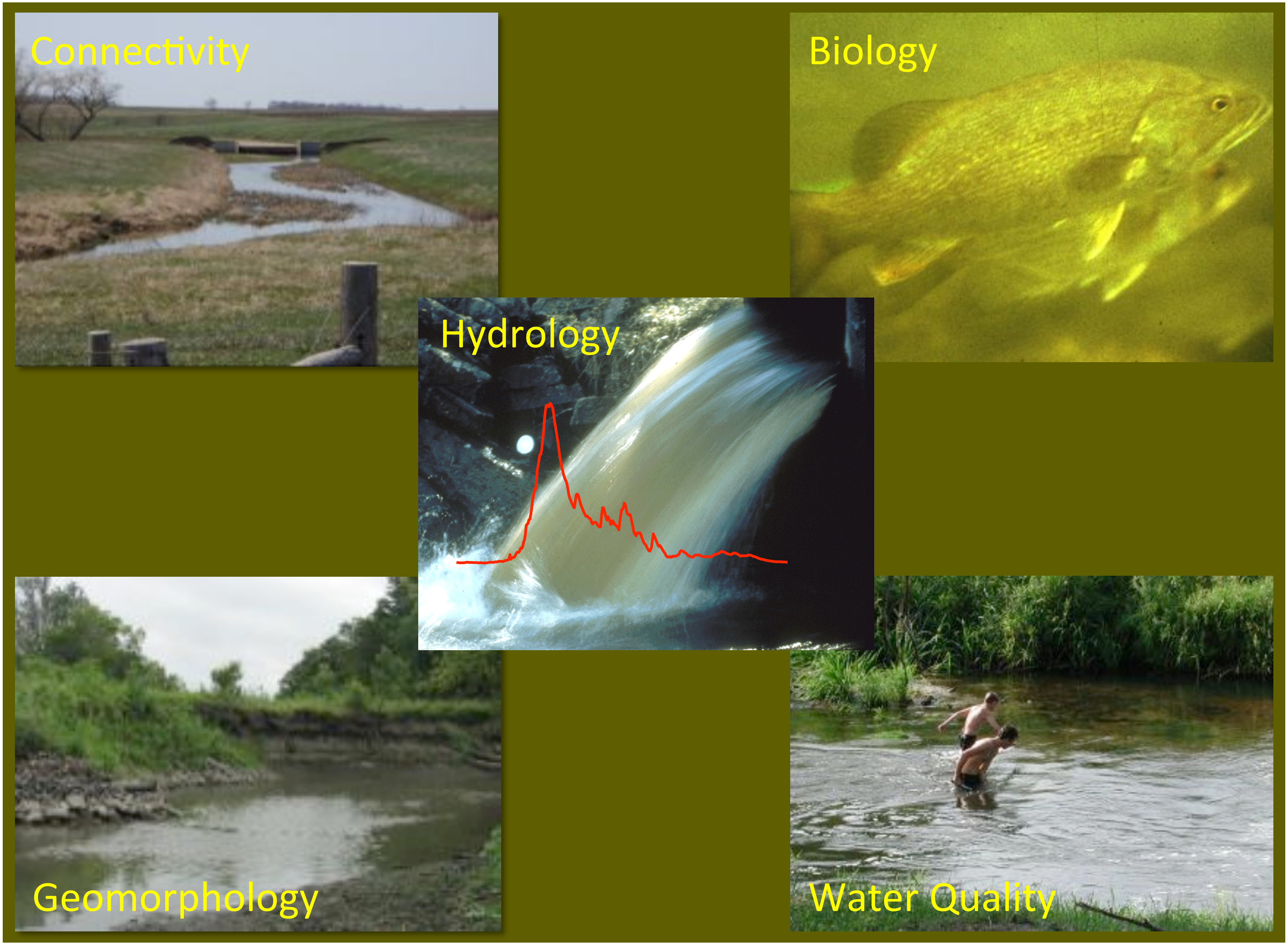
- Objective Function

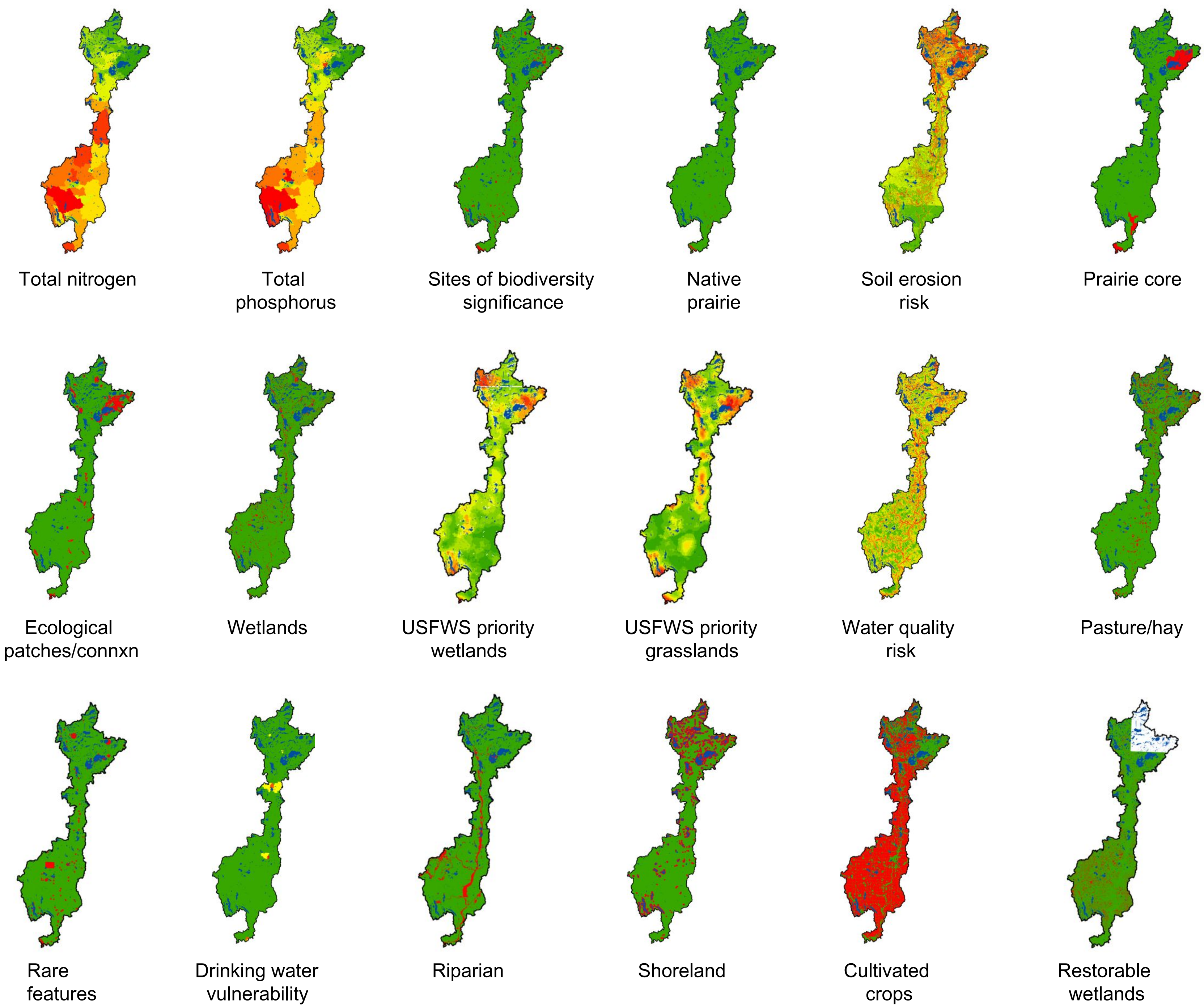
4 different functions; additive benefit function:

$$V(P) = \Sigma w_j R_j(P)^{z_j} - \Sigma w_k R_k(P)^{z_k}$$

Value = conservation features – non-conservation features

the value of a plot [V(P)] is this summation of weighted (w), normalized (R) conservation features (j) minus the summation of alternative features (k), each to the power z.


Connectivity
Biology
Hydrology
Geomorphology
Water Quality


Total nitrogen
Total phosphorus
Sites of biodiversity significance
Native prairie
Soil erosion risk
Prairie core
Ecological patches/connxn
Wetlands
USFWS priority wetlands
USFWS priority grasslands
Water quality risk
Pasture/hay
Rare features
Drinking water vulnerability
Riparian
Shoreland
Cultivated crops
Restorable wetlands

Using Zonation in Conservation Priority Setting

1. Formulate the Objective

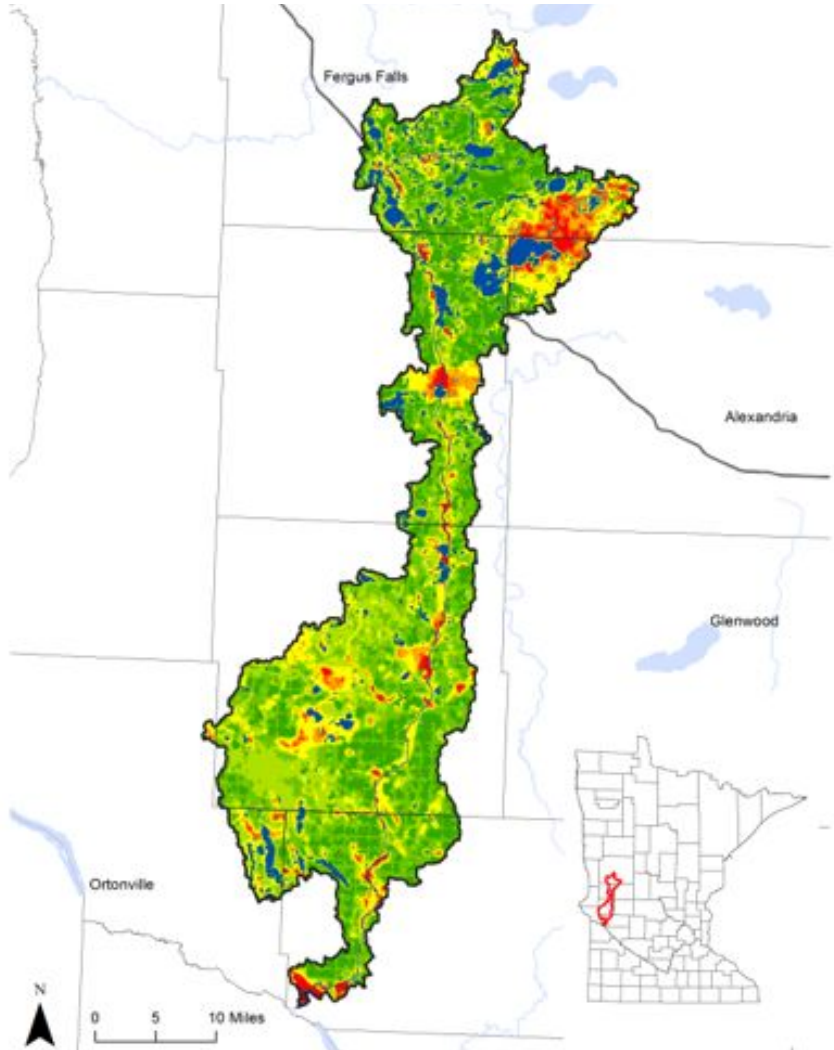
- What conservation features are valued?
- How are the conservation features aggregated?
- How to account for connectivity of features?

2. Set weights on each conservation feature

- Should reflect social valuation
- Analytic Hierarchy Process

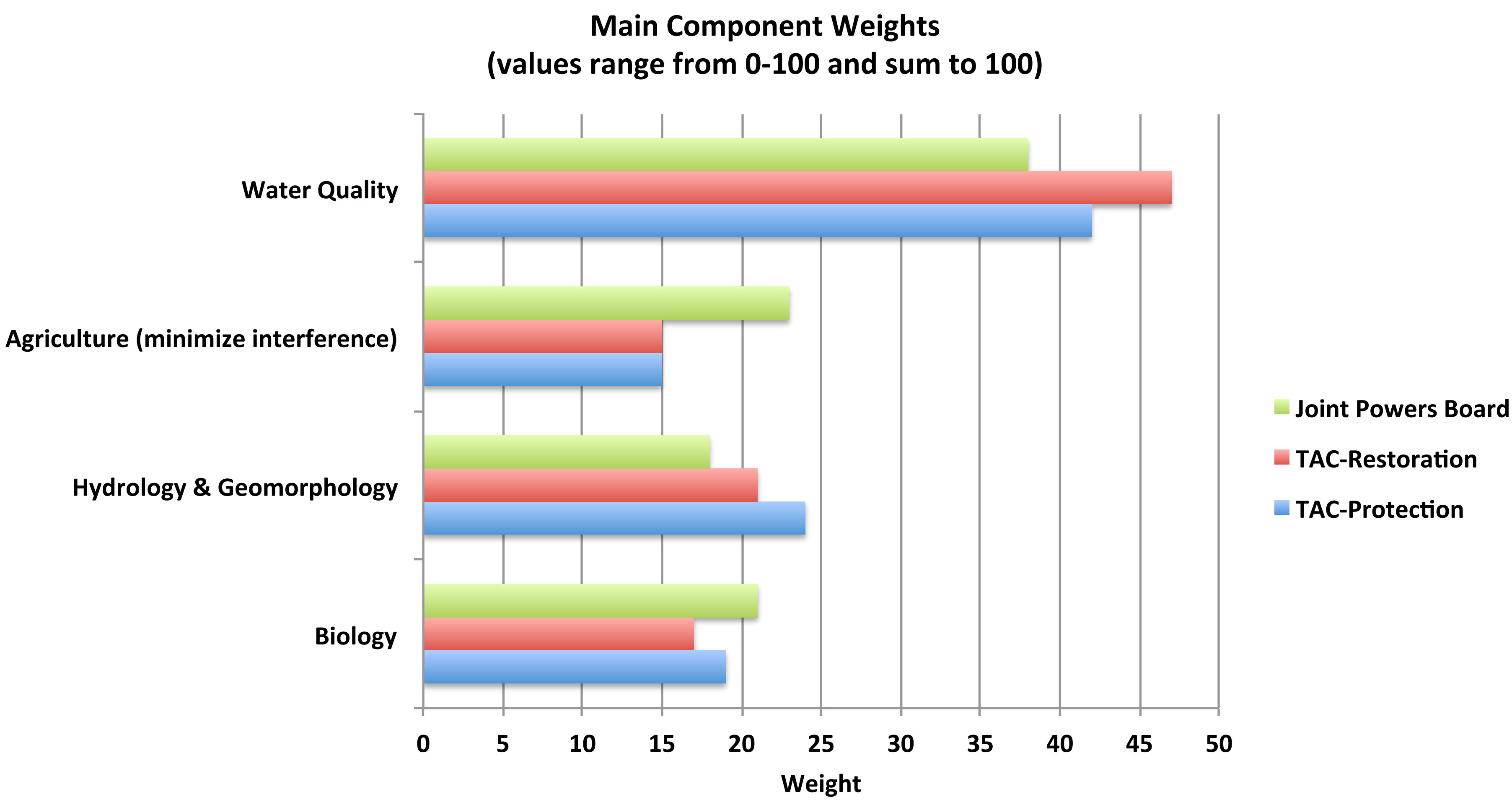
3. Apply the optimization algorithm

4. Synthesis



Analytic Hierarchy Process (AHP)

Weight Setting


Main Component Weights
(values range from 0-100 and sum to 100)
Water Quality
Agriculture (minimize interference)
Hydrology & Geomorphology
Biology
0
5
10
15
20
25
30
35
40
45
50
Weight
Joint Powers Board
TAC-Restoration
TAC-Protection

Using Zonation in Conservation Priority Setting

1. Formulate the Objective

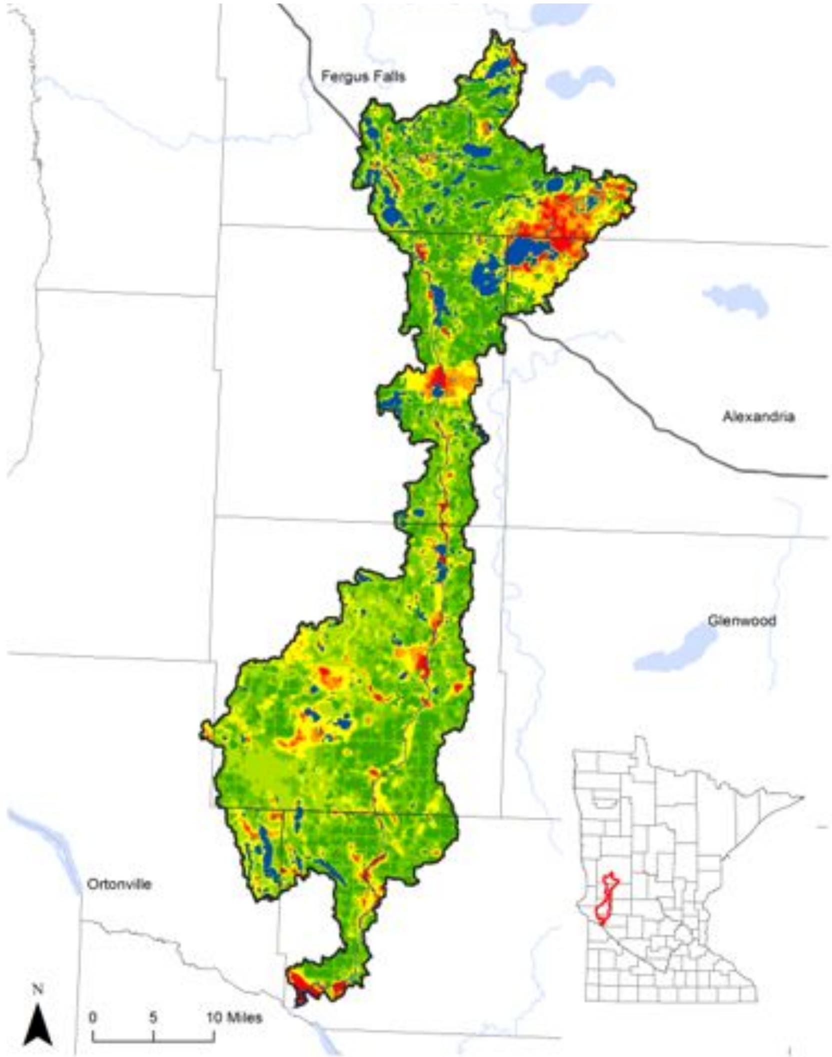
- What conservation features are valued?
- How are the conservation features aggregated?
- How to account for connectivity of features?

2. Set weights on each conservation feature

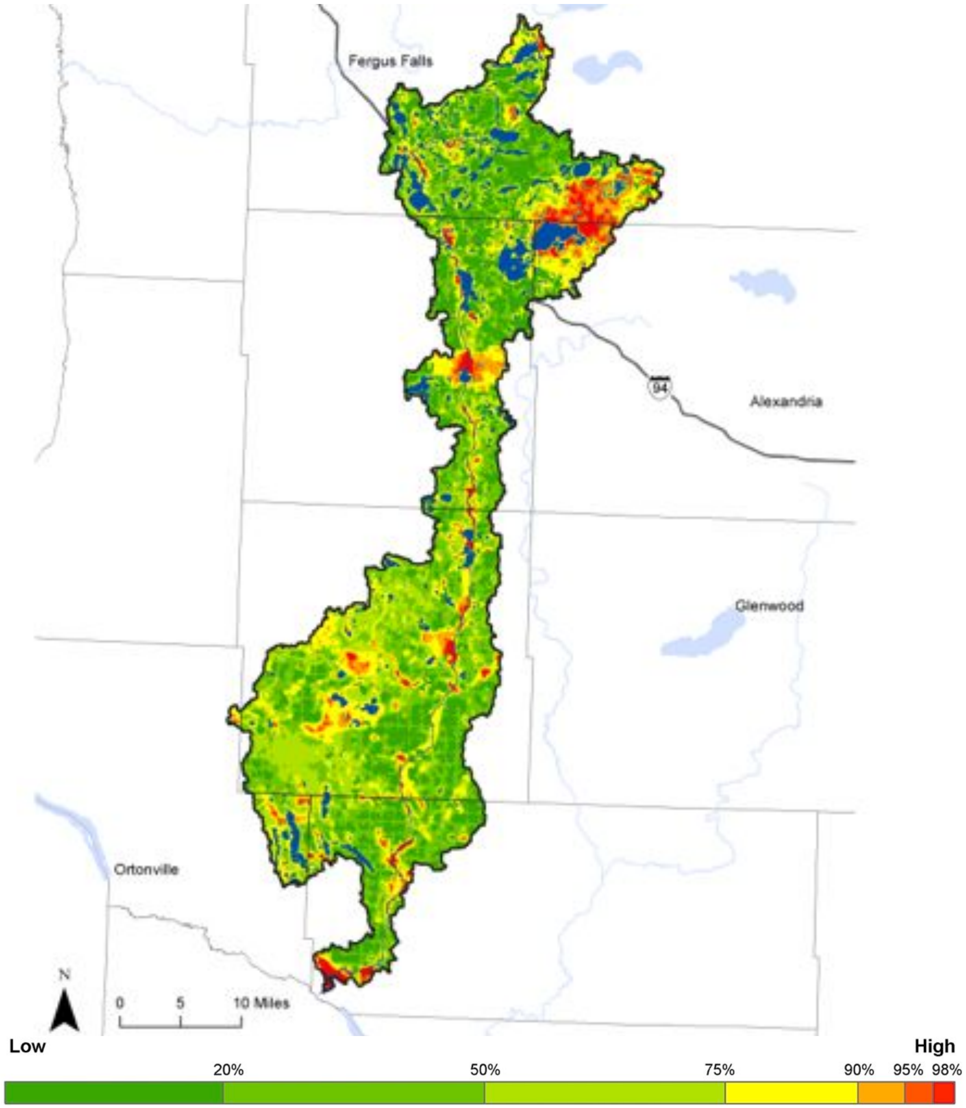
- Should reflect social valuation
- Analytic Hierarchy Process

3. Apply the optimization algorithm

4. Synthesis

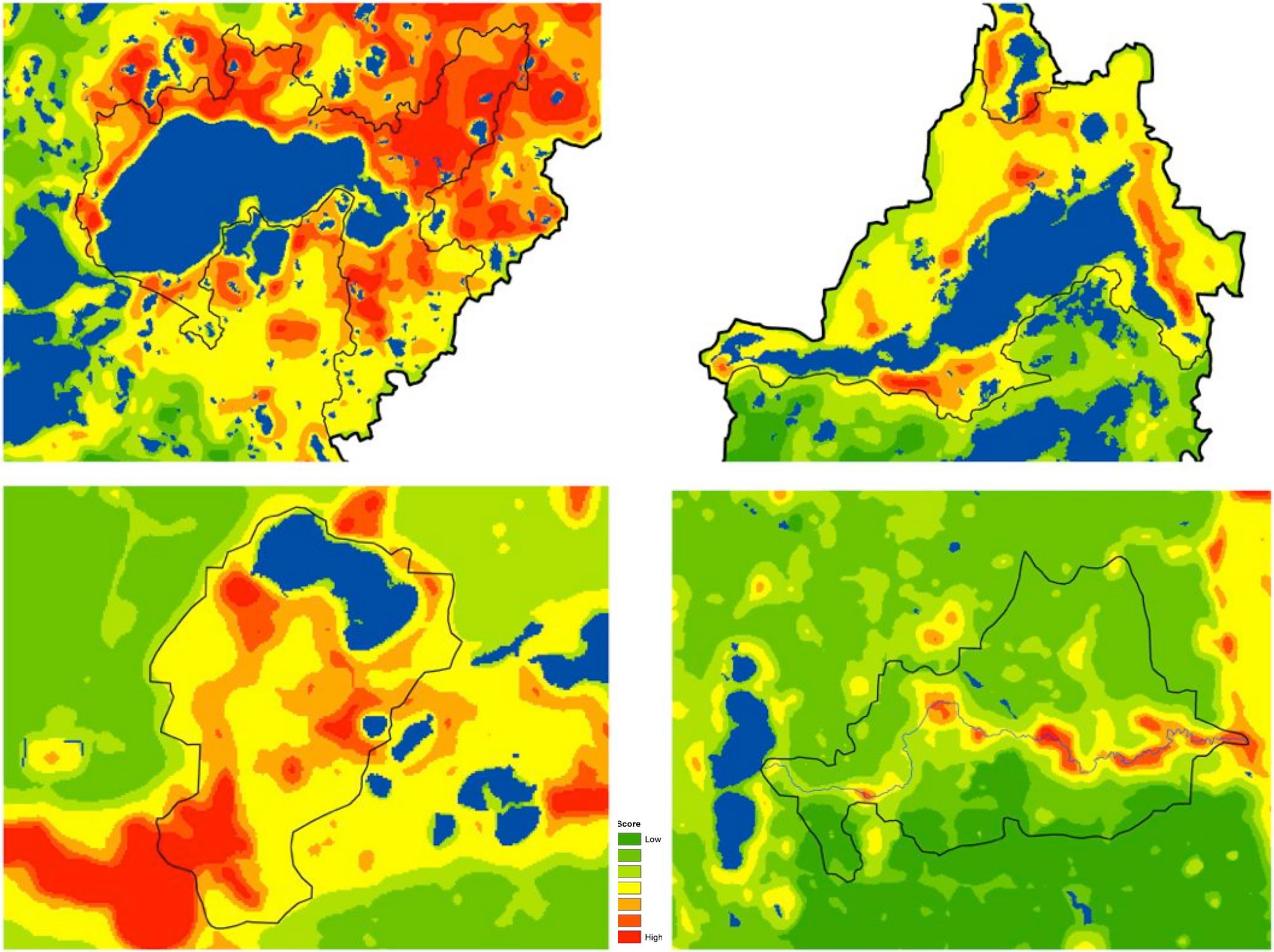


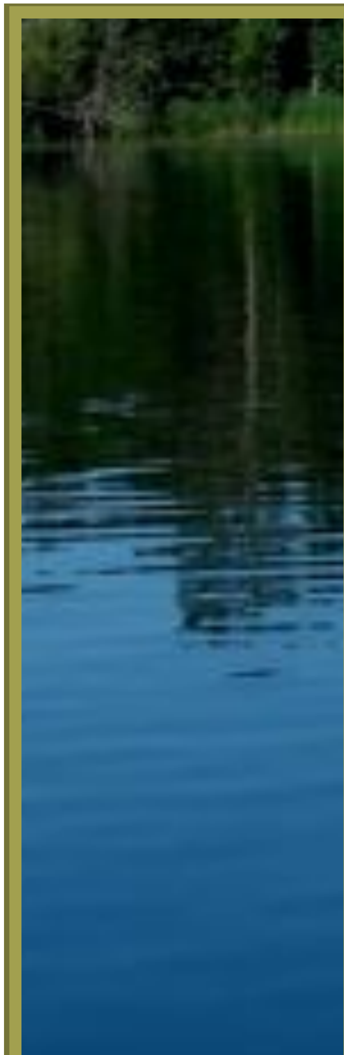
What Does a Map Mean?



Pomme de Terre River Watershed – 3 key areas:

1. Pelican Creek subwatershed
2. City of Barrett
3. Riparian areas


Score
Low
High



Summary

- Many benefits of a formal, quantitative planning framework.
- The approach facilitates an efficient, organized process to analyze priorities.
- Priorities for clean water can be integrated with other priorities (multiple benefits).

Systematic Conservation Planning Process – How?

1. 5-Component Framework/Zonation
2. Organize Data & Discuss Additions/Subtractions
3. Preliminary Analysis using Zonation
4. Add Data based on input
5. Prepare draft Questionnaire consistent with an AHP
6. Revise Questionnaire based on input
7. Assist in Questionnaire deployment & analysis
8. Analysis using Zonation [& AHP]
9. Draft Final Analysis (maps and GIS data)
10. Revise results based on staff review
11. Provide summary of methods & results
12. Provide all data and results in ArcMap format

Name/Affiliation:

Prioritization within the Leech Lake River Watershed

The purpose of this survey is to prioritize ***where conservation investments and activities in the Leech Lake River watershed should be located***. The land prioritization is loosely based on the DNR's healthy watershed framework (water quality, hydrology, connectivity, geomorphology, and biology).

First, you will be asked to identify your priorities at a broad scale (i.e., the components of a healthy watershed). Second, you will be asked to identify your priorities at a finer scale (i.e., the data layers that make up the components). You will be identifying your priorities as they relate primarily to protection of water quality and in some cases restoration. A list of data layer descriptions is provided to assist you.

For each paired choice, please check the box to indicate which criterion you think is more important within the watershed[1]. Make only one selection for every row.

Example:

	Strongly Prefer	**Prefer**	**Equal**	**Prefer**	**Strongly Prefer**	
Dog	☐	☐	☐	☐	☐	Cat

[1] Selecting "prefer" or "strongly prefer" for a criterion indicates that you believe protection and restoration efforts within the watershed should be focused on that criterion. Accordingly, criteria that are preferred or strongly preferred will be given a higher weight in the model that prioritizes areas for protection and restoration. "Equal" means you find these criteria equally important.

Part 1. Broad-Scale Survey

You will be asked to identify your priorities at a broad scale to obtain the overall goal of protecting and improving water quality. A list of descriptions used in the survey on the next page includes:

Objective	Description
Protect or Improve **Waters of Concern**	Waters of special concern include vulnerable groundwater or drinking water supplies, catchments of lakes and rivers with high pollution loads, catchments of lakes with declining water quality, and catchments of lakes vulnerable to pollution.
Reduce **Erosion & Runoff**	Erosion and runoff can be become more prevalent and severe due to human alteration of the land. When wetlands are removed, water runs off the land faster. Also, more water runs off land with impervious surfaces in urban areas and areas that have been deforested.
Enhance **Connectivity**	Connectivity refers to terrestrial pathways and corridors that allow animal movements across an area. Different land uses have fragmented habitat and disrupted habitat connectivity. Fragmentation may lead to the decline or disappearance of plant and animal populations.
Protect or Improve **Fish & Wildlife Habitat**	Habitat provides food, shelter, and breeding territory for animals. The size, shape, and distance between habitat parcels are all important to sustaining populations of plants and animals. Shoreland disturbance and loss of natural vegetation in riparian areas decreases cover for animals and alters the temperature and chemical nature of their environment.
Protect or Improve **Lands of Concern**	This objective includes the protection of valuable timber land, culturally valuable land, and lands near existing protected lands and high-growth areas. It also involves identification of project areas for best management practices on agricultural lands. Timber Land: valuable timber areas and forest lands. Maximize values in forest areas by protecting natural areas for timber production, recreation, and multiple benefits and the identification of project areas for best management practices, including forest stewardship. Culturally Valuable Land: lands valuable to native peoples and citizens of the watershed. Protect or restore identified culturally valuable lands. Protected Land: publically owned lands, including existing Federal, State, and County lands. Increase value of existing protected land by protecting additional nearby lands. Agricultural land: includes row crop agriculture (corn, soybeans and other row crop cultivation), livestock feedlot agriculture (lots and/or buildings for confined feeding, breeding, raising, or holding of animals), and pasture (grass and other plants for grazing). The identification of project areas for best management practices.

Exercise 1: Broad-scale Priorities

Goal: Maintain water quality and protect the high-quality conservation features within the Leech Lake River watershed.

Instructions for online completion: Hover cursor over the box of your choice, the box will highlight in light blue, click on the highlighted box, click again on the highlighted side box that appears, hit x for your choice. When completed save the survey and email either the word document or scanned document to westcom@brainerd.net

	Strongly Prefer	Prefer	Equal	Prefer	Strongly Prefer	
Protect/Improve Waters of Concern	☐	☐	☐	☐	☐	Reduce Erosion & Runoff
Protect/Improve Waters of Concern	☐	☐	☐	☐	☐	Enhance Connectivity
Protect/Improve Waters of Concern	☐	☐	☐	☐	☐	Protect/Improve Fish & Wildlife Habitat
Protect/Improve Waters of Concern	☐	☐	☐	☐	☐	Protect/Improve Lands of Concern
Reduce Erosion & Runoff	☐	☐	☐	☐	☐	Enhance Connectivity
Reduce Erosion & Runoff	☐	☐	☐	☐	☐	Protect/Improve Fish & Wildlife Habitat
Reduce Erosion & Runoff	☐	☐	☐	☐	☐	Protect/Improve Lands of Concern
Enhance Connectivity	☐	☐	☐	☐	☐	Protect/Improve Fish & Wildlife Habitat
Enhance Connectivity	☐	☐	☐	☐	☐	Protect/Improve Lands of Concern
Protect/Improve Fish & Wildlife Habitat	☐	☐	☐	☐	☐	Protect/Improve Lands of Concern

Part 2. Fine-Scale Survey

You will be asked to identify your priorities for water quality protection at a fine scale to determine preferences for specific conservation features at each broad scale objective. Lists of category descriptions for the survey and/or data layers to be used in the model follow. Use the same instructions as broad scale survey for completing the fine scale survey.

Objective	Description
Protect or Improve Waters of Concern	
Focus on Drinking Water Supply Management Area (DWSMA) vulnerability	The risk associated with potential contaminant sources within a public water supply DWSMA to contaminate its drinking water supply. This risk is based on the aquifer's inherent geologic sensitivity, the assessed vulnerability of the public water supply well(s), and the composition of the groundwater. In highly vulnerable DWSMAs, there is a strong causal relationship between land use activities on the surface and groundwater quality. Includes Special Well and Boring Construction Areas as designated by the Minnesota Department of Health (MDH).
Focus on Catchments with higher pollution	Estimated total suspended solids, total nitrogen, and total phosphorus by catchment as determined by hydrological models.
Focus on Catchments of lakes with declining water quality	Lakes where long-term data suggest declining water quality.
Focus on Groundwater contamination susceptibility	The relative susceptibility of an area to groundwater contamination (based on geologic stratigraphy, aquifer transmissivity, and recharge potential).
Focus on Catchments identified as at risk by MDNR-Fisheries	Catchments that have between 25 and 60 percent land cover disturbance and that are less than 75 percent protected (publicly owned or protected by conservation easement). Determined by Minnesota Department of Natural Resources (MDNR) – Section of Fisheries for water quality habitat purposes.
Focus on Catchments of lakes vulnerable to phosphorus addition	Catchments of lakes that are vulnerable to nutrient loading. Determined by MDNR using water mass balance models.

Reduce Erosion & Runoff	
Reduce Soil erosion risk	Susceptibility of soils to erosion. This variable is from the BWSR and UMN's Environmental Benefits Index; it was calculated from a subset of the universal soil loss equation.
Focus on Areas with high erosive potential	Stream Power index: This is an index of the channelized flow erosive potential. Calculated from LiDAR data.
Focus on Areas close to water	Lands close to a stream and lake are more valuable in the protection of water quality than those farther away. The data are the inverse distance from water.
Protect Existing wetlands	Remaining wetlands as documented by the National Wetland Inventory (NWI).
Restore Ditched streams	Ditched, potentially restorable streams that may be considered for abandonment. The ditched area and associated riparian areas were identified by Cass County.

Enhance Connectivity	
Protect or Restore Stream riparian areas	Stream riparian areas and potential flood zones (based on location, elevation and soil type). Includes 'Exceptional' river reach riparian areas as a class.
Protect Ecological connections	Ecological corridors between generally large, intact, native or "semi-natural" terrestrial habitat patches.
Protect or Restore Shoreland	Land within 1000 feet of lake shoreline.

Protect or Improve Fish & Wildlife Habitat	
Protect Sites of biodiversity significance	Areas with varying levels of native biodiversity that may contain high quality native plant communities, rare plants, rare animals, and/or animal aggregations. Identified by Minnesota Biological Survey.
Protect or Restore Sensitive lakeshore	Lakeshore areas that provide unique or critical ecological habitat. Protocols for identifying these areas were developed by the MDNR.
Protect or Improve Lakes of biological significance	Catchments of high quality lakes. MDNR list of high quality lakes based on dedicated biological sampling.
Protect High-value forests	MDNR designated high conservation value forests due to plant and animals present and MDNR designed old-growth forests.
Protect or Restore Trout stream catchments	MDNR designated trout stream catchments.
Protect Rare features	Locations of species currently tracked by the MDNR, including Endangered, Threatened, and Special Concern plant and animal species as well as animal aggregation sites.

Protect or Improve Lands of Concern	
Implement BMPs on Pasture/hay lands	Land cover type is pasture or hay (areas used for livestock grazing or planted with perennial or hay crops).
Implement BMPs on Cultivated croplands	Land cover type is cultivated crops (areas used for the production of annual crops or actively tilled areas).
Protect Valuable timber lands	Forest lands that have been identified by forestry managers as important.
Protect Lands close to protected lands	Lands close to protected lands may be more important for conservation, as larger, contiguous areas often have more value than smaller, fragmented lands. The data are the inverse distance to existing protected lands.
Protect Culturally valuable lands	Culturally lands valuable to native peoples and other citizens of the watershed.
Protect Lands in high-growth areas	Lands close to existing development may be more likely to be developed, and some of these lands that provide ecosystem services may be of conservation value.

Exercise 2: Fine-scale Priorities

Protect or Improve Waters of Concern							
	Strongly Prefer	Prefer	Equal	Prefer	Strongly Prefer		I Don't Know
Focus on Drinking water mgmt. area vulnerability	☐	☐	☐	☐	☐	Focus on Catchments with higher pollution	☐
Focus on Drinking water mgmt. area vulnerability	☐	☐	☐	☐	☐	Focus on Catchments with declining water quality	☐
Focus on Drinking water mgmt. area vulnerability	☐	☐	☐	☐	☐	Focus on Groundwater contamination susceptibility	☐
Focus on Drinking water mgmt. area vulnerability	☐	☐	☐	☐	☐	Focus on Catchments identified at risk by DNR-Fisheries	☐
Focus on Drinking water mgmt. area vulnerability	☐	☐	☐	☐	☐	Focus on Catchments of lakes vulnerable to phosphorus addition	☐
Focus on Catchments with higher pollution	☐	☐	☐	☐	☐	Focus on Catchments with declining water quality	☐
Focus on Catchments with higher pollution	☐	☐	☐	☐	☐	Focus on Groundwater contamination susceptibility	☐
Focus on Catchments with higher pollution	☐	☐	☐	☐	☐	Focus on Catchments identified at risk by DNR-Fisheries	☐
Focus on Catchments with higher pollution	☐	☐	☐	☐	☐	Focus on Catchments of lakes vulnerable to phosphorus addition	☐
Focus on Catchments with declining water quality	☐	☐	☐	☐	☐	Focus on Groundwater contamination susceptibility	☐
Focus on Catchments with declining water quality	☐	☐	☐	☐	☐	Focus on Catchments identified at risk by DNR-Fisheries	☐
Focus on Catchments with declining water quality	☐	☐	☐	☐	☐	Focus on Catchments of lakes vulnerable to phosphorus addition	☐
Focus on Groundwater contamination susceptibility	☐	☐	☐	☐	☐	Focus on Catchments identified at risk by DNR-Fisheries	☐
Focus on Groundwater contamination susceptibility	☐	☐	☐	☐	☐	Focus on Catchments of lakes vulnerable to phosphorus addition	☐
Focus on Catchments identified at risk by DNR-Fisheries	☐	☐	☐	☐	☐	Focus on Catchments of lakes vulnerable to phosphorus addition	☐

2) Fine-scale Priorities, continued

Reduce Erosion & Runoff							
	Strongly Prefer	Prefer	Equal	Prefer	Strongly Prefer		I Don't Know
Reduce Soil erosion risk	☐	☐	☐	☐	☐	Focus on Areas with high erosive potential	☐
Reduce Soil erosion risk	☐	☐	☐	☐	☐	Focus on Areas close to water	☐
Reduce Soil erosion risk	☐	☐	☐	☐	☐	Protect Existing wetlands	☐
Reduce Soil erosion risk	☐	☐	☐	☐	☐	Restore Ditched streams	☐
Focus on Areas with high erosive potential	☐	☐	☐	☐	☐	Focus on Areas close to water	☐
Focus on Areas with high erosive potential	☐	☐	☐	☐	☐	Protect Existing wetlands	☐
Focus on Areas with high erosive potential	☐	☐	☐	☐	☐	Restore Ditched streams	☐
Focus on Areas close to water	☐	☐	☐	☐	☐	Protect Existing wetlands	☐
Focus on Areas close to water	☐	☐	☐	☐	☐	Restore Ditched streams	☐
Protect Existing wetlands	☐	☐	☐	☐	☐	Restore Ditched streams	☐

Enhance Connectivity							
	Strongly Prefer	Prefer	Equal	Prefer	Strongly Prefer		I Don't Know
Protect/Restore Riparian areas	☐	☐	☐	☐	☐	Protect Ecological Connections	☐
Protect/Restore Riparian areas	☐	☐	☐	☐	☐	Protect/Restore Shorelands	☐
Protect Ecological Connections	☐	☐	☐	☐	☐	Protect/Restore Shorelands	☐

2) Fine-scale Priorities, continued

Protect or Improve Fish & Wildlife Habitat							
	Strongly Prefer	**Prefer**	**Equal**	**Prefer**	**Strongly Prefer**		**I Don't Know**
Protect Sites of biodiversity significance	☐	☐	☐	☐	☐	Protect/Restore Sensitive lakeshore	☐
Protect Sites of biodiversity significance	☐	☐	☐	☐	☐	Protect/Improve Lakes of Biological Significance	☐
Protect Sites of biodiversity significance	☐	☐	☐	☐	☐	Protect High Value Forests	☐
Protect Sites of biodiversity significance	☐	☐	☐	☐	☐	Protect/Restore Trout Stream Catchments	☐
Protect Sites of biodiversity significance	☐	☐	☐	☐	☐	Protect Rare features	☐
Protect/Restore Sensitive lakeshore	☐	☐	☐	☐	☐	Protect/Improve Lakes of Biological Significance	☐
Protect/Restore Sensitive lakeshore	☐	☐	☐	☐	☐	Protect High Value Forests	☐
Protect/Restore Sensitive lakeshore	☐	☐	☐	☐	☐	Protect/Restore Trout Stream Catchments	☐
Protect/Restore Sensitive lakeshore	☐	☐	☐	☐	☐	Protect Rare features	☐
Protect/Improve Lakes of Biological Significance	☐	☐	☐	☐	☐	Protect High Value Forests	☐
Protect/Improve Lakes of Biological Significance	☐	☐	☐	☐	☐	Protect/Restore Trout Stream Catchments	☐
Protect/Improve Lakes of Biological Significance	☐	☐	☐	☐	☐	Protect Rare features	☐
Protect High Value Forests	☐	☐	☐	☐	☐	Protect/Restore Trout Stream Catchments	☐
Protect High Value Forests	☐	☐	☐	☐	☐	Protect Rare features	☐
Protect/Restore Trout Stream Catchments	☐	☐	☐	☐	☐	Protect Rare features	☐

2) Fine-scale Priorities, continued

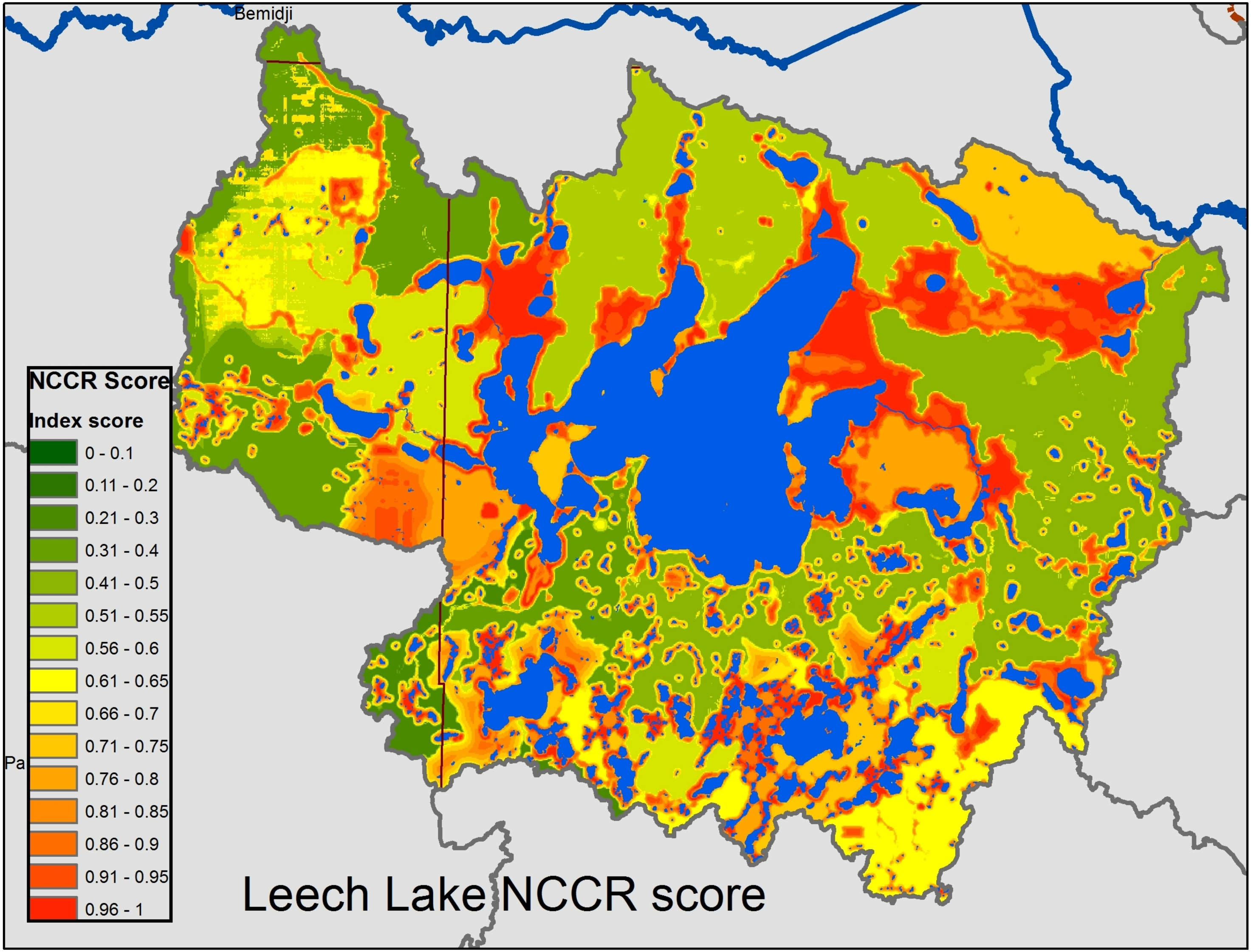
Protect or Improve Lands of Concern							
	Strongly Prefer	Prefer	Equal	Prefer	Strongly Prefer		I Don't Know
Implement BMPs on Pasture/hay lands	☐	☐	☐	☐	☐	Implement BMPs on Cultivated croplands	☐
Implement BMPs on Pasture/hay lands	☐	☐	☐	☐	☐	Protect Valuable timber lands	☐
Implement BMPs on Pasture/hay lands	☐	☐	☐	☐	☐	Protect Lands close to protected lands	☐
Implement BMPs on Pasture/hay lands	☐	☐	☐	☐	☐	Protect Culturally valuable lands	☐
Implement BMPs on Pasture/hay lands	☐	☐	☐	☐	☐	Protect Undeveloped lands in high growth areas	☐
Implement BMPs on Cultivated croplands	☐	☐	☐	☐	☐	Protect Valuable timber lands	☐
Implement BMPs on Cultivated croplands	☐	☐	☐	☐	☐	Protect Lands close to protected lands	☐
Implement BMPs on Cultivated croplands	☐	☐	☐	☐	☐	Protect Culturally valuable lands	☐
Implement BMPs on Cultivated croplands	☐	☐	☐	☐	☐	Protect Undeveloped lands in high growth areas	☐
Protect Valuable timber lands	☐	☐	☐	☐	☐	Protect Lands close to protected lands	☐
Protect Valuable timber lands	☐	☐	☐	☐	☐	Protect Culturally valuable lands	☐
Protect Valuable timber lands	☐	☐	☐	☐	☐	Protect Undeveloped lands in high growth areas	☐
Protect Lands close to protected lands	☐	☐	☐	☐	☐	Protect Culturally valuable lands	☐
Protect Lands close to protected lands	☐	☐	☐	☐	☐	Protect Undeveloped lands in high growth areas	☐
Protect Culturally valuable lands	☐	☐	☐	☐	☐	Protect Undeveloped lands in high growth areas	☐

We would appreciate your input. Are there any other issues you want to comment on?

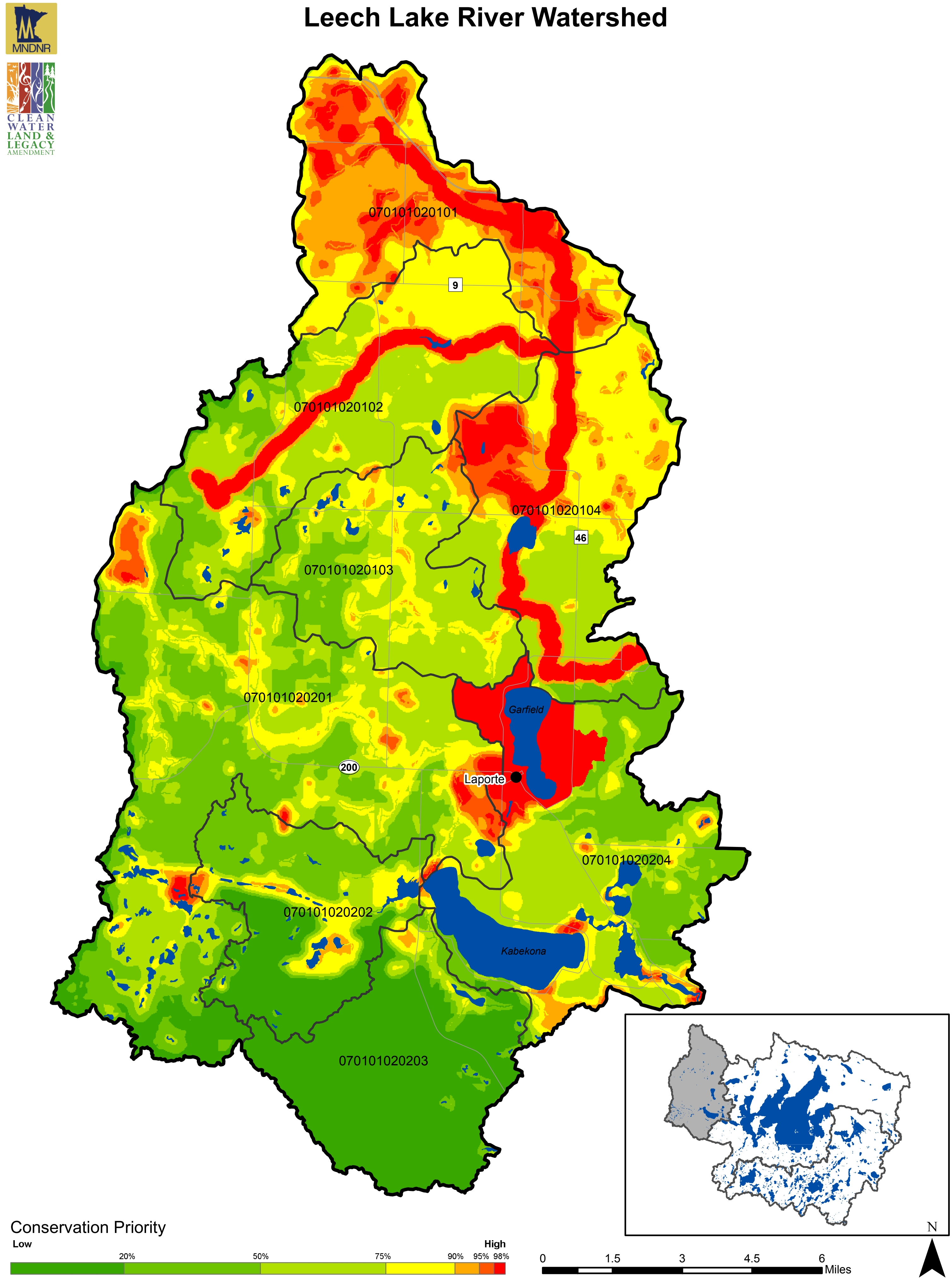
Comments:

Thank you!

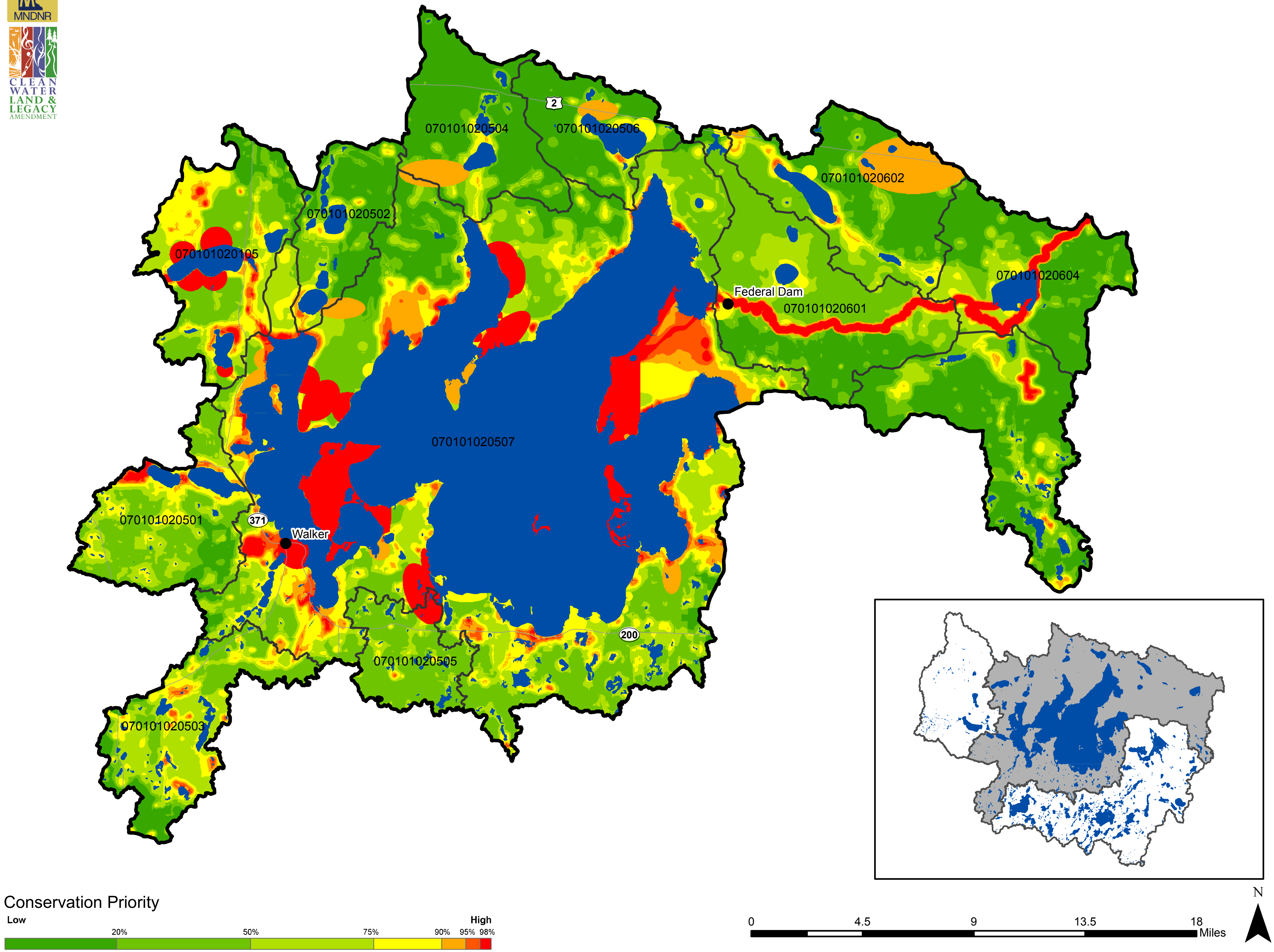
Please save and email word or scanned copy to: westcom@brainerd.net by no later than September 12.


Bemidji
Pa
NCCR Score
Index score
0 - 0.1
0.11 - 0.2
0.21 - 0.3
0.31 - 0.4
0.41 - 0.5
0.51 - 0.55
0.56 - 0.6
0.61 - 0.65
0.66 - 0.7
0.71 - 0.75
0.76 - 0.8
0.81 - 0.85
0.86 - 0.9
0.91 - 0.95
0.96 - 1
Leech Lake NCCR score

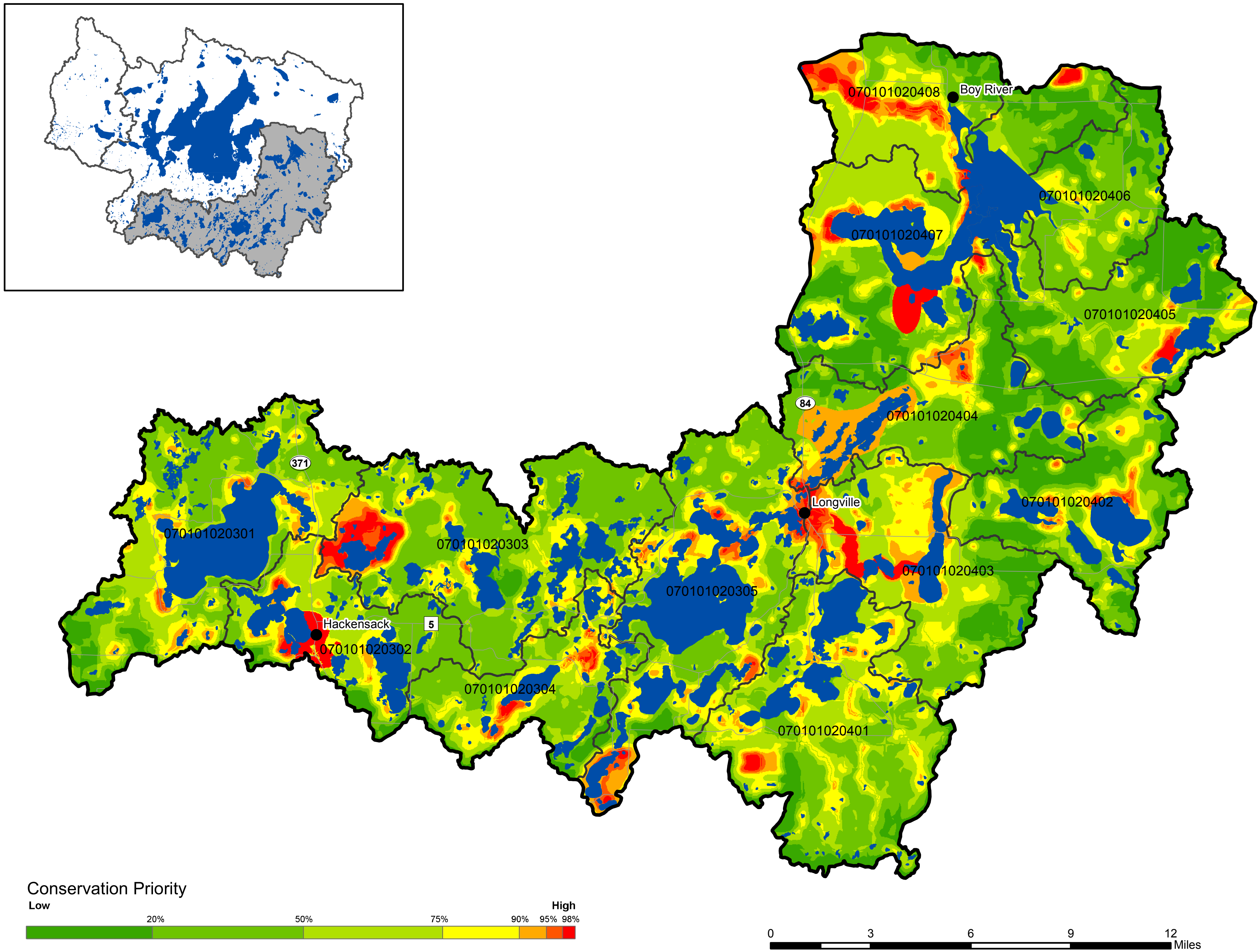
Leech Lake River Watershed



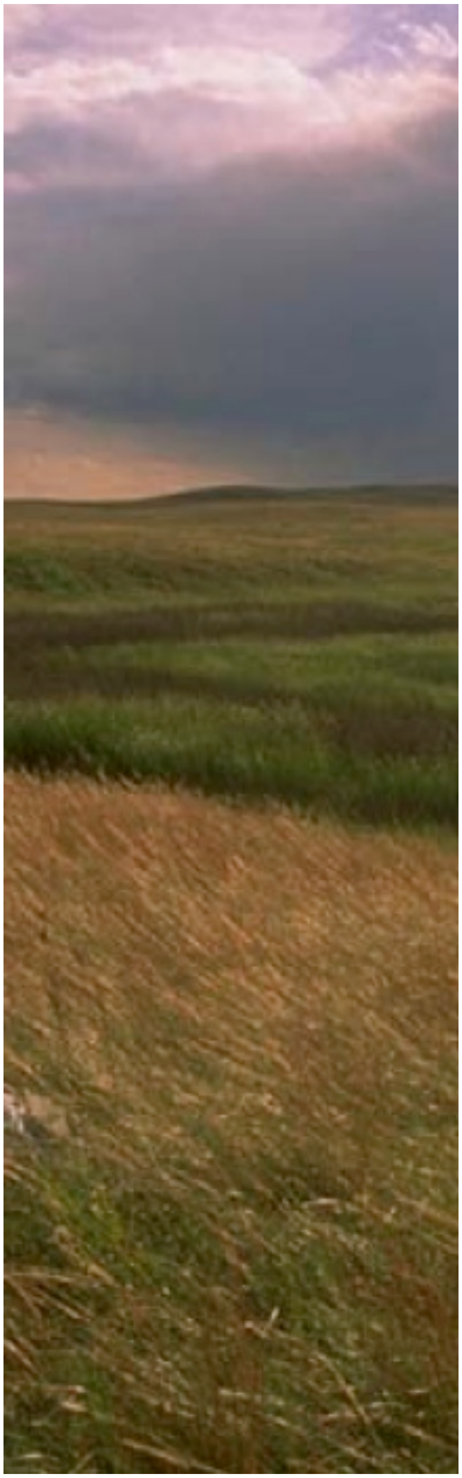
Leech Lake River Watershed



Leech Lake River Watershed



HOW TO PRIORITIZE AREAS FOR WATERSHED MANAGEMENT?



Introduction

There are six common mistakes in conservation planning (Game et al. 2013):

1. Not Acknowledging that Plans are Prioritizations

2. Trying to Solve an Ill-Defined Problem

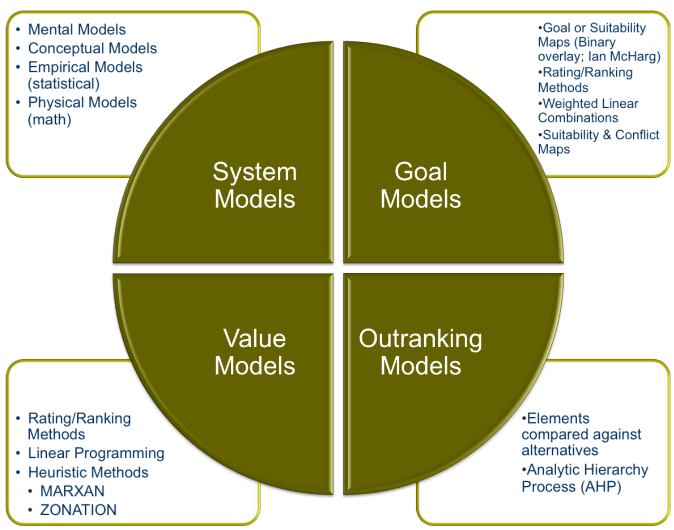
3. Arbitrariness

4. Hidden Value Judgments

5. Not Prioritizing Actions

6. Not Acknowledging Risk of Failure

How do we minimize these mistakes? Part of the answer is understanding the goals and needs of the watershed plan. Then we must use the correct approach for the existing conditions. Which conservation planning method can work for you? Here are the common approaches:

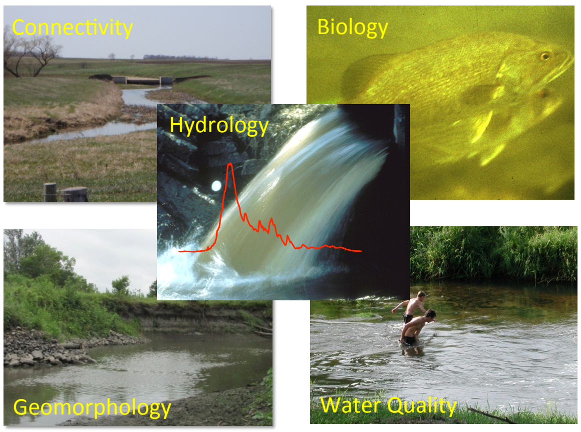


Value Modeling

A common approach to prioritization is value models. There are numerous frameworks used for conservation planning (e.g., Environmental Benefits Index, MARXAN, and Zonation).

Value Modeling Steps:

1. Determine what is valued. We structure important conservation features within 5 components:



2. Formulate the Objective Function.

   - Additive Benefits Function; find areas that provide multiple benefits (across the 5 components)
   - Core Area Objective Function; find areas that are the best-of-the-best (core)
   - Target Based Objective Function; find areas based on the proportion of the watershed you want conserved

3. Set the numeric weights within the Objective Function

   - BOGSAT
   - Swing Weight Matrix
   - Analytic Hierarchy Process (AHP)

Individual and group values/preferences can be aggregated with AHP. This decision-making method is popular because paired comparisons are natural and intuitive for most people to complete.

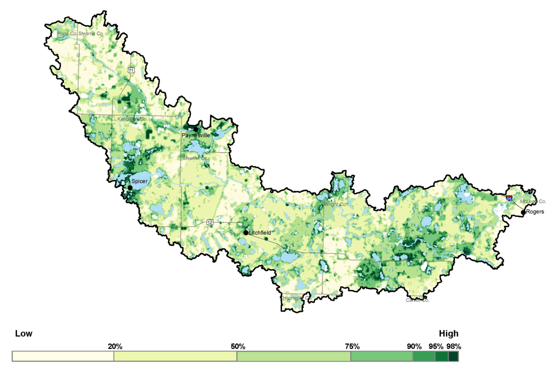
4. Synthesis

Sample questionnaire:

1) Broad-scale prioritization

	Strongly Prefer	Prefer	Equal	Prefer	Strongly Prefer	
Fish & Wildlife Habitat	☐	☐	☐	☐	☐	Water Quality
Ag Land Restoration	☐	☐	☐	☐	☐	Fish & Wildlife Habitat
Water Quality	☐	☐	☐	☐	☐	Reduce Flooding & Erosion
Reduce Flooding & Erosion	☐	☐	☐	☐	☐	Ag Land Restoration
Reduce Flooding & Erosion	☐	☐	☐	☐	☐	Minimize Interference w/Ag Land
Ag Land Restoration	☐	☐	☐	☐	☐	Water Quality
Connectivity	☐	☐	☐	☐	☐	Minimize Interference w/Ag Land
Fish & Wildlife Habitat	☐	☐	☐	☐	☐	Minimize Interference w/Ag Land
Reduce Flooding & Erosion	☐	☐	☐	☐	☐	Connectivity
Water Quality	☐	☐	☐	☐	☐	Connectivity
Connectivity	☐	☐	☐	☐	☐	Ag Land Restoration
Water Quality	☐	☐	☐	☐	☐	Minimize Interference w/Ag Land
Fish & Wildlife Habitat	☐	☐	☐	☐	☐	Connectivity
Ag Land Restoration	☐	☐	☐	☐	☐	Minimize Interference w/Ag Land
Fish & Wildlife Habitat	☐	☐	☐	☐	☐	Reduce Flooding & Erosion

Sample Prioritization results:



Conclusion

There are many benefits of a formal, quantitative planning framework. A values model approach facilitates an organized process to analyze priorities. In addition, priorities for clean water can be integrated with other priorities to achieve multiple benefits. Finally, a values model approach is an effective and efficient method of determining conservation priorities.

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Minnesota DEPARTMENT OF NATURAL RESOURCES

Appendix 8: TNC Multiple Benefit Module

Multiple Benefits for People and Nature:

Mapping and Modeling Tools to Identify Priorities for the Nature Conservancy's Freshwater Program and the Minnesota Headwaters Fund

The goal of the Conservancy's freshwater program is to conserve the lands that protect clean water, and to support high-impact conservation projects to protect clean water in Minnesota's lakes and rivers for the benefit of nature, people and the economy. As threats to continue to mount, it is becoming increasingly important to identify and conserve high-priority areas for habitat and clean water benefits. Identifying where in the landscape conservation can provide multiple, overlapping benefits can help more effectively target efforts and more efficiently utilize limited resources. Examples of protection and conservation approaches throughout the Upper Mississippi River basin include easements, stream bank and floodplain restoration, and other projects that prevent pollutants such as nitrates and sediment from entering key rivers and lakes.

This document and accompanying spreadsheet describes the methodology and criteria developed to make recommendations for investments to support clean water for people and nature. The purpose of this exercise was initially to support TNC in developing programmatic priorities for freshwater, and to set goals and targets for the Freshwater Business Plan. This includes recommendations for Protection, Restoration & Management, as well as investments in natural infrastructure for multiple ecosystem service benefits.

The intent of the process was to develop and score priorities **<u>according to specific but multiple cross-cutting needs, and looking for the "Sweet Spot"</u>** where multiple benefits overlap (habitat, water quality, water user benefit, flood benefit). We conducted priority area mapping based on criteria and key attributes for determining freshwater priorities.

Evaluation criteria should be dynamic, reflecting the evolution of better and more accurate tools, and may include

- Aquatic Protection priorities
- Terrestrial protection priorities
- Lands important to drinking water quality or other benefits to people
    - Close to a threshold
    - Vulnerable to conversion
    - Important or disproportionate impact on water quality

We also attempted to develop a map-based classification for STRATEGY (Protection vs Restoration). Ongoing needs include the need to better understand threats, thresholds, and how much conservation is enough at multiple watershed scales (small watersheds, large watersheds, and river basins); to identify management/habitat improvement opportunities on already public/protected land; which lands need to be acquired to reach those desired goals; measuring and documenting the effectiveness of habitat restoration and protection activities; and setting targets and goals for landscape scale conservation. Interpretation of output needs to consider appropriate SCALE (major Huc8 watershed, minor Huc12 watershed, project-based).

MULTIPLE BENEFITS MODULES FOR PRIORITIZING FRESHWATER CONSERVATION INVESTMENTS

We built on a systematic approach originally pursued by NCCR in 2014, working with MNDNR's Division of Ecological Resources team in Brainerd (Paul Radomski and Kristin Carlson), to develop a "blueprint" of conservation priorities across the Mississippi headwaters region. The approach uses a software tool called "Zonation", which allows stakeholders to aggregate multiple layers representing landscape features and conservation criteria, using an objective weighting function. The weighting is based on the relative value participants ascribe to each layer. The result is a map showing weighted priorities within the landscape for conservation, protection or restoration. This approach has been widely adopted at the major watershed (Huc-8) scale in the context of the MPCA's Watershed Restoration and Protection Strategy (WRAPS) planning process. In part because not all WRAPS in the Mississippi headwaters basin are on the same timeline, nor are they being done exactly the same way, the NCCR chose to conduct a prioritization model that would be consistent across the entire Mississippi headwaters.

The initial blueprint was reviewed, tweaked, and adopted by NCCR to help inform and coordinate support for partner priority projects across the Headwaters. However, at the time it was observed that the blueprint scored equally high large areas across , and that in some cases component layers may have contributed to scores that were counterintuitive to that which best professional judgement. Furthermore a number of new data layers became available only after the NCCR Zonation model was completed. In addition, partners were concerned that the final output layer showing all the combined outputs for protection, drinking water, and restoration was difficult to interpret. For example, priority scores for pollutant load reduction might effectively "cancel out" priority areas for habitat protection in the final weighting; therefore there was a desire to separate out the major model components to facilitate interpretation and development of appropriate strategies.
Finally, the NCCR geographic scope did not include the entire Mississippi headwaters, rather it extended only as far downstream as the Mississippi River – Platte River major watershed at Little Falls.

Based on all of these considerations, the Nature Conservancy took the initiative to develop a second iteration of this approach for the entire Mississippi headwaters that would incorporate newly available data layers, include the entire Mississippi headwaters, and be designed to be modular based on similar types of benefits.

Multiple Benefits v2.0 Methods and Data Layers

The tool is composed of 3-4 primary modules:

1. Fish and Wildlife
2. Drinking Water and Groundwater Quality
3. Flooding and Erosion
4. Groundwater Quantity

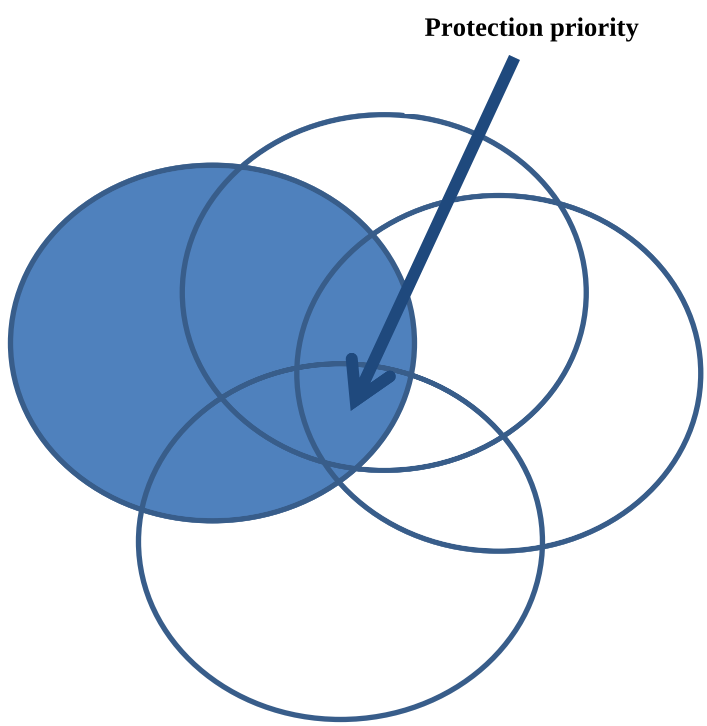
In addition, the Shoreland module is straightforward and can be viewed as an independent auxiliary layer where shoreland protection is identified as a priority for its own sake.

Fish & Wildlife Habitat Benefits
- Ecological patches and connections
- Protected lands
- Rare features
- Sites of biodiversity significance
- Sensitive lakeshore
- High quality wild rice lakes
- High quality cisco lakes
- High Conservation Value Forests
- Old Growth Forests

Drinking Water/Source Water Benefits
- Drinking water management supply area vulnerability
- Groundwater contamination susceptibility
- Proximity to water

Reduce Erosion, Enhance Storage, and Reduce Hydrologic Alteration
- Existing wetlands, riparian areas, and floodplains providing storage and retention benefits
- Areas vulnerable to erosion

Protect Groundwater Quantity – Protect recharge and managed withdrawals



Detailed Methods

Fish and Wildlife Module

The Fish and Wildlife module is intended to represent priority areas for ***protection*** based primarily on aquatic habitat protection value and secondarily on terrestrial fish and wildlife benefits. The module incorporates available data layers designed to represent parts of the basin where protection will have the highest benefits to fish and wildlife and their habitats. Much of the northern half of the Basin, including Itasca State Park, Leech and Cass Lake, the area around the Chippewa National Forest, northern Brainerd Lakes and Gull lake areas, Lake Alexander, Mille Lacs, and the Mississippi River corridor score highest on this module.

Components – Each of the component layers described below is re-scaled so that contributes equal weight in the final fish and wildlife module (3 of 30 points). For more information on how each individual layer is scored and weighted in the model, see the Appendix.

1. <u>RWI Benefit to Species Value:</u> This layer is a component of the Restorable Wetland Prioritization Tool developed by researchers at the University of Minnesota- Duluth Natural Resources Research Institute to prioritize wetland restoration and protection[1]. The *Species benefits* layer was developed using a subset of the individual habitat components from the Ecological Benefits Index (EBI) including sites of biodiversity significance, Species of greatest conservation need (SGCN) (number of species of greatest conservation need for which the land may provide suitable habitat); Potential bird habitat (probable number of birds from a modeled set of 17 that might use that habitat); and weighted habitat protection – the number of terrestrial vertebrate species potentially using this land weighted by the current level of habitat protection statewide for each species. The individual EBI inputs were combined using a weighting process to form a single species benefits decision layer designed to predict potential habitat enhancements that would result from wetland restoration or protection. This layer was included in the module as a statewide data layer representing overall habitat value weighted approximately equally for aquatic and terrestrial species and SGCN. *Caveats: this layer is more updated and less redundant with the layers below than the layer from the LCCMR Strategic Habitat Plan used by LSOHC. It should perhaps be replaced by the Wildlife Action Network from the 2015 MN Wildlife Action Plan Update.*

2. <u>Biodiversity Significance Score:</u> The Minnesota Biological Survey has assigned a biodiversity significance rank to surveyed sites across the state intended to reflect landscape context and ecological function, existing native plant community quality and rarity, and species quality and rarity. There are four biodiversity significance rankings: outstanding, high, moderate, and below. This layer is included in the freshwater Fish and Wildlife module to give greater weight in the final model to areas with moderate (1 pt), high (2 pts) and outstanding (3 pts) biodiversity.

3. <u>Lakes of Biological Significance</u>: This layer is based on the lake catchment for lakes designated as **Lakes of Biological Significance (LBS)[2]**. Lakes were identified and classified by DNR subject matter experts on objective criteria for four community types (aquatic plants, fish, amphibians, birds); or if the lake is included in the Conservancy's lake portfolio. Scored meeting standard (1 pt), higher (2 pts) and highest (3 pts).

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[1] http://www.mnwetlandrestore.org/project-description/subtopic-copy/subtopic-copy-2/

[2] https://gisdata.mn.gov/el/dataset/env-lakes-of-biological-signific

4. Index of Biological Integrity: This layer includes lake catchments with outstanding IBI scores based on the preliminary fisheries lake IBI[3]. The IBI *(Index of Biotic Integrity)* is a biologically-based, multi-metric method for measuring the integrity of aquatic systems. Minnesota DNR Fisheries Research has developed a fish-based lake IBI that incorporates fish data collected by various methods (trap nets, gill nets, shoreline seines, and backpack electrofishing units) into 8-15 metrics in three categories: species richness, community assemblage, and trophic composition. Lake catchments are scored based on the highest scoring lake meeting the IBI standard: meeting standard (1 pt) above standard (2 pts) and exceptional (3 pts), plus (+1 pt) if catchment contains a lake in the TNC lake portfolio.

5. Wild rice catchments: Wild rice is a unique resource in Minnesota, important culturally as well as to migrating waterfowl and other wildlife. Because wild rice is so important as well as sensitive to hydrologic and water quality disturbance, lake catchments identified as having significant wild rice were included as a layer in this module.

6. Coldwater refuge - cisco – This layer represents the level 8 DNR lake catchments for lakes identified by the Minnesota DNR to be the most resilient, likely refugia for ciscoes (tullibee, *Coregonus artedi*), a keystone species for Minnesota's deep, coldwater lake class. Because these lakes are likely to be the most resilient in the face of climate change, they are priorities for protection in the Minnesota DNR Aquatic Habitat Strategic Plan.

7. High Conservation Value Forests: The original NCCR model only included forests designated as "old-growth". We used FLEET results (ecological value) for northern headwaters. However, because FLEET does not extend beyond the Superior Mixed Forest ecoregion to include the entire Mississippi River headwaters basin, we rescaled the USFWS Upper Mississippi River Forest Partnership Priority Forest for Drinking Water to use those scores for the portion of the Basin not covered by FLEET. Caveat: This obviously results in a problem, since the methodology is not the same across the study area, especially significant when evaluating finer scale scores along the Superior Mixed Forest border. Future iterations of the tool could be revised to use a cumulative forest disturbance layer currently being developed by MN DNR (Corcoran 2015). For this version we made the choice to use the ecological value layer.

8. Ecological Patches or Connections: Statewide, riparian corridors constitute some of the most extensive and complete terrestrial habitat corridors for fish and wildlife, particularly in areas disturbed by urban or agricultural land use. We created a layer representing landscape habitat connectivity for both aquatic and terrestrial species based on perennial lands within the Active River Area (ARA) layer as derived for the Mississippi headwaters (2014).

9. Proximity (inverse distance) to protected lands This layer is scaled 0-100 based on inverse distance to protected lands, on the assumption that all else being equally, lands more closely connected to an existing network of protected lands are of relatively higher conservation value.

10. Proximity (inverse distance) to water. This layer is scaled 0-33 based on inverse distance to water features, on the assumption that the value of lands to fish and wildlife is in direct proportion to their distance from water.

[3] https://gisdata.mn.gov/el/dataset/env-ibi-lakes-fisheries

Drinking Water Quality Module

The Drinking Water module is intended to represent priority areas for protection ***and/or*** restoration, weighted on the relative potential impact on estimated actual users where they obtain their drinking water. This module may be used with or without the groundwater recharge module. Inclusion of the groundwater recharge module reduces the apparent resolution of the visual output from the module, because the latter is based on larger, coarser grid cell resolution of the Smith et al. (2015) analysis.

Caveats:

- Because of the limitations of the resolution and projection accuracy of the groundwater susceptibility component in particular, parcel scores evaluated on this module should not be over-interpreted in local project context.
- The methodology for assigning relative importance of ARA lands upstream in terms of influence on downstream surface water drinking intakes is approximate, and could be improved in collaboration with the drinking water utilities and others working to develop similar tools.

Module Components

1. Drinking Water Management Supply Area Vulnerability: This is a delineation of areas of concern for and relative risk for a potential contaminant source within the drinking water supply management are to contaminate a public water supply well based on the aquifer's inherent geological sensitivity; and the chemical and isotopic composition of the ground water. Source: MDH.

   Wellhead Protected Areas: WPA is the surface and subsurface area surrounding a public water supply well or well field that supplies a public water system, through which contaminants are likely to move toward and reach the well or well field. Source: MDH.

   The maximum score for these two layers is scored 1-5 (0 for non-DWSMA or WHPA areas). (They do not have 100% overlap).

2. Groundwater Contamination Susceptibility: A broad, generalized interpretation of ground water contamination susceptibility for the state, based on modeling relying on data inputs from the MLMIS40 (40-acre raster) soils and geology data, with additional geology inputs[4]. The parameters that control ground water susceptibility to contamination are quite varied and overlapping, and include: soil media, topography, depth to water, aquifer media, vadose zone materials, net recharge, hydraulic conductivity of aquifer, hydraulic gradient, distance to nearest drinking water supply, depth to bedrock, unsaturated zone permeability and thickness, and net precipitation. *Caveats: this layer does not display accurately into UTM15 NAD83 projection; it is offset by up to 300 m. Metadata reinforces that it is not appropriate for site-specific use.*

3. Proximity to mainstem river water supply (Mississippi River and Major Tributaries) Lands within the ARA upstream of surface water intakes for major drinking water supply areas are assigned zonal values based on downstream distance to the supply area.

4. Private well density – This layer summarizes the County Well Index (CWI) layer (Source: MDH[5]) by Huc12 watershed to summarize the number of private domestic water supply wells in each 12-digit

[4] http://www.mngeo.state.mn.us/chouse/metadata/gwc.html
[5] http://www.health.state.mn.us/divs/eh/cwi/

watershed that are located in a vulnerable or highly vulnerable groundwater area, and is converted to 10 density classes by Huc12. The CWI layer is known to be dated and incomplete, but represents an accurate representation of the population density relying on private domestic groundwater wells.

Flooding and Erosion Module Components:

1. Benefits to Water (RWI)[6]: This water quality later predicts the potential water quality benefits in the form of reduced erosion risk from wetland restoration or protection. The layer utilizes the data inputs soil erosion risk and water quality risk from the Environmental Benefits Index along with the downstream flow distance to open water. The EBI is an ecological ranking tool (30 m grids) developed by Minnesota Board of Soil and Water Resources (MNBWSR) and NRRI.
    - The soil erosion layer estimates the potential risk of soil erosion on a 0-100 scale based on components of the Universal Soil Loss Equation (USLE) (rainfall runoff factor, slope length slope gradient, and soil erodibility factor) at a 30 m resolution. NRRI modified the layer to predict the potential flow accumulated soil erosion risk downstream to the nearest second order stream for each 30 m cell.
    - The water quality risk layer estimates each 30 m cell's risk to water quality based on the likelihood of overland flow during a rain event and its proximity to water. The likelihood of overland flow was estimated from stream power index (SPI). The downstream flow distance to water measures the closest downstream distance to water.

    The flow accumulated soil erosion risk, water quality risk and downstream flow distance to water were combined through a weighting process to form a single water quality/erosion benefits layer.

2. Sediment Retention Benefits: Mosaic of the following 3 layers, then averaged over a focal statistics rectangle 9 cells wide & tall.
    - Existing Perennial cover x Sediment Retention from Invest Model: InVest – Integrated Valuation of Ecosystem Services and Tradeoffs is an open-source software suite aimed at quantifying and mapping ecosystem services. The nutrient and sediment loading models are described elsewhere. The sediment results were generated January-February 2015 using InVEST 3_1_0b1 version of the sediment delivery and retention model. This layer represents the lands already in perennial land cover that had the highest scores for sediment retention.
    - Existing ARA x Sediment Retention from Invest Model : This layer represents the lands within the Active River Area that had the highest scores for sediment retention (see above).
    - Existing NWI x Sediment Retention from Invest model : This layer represents wetlands with the highest scores for sediment retention (see above).

3. Total upstream contributing area / wetland acres (storage) : Relative ecosystem service value of existing wetland storage. This layer represents the ratio of upstream watershed delivery area to existing wetlands, on the assumption that the greater the upstream contributing area, the greater the relative contribution to storage of any given area of wetland storage. Research suggests that the value of remaining wetland storage increases exponentially as percentage of wetlands decreases, and that there is a hydrologic threshold at around 10% wetlands.

[6] http://www.mnwetlandrestore.org/project-description/subtopic-copy/subtopic-copy-2/

Groundwater Recharge Module Components

1. Groundwater Recharge (inches/year) (Smith et. al 2015) and Groundwater recharge (inches/year) (Lorenz and Delin 2007)

   The two layers are averaged together to yield a long term potential average recharge (in inches / year of rainfall that recharges groundwater and supports streamflow).

2. Water use vulnerability Index, Predicted Vulnerability -- DNR Watershed Health Assessment Framework Catchment Score
   http://www.dnr.state.mn.us/whaf/about/scores/hydrology/waterwithdraw.html

   The index is based on the sum of permitted withdrawal from surface water and groundwater. Using the State Water Use Database (SWUD), total potential consumption was calculated by summing permitted use and comparing to annual runoff. The "water use vulnerability index" is scaled as the greater the amount of water used as percent of runoff, the lower the score. The Catchment Predicted Vulnerability is the five year trend in reported use as a percentage of runoff.

Shoreland Module Components

1. Shoreland – 1000 ft lake buffer. Scaled 0-15 pts based on lake size (larger lakes get higher score for shoreland value.)
2. Sensititve lakeshore – Highly sensitive = 5 pts. High/moderate=3 pts.

This module is considered "auxiliary" because (a) the Fish and Wildlife Module already weights shorelands, and (b) the module should be revised to reflect specific types of benefits (not already accounted for in the Drinking Water and F&W modules).

Multiple Benefits Map

An overlay of the top quartile scoring areas for each of the Fish and Wildlife, Drinking Water, Flooding and Erosion, and Groundwater Quantity Modules. The value is the total number of modules for which the area scores in the top quartile.

Combined Quartile Scores

A combined overlay of the quartile scores for each of the Fish and Wildlife, Drinking Water, Flooding and Erosion, and Groundwater Quantity Modules, where each layer is scored 1-4 with 4 representing the highest quartile. The value is the total sum of quartile scores.

Interpreting and Using Mapped Results to Implement Conservation

Mapped scores are intended to reflect priority areas for protection and/or restoration based on multiple benefits. High scores for riparian lands, shorelands, and large floodplain areas, including the Mississippi River corridor from Grand Rapids to St. Cloud reflect the fact that these lands score on multiple modules. The lake-rich areas south of Walker and Aitkin and north of Brainerd and Grand Rapids also score high. This reflects the high priority of shorelands as well as the fact that shorelands often occur in areas of high groundwater contaminant susceptibility, and along the river corridors in proximity to important drinking water supply areas (e.g., Park Rapids, Grand Rapids, St. Cloud).

The model is intended as a tool to help the Conservancy and our partners set programmatic direction goals as well as identify opportunities and focus areas. It is designed to be used in conjunction with information on ***opportunities, threats,*** and ***costs***–none of which the model is designed to account for--to evaluate benefits and tradeoffs among potential conservation projects.

Already Protected Lands:

Protected.tif --All publicly or privately owned lands managed for natural resource values, plus privately owned wetlands nominally (effectively?) protected under the Minnesota Wetland Conservation Act.

Pubownease.tif—Publicly owned lands as well as privately owned lands with natural resource easements

Prioritizing Protection.

Protect.tif è This layer shows the final multiple benefits scores for the complete module *for lands already in perennial cover only*, with already protected lands and waters “zeroed” out. It represents the relative multiple benefits scores for all lands that are privately owned and therefore not protected.

Protect_grass.tif è This layer shows the final multiple benefits scores for the complete module *for lands identified as in grass/pasture*, with already protected lands and waters “zeroed” out. It represents the relative multiple benefits scores for all lands that are privately owned and therefore not protected.

Protect_wetlands.tif è This layer shows the final multiple benefits scores for the complete module *for lands identified in the National Wetlands Inventory/Minnesota Wetlands* layer as protected wetlands. Despite the fact that wetlands are protected by law, recent analysis suggests Minnesota continues to lose wetlands to agriculture and development (Lark et al. 2015).

Prioritizing Restoration

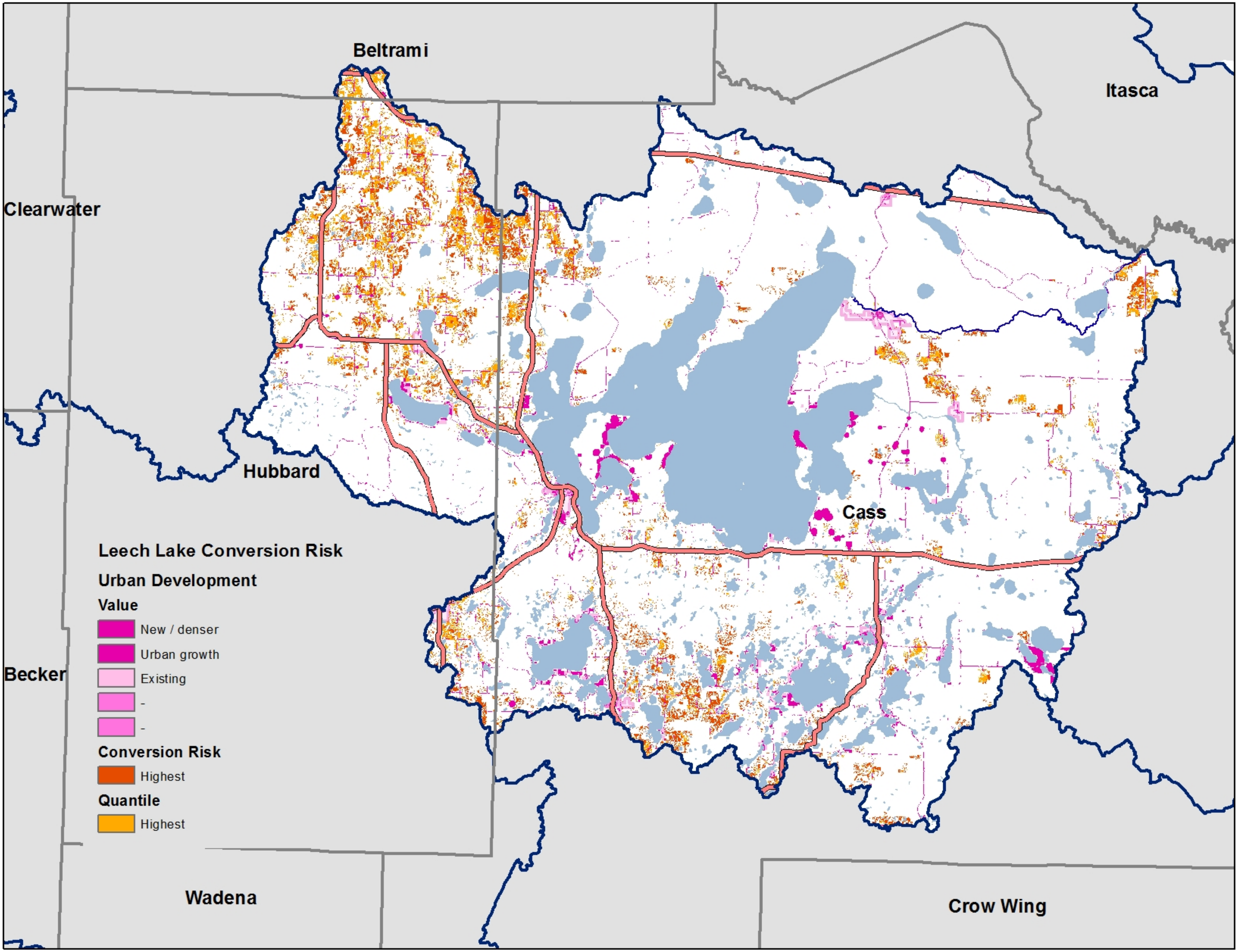
Restore.tif è This layer shows the final multiple benefits scores for the complete module *for lands identified in agriculture* . It represents areas with multiple benefits for lands that are in row crop agriculture.

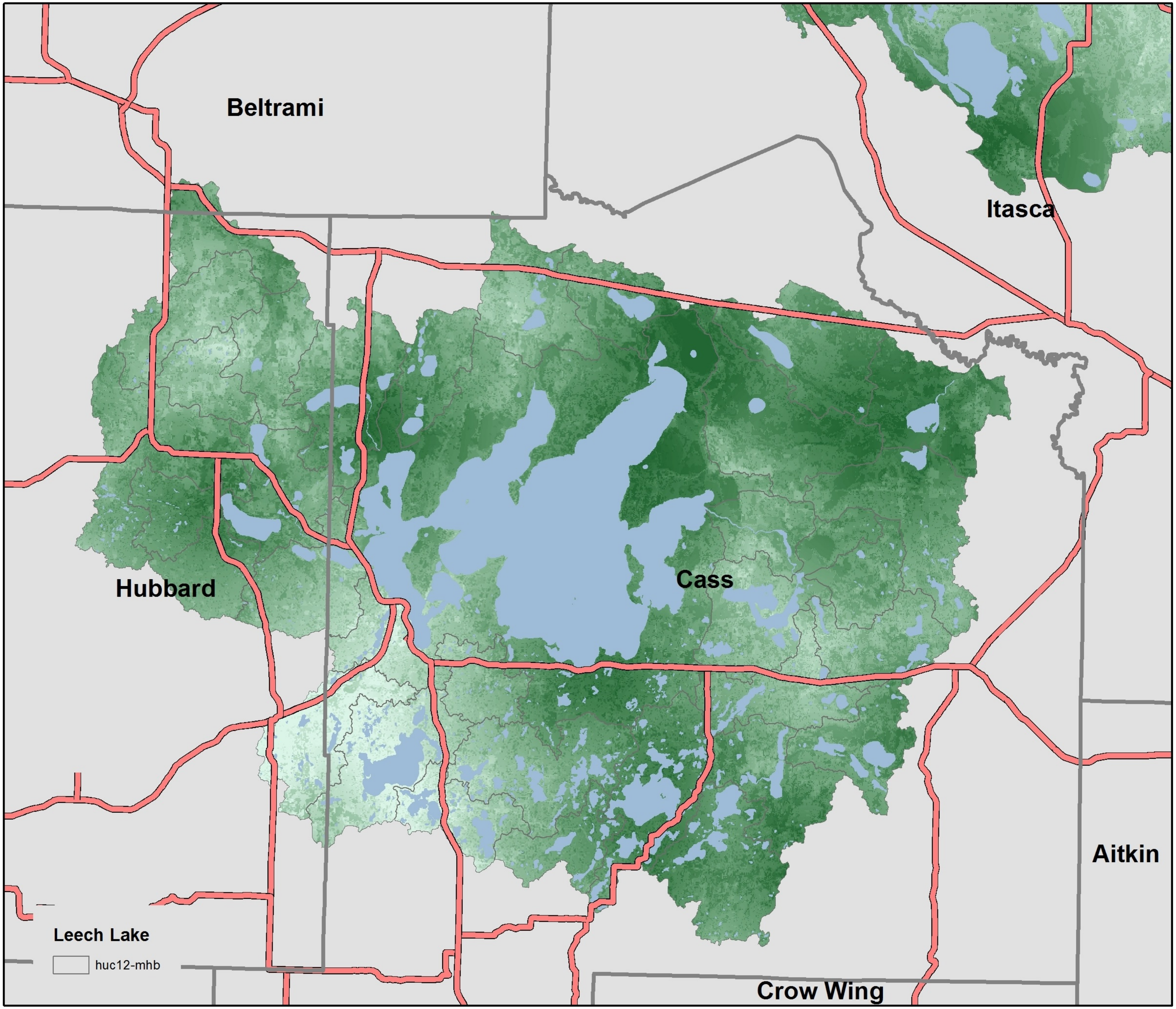
These could be interpreted as priority areas where BMPs targeted to the appropriate existing land use are likely to have disproportionate benefits to water. However, planning specific projects, strategies, and answering the question of “how much is enough?” should be done with additional resources.

Restore_wetlands.tif è This layer shows the final multiple benefits scores for the complete module *for lands identified as Restorable Wetlands* using the NRRI Restorable Wetlands Prioritization Tool (http://www.mnwetlandrestore.org/media/cms_page_media/53/rwi_meta.htm). It represents areas with multiple benefits for lands that are in row crop agriculture, overlaid with the multiple benefits quartile score.

Emerging and Companion Tools

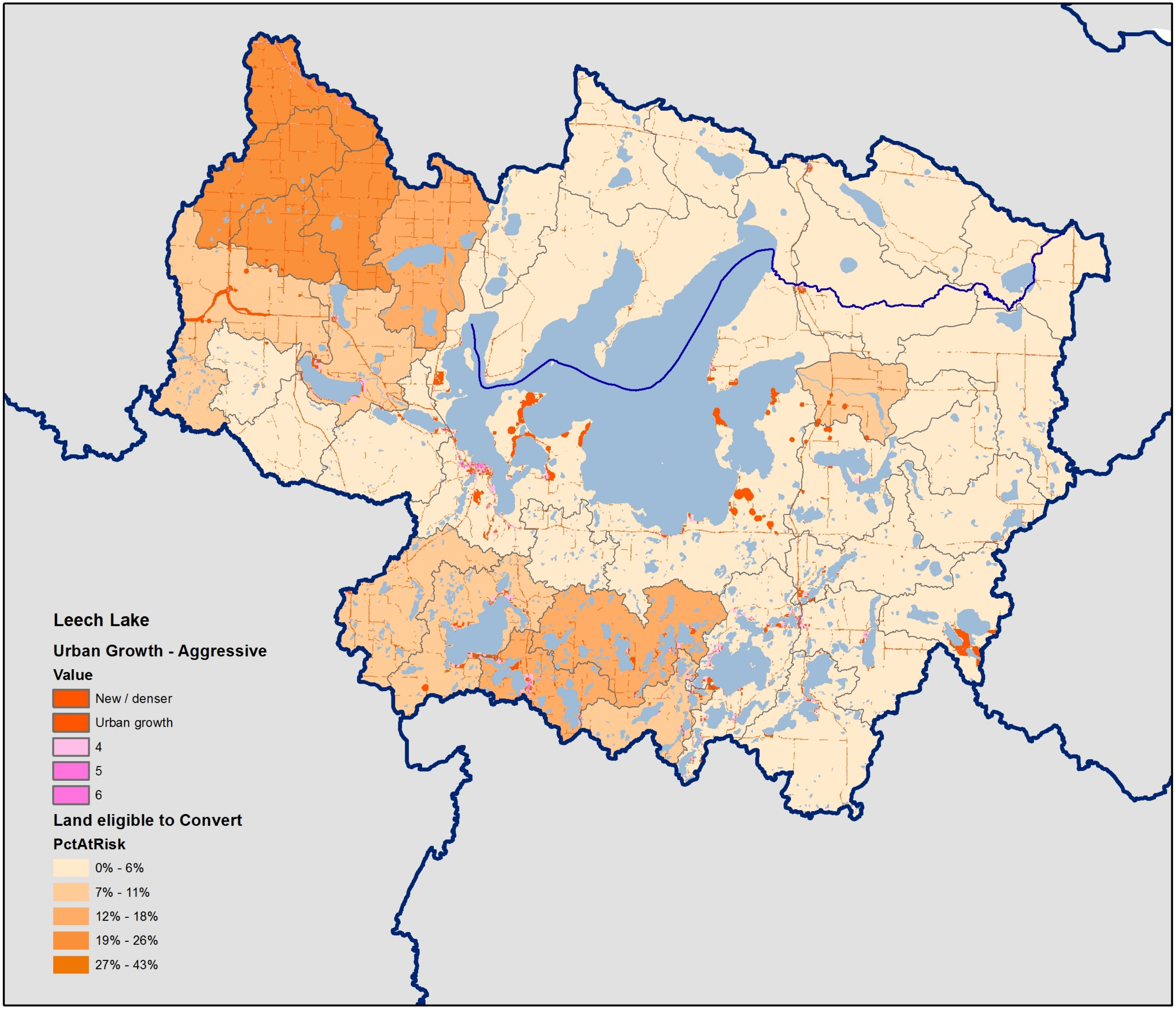
-Threat Assessments
- Minnesota DNR Watershed Health Assessment Framework (WHAF)
- HSPF model nutrient loading and flow results
- Scenario Application Manager

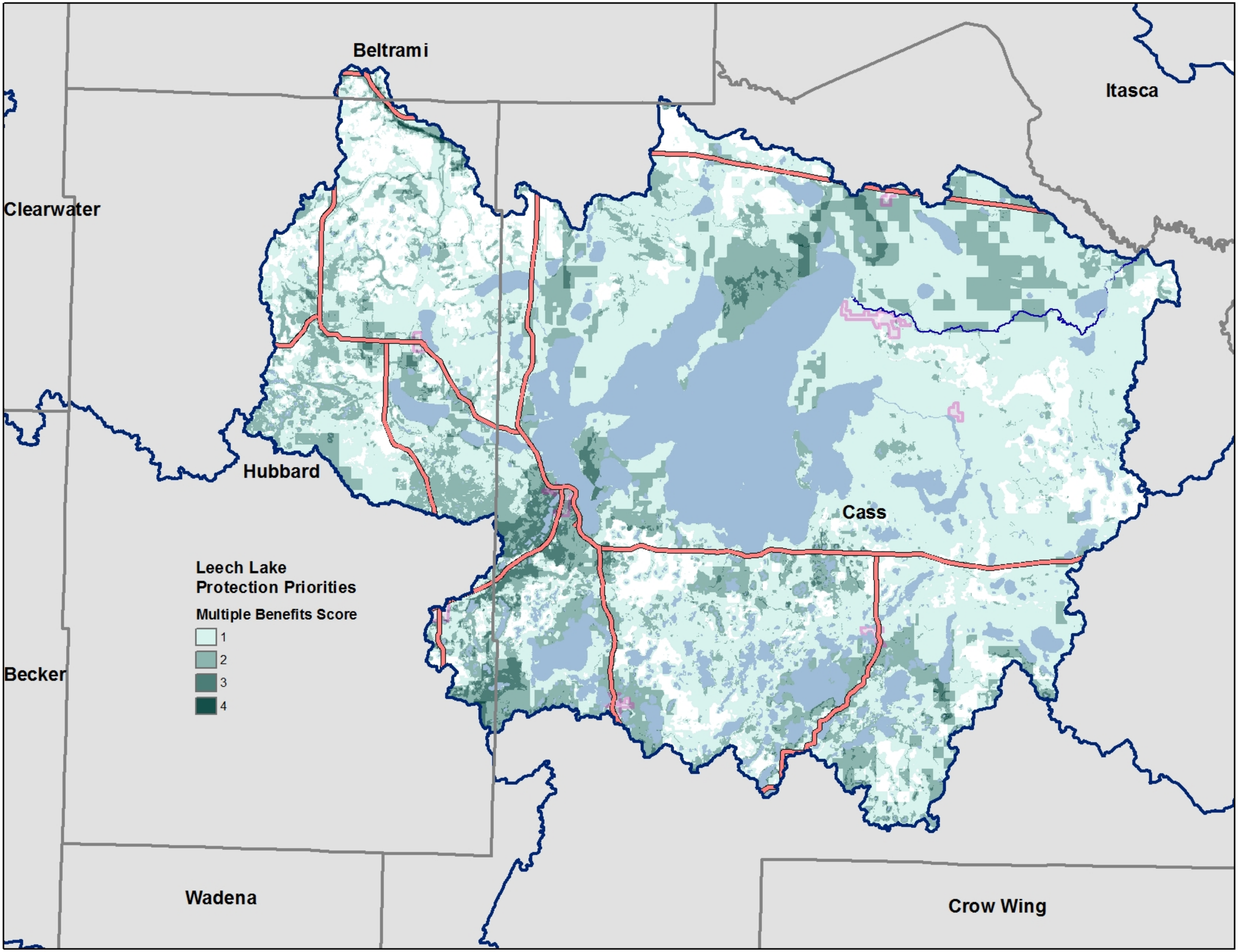

Beltrami
Itasca
Clearwater
Hubbard
Cass
Becker
Wadena
Crow Wing
Leech Lake Conversion Risk
Urban Development
Value
New / denser
Urban growth
Existing
-
-
Conversion Risk
Highest
Quantile
Highest



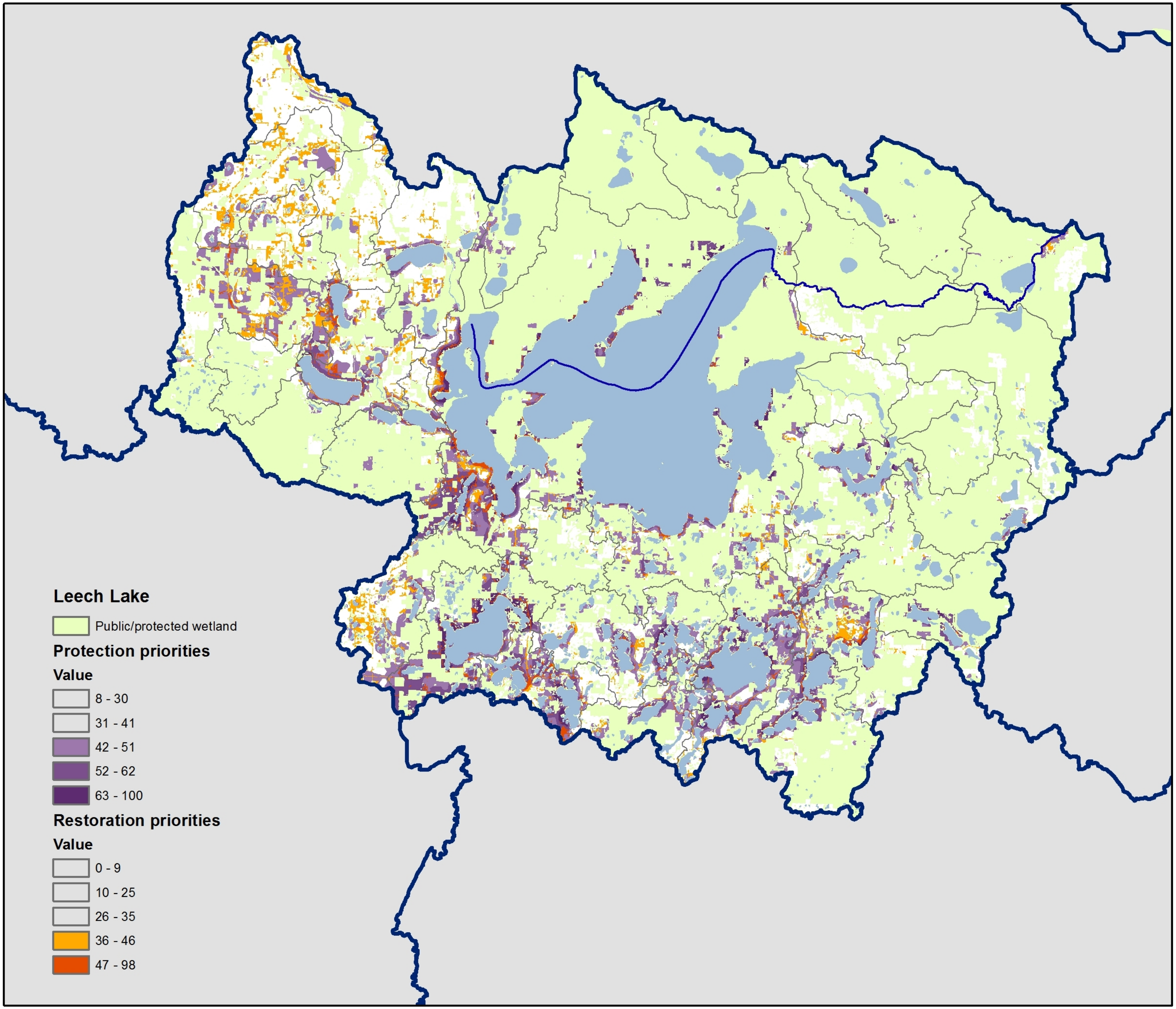
Forest Ecological Score on Forest Legacy Ecological Evaluation Tool

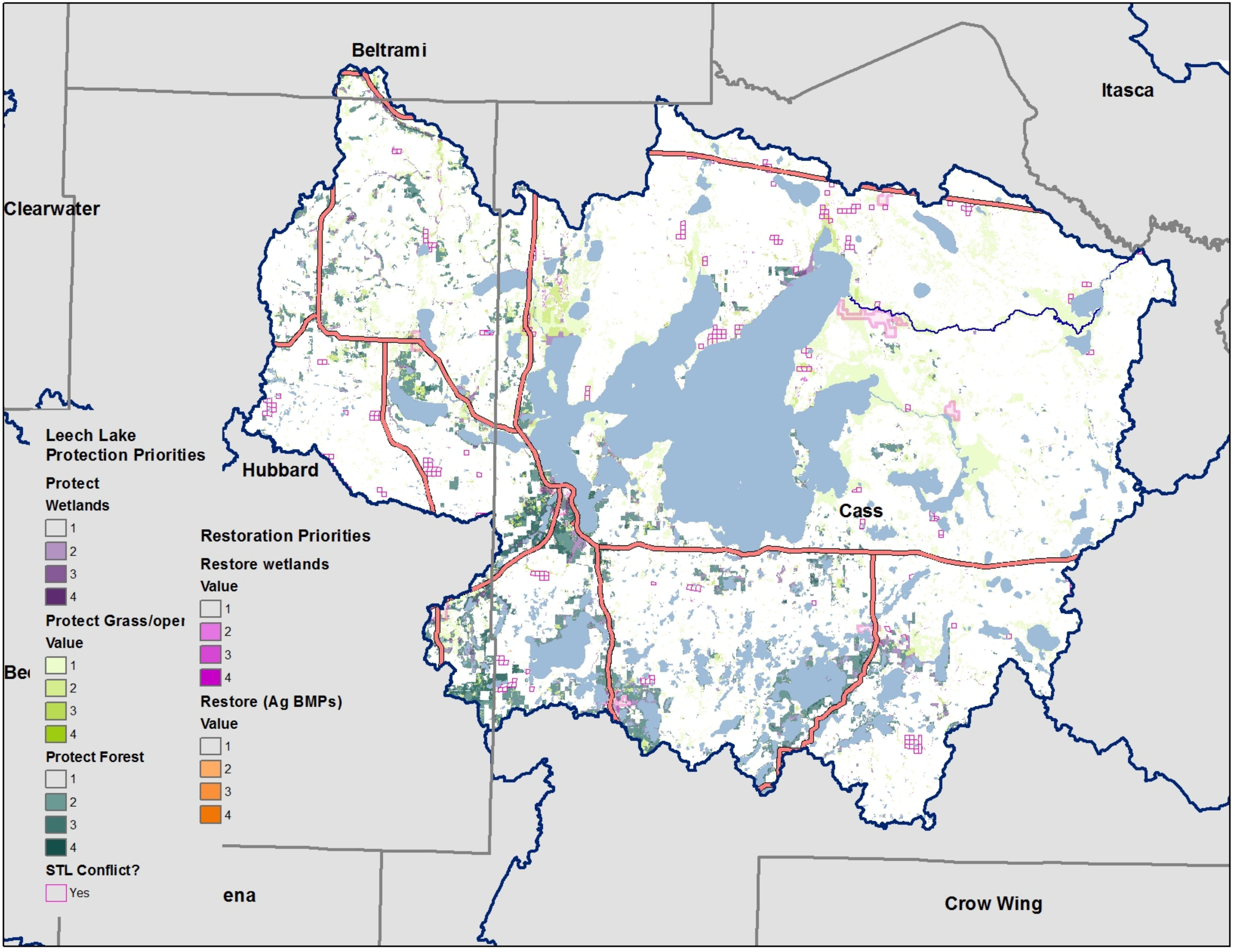
darker green= higher value


Leech Lake
Urban Growth - Aggressive
Value
New / denser
Urban growth
4
5
6
Land eligible to Convert
PctAtRisk
0% - 6%
7% - 11%
12% - 18%
19% - 26%
27% - 43%



Beltrami
Itasca
Clearwater
Hubbard
Cass
Leech Lake
Protection Priorities
Multiple Benefits Score
1
2
3
4
Becker
Wadena
Crow Wing


Leech Lake
Public/protected wetland
Protection priorities
Value
8 - 30
31 - 41
42 - 51
52 - 62
63 - 100
Restoration priorities
Value
0 - 9
10 - 25
26 - 35
36 - 46
47 - 98


Beltrami
Itasca
Clearwater
Hubbard
Cass
Be
ena
Crow Wing
Leech Lake
Protection Priorities
Protect
Wetlands
1
2
3
4
Protect Grass/oper
Value
1
2
3
4
Protect Forest
1
2
3
4
STL Conflict?
Yes
Restoration Priorities
Restore wetlands
Value
1
2
3
4
Restore (Ag BMPs)
Value
1
2
3
4

Appendix 9: Miscellaneous Resources

Forests, Water and People

Drinking water supply and forest lands in Minnesota

USDA Forest Service
Northeastern Area
State and Private Forestry

Project Description

In the Northeast and Midwest United States, forests are critically important to the supply of clean drinking water. Protecting and managing forests in source watersheds is an essential part of future strategies for providing clean safe drinking water that citizens can afford. The Forests, Water and People analysis identified private forests that are most important for drinking water supply and most in need of protection from development pressure. This fact sheet gives the results of the analysis for the State of Minnesota. For more detailed description of methods, and results for the Northeast and Midwest United States, see the **full report**.

The Process

Through a 4 step GIS-based overlay analysis, four indices were developed for each watershed (see Figure 1).

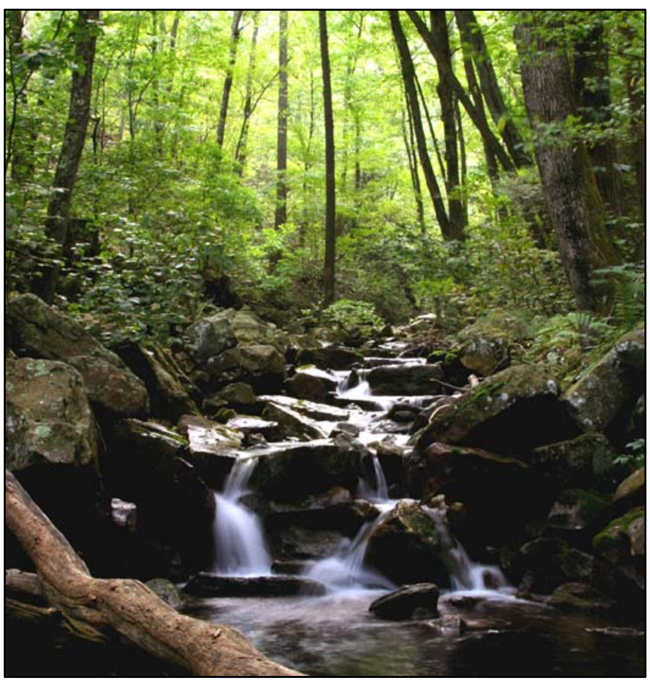
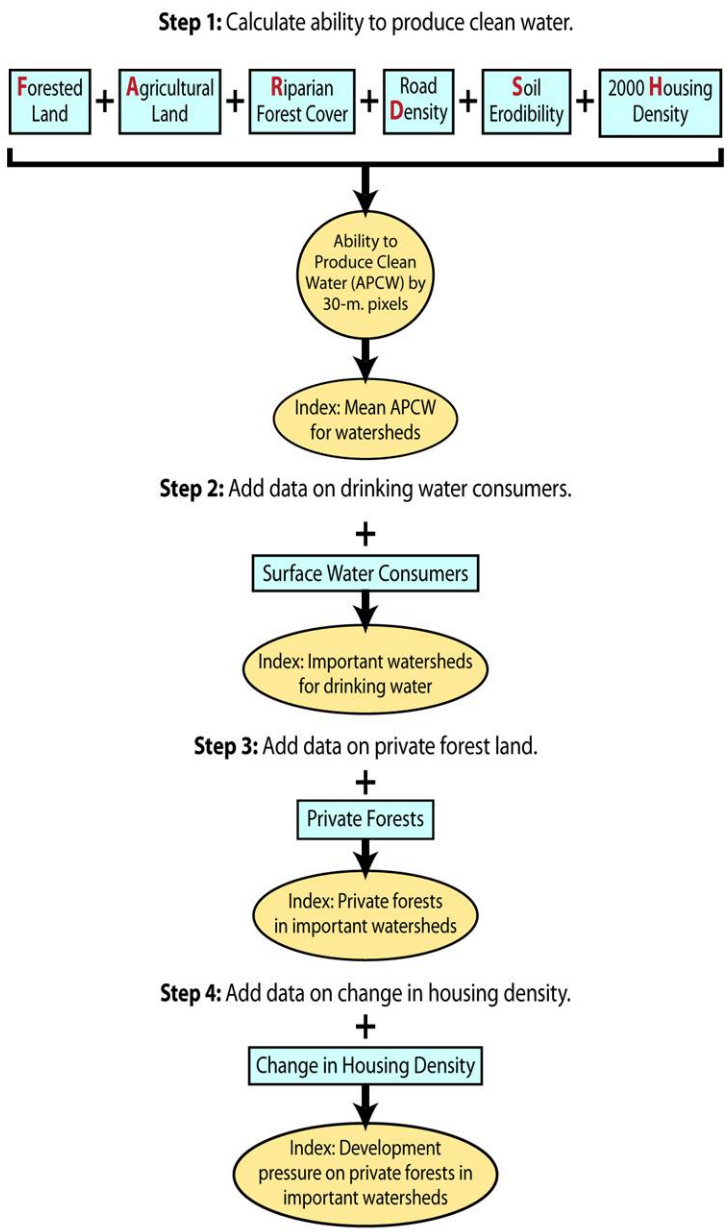


Photo by Michael Land.

"Water, in all its uses and permutations, is by far the most valuable commodity that comes from the forest land that we manage, assist others to manage, and/or regulate." Policy Statement, National Association of State Foresters

Figure 1. *Nine layers of GIS data (boxes) were combined in stepwise fashion, to produce four indices (ovals) of watershed importance for drinking water supplies and the need for private forest management to protect those supplies.*



Minnesota Results

Highlights

- The watersheds in northeastern Minnesota scored above average in each step of the analysis, with the highest scores in step 1. The State contains large protected forest areas in the northeast, an even mix of private and publicly owned forest (51 percent private), and high development pressure around the Twin Cities.
- Those Minnesota watersheds that scored highest in their ability to produce clean water (step 1) are located in the northeastern part of the State, where there are large areas of forested land. Eleven watersheds in Minnesota (or fourteen percent of all the State's watersheds) tied for the highest score in step 1.
- In the ability of watersheds to provide drinking water to the most people (step 2), several Minnesota watersheds scored above average, particularly those in the northeastern part of the State. The scores were not as high as in other parts of the study area due to the fact that many areas of Minnesota get their drinking water from ground water supplies, which are not included in this study. The area far to the north of the Twin Cities scored highest, including the Mississippi Headwaters, Leech Lake, Prairie-Willow, and Pine watersheds.
- In the ability of watersheds to provide drinking water on private lands (step 3), the same area far to the north of the Twin Cities scored highest, including the Mississippi Headwaters, Leech Lake, Prairie-Willow, and Pine watersheds.
- Step 4 ranked watersheds based on their development pressure and land ownership status (private lands ranked higher because they are subject to conversion). The two highest ranked watersheds were the Pine and Rum watersheds, which were in the top sixteen percent of all the study area's watersheds, and are located north of the Twin Cities region.

Table 1. Watershed results for Minnesota

Watershed Name	Hydrologic Unit Code	Mean APCW for watersheds	Surface drinking water consumers	% private forest in watershed	% watershed with housing density increase	Index: Development pressure on private forests important for drinking water supply Score (Step 4)	Rank (Step 4)
Pine	07010105	9 of 10	30,373	39 %	6 %	28 of 40	88 of 540
Rum	07010207	6 of 10	61,437	35 %	14 %	28 of 40	88 of 540
Clearwater-Elk	07010203	5 of 10	108,809	20 %	18 %	26 of 40	126 of 540
Mississippi Headwaters	07010101	9 of 10	78,755	27 %	4 %	26 of 40	126 of 540
Prairie-Willow	07010103	10 of 10	81,990	38 %	2 %	26 of 40	126 of 540
Leech Lake	07010102	9 of 10	54,552	24 %	4 %	25 of 40	148 of 540
Crow Wing	07010106	7 of 10	78,453	39 %	3 %	25 of 40	148 of 540
Elk-Nokasippi	07010104	8 of 10	66,491	41 %	4 %	25 of 40	148 of 540
Upper St. Croix	07030001	9 of 10	0	45 %	6 %	23 of 40	199 of 540
St. Louis	04010201	10 of 10	15,171	38 %	2 %	22 of 40	229 of 540
Long Prairie	07010108	6 of 10	35,390	27 %	3 %	22 of 40	229 of 540
Platte-Spunk	07010201	6 of 10	40,010	24 %	5 %	22 of 40	229 of 540
Crow	07010204	4 of 10	57,637	12 %	12 %	22 of 40	229 of 540
Beartrap-Nemadji	04010301	9 of 10	0	44 %	3 %	21 of 40	264 of 540
Twin Cities	07010206	1 of 10	42,350	14 %	22 %	21 of 40	264 of 540
Snake	07030004	8 of 10	0	34 %	6 %	21 of 40	264 of 540
Vermilion	09030002	10 of 10	11,495	31 %	1 %	21 of 40	264 of 540
Kettle	07030003	8 of 10	0	50 %	3 %	21 of 40	264 of 540
Lower St. Croix	07030005	5 of 10	0	24 %	22 %	20 of 40	289 of 540
Upper Red	09020104	2 of 10	125,099	2 %	10 %	20 of 40	289 of 540
Beaver-Lester	04010102	9 of 10	0	41 %	2 %	20 of 40	289 of 540
Redeye	07010107	6 of 10	34,724	28 %	1 %	20 of 40	289 of 540
Upper Rainy	09030004	10 of 10	6,703	27 %	0 %	20 of 40	289 of 540
La Crosse-Pine	07040006	5 of 10	0	39 %	12 %	20 of 40	289 of 540
South Fork Crow	07010205	4 of 10	50,183	6 %	9 %	19 of 40	320 of 540
Otter Tail	09020103	6 of 10	13,470	22 %	4 %	18 of 40	337 of 540
Sauk	07010202	4 of 10	40,750	12 %	4 %	18 of 40	337 of 540
Little Fork	09030005	10 of 10	0	40 %	0 %	18 of 40	337 of 540
Rush-Vermillion	07040001	3 of 10	0	15 %	19 %	17 of 40	352 of 540
Coon-Yellow	07060001	5 of 10	0	37 %	3 %	17 of 40	352 of 540
Cloquet	04010202	10 of 10	0	30 %	0 %	17 of 40	352 of 540

Watershed Name	Hydrologic Unit Code	Mean APCW for watersheds	Surface drinking water consumers	% private forest in watershed	% watershed with housing density increase	Index: Development pressure on private forests important for drinking water supply Score (Step 4)	Rank (Step 4)
Baptism-Brule	04010101	10 of 10	0	19 %	0 %	17 of 40	352 of 540
Red Lakes	09020302	9 of 10	0	31 %	1 %	17 of 40	352 of 540
Lower Rainy	09030008	8 of 10	0	29 %	0 %	16 of 40	380 of 540
Rainy Lake	09030003	10 of 10	0	25 %	0 %	16 of 40	380 of 540
Lake of the Woods	09030009	8 of 10	0	32 %	1 %	16 of 40	380 of 540
Rapid	09030007	10 of 10	0	20 %	0 %	16 of 40	380 of 540
Big Fork	09030006	10 of 10	0	18 %	0 %	15 of 40	394 of 540
Rainy Headwaters	09030001	10 of 10	3,724	10 %	0 %	15 of 40	394 of 540
Buffalo-Whitewater	07040003	5 of 10	0	33 %	3 %	15 of 40	394 of 540
Red Lake	09020303	4 of 10	40,574	13 %	1 %	14 of 40	407 of 540
Lower Minnesota	07020012	3 of 10	0	10 %	11 %	14 of 40	407 of 540
Lower Big Soiux	10170203	2 of 10	128,000	2 %	3 %	13 of 40	427 of 540
Cannon	07040002	3 of 10	0	9 %	8 %	13 of 40	427 of 540
Sandhill-Wilson	09020301	3 of 10	24,661	4 %	3 %	13 of 40	427 of 540
Zumbro	07040004	2 of 10	0	8 %	8 %	12 of 40	442 of 540
Middle Minnesota	07020007	4 of 10	0	7 %	4 %	12 of 40	442 of 540
Root	07040008	4 of 10	0	20 %	1 %	12 of 40	442 of 540
Clearwater	09020305	6 of 10	0	22 %	0 %	12 of 40	442 of 540
Roseau	09020314	6 of 10	0	15 %	0 %	11 of 40	454 of 540
Thief	09020304	7 of 10	0	9 %	0 %	11 of 40	454 of 540
Upper Iowa	07060002	4 of 10	0	17 %	0 %	10 of 40	465 of 540
Upper Minnesota	07020001	4 of 10	20,237	2 %	0 %	10 of 40	465 of 540
Two Rivers	09020312	5 of 10	0	13 %	0 %	10 of 40	465 of 540
Redwood	07020006	3 of 10	0	2 %	3 %	10 of 40	465 of 540
Eastern Wild Rice	09020108	5 of 10	0	16 %	0 %	10 of 40	465 of 540
Le Sueur	07020011	4 of 10	0	5 %	3 %	10 of 40	465 of 540
Upper Big Soiux	10170202	2 of 10	0	2 %	3 %	9 of 40	484 of 540
Upper Wapsipinicon	07080102	4 of 10	0	8 %	1 %	9 of 40	484 of 540
Grand Marais-Red	09020306	2 of 10	4,516	2 %	1 %	9 of 40	484 of 540
Cottonwood	07020008	4 of 10	0	3 %	1 %	9 of 40	484 of 540
Blue Earth	07020009	3 of 10	10,947	3 %	1 %	9 of 40	484 of 540
Upper Cedar	07080201	3 of 10	0	5 %	1 %	8 of 40	498 of 540
Snake	09020309	4 of 10	0	6 %	0 %	8 of 40	498 of 540
Hawk-Yellow Medicine	07020004	3 of 10	0	4 %	1 %	8 of 40	498 of 540
Chippewa	07020005	3 of 10	0	6 %	0 %	8 of 40	498 of 540
Little Sioux	10230003	3 of 10	8,388	2 %	1 %	8 of 40	498 of 540
Buffalo	09020106	3 of 10	0	7 %	1 %	8 of 40	498 of 540
Winnebago	07080203	3 of 10	0	3 %	1 %	8 of 40	498 of 540
Pomme De Terre	07020002	3 of 10	0	6 %	1 %	8 of 40	498 of 540
Upper Des Moines	07100002	4 of 10	0	2 %	0 %	7 of 40	511 of 540
East Fork Des Moines	07100003	4 of 10	0	2 %	0 %	7 of 40	511 of 540
Des Moines Headwaters	07100001	3 of 10	0	2 %	1 %	7 of 40	511 of 540
Watonwan	07020010	4 of 10	0	3 %	0 %	7 of 40	511 of 540
Lower Red	09020311	3 of 10	1,555	6 %	0 %	7 of 40	511 of 540
Shell Rock	07080202	3 of 10	0	4 %	0 %	7 of 40	511 of 540
Bois De Sioux	09020101	3 of 10	0	1 %	0 %	6 of 40	528 of 540
Mustinka	09020102	3 of 10	0	2 %	0 %	6 of 40	528 of 540
Lac Qui Parle	07020003	3 of 10	0	2 %	0 %	6 of 40	528 of 540
Elm-Marsh	09020107	2 of 10	0	2 %	0 %	5 of 40	535 of 540
Rock	10170204	2 of 10	0	1 %	0 %	5 of 40	535 of 540

Average or total value for all watersheds listed in Table 1

Mean APCW for watersheds:		5.4	of 10
Important watersheds for drinking water composite score:		8.0	of 20
Private forests in important watersheds composite score:		11.1	of 30
Development pressure on private forests in important watersheds composite score:		14.7	of 40
Forested Land (acres):	22,617,959.2		
Private Forest (acres):	11,552,201.8		
Private Forest Land under Development Pressure by 2030 (acres):	579,747.9		
(% private forest land):	5.0%		

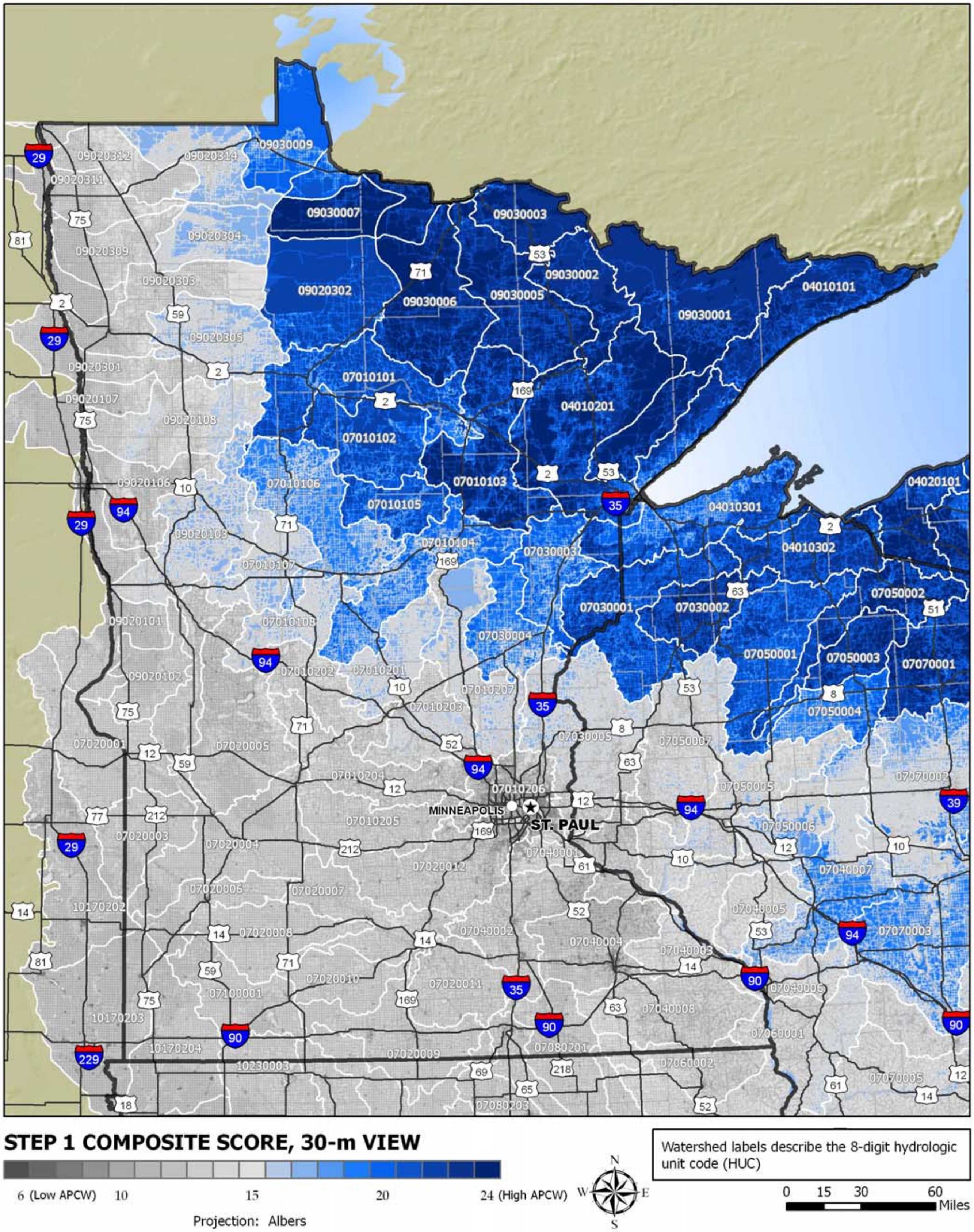
Note: If a watershed fell partially in Minnesota, the whole watershed was considered for this project. State results reflect the total acreage for all watersheds that impact that State (this may account for a higher acreage figure than if only lands within State boundaries were considered).

Maps

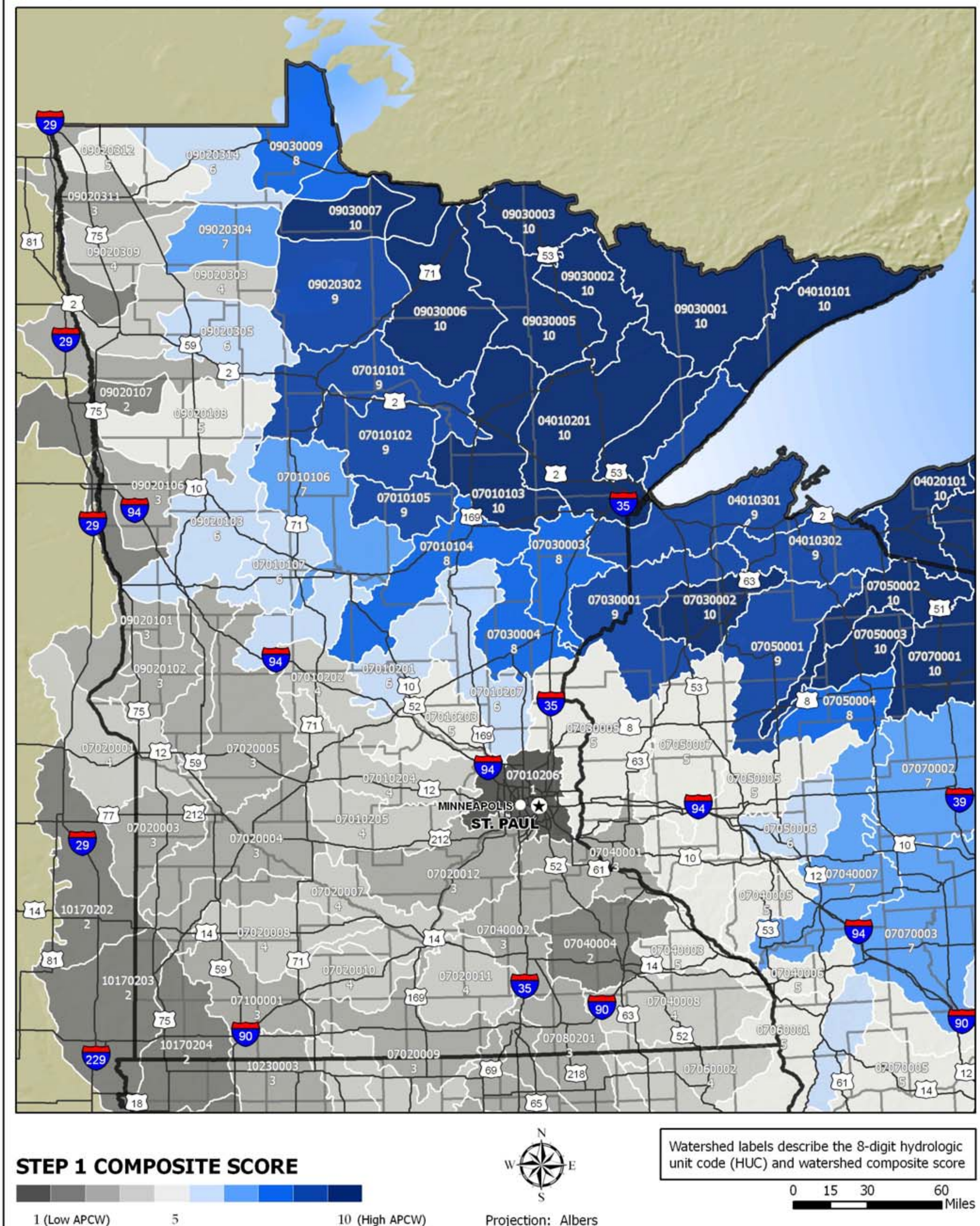
The following maps depict the results of each step in the Forests, Water and People analysis. Each watershed is labeled with the eight-digit HUC and the watershed composite score for the analysis step. (Note: the APCW, 30-m. pixel view does not have a watershed score)

All of the maps were produced by Rebecca Whitney Lilja, Office of Knowledge Management, Northeastern Area State and Private Forestry.

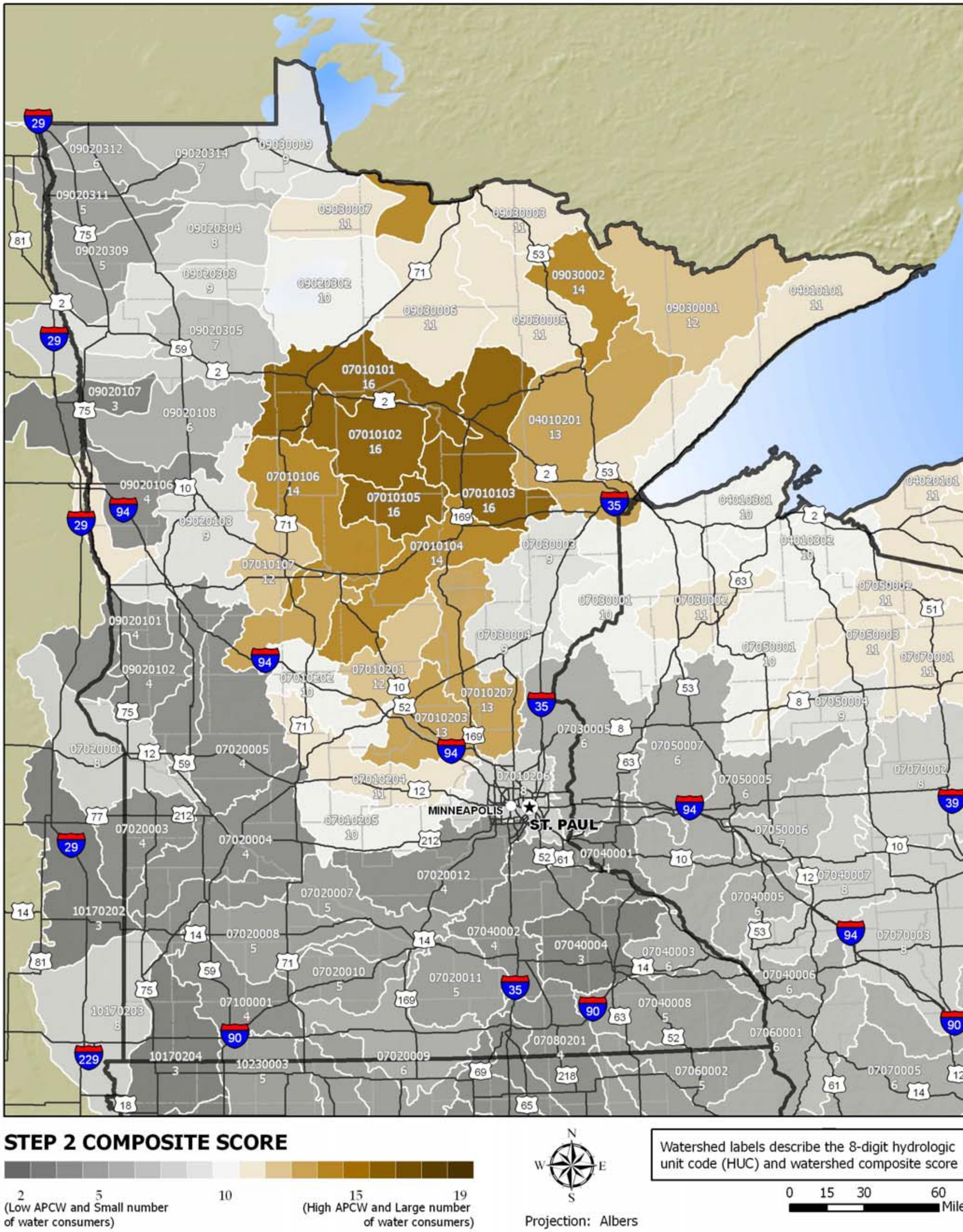
Ability to Produce Clean Water (APCW) (Step 1), 30-m View - Minnesota



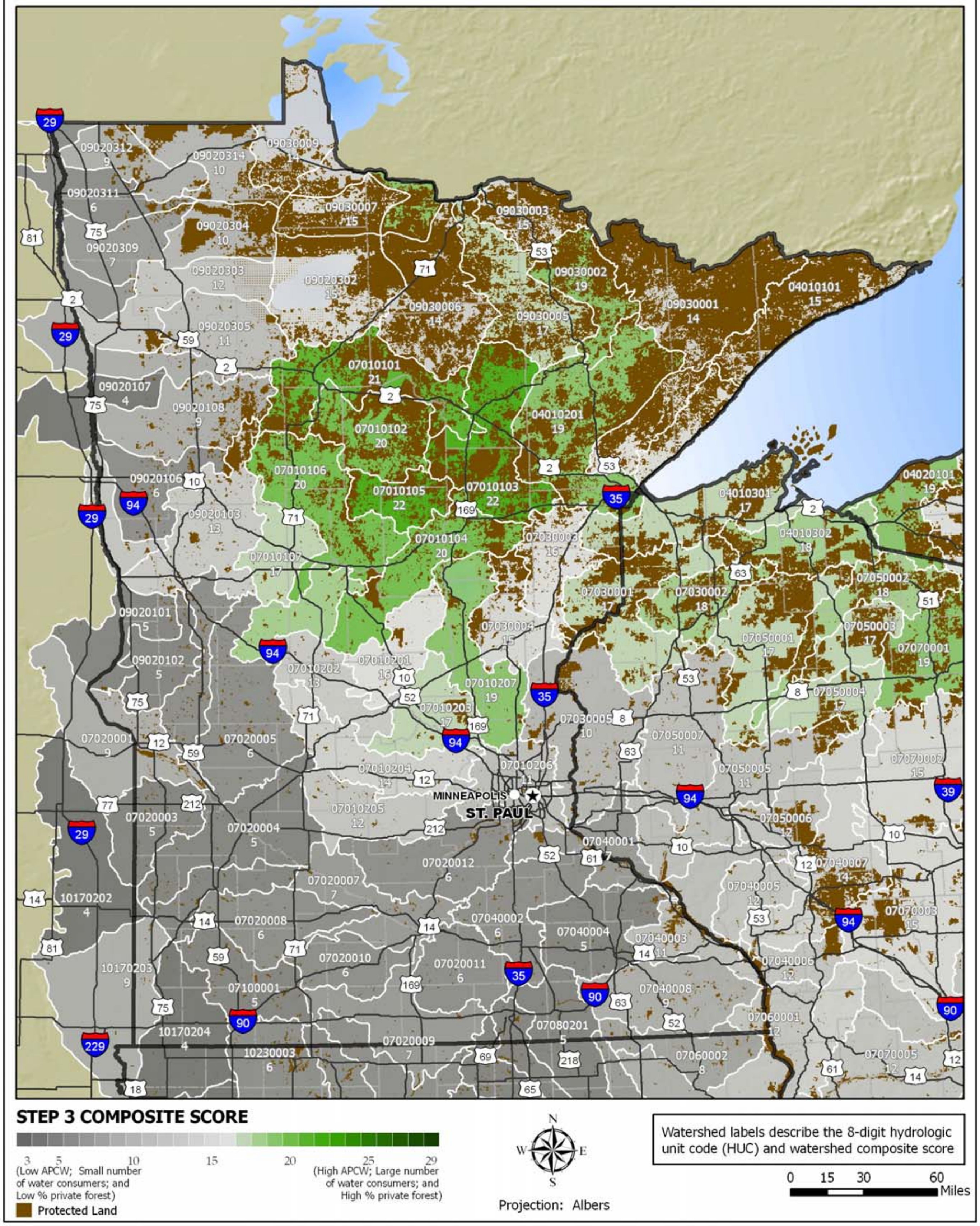
Mean Ability to Produce Clean Water (APCW) by Watershed (Step 1, Continued) - Minnesota



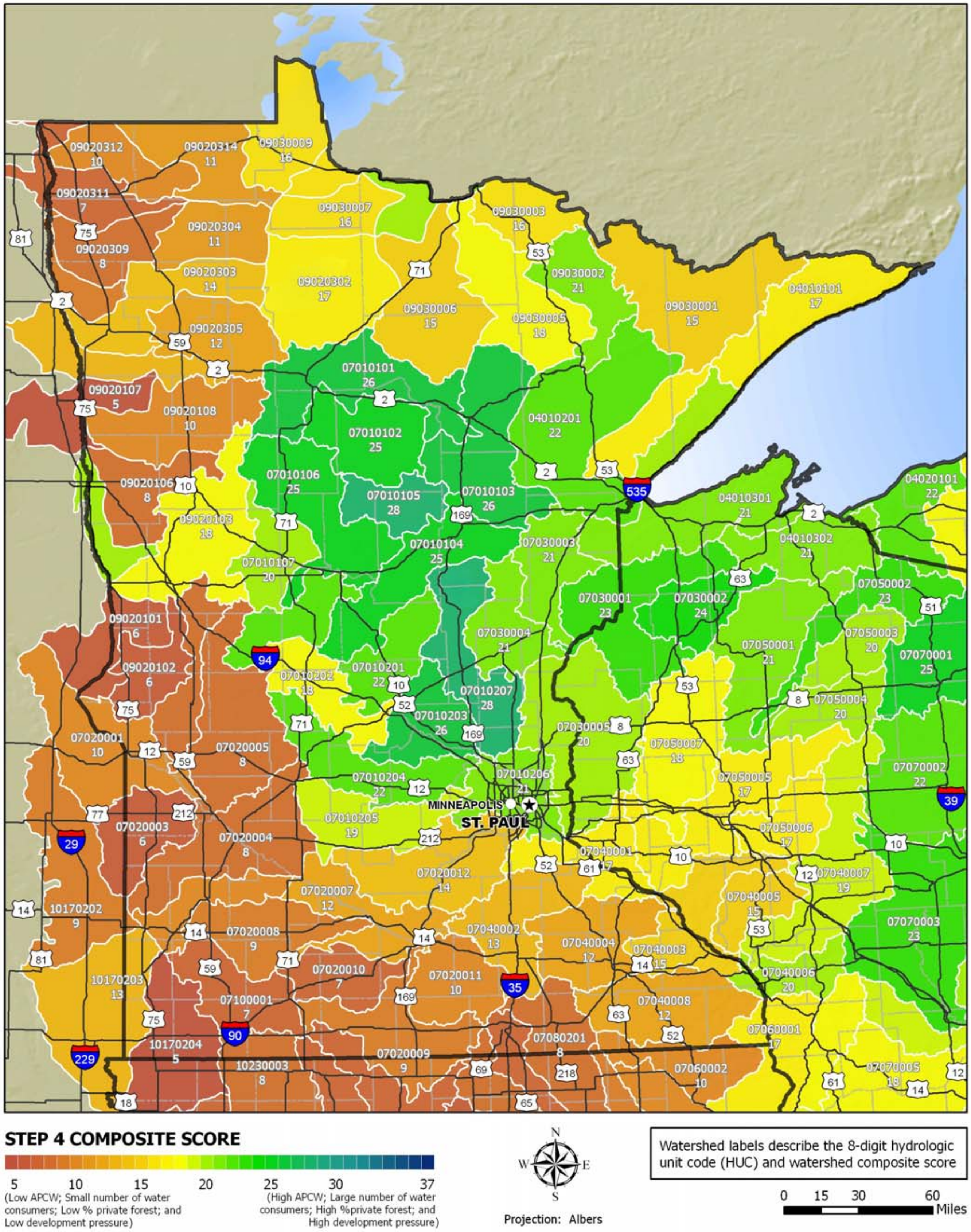
Importance of watersheds for drinking water supply (Step 2) - Minnesota



Importance of watersheds and private forest for drinking water supply (Step 3) - Minnesota



Development pressure on private forests in drinking water supply watersheds (Step 4) - Minnesota



References

Table 2. Datasets used in the Forests, Water and People Analysis

Attribute	Dataset	Source*
Forest land	1992 National Landcover Dataset	U.S. Geological Survey 1999
Agricultural land by watershed	1992 National Landcover Dataset	U.S. Geological Survey 1999
Riparian forest cover by watershed	1:100,000-scale National Hydrography Dataset, buffered to 30 meters	Hatfield 2005
Road density	2002 Bureau of Transportation Statistics (BTS) Roads	U.S. Department of Transportation 2002
Soil erodibility	STATSGO Soil Dataset, kffact	Miller and White 1998
Housing density by watershed	Housing density in 2000	Theobald 2004
Surface drinking water consumers per unit area	Public Drinking Water System (PWS) Consumers by eight-digit HUC; City Drinking water consumers for New York City, Philadelphia, St. Louis, St. Paul, and Washington DC	U.S. Environmental Protection Agency 2005
Private forest by watershed	Protected Areas Database, Version 4; Wisconsin Stewardship Data	Conservation Biology Institute 2006; U.S. Geological Survey, Upper Midwest Environmental Sciences Center 2005
Development pressure per unit area	Housing density in 2000 and 2030	Theobald 2004

*Note: See the **full report** for complete reference citations.

Watershed Resources

Northeastern Area Watershed— http://www.na.fs.fed.us/watershed

Forest-to-Faucet Partnership—http://www.wetpartnership.org/index.html

Trust for Public Land Source Water Stewardship Project—http://www.tpl.org/

Forests on the Edge—http://www.fs.fed.us/openspace/fote/index.html

American Water Works Association—Professional and Technical Resources—
http://www.awwa.org/Resources/index.cfm?&navItemNumber=1416

Source Water Collaborative—http://www.protectdrinkingwater.org/

Environmental Protection Agency—Surf Your Watershed—http://cfpub.epa.gov/surf/locate/index.cfm

Environmental Protection Agency—Safe Drinking Water Information System—

http://www.epa.gov/enviro/html/sdwis/sdwis_ov.html

This project was a collaborative effort between the Northeastern Area and Dr. Paul K. Barten, Associate Professor, University of Massachusetts-Amherst and Co-director of the Forest-to-Faucet Partnership.

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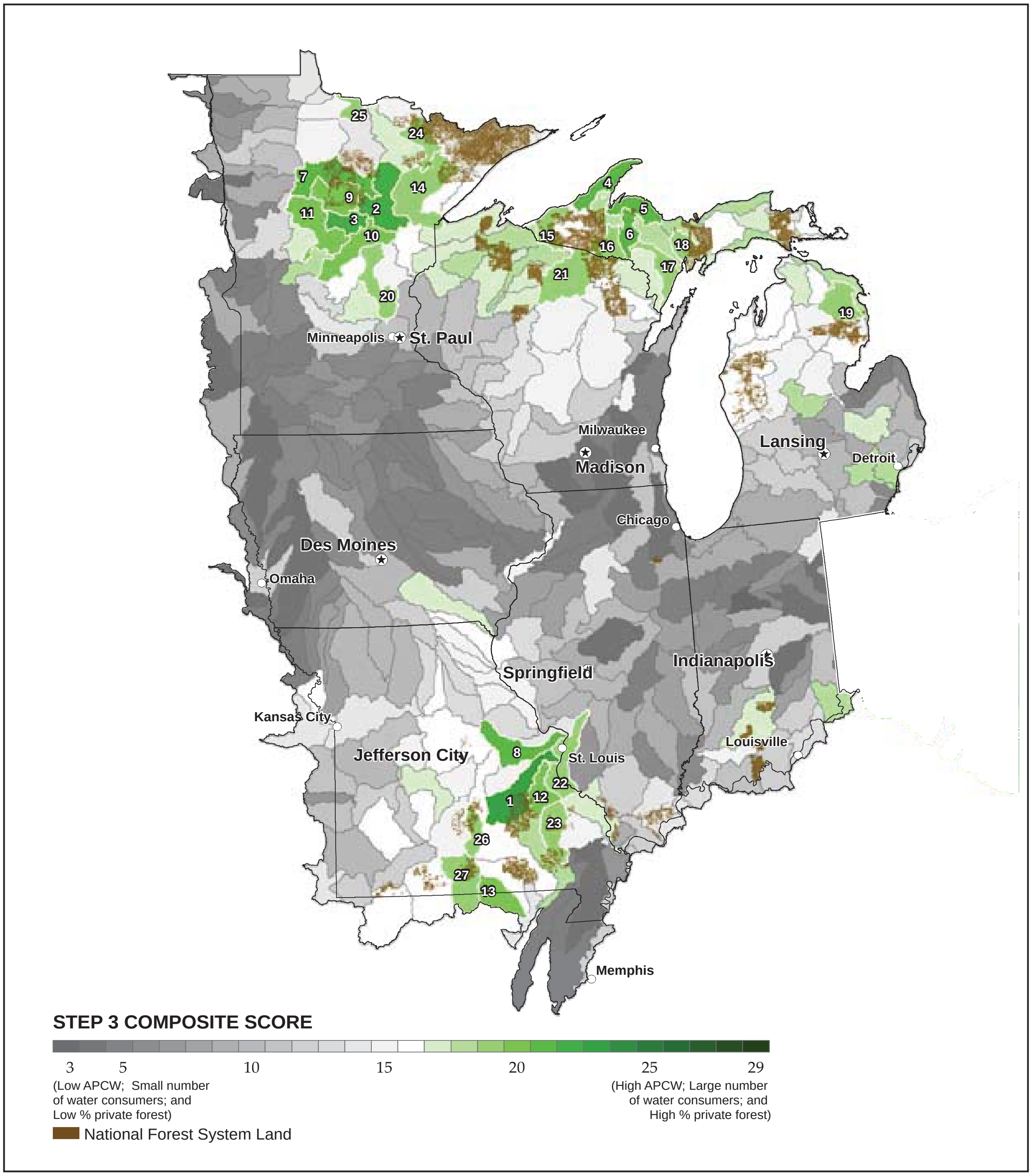
June 2009

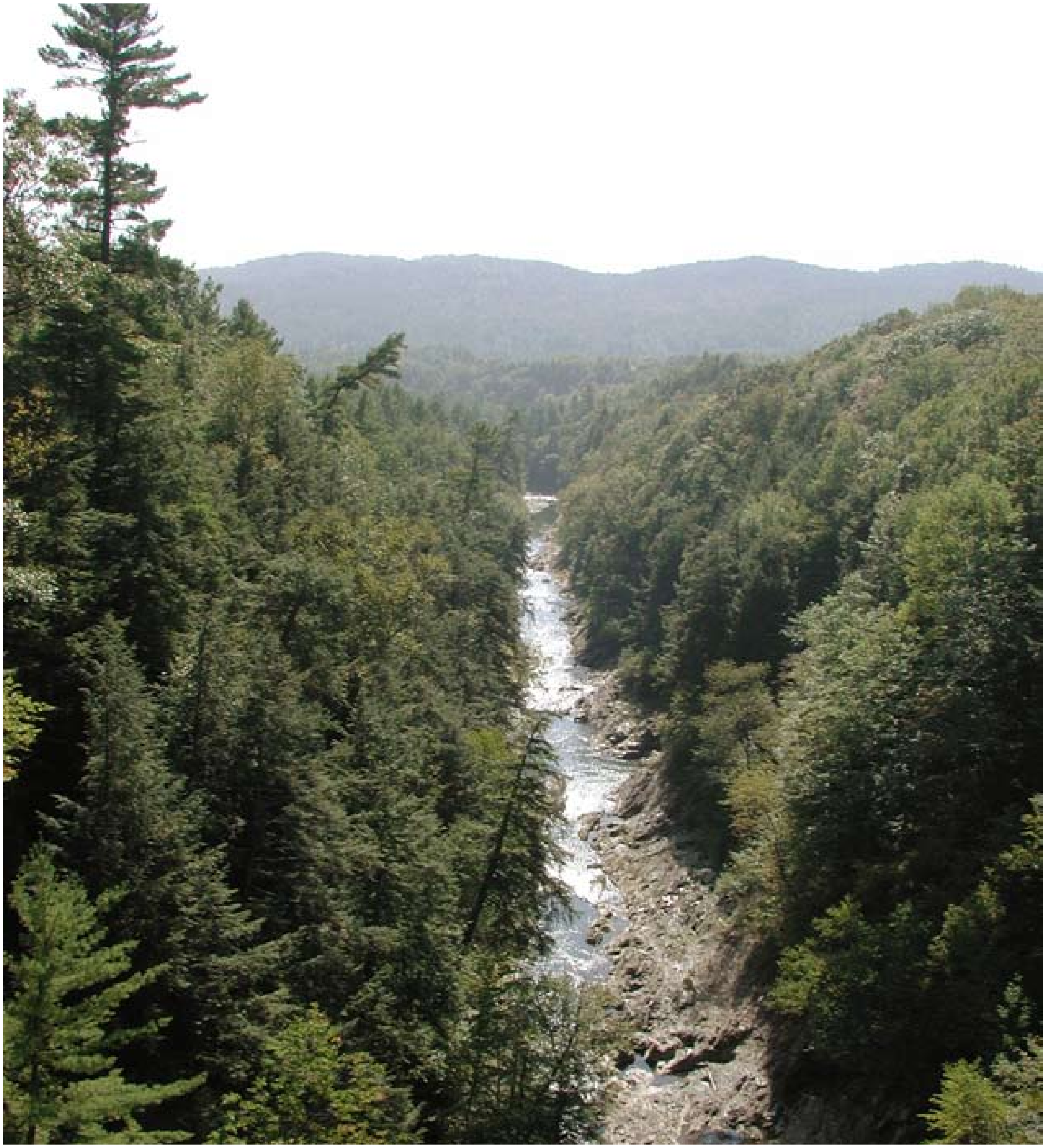
systems mean that the analysis spreads water demand across a large landscape, reducing the watershed scores. In addition, states west of Ohio depend to a much greater degree on groundwater sources for drinking water, both as a factor of geology and because ambient water quality problems in many tributaries are brought on by intensive agriculture as a dominant land use. Since this study focuses on surface water supply systems, watersheds that depend on groundwater scored lower and are inherently more difficult to link directly to the influence of forest cover.



Map 10: *Importance of watersheds and private forests for drinking water supplies in the western portion of the study area, watershed view.* *High scoring watersheds in terms of importance of watersheds and private forests for drinking water supply in the western portion of the study area did not score as high as watersheds in the eastern portion (Map 9). See Table 8 for more information about each watershed.*

Table 8: Top-scoring watersheds in the western portion of the study area, in terms of private forests important for drinking water supply, by label in map 10 and composite score.

Label in map 10	Composite score	Watershed	HUC	State
1	23	Meramec	07140102	MO
2	22	Prairie-Willow	07010103	MN
3	22	Pine	07010105	MN
4	21	Keweenaw Peninsula	04020103	MI
5	21	Dead-Kelsey	04020105	MI
6	21	Michigamme	04030107	MI
7	21	Mississippi Headwaters	07010101	MN
8	21	Lower Missouri	10300200	MO
9	20	Leach Lake	07010102	MN
10	20	Elk-Nokasippi	07010104	MN
11	20	Crow Wing	07010106	MN
12	20	Big	07140104	MO
13	20	Spring	11010010	AR MO
14	19	St. Louis	04010201	MN WI
15	19	Black-Presque Isle	04020101	MI WI
16	19	Brule	04030106	MI WI
17	19	Cedar-Ford	04030109	MI
18	19	Tacoosh-Whitefish	04030111	MI
19	19	Thunder Bay	04070006	MI
20	19	Rum	07010207	MN
21	19	Upper Wisconsin	07070001	MI WI
22	19	Cahokia-Joachim	07140101	IL MO
23	19	Upper St. Francis	08020202	MO
24	19	Vermilion	09030002	MN
25	19	Upper Rainy	09030004	MN
26	19	Big Piney	10290202	MO
27	19	North Fork White	11010006	AR MO



Forests, Water and People:
Drinking water supply and forest lands in the Northeast and Midwest United States

Martina C. Barnes, Albert H. Todd, Rebecca Whitney Lilja, and Paul K. Barten

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NA-FR-01-08
June 2009

ACKNOWLEDGMENTS

The authors give special thanks to Robin Morgan, Northeastern Area State and Private Forestry (now with the Northern Research Station), Forest Service, U.S. Department of Agriculture, for her support and guidance in development of this project; and to Carl Reeverts, U.S. Environmental Protection Agency, for his help in providing critical data sets on drinking water consumers and supplies. Thanks go to Rebecca Whitney Lilja, Office of Knowledge Management, Northeastern Area State and Private Forestry, for producing all of the maps in this report, and for her patience through many rounds of changes. Thanks also go to Russ Lafayette, Eastern Region (R9) of the Forest Service, for his helpful comments on the draft report.

Cover: *The Quechee Gorge in Windsor County, Vermont, is part of the high-ranking Black-Ottauquechee watershed. Photo by Sherri Wormstead.*

Forests, Water and People:
Drinking water supply and forest lands in the Northeast and Midwest United States

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June 2009
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CONTENTS

Text Boxes

Tables

Figures

Maps

ABSTRACT

Forests are critically important to the supply of clean drinking water in the Northeast and Midwest portion of the United States. In this part of the country more than 52 million people depend on surface water supplies that are protected in large part by forested lands. The public is generally unaware of the threats to their water supplies or the connection between clean water and the extent and condition of forest lands in source water watersheds. The future security of water supplies will not be ensured by a focus on water treatment alone. Protecting and managing forests in source watersheds is an essential part of future strategies for providing clean, safe drinking water that citizens can afford. This analysis uses a GIS-based process and a series of maps to create a watershed condition index based on physical and biological attributes. Using a multi-step process, this index is then used to compare 540 watersheds across 20 States and the District of Columbia, in terms of their ability to produce clean water. The study also quantifies the magnitude and scope of forest-dependent drinking water supplies, and their dependence on private forests; and it identifies watersheds that are threatened by land use change or are in need of management to sustain and improve forests that protect water supplies. The final maps and data display development pressure on private forests in watersheds important for drinking water.

INTRODUCTION

Forests in the 20 States and Washington, DC, served by the Northeastern Area State and Private Forestry, Forest Service, U.S. Department of Agriculture, help to protect more than 1,600 drinking water supplies that are the source of water for more than 52 million Americans (U.S. Department of Agriculture, Forest Service 2005). More than two-thirds of the population in this region depend on water from streams, lakes, and reservoirs. The quality of this water depends, in part, on the forest lands in their watersheds. Besides providing this valuable public benefit, these forests are also often managed for timber products, wildlife, and recreation that help to conserve them as open space. While many citizens who depend on surface water from municipal sources live very close to their water supply system, the value of forests specifically to water quality and water supply is often overlooked by both the public and policymakers.

Objectives of This Report

This project had two main objectives. The first was to illustrate the direct geographic connection between forests, water, and people—sometimes called the "forest-to-faucet" connection. The maps and data for this objective display a watershed's ability to produce clean water. The second objective was to demonstrate the importance of private forests to protecting surface drinking water quality and the potential threats to those forests. The maps and data for this objective display development pressure on private forests in watersheds important for drinking water. By looking at these relationships on a landscape scale, priorities for management action can be better determined.

The unique results of this analysis can be used in a number of ways: to guide strategies for forest land protection, outreach, and technical assistance to municipal water providers, and to refine and target assistance to individual forest landowners.

Multiple Barrier Approach to Water Protection

The time-tested multiple barrier approach to water protection remains vitally important to protecting drinking water supplies (National Research Council 2000). Multiple barriers to disease agents provide the greatest protection to public health. This approach involves several consecutive and interrelated steps; (1) protecting source areas, (2) treating drinking water, and (3) monitoring the drinking water distribution system to ensure success. The single most important barrier has proven to be source water protection.

Figure 1: *As in the watershed of the Quabbin Reservoir in western Massachusetts, sustainably managed forests provide insurance against pollution from roads, sewers, and urban runoff. Photo by Martina Barnes.*

In the Northeast and Midwest United States and throughout much of the world, forests are the crucial first barrier for source water protection (Dudley and Stolton 2003, National Research Council 2000, Platt and others 2000). Some of the Northeast's biggest cities, such as Boston, Hartford, and New York, took action more than a century ago to protect their water supplies by purchasing land in the watersheds that are the source of their drinking water. Even today, these cities are able to provide clean, safe water to millions of their citizens with minimal need for treatment (Barten and others 1998; Barten 2005). Yet, most people are unaware of the connection between clean water and the extent and condition of forest lands, or of the threats to their water supplies posed by development pressure (Ernst 2004).

Source Protection Versus Water Treatment

The future security of water supplies will not be ensured by a focus on water treatment alone. Protecting and managing forests in source watersheds are essential parts of future strategies for providing clean, safe drinking water that citizens can afford (Barten and Ernst 2004). One of the main reasons suppliers are revisiting the idea of source protection is the growing realization that allowing untreated water quality to degrade, in addition to threatening public health, also increases treatment and capital costs.

Advancements in the science of water treatment (filtration and disinfection) have enabled most cities to effectively treat water to remove known contaminants and provide safe drinking water. However, these same advancements have sometimes led to the false assumption that the quality of untreated water supplies is less critical today (Ernst 2006). Many small and medium-sized municipal water suppliers have been moving away from protecting and managing their source lands in favor of filtration and new treatment technologies. Some municipalities are even selling these lands, as they consider them unnecessary assets.

As the degree of water treatment and disinfection has increased, so has concern over the potential health effects of exposure to the byproducts of extensive disinfection (Ernst 2004). A continually expanding list of diverse contaminants, coupled with greater pollutant loads and fewer natural barriers, has also made water treatment more expensive and increased the risk that contaminants may reach the faucet (Ernst and others 2004). Water suppliers who draw water from intensively used source lands face treatment challenges, such as these:

Figure 2: *New York City's commitment to quality land management in its source watershed translates directly to abundant quality drinking water for city residents, and annually avoids over $300 million in filtration costs. Photo courtesy of George M. Aronson, photographer.*

1. Emergence of new contaminants that suppliers may not be prepared to test for or treat, or that may be in the water long before they are identified as a threat to public health,
2. Spikes in pollutant loads after storms that make treatment more difficult,
3. Increased treatment and capital costs due to higher loads and changing regulations.

Reliance on treatment alone can also be a costly alternative in the long run (National Research Council 2000). By protecting the watershed of the Quabbin Reservoir in western Massachusetts and practicing sustainable forestry since the 1930s, Boston made a cost-effective investment in clean source waters that will never be threatened by pollution from roads, sewers, or urban runoff (Figure 1). Allowing untreated water quality to degrade, in addition to threatening public health, also increases treatment and capital costs. New York City estimated the cost of installing filtration alone to be nearly $7 billion, with over $300 million in annual operating costs. As a result, New York City has chosen to sustain the quality of land management in its source watershed in order to sustain high water quality for a substantially lower investment (Figure 2).

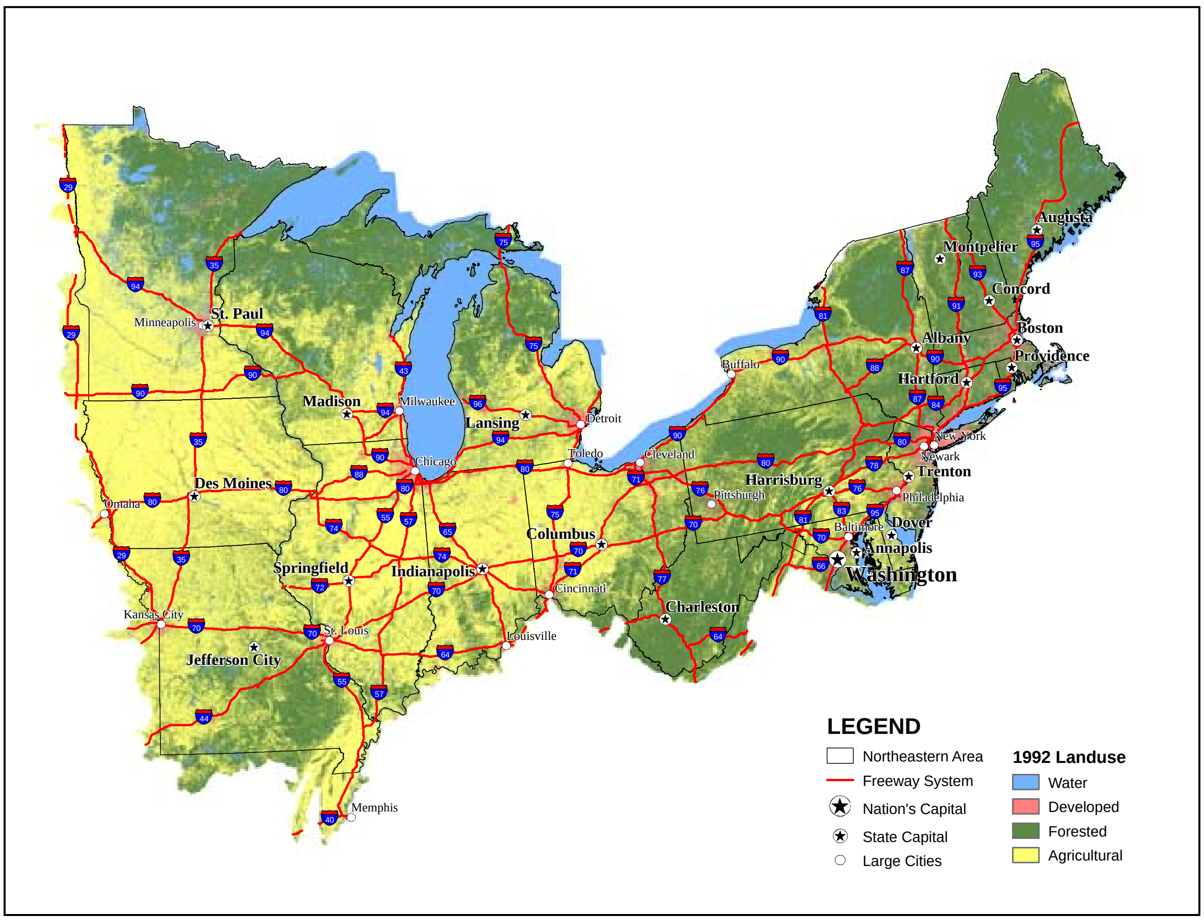
Current research on the public health impacts of urban and agricultural runoff in untreated water sources, and a recognition of the high costs and limitations of technological fixes reinforce two principles that were taken for granted a century ago: (1) the public water supply should be reasonably clean to begin with, and (2) forests and natural lands are critical to the quantity and quality of water supplies.

A recent report from the World Bank, titled *Running Pure*, concluded that protecting forests around water catchment areas is no longer a luxury but a necessity (Dudley and Stolton 2003). Protecting forests—which reduce erosion and sediment, improve water purity, and in some cases capture and store water—is a cost-effective way to provide clean drinking water. When forests are removed, the costs of providing clean and safe drinking water to urban areas increase dramatically (Dudley and Stolton 2003).

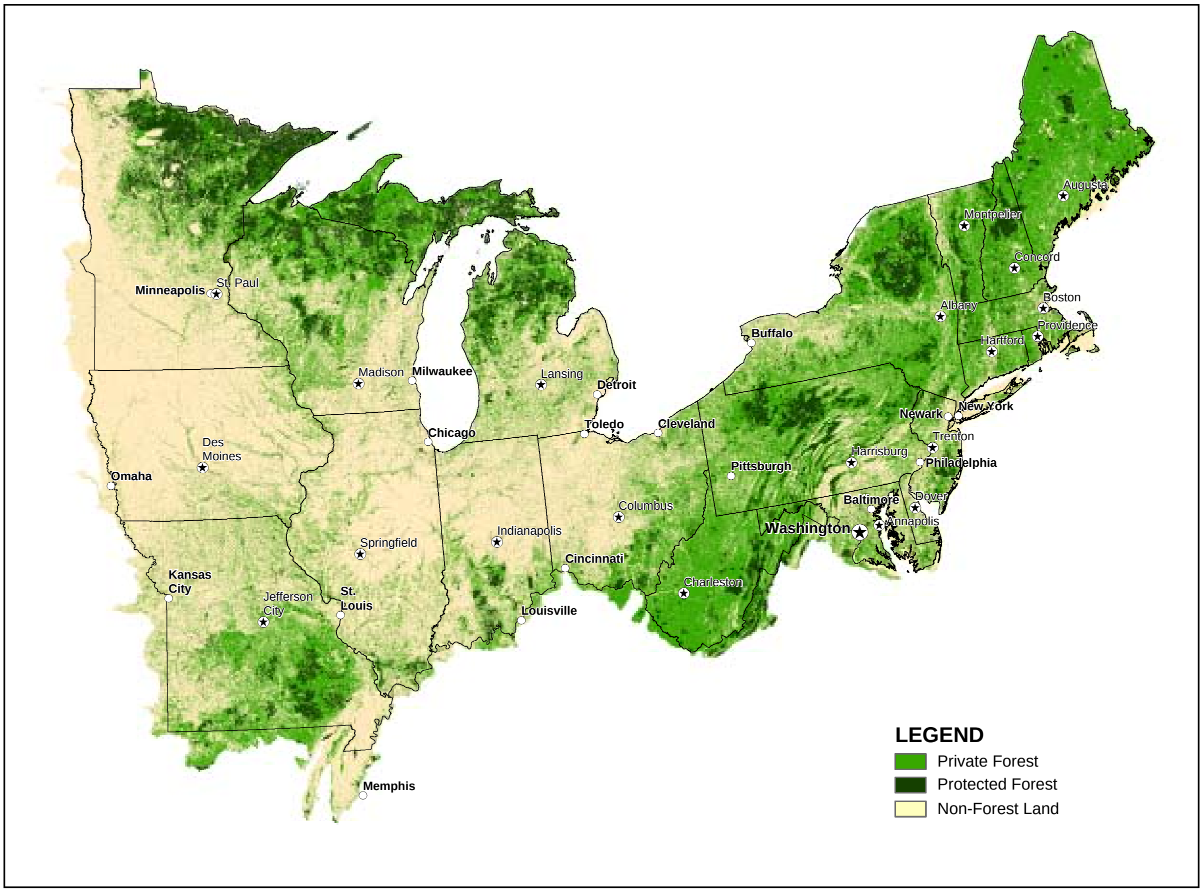
A study of water suppliers conducted by the Trust for Public Land in association with the U.S. Forest Service and the American Water Works Association's Source Water Protection Committee has found that operating treatment costs decrease as forest cover in a source area increases (Ernst and others 2004).

STUDY AREA

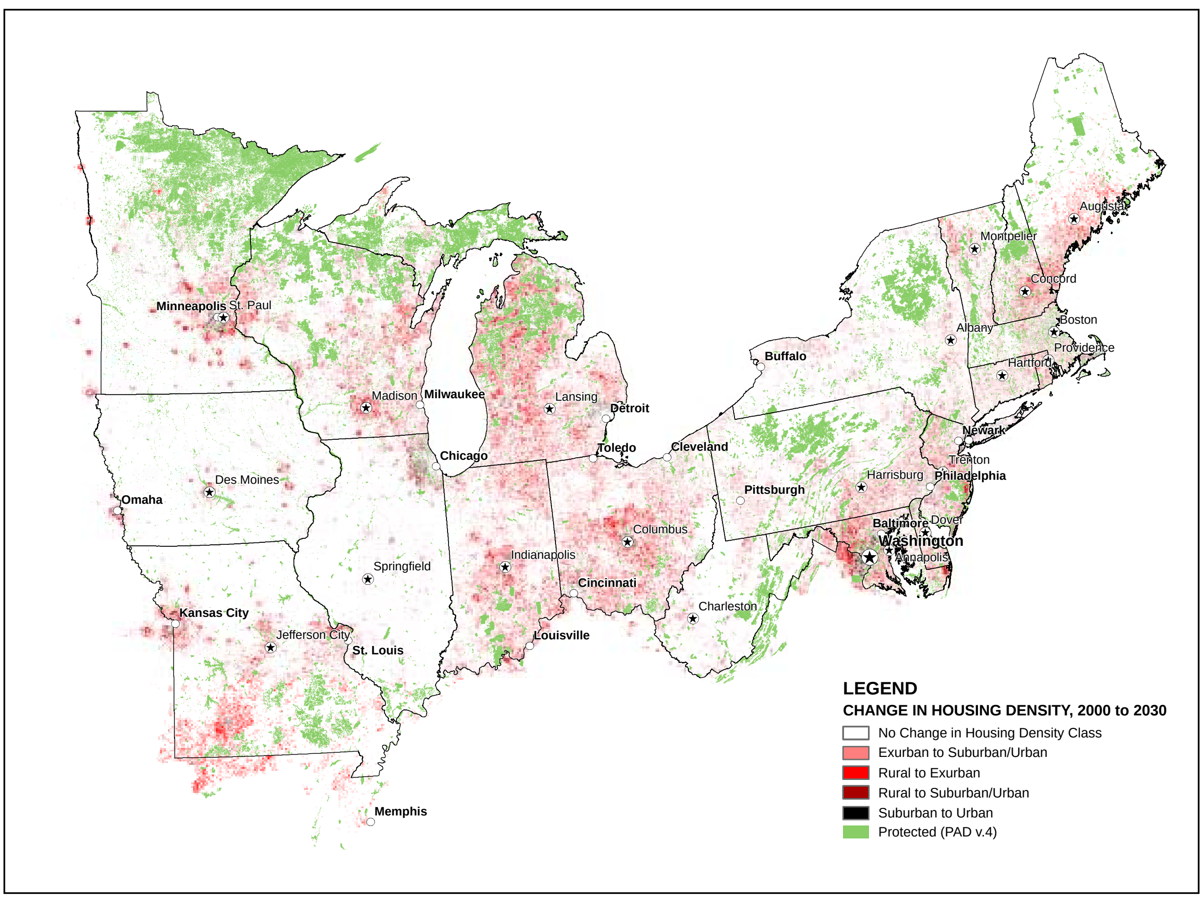
The 20-State study area, including the District of Columbia, stretches from the mountains of northern Maine to the banks of the Mississippi River, and from the hills of Missouri to the Chesapeake Bay (Map 1). The area is both the most populated and the most forested part of the country. While the study area makes up only 18 percent of the land area of the United States (Smith and others 2004), it is home to over 43 percent of its population (U.S. Bureau of the Census 2000). Before European settlement, roughly 300 million acres of forest covered this region (Smith and others 2004). Today, about 4 out of every 10 acres in this region is covered by forest, representing some 170 million acres and 23 percent of the nation's forest land. Of these forests, 92 percent are non-federally owned, with 76 percent owned by private landowners, which includes non-industrial private forest (NIPF) owners (Map 2; Smith and others 2004).



Map 1: Study area. *The study area includes the District of Columbia and 20 States in the Northeast and Midwest United States.*



Map 2: Private and protected forest land. *Most forests in the Northeast and Midwest United States are privately owned.*



Map 3: Change in housing density, 2000 – 2030. *Housing density in the study area is projected to increase from 2000 to 2030.*

Land Use

Although forest acreage has been increasing for most of the last 100 years, a growing population and increasing consumption of water, wood, and energy have outpaced increases in forest cover. More than 2,000 acres of forest land are cleared for development each day in the United States, and growth projections suggest that as many as 138 million acres of private forest land will be threatened by development between 2005 and 2030 (Stein and others 2005). In the Northeast and Midwest States, nearly 3.8 million acres of forest were lost to development between 1982 and 1997, with another 12 million acres projected to be lost by the year 2030 (Lund 2005; Map 3). Much of this increase in development is occurring outside metropolitan centers and spreading across the landscape in what is often referred to as "sprawl." Because of the need for dispersed transportation and business centers, this pattern of development tends to consume a much greater amount of open space than more compact and historic urban development. As a result, there were more people per square mile of forest in 2000 than in 1900 (Table 1).

Table 1: Population and forest area in the Northeast and Midwest in 1900 and 2000, by State

State	Year	Population*	Forest area (mi^2)† ‡	People per square mile of forest	Forest acres per person
Connecticut	1900	910,000	3,305	275	2.3
	2000	3,282,031	6,886	477	1.3
Delaware	1900	180,000	547	329	1.9
	2000	754,000	598	1,261	0.5
Illinois	1900	4,800,000	3,906	1,229	0.5
	2000	12,130,000	6,767	18,953	0.3
Indiana	1990	2,500,000	6,250	400	1.7
	2000	5,940,000	7,033	845	0.8
Iowa	1900	2,200,000	3,906	563	1.1
	2000	2,900,000	3,203	905	0.7
Maine	1900	694,466	23,730	29	21.9
	2000	1,274,923	27,639	46	13.9
Maryland	1900	1,200,000	3,438	349	1.8
	2000	5,200,000	4,009	1,297	0.5
Massachusetts	1900	2,788,000	5,824	479	1.3
	2000	6,175,169	10,545	586	1.1
Michigan	1900	2,400,000	24,218	99	6.5
	2000	9,860,000	30,127	327	1.9
Minnesota	1900	1,700,000	23,492	72	8.8
	2000	4,920,000	26,094	188	3.3
Missouri	1900	3,100,000	28,594	108	5.9
	2000	5,500,000	21,863	252	2.5
New Hampshire	1900	412,000	8,896	46	13.9
	2000	1,201,134	18,240	66	9.7
New Jersey	1900	1,883,669	2,500	754	1.0
	2000	8,414,350	3,672	2,292	0.3
New York	1900	7,283,000	9,445	771	0.8
	2000	18,196,601	28,841	631	1.0
Ohio	1900	4,200,000	7,500	560	1.1
	2000	11,260,000	12,273	918	0.7
Pennsylvania	1900	6,302,115	8,600	740	0.9
	2000	12,281,054	26,562	462	1.4
Rhode Island	1900	430,000	754	570	1.1
	2000	990,819	1,339	740	0.9
Vermont	1900	343,641	3,419	10	6.4
	2000	608,827	7,233	84	7.6
West Virginia	1900	960,000	14,219	68	9.5
	2000	1,800,000	18,919	95	6.7
Wisconsin	1900	2,100,000	25,000	84	7.6
	2000	5,250,000	24,942	210	3.0

* Gibson and Lennon 1999; U.S. Bureau of the Census, Population Division 2000 (2000 population data).

† Barten 2007; Smith and others 2001, Table 3 (forest area for all non-New England states served by the Northeastern Area); Foster 1990 (forest area for Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont); Kellogg 1909 (1900 forest area data).

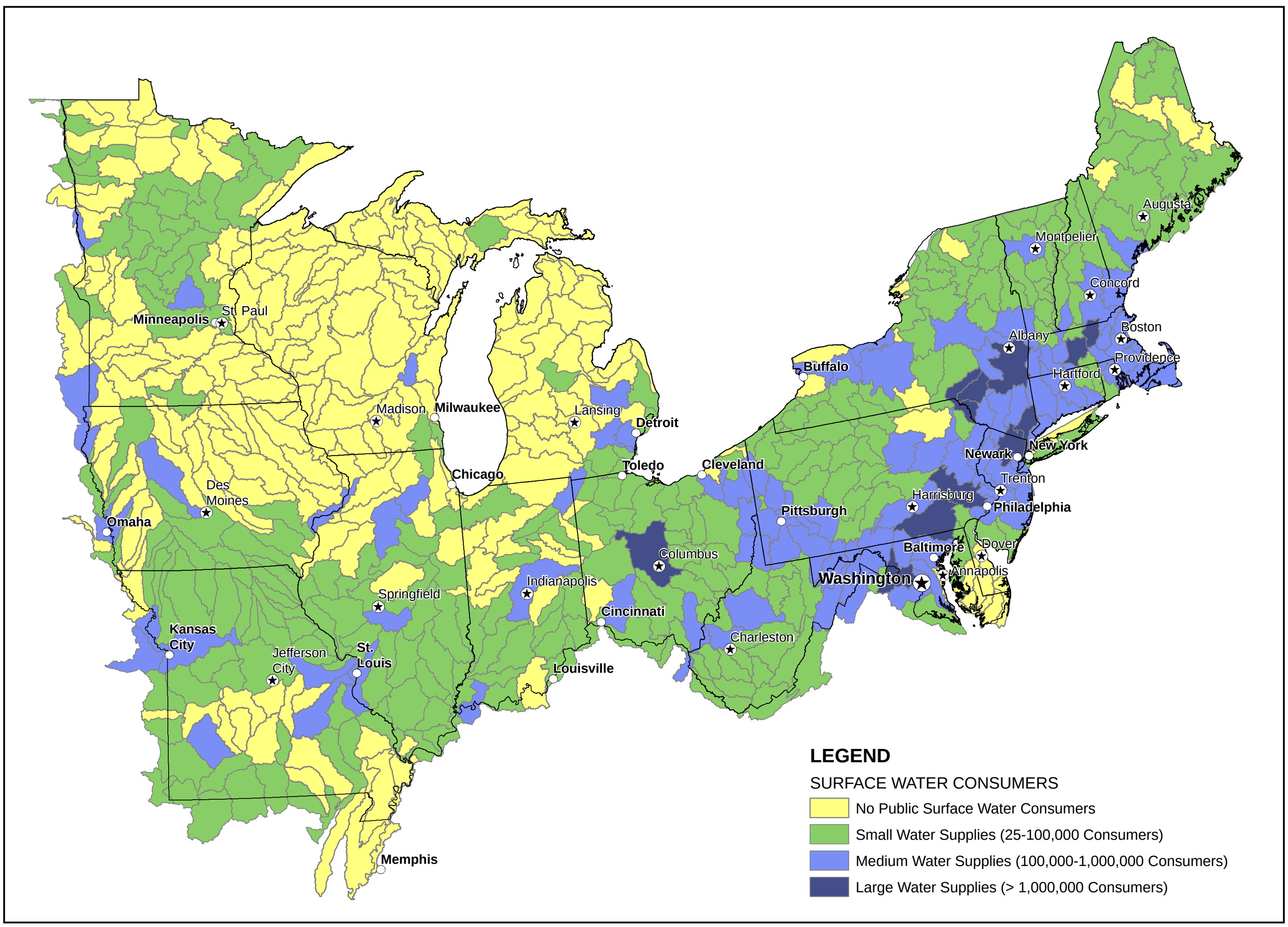
‡ 1 square mile (mi2) = 640 acres.

Water Consumption

Across the study area, daily household water use exceeds 4 trillion gallons. This figure is based on water use of approximately 75 gallons daily per capita (household water use only, not including irrigation or power generation). This amounts to more than 27,000 gallons per person per year or more than three 20-foot diameter swimming pools! By comparison, per capita water use in 1900 was 5 to 10 gallons per day. In the New York City metropolitan area alone, water consumers use nearly 2 billion gallons of water per day (National Research Council 2000). Major cities like New York and Boston have undertaken comprehensive programs to protect large forested watersheds far from these cities. Most small to mid-sized systems, however, are within 10 to 20 miles from the point of use, with limited opportunities for expansion to new forested watersheds (Sedell and Apple 2002).

Large water supplies.

Generally, large water supply systems serve more than 1 million consumers and are owned and operated by public agencies with significant budgets and proactive management programs. The Catskill, Delaware, and Croton watersheds deliver 1.2 billion to 2.3 billion gallons per day to 9 million consumers in the New York metropolitan area. Most forest land in these watersheds is privately owned. The City and the Watershed Agricultural Council have promoted a program of outreach to forest landowners to improve timber management activities in the watershed. The Quabbin, Ware, and Wachusett Rivers serve over 2.2 million people in 47 communities and the City of Boston. This water supply system is predominantly publicly owned, and the Commonwealth of Massachusetts manages more than 100,000 acres of watershed forest. Of this acreage, 75 percent is actively managed, also producing nearly 10 million board feet of timber each year.



Map 4: Surface water consumers. *Most surface drinking water supply systems in the Northeast and Midwest are small, each serving less than 100,000 people.*

Medium-sized water supplies.

Medium-sized surface water supply systems generally serve more than 100,000 people with a mix of public and private lands, and may have moderately funded systems with some ongoing planning, protection, and management.

Small water supplies.

The majority of surface water supply systems are small, serving communities of 25 to less than 100,000 people (Map 4). These watersheds generally have minimal public ownership (except areas buffering small reservoirs), as well as minimal planning, and infrequent forest management. These smaller water supply systems often lack staffing or adequate management expertise and violate drinking water standards almost twice as often as those serving larger communities (Ernst and Hart 2005). The protection and proper management of forest lands for small and large systems alike is a critical and cost-effective approach to ensuring quality drinking water in the future.

Table 2: Surface water supply systems in the Northeast and Midwest and population served in 2005, by State (U.S. Environmental Protection Agency 2005).

State	Public water supplies*	Population served†
Connecticut	36	2,231,610
Delaware	‡	4,510
Illinois	87	1,657,750
Indiana	36	1,710,050
Iowa	29	632,860
Maine	59	393,240
Maryland and District of Columbia	40	4,085,850
Massachusetts	103	4,901,910
Michigan	17	1,295,335
Minnesota	15	973,828
Missouri	84	2,502,640
New Hampshire	40	480,780
New Jersey	30	3,482,340
New York	297	11,555,950
Ohio	126	3,133,310
Pennsylvania	305	7,530,110
Rhode Island	11	566,601
Vermont	63	261,710
West Virginia	139	1,621,140
Wisconsin	5	199,460
System intakes outside the Northeast	84	3,193,294
Total	**1,608**	**52,411,270**

* Public water supplies are community or public drinking water systems as defined by the EPA, www.epa.gov/OGWDW/guide/sen104.html.

† Water consumer data were provided by watershed, and then prorated by watershed area to estimate consumers by State.

‡ Part of Philadelphia's water supply system.

Water supplies in the Northeast are finite and irreplaceable, and—with the exception of large rivers and lakes—most water sources have already been tapped. There are few ecologically or economically viable ways to dramatically augment current supplies. While they have been regular news in the West, water shortages have now taken center stage in the humid East as well. In addition to natural conditions such as drought, the primary threats to water supplies in the Northeast and Midwest are loss of forest to development, agriculture, or other land uses. If these threats are realized, the result is chronic erosion, altered and unstable streams, loss of riparian vegetation, and diminished forest health or watershed condition left by historic land use.

ANALYSIS METHODS

The study used a GIS-based process and a series of maps to create a watershed condition index based on physical and biological attributes. Using a multi-step process, this index was then used to compare watersheds across the 20 States and District of Columbia, in terms of their ability to produce clean water. Through regional maps, this analysis also accomplishes the following: quantifies the magnitude and scope of forest-dependent drinking water supplies and their dependence on private forests; and identifies watersheds that are threatened by land use change or that are in need of forest management to sustain and improve forests that protect water supplies.

To score the importance of watersheds across the 20-State study area, four indices were developed for each watershed:

1. Ability to produce clean drinking water
2. Importance for drinking water supply
3. Dependence on unprotected private forest land for drinking water supply
4. Threat of forest conversion or need for management, to sustain and improve forest conditions to protect drinking water supply

Each index was created by overlaying spatial data in a Geographic Information System (GIS) (Figure 3). Data layers were given equal weight in the overlay process to avoid potential bias; all resources were considered equally important. Each dataset was converted into a 30-meter resolution spatial grid and then summarized by watershed. Watersheds with eight-digit Hydrologic Unit Codes (HUCs) developed by the U.S. Geological Survey were selected as the summary units of the analysis, because they were large enough to ensure consistent data between units of analysis but small enough to identify priorities based on localized variations. The HUCs also facilitate the identification of problems and opportunities by hydrological boundaries rather than political ones. Within the study area are 540 separate HUC-8 watersheds. Where watersheds fell partly outside the political boundary of the study area, however, the entire watershed area was included in the analysis.

To maintain consistency across the 20-state area, nine standard nation-wide datasets were collected, scored, and overlaid to create the indices. While more current data was available for several states, this method used a seamless dataset to avoid dramatic changes from one State to another. A variety of other data sets were evaluated but were not used, due to problems identified with data consistency or appropriate scale. For example, the percent of impaired streams data provided by the U.S. Environmental Protection Agency were considered. Due to wide variations in State reporting of impaired streams, however, the layer was not included in this analysis (Table 3).

Table 3: Data sets used in the watershed analysis, by attribute (Appendix B).

Attribute	Datasets	Source
Forest land	1992 National Landcover Dataset	U.S. Geological Survey 1999
Agricultural land by watershed	1992 National Landcover Dataset	U.S. Geological Survey 1999
Riparian forest cover by watershed	1:100,000-scale National Hydrography Dataset, buffered to 30 meters	Hatfield 2005
Road density	2002 Bureau of Transportation Statistics (BTS) Roads	U.S. Department of Transportation 2002
Soil erodibility	STATSGO Soil Dataset, kffact	Miller and White 1998
Housing density by watershed	Housing density in 2000	Theobald 2004
Surface drinking water consumers per unit area	Public Drinking Water System (PWS) Consumers by eight-digit HUC; City Drinking water consumers for New York City, Philadelphia, St. Louis, St. Paul, and Washington DC	U.S. Environmental Protection Agency 2005
Private forest by watershed	Protected Areas Database, Version 4; Wisconsin Stewardship Data	Conservation Biology Institute 2006; U.S. Geological Survey, Upper Midwest Environmental Sciences Center 2005
Development pressure per unit area	Housing density in 2000 and 2030	Theobald 2004

Step 1: Calculate Ability to Produce Clean Water (APCW)

APCW Index by 30-meter pixels

The APCW Index characterized a variety of biophysical conditions in each watershed known to influence water quality. This index of water quality and watershed integrity uses six attributes: forest land, agricultural land, riparian forest cover, road density, soil erodibility, and housing density. Many other activities such as industrial pollution and mining, and natural variables such as climate change, floods, and fires, can also impact water quality. The evaluation of source water threats beyond traditional land use were not within the scope of this study but would be of value in more detailed source water analyses.

The forest land, agricultural land, and riparian forest buffer data were summarized by watershed and converted to a 30-meter spatial grid. The soil erodibility, road density, and housing density data were kept in their original 30-meter grid format and not summarized by watershed. Each of the six attributes was rated from 1 to 4 (low to very high) based on scientifically accepted standards (Table 4). Where standards or parameters were not available, the data was divided into quartiles for the purpose of analysis.

The six attributes were summed to determine the APCW Index for each 30-meter grid cell:

$$F + A + R + D + S + H = APCW$$

where,

F = Forest land (percent)

A = Agricultural land (percent)

R = Riparian forest cover (percent)

D = Road density (quartiles)

S = Soil erodibility (k factor)

H = Housing density (acres per housing unit, in 2000), and

APCW = Ability to Produce Clean Water

The resulting index has a total potential value of 6 to 24.

The APCW attributes are surrogates for important watershed characteristics that influence water yield and water quality. The goal of this project was not to make deterministic predictions of changes in nutrient, sediment, or other nonpoint source pollutant loading or flow regime, but rather to rank the 540 watersheds in the study area on a common scale. This ranking required the normalization of several attributes to enable objective comparison on a unit area basis (i.e., very large watersheds were not "advantaged" and comparatively small watersheds were not "disadvantaged"). This normalization produced a sufficient range of numerical variation in scores and more clearly identified critical watersheds. Characteristics of critical watersheds are a very high APCW, a large number of water consumers (per unit area), a large proportion of private forest land (that is potentially available for development and conversion to other land uses), and a high rate of forest conversion projected for 2030 (Stein and others 2005).

The scoring (i.e., low, moderate, high, very high) of the APCW layer was derived from a comprehensive review of salient literature (de la Cretaz and Barten 2007, Ice and Stednick 2004; National Research Council 2000 Stein and others 2005) and results of the Northeastern Area State and Private Forestry's Spatial Analysis Project and the Chesapeake Bay Resource Lands Assessment (U.S. Department of Agriculture, Forest Service 2006, U.S. Geological Survey 2000).

The following is an explanation of the basis for the APCW scores.

Forest land: Long-term watershed studies have shown that 20 to 30 percent of the catchment area must be treated (or forest biomass harvested) to produce measurable water yield increases and associated water quality changes. Hence, the "very high" score was defined as 75-100% forested—and the other scores were apportioned equally.

Agricultural land by watershed: Agricultural land use, especially row crops, typically generates more substantial changes in water yield and quality in relation to watershed area (de la Cretaz and Barten 2007, Chapters 7 and 9). The proportional areas reflect these thresholds and were successfully tested during a decade of earlier work in the Chesapeake Bay watershed.

Riparian forest cover by watershed: The area and continuity of riparian forest cover directly influences water quality in ways that parallel the effects of forest cover at the watershed scale (de la Cretaz and Barten 2007, Chapter 5).

Road density: Road density is the surrogate layer for "development" and the addition of impervious surfaces and pollution sources to watersheds. Since there is neither detailed spatial data nor a consistent relationship between development, streamflow, and water quality, a straightforward quartile division was used to score watersheds.

Soil erodibility: The soil erodibility layer uses commonly accepted categories within the USDA Natural Resouces Conservation Service's National Soils Database to represent the likelihood that—other characteristics being equal—the combined effects of soil texture and structure influence surface erosion, sediment transport, and water quality degradation.

Housing density by watershed: The housing density layer used for this analysis was based on past and current statistics on housing density and population, road density, past growth patterns, and locations of urban areas. The same model was used in the Forests on the Edge study (Stein and others 2005), which was based on research published in a peer-reviewed article in Ecology and Society (Theobald 2005). To date, Theobald's housing density research has been used in three research reports published by the Forest Service (Stein and others 2005, 2006, 2007).

Table 4: Biophysical characterization for 30-meter pixels, by attribute and ability to produce clean water (APCW). Higher scores indicate greater ability to produce clean water.

Attribute	Scoring for 30-meter grid cell			
	Low (1 point)	Moderate (2 points)	High (3 points)	Very high (4 points)
Percent forest land (F)	0 – 24	25 – 49	50 – 75	>75
Percent agricultural land (A)	>30	21 – 30	10 – 20	<10
Percent riparian forest cover (R)	0 – 29	30 – 50	51 – 70	>70
Road density (D; quartiles)	75 – 100th percentile	50 – 74th percentile	25 – 49th percentile	0 – 24th percentile
Soil erodibility (S; k factor)	>0.34	0.28 – 0.34	0.2 – 0.28	0 – 0.2
Housing density (H; acres per housing unit in 2000)	< 0.6 acre/ unit	0.6 – 5.0 acres/ unit	5.0 – 20.0 acres/unit (east) 5.0 – 40.0 acres/unit (west)	> 20.0 acres/unit (east) > 40.0 acres/unit (west)
Total APCW	Potential value 6 – 24			

Note: Letters in parentheses correspond to the equation in the text. For more detailed information on any of the above data layers, please refer to the technical information in appendix B.

Mean APCW for Watersheds

The APCW values were averaged to create a mean APCW for a watershed. This mean was divided into 10 quantiles, with the 1st quantile receiving a score of 10 (very high) and the 10th quantile receiving a score of 1 (low) (Table 5).

Step 2: Add Data on Drinking Water Consumers

Step 2 combined the results of Step 1, the watershed's mean Ability to Produce Clean Water, with water use data from the U.S. Environmental Protection Agency's (EPA) Surface Drinking Water Information System (SDWIS).

Selecting only surface water consumers (reservoirs and streams), the total number of drinking water consumers was summed for each eight-digit watershed and divided by the watershed area. For cities that use large river or lake intakes, such as Philadelphia, St. Louis, St. Paul, Chicago, and Washington, DC, the number of drinking water consumers was allocated among all upstream watersheds in relation to the drainage area that contributes water to the point of intake or diversion. For cities with municipal systems with multiple reservoirs in different eight-digit watersheds—including the New York City Watershed (Croton and Catskill/Delaware systems), Bridgeport and surrounding communities in southwestern Connecticut (reservoirs managed by Aquarion Water), metropolitan Boston, MA (Quabbin and Wachusett Reservoirs), and Springfield, MO—water consumers were allocated to reservoirs in relation to their storage volume and contribution to the total system capacity. The result for all watersheds and water supply systems was divided into 10 quantiles and combined with the APCW quantiles to yield a potential composite score of 2 to 20 (Figure 3, Table 5).

Step 3: Add Data on Private Forest Land

Step 3 combines the results of Step 2 with the percent of private forests in the watershed to highlight those private forest areas important for surface water drinking supply. The private forest database was derived using a subset of the Conservation Biology Institute's Protected Areas database and an updated Wisconsin dataset (U.S. Geological Survey 2005). Only permanently protected lands (Federal, State, county, local, or permanent conservation easements) were considered "protected;" all other lands were considered unprotected, having the potential to be developed. The percent private forest by watershed was divided into 10 quantiles, and then combined with the results of Step 2 to yield a total potential of 3 to 30 (Figure 3, Table 5).

Step 4: Add Data on Change in Housing Density

Step 4 combines the results of Step 3 with the development pressure of future housing density increase on forests. Development pressure was calculated by subtracting the housing density in 2000 from projections for 2030. If housing density would have increased from rural to exurban, rural to suburban/urban, or exurban to suburban/urban between 2000 and 2030, development pressure was said to occur (Stein and others 2005, Theobald 2004; see Appendix B for detailed definitions). The total acreage of land under development pressure in the watershed was divided by the watershed area, divided into 10 quantiles, and then combined with the results of Step 3 to yield a total potential score of 4 to 40 (Figure 3, Table 5). The use of 10 quantiles to map the four steps in this analysis satisfied the practical need to generate an objective numerical gradient that would describe the many possible combinations of biophysical characteristics, water use, current development, and projected forest conversion to the year 2030.

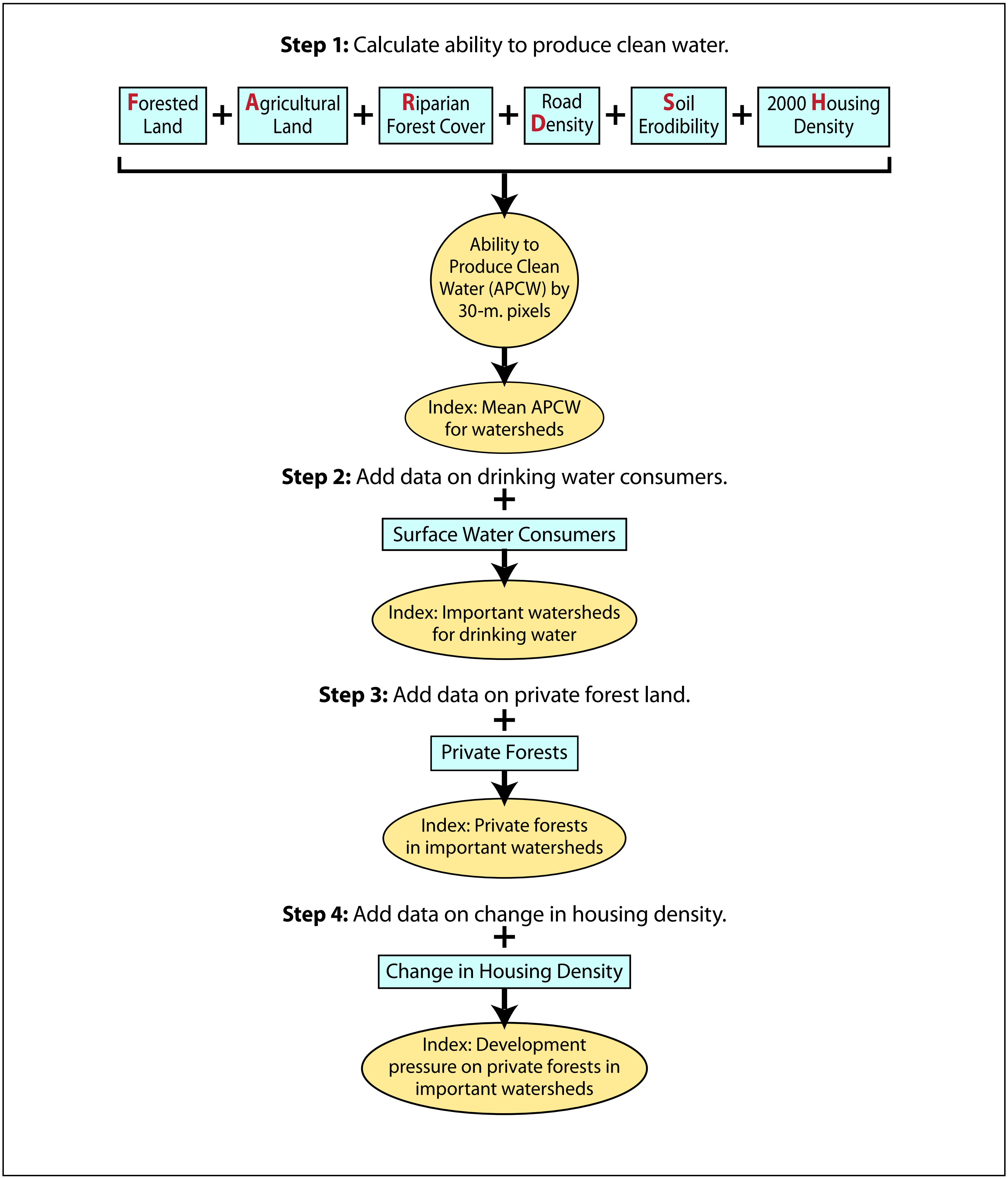
Watersheds with the highest scores have the greatest ability to produce clean water for the greatest number of drinking water consumers. High ranking watersheds also have the largest amount of private forest land that is under the greatest pressure for development and conversion to other uses.

Table 5: Summary of watershed analysis and prioritization, by steps in the GIS overlay process

GIS Overlay	Analysis result	Watershed scoring			
		Low (1 point)	Moderate-high (2-9 points)	Very high (10 points)	Potential composite score (points)
Step 1—Average APCW data for pixels in watershed	Watershed mean APCW	10th quantile	2nd – 9th quantile	1st quantile	1– 10
Step 2—Add data on surface water consumers	Watershed importance to drinking water consumers	10th quantile	2nd – 9th quantile	1st quantile	2 – 20
Step 3—Add data on private forest	Private forest in important watershed	10th quantile	2nd – 9th quantile	1st quantile	3 – 30
Step 4—Add data on change in housing density	Development pressure on private forest in important watershed	10th quantile	2nd – 9th quantile	1st quantile	4 – 40

Note: For more detailed information on any of the above data layers, please refer to the technical information in appendix B.

Figure 3: Nine layers of GIS data (boxes) were combined in stepwise fashion, to produce four indices (ovals) of watershed importance for drinking water supplies and the need for private forest management to protect those supplies.



RESULTS AND DISCUSSION

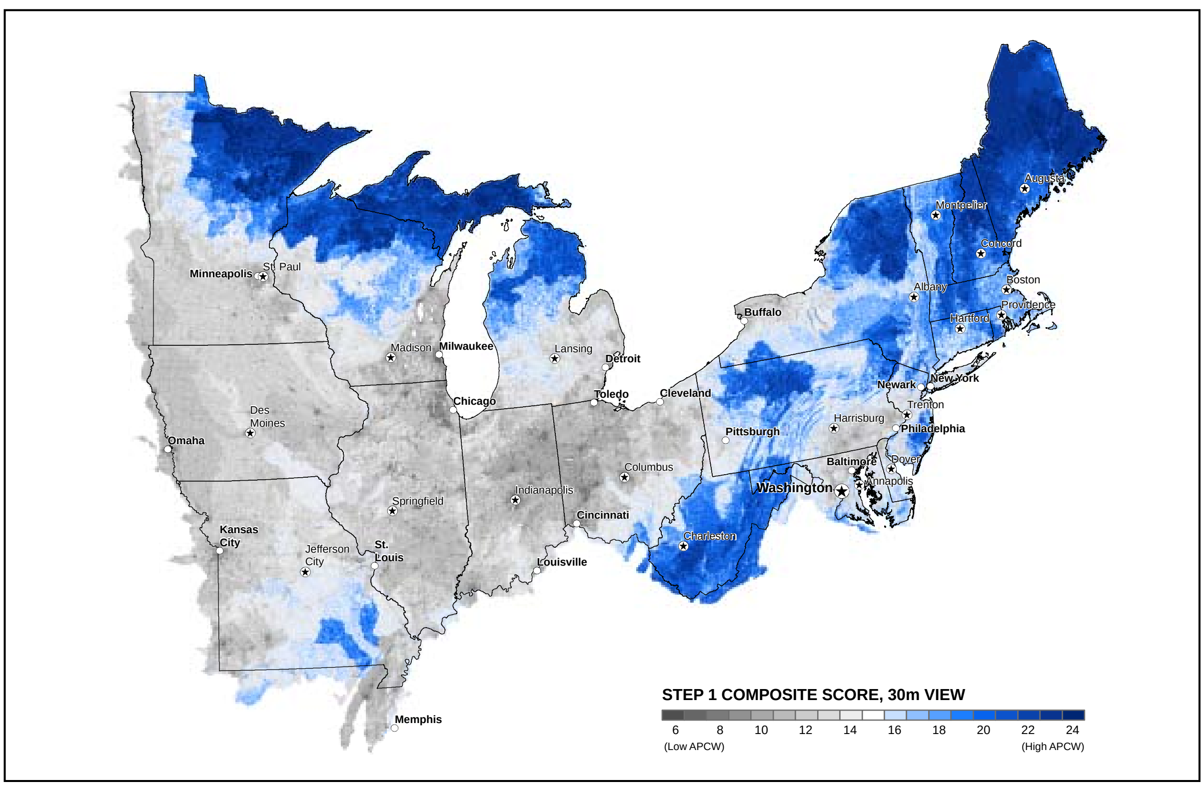
Index of a Watershed's Ability to Produce Clean Water (APCW) (Step 1)

Water quality is a function of biophysical conditions as well as the nature and intensity of land use in a watershed. Watersheds with a large proportion of forest land are more likely to be associated with good water quality. Forests provide the best land cover when it comes to protecting soil, moderating streamflow, supporting healthy aquatic systems, and sustaining good water quality. In the absence of mitigating actions, conversion of forest to other land uses leads to reduced water quality via a net increase in runoff, soil erosion, downstream flooding, and the flow of nutrients and other pollutants into rivers and streams (de la Cretaz and Barten 2007).

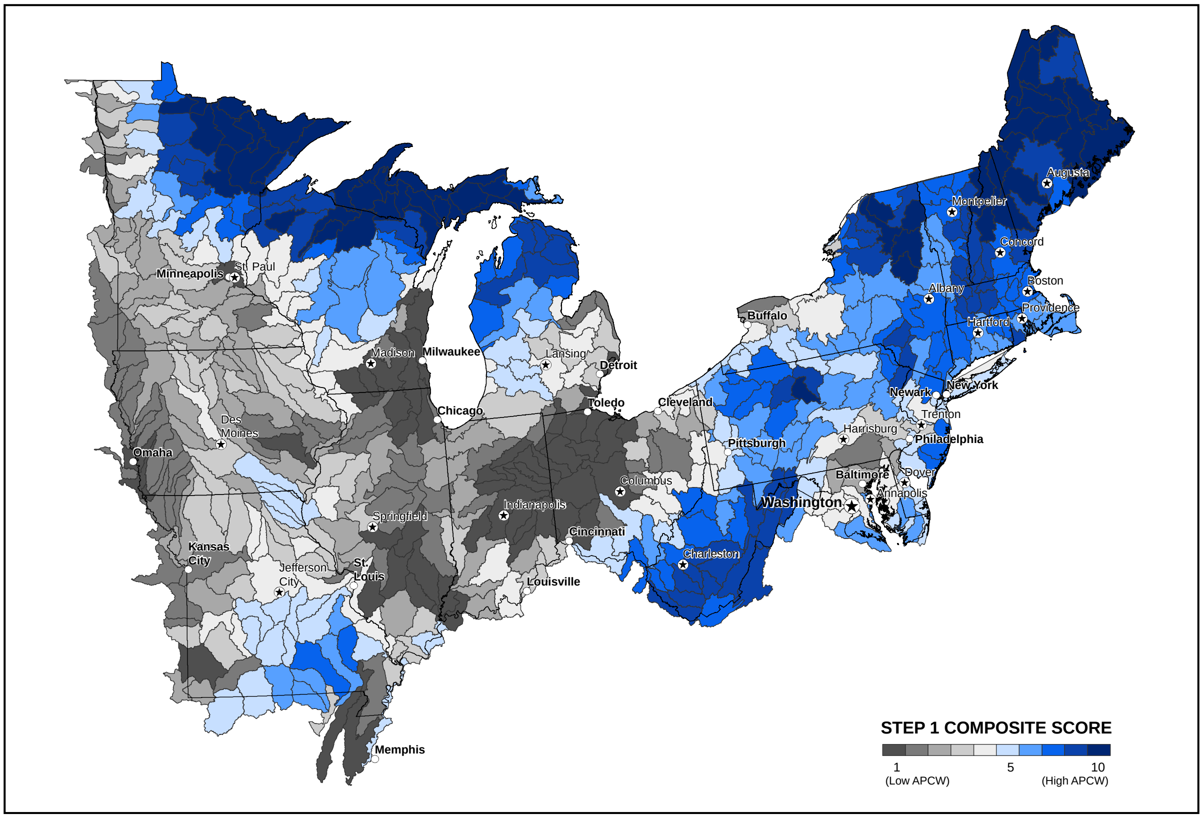
Land uses that tend to dramatically alter natural hydrologic and biological processes also have the greatest potential to negatively influence the flow and quality of water from these watersheds. For example, areas that contain a high percent of forested riparian buffers contribute positively to the ability to produce clean water, while higher amounts of cropland or development are expected to have a negative influence on watershed function and the ability to produce clean water.

Each of the six GIS-based layers that were used to develop the index of APCW (percent forest land by watershed, percent agricultural land by watershed, percent riparian forest cover by watershed, road density, soil erodibility, and 2000 housing density) were ranked from 1 (low APCW) to 4 (very high APCW) according to scientifically accepted breaks or quartiles (Table 4). Map 5 displays the results of the spatial overlay of these six biophysical layers. Map 5 is textured with each 30-meter pixel shown by its composite score.

Map 6 displays an average of these 30-meter pixel scores by eight-digit Hydrologic Unit Code (HUC) watershed, or subbasin, with scores normalized for watershed size on a relative scale of 1 to 10.



Map 5: ***Index of the Ability to Produce Clean Water, 30-meter pixel view.*** *The index of the ability to produce clean water was developed by combining six layers of spatial data: forest and agricultural lands, riparian forest cover, soil erodibility, road density, and housing density. Areas with higher scores have greater ability to produce clean water.*



Map 6: ***Index of the Ability to Produce Clean Water, watershed view.*** *The index of the ability to produce clean water indicates the probability of finding surface waters of high quality in a watershed. Higher scores indicate higher probability***.**

Maps 5 and 6 highlight the differences across the Northeast and Midwest United States in terms of land-use characteristics. Watersheds in a darker shade of blue show where forest land is likely to have a positive influence on surface water supply. On the other hand, shades of gray indicate that intensive agriculture and imperviousness are likely to degrade water quality. Analysis at the eight-digit HUC scale does mask some of these influences. Within a single large watershed, water quality and land use may vary widely and be distributed in broadly disparate patterns. Averaging conditions across a large watershed area gives a general probability of finding good or poor conditions but not a true spatial representation of the precise on-the-ground conditions at any given point. Therefore, a high score in this index does not imply that no water quality problems exist in a given watershed, but rather that the probability of finding surface waters of high quality is greater than in a lower-ranked watershed.

Areas that ranked highest for their ability to produce clean water are northern Minnesota and Wisconsin, Michigan's Upper Peninsula, the Adirondack region of northern New York, central Pennsylvania, most of Maine, and northern New Hampshire. Other high scoring areas include upper Michigan, southern West Virginia, north-central Pennsylvania near the Allegheny National Forest, eastern Vermont and western New Hampshire, western Massachusetts, and northeastern New York.

In contrast, forest and grassland ecosystems that have been converted to intensive agriculture ranked lowest in APCW. Across large areas of the Midwest, where groundwater systems are the primary supply for rural communities, the influence of agriculture on nutrient cycling, soil erosion, pesticide residues, and other contaminants dwarfs the influence of forests (which comprise a small proportion of the landscape) (de la Cretaz and Barten 2007).

Not all areas scoring low in the APCW have poor surface water quality; however, the likelihood of finding clean drinking water requiring less chemical treatment is greater in higher scoring areas. High density population centers, especially around St. Paul – Minneapolis, Chicago, Indianapolis, Cincinnati, and Columbus, ranked lowest due to their high level of development combined with low percent forest, high soil erodibility, and high percent agriculture.

The APCW index may have its greatest utility in characterizing the areas where a focus on protection or restoration or a combination of these strategies may be most appropriate. In addition, scoring of individual watersheds can be repeated at intervals to show trends in watershed condition in the broadest sense over time. Where finer scale watershed delineation and hydrography exist, these same data layers could be used to produce a more accurate local depiction of the index.

Case Study—Low-Scoring Watershed

South Fork Sangamon River, Springfield, IL

Watershed Score for Step 1: 1 out of 10

Watershed Rank: 487 of 540

The 784-square-mile South Fork Sangamon River Watershed supplies over 22 million gallons per day (MGD) of water to over 150,000 people in the Springfield, IL, area. The local utility owns Lake Springfield, which serves as the primary storage and source of drinking water. Constructed in 1935, this 4,200-acre reservoir is the largest municipally owned lake in Illinois. Besides water supply, the lake is a major central Illinois recreation center, as well as the source of condenser cooling water for the utility's lakeshore power plant complex. The lake, shoreline, and lake-area parks host some 600,000 recreational visitors each year.

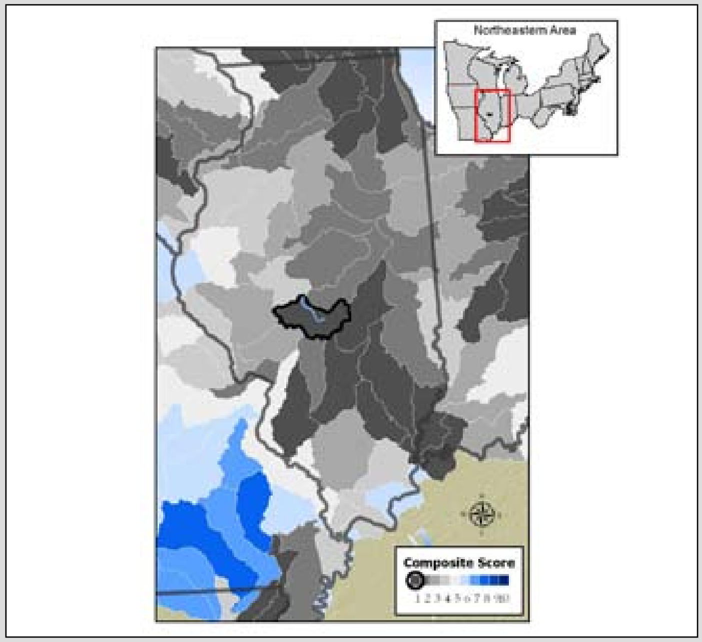
Land use in the watershed is primarily agricultural, with only 4 percent forest cover overall. Corn and soybeans are primary crops. Riparian buffers are also dominated by agricultural lands with less than 20 percent in forests.

This watershed ranked low in Step 1 of the analysis. This score means that in comparison to other watersheds in the study area, it has a lower ability to produce clean water because it has a high percent of agriculture and a low percent of forested land.

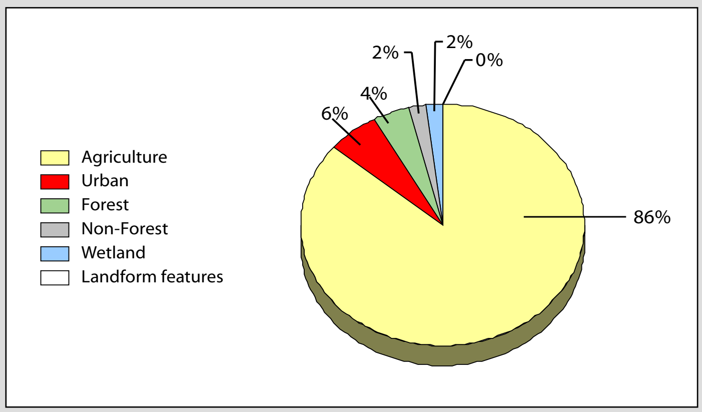
Water undergoes a rigorous purification and testing process, to ensure it is free of harmful bacteria and particulate matter. Untreated water quality is lower than average with average turbidity of 9.3 nepholometric turbidity units (NTUs). Turbidity is a water quality measure that reflects the level of fine suspended particles of clay, silt, organic and inorganic matter, plankton, and other microscopic organisms that are in the water. Water designated for drinking must have turbidities consistently below 1 NTU. The watershed may also have untreated water quality higher than typical agricultural watersheds, because the upper arms of Lake Springfield trap more than 50% of the sediment that enters the reservoir.

Generally, this water supply system has higher-than-average chemical treatment costs of $96.50/MGD on average. Plant operators noted that water quality has been stable or improving and that cooperation with agricultural partners was a reason for improvement. Farmers have reduced atrazine applications and planted 600 acres of filter strips. Restoring lakeside prairie grass may also have contributed to improved water quality.

www.cwlp.com/lake_springfield/lake.htm



Step 1 results show where the ability to produce clean water is greatest in the South Fork Sangamon River Watershed, a low-scoring watershed.

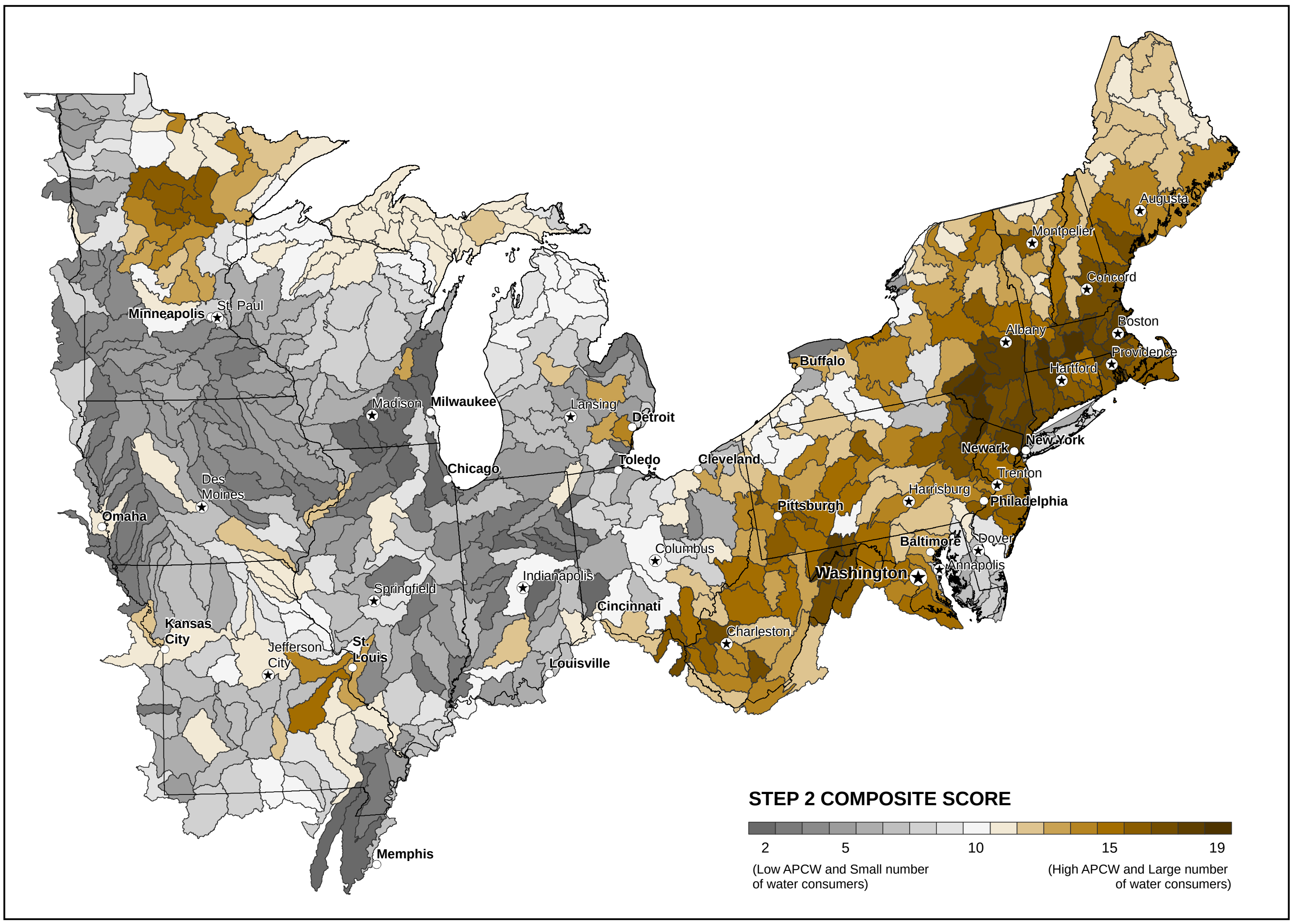


Land use in the low-scoring South Fork Sangamon River Watershed is primarily agricultural.

Lake Springfied dam gates. Lake Springfield is the largest municipally owned lake in Illinois and is the primary storage reservoir for the South Fork Sangamon River Watershed. Photo by Ted Meckes, City, Water, Light and Power Co., Springfield, IL.

Importance of Watersheds for Drinking Water Supply (Step 2)

Map 7 combines the index of Ability to Produce Clean Water with the total number of drinking water consumers served by that watershed to highlight those areas that provide high quality water to the largest population. Watersheds scoring high on this map are important forested watersheds and highlight the location of leading municipal water providers, both public and private. This region-wide map displays the eight-digit HUC watershed scores on a relative scale of 2 to 20.



Map 7: ***Importance of watersheds providing drinking water supply, watershed view.*** *Watersheds with the highest scores have the greatest ability to produce high quality water for the largest population***.**

Table 6: Top scoring watersheds for drinking water supply in the Northeast and Midwest, by composite score and Hydrologic Unit Code (HUC)

Composite score	HUC	Watershed	States
19	01080204	Chicopee	MA
19	01080206	Westfield	CT MA
19	02040102	East Branch Delaware	NY
19	02040104	Middle Delaware-Mongaup-Brodhead	NJ NY PA
18	01070004	Nashua	MA NH
18	01080207	Farmington	CT MA
18	01090001	Charles	MA
18	01090003	Blackstone	MA RI
18	02020005	Schoharie	NY
18	02020006	Middle Hudson	CT MA NY
18	02030101	Lower Hudson	CT NJ NY
18	02030103	Hackensack-Passaic	NJ NY
18	02040101	Upper Delaware	NY PA
18	02070002	North Branch Potomac	MD PA WV

Areas scoring highest are likely to be forested watersheds near large population centers. Many of these watersheds with a high APCW are the same watersheds that serve drinking water consumers in the eastern United States. The top scoring watersheds include southeastern New York (the New York City watersheds), northeastern Pennsylvania (the Pocono Mountains), central and western Massachusetts (Quabbin Reservoir and Berkshire Mountains), northern Connecticut (Hartford), and the Highlands of New Jersey. Other high scoring areas reflect the large amount of forest cover in the Northeast, and include portions of New England—including coastal Maine, Massachusetts, Connecticut, and Rhode Island—and large portions of Pennsylvania, western Maryland, and West Virginia. Relatively high scoring watersheds were also located in northern Minnesota (around St. Paul – Minneapolis) and eastern Missouri (west of St. Louis).

In general, States including and to the west of Ohio ranked lower than the New England and Mid-Atlantic States. The reasons for these results include (1) the smaller numbers of surface water consumers in States west of and including Ohio, since groundwater supplies are more common there; (2) the lower overall forest cover and higher percentage of agricultural lands in much of the region west of Ohio; and (3) the number of drinking water consumers is allocated among all upstream watersheds that rely on large intakes (such as the Upper Mississippi River or Lake Michigan) and systems where a large watershed contributes to the point of diversion.

Watersheds with a high score in Map 7 should be recognized as critically important to the health and welfare of a large percentage of the population in the Northeast and Midwest. These are the workhorses of water supply in the region.

Importance of Watersheds With Private Forests for Drinking Water Supply (Step 3)

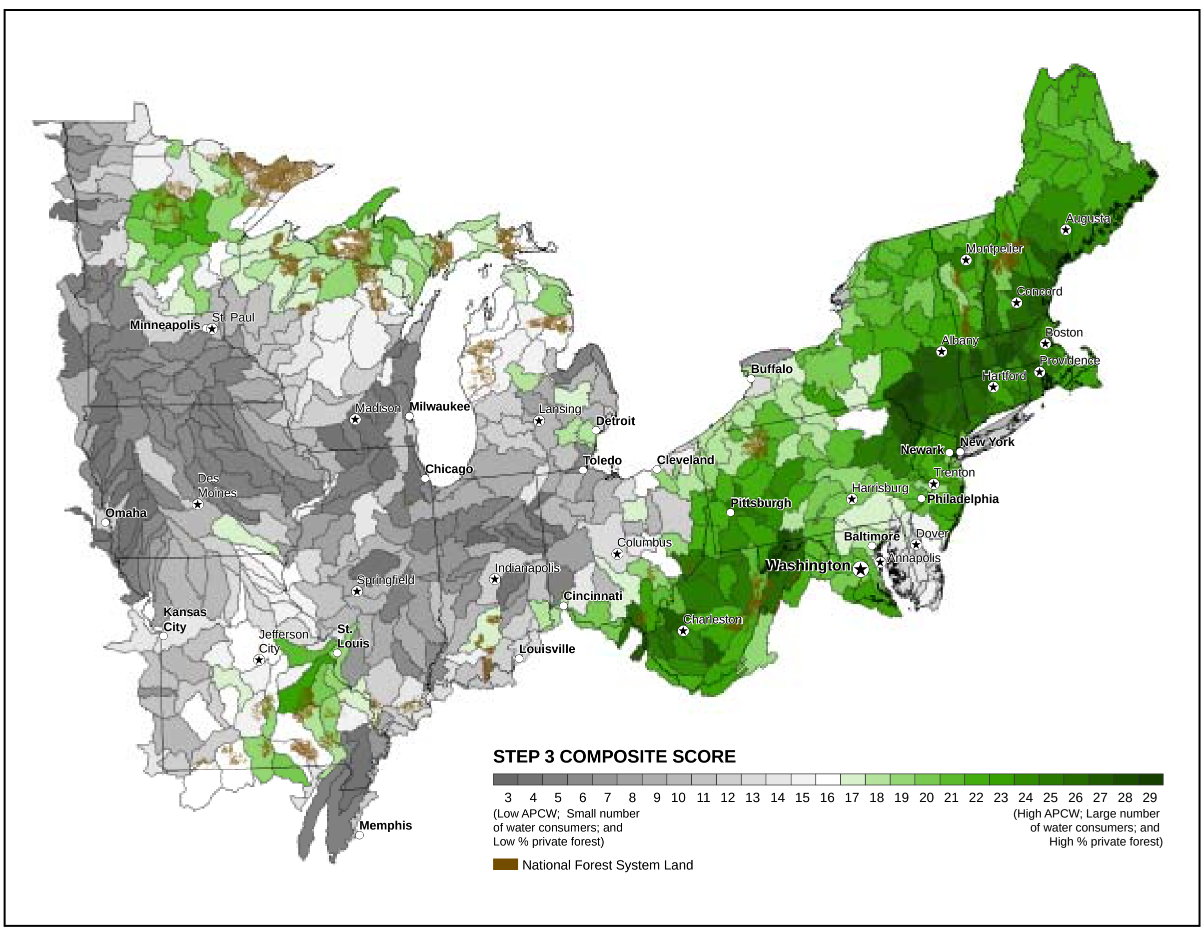
It is a common misconception that all or most lands that supply public drinking water are publicly owned or otherwise protected. Some highly valued drinking water supplies do come from public or other lands that are protected from future development or land-use impacts. Other water supply system lands have limited protection zones, often surrounding reservoirs, lakes, or intakes, while the remainder of the watershed is vulnerable to land-use change. Many small watershed supplies, however, contain only private lands with little or no protective agreements or special land-use provisions.

Map 8 combines the results of the Ability to Produce Clean Water, number of surface drinking water consumers served, and the percent private forest land, to illustrate the important role that private forest lands play in protecting water supplies. As described under Analysis Methods, each of the three data layers was ranked from 1 to 4 in quartiles (very high = 4 points, high = 3 points, intermediate = 2 points, and low = 1 point), and then summed for each eight-digit HUC watershed, resulting in composite scores ranging from 3 to 30.

Map 8 shows that most of the watersheds that ranked highest for their ability to produce clean water for large numbers of water consumers are also characterized by a high percent of private forest land. In general, areas scoring highest (dark green) as private forested watersheds with surface drinking water supply areas are east of Ohio. The highest scoring watersheds in this part of the analysis were in southern Maine, eastern New Hampshire, central and western Massachusetts, western Connecticut, southeastern New York, northeastern Pennsylvania, western Maryland, and southern West Virginia.

Map 8 illustrates those important water supplies where current protection relies primarily on the decisions made by hundreds or even thousands of private forest landowners. In other words, watersheds that score high on this map contain very little protected land and are highly dependent on the management of forests by private landowners in order to protect water quality.

Map 8 also illustrates the importance of the 1911 Weeks Act in establishing National Forests, by authorizing the Federal purchase of forest lands in and around the headwaters and watersheds of navigable streams. By 1980, more than 12.1 million acres of land had been



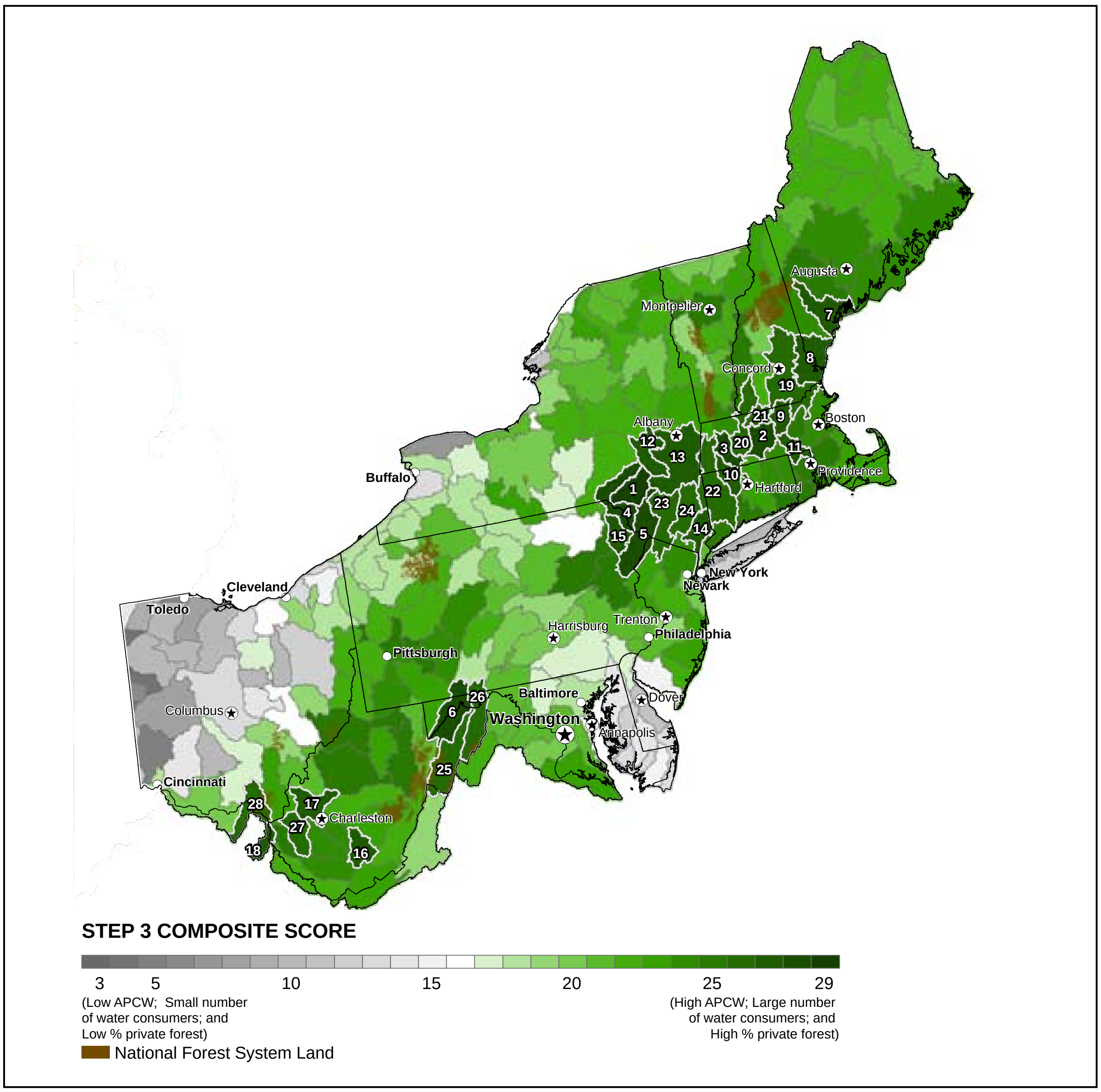
Map 8: *Importance of watersheds and private forests for drinking water supplies, watershed view.* *Watersheds that scored high in their ability to produce high quality water for the largest population also scored high in the amount of private forested land they encompassed.*

added, through purchase, to the National Forest system within the study area boundary. Maps A-1, A-2, and A3 show the National Forest System lands relative to the high scoring watersheds for drinking water. Although most of the forest land in the region is privately owned, passage of the Weeks Act helped to emphasize the importance of protecting lands near water supply watershed areas (Buie 1979, p. 3).

Top scoring watersheds—Eastern portion of the study area

The study area was divided into eastern and western components for ease of discussion and to more easily view the geographic distribution of priority watersheds.

Most states in the eastern portion of the study area (Map 9, Table 7) scored high because approximately 75 percent of the privately owned forested lands in the study area are found here.



Map 9: ***Importance of watersheds and private forests for drinking water supplies in the eastern portion of the study area, watershed view.*** *Watersheds that scored highest in terms of importance for drinking water and for private forests important for drinking water supply were in the eastern portion of the study area. See Table 7 for more information about each watershed.*

Table 7: Top-scoring watersheds in the eastern portion of the study area in terms of private forests important for drinking water supply, by label in Map 9 and composite score.

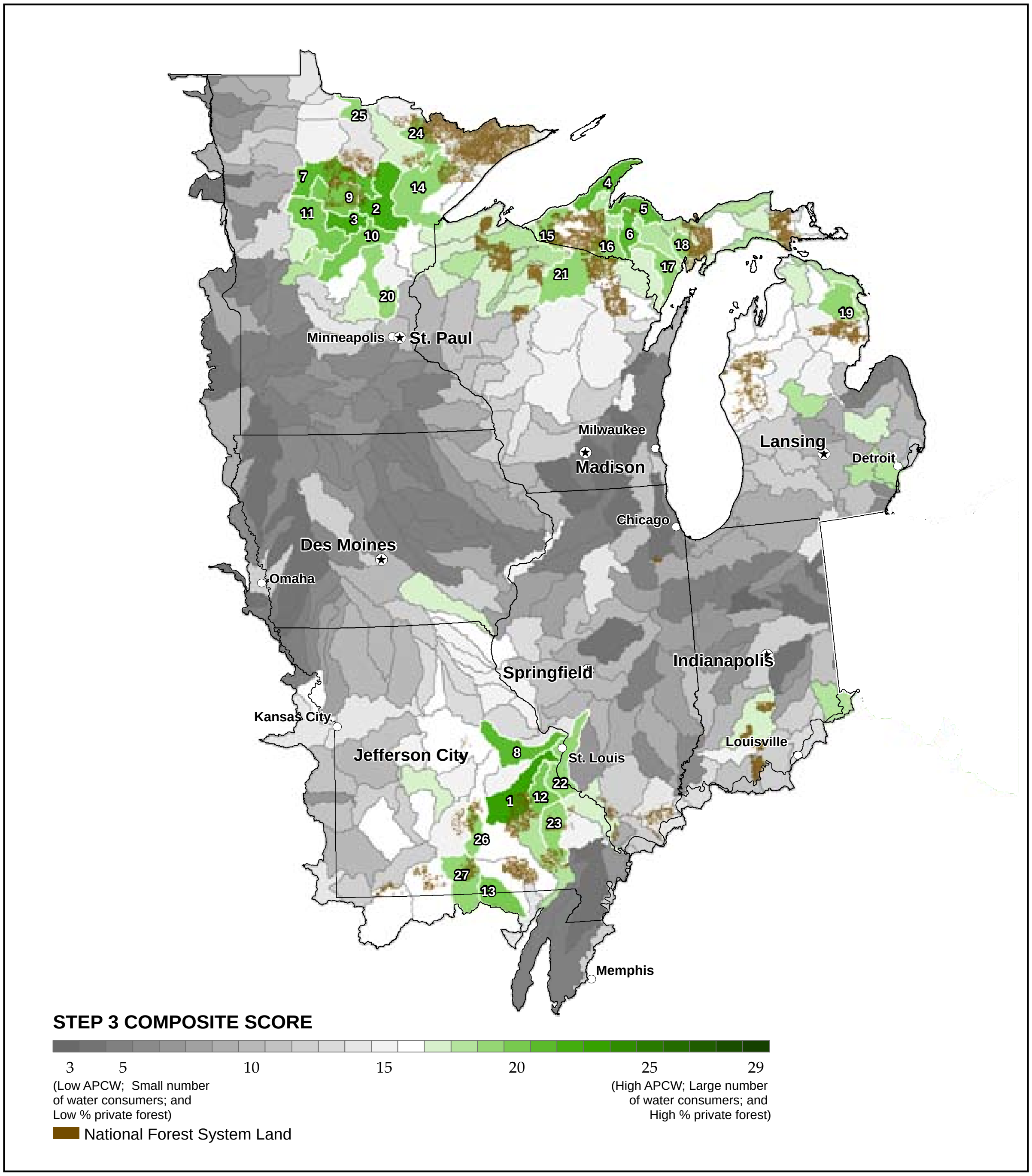
Label in map 9	Composite score	Watershed	HUC	State
1	29	East Branch Delaware	02040102	NY
2	28	Chicopee	01080204	MA
3	28	Westfield	01080206	CT MA
4	28	Upper Delaware	02040101	NY PA
5	28	Middle Delaware-Mongaup-Brodhead	02040104	NY PA NJ
6	28	North Branch Potomac	02070002	MD PA WV
7	27	Presumpscot	01060001	ME
8	27	Piscataqua-Salmon Falls	01060003	ME NH MA
9	27	Nashua	01070004	MA NH
10	27	Farmington	01080207	CT MA
11	27	Blackstone	01090003	MA RI
12	27	Schoharie	02020005	NY
13	27	Middle Hudson	02020006	CT MA NY
14	27	Lower Hudson	02030101	CT NY NJ
15	27	Lackawaxen	02040103	PA
16	27	Lower New	05050004	WV
17	27	Lower Kanawha	05050008	WV
18	27	Big Sandy	05070204	KY WV
19	26	Merrimack	01070002	MA NH
20	26	Middle Connecticut	01080201	MA NH VT
21	26	Miller	01080202	MA NH
22	26	Housatonic	01100005	CT MA NY
23	26	Rondout	02020007	NJ NY
24	26	Hudson-Wappinger	02020008	NY
25	26	South Branch Potomac	02070001	MD VA WV
26	26	Cacapon-Town	02070003	MD PA VA WV
27	26	Lower Guyandotte	05070102	WV
28	26	Little Scioto-Tygarts	05090103	KY OH WV

Top scoring watersheds—Western portion of the study area

Overall, watersheds in the western portion of the study area (Map 10, Table 8) scored lower than watersheds in the eastern portion. This result is not unexpected.

The highest scores were in northern Minnesota, western Missouri, and Michigan's Upper Peninsula. Much like the results of Step 2, these results are likely due to the fact that this part of the country is less forested overall and relies much less on small surface water supplies for drinking water sources. In the western half of the region, the areas that scored highest are aligned more closely with the watersheds in and around National Forest boundaries. For more information on National Forest System lands important for drinking water, see Appendix A. The protection of water quality is a high priority for management of these public lands; results of the analysis show that high priority watersheds are near public lands.

Soils, geology, geography, and land use have led to a greater dependence on large surface water supply systems such as the Great Lakes, or rivers such as the Mississippi or Ohio. These large lake or run-of-the-river systems mean that the analysis spreads water demand across a large landscape, reducing the watershed scores. In addition, states west of Ohio depend to a much greater degree on groundwater sources for drinking water, both as a factor of geology and because ambient water quality problems in many tributaries are brought on by intensive agriculture as a dominant land use. Since this study focuses on surface water supply systems, watersheds that depend on groundwater scored lower and are inherently more difficult to link directly to the influence of forest cover.



Map 10: ***Importance of watersheds and private forests for drinking water supplies in the western portion of the study area, watershed view.*** *High scoring watersheds in terms of importance of watersheds and private forests for drinking water supply in the western portion of the study area did not score as high as watersheds in the eastern portion (Map 9). See Table 8 for more information about each watershed.*

Table 8: Top-scoring watersheds in the western portion of the study area, in terms of private forests important for drinking water supply, by label in map 10 and composite score.

Label in map 10	Composite score	Watershed	HUC	State
1	23	Meramec	07140102	MO
2	22	Prairie-Willow	07010103	MN
3	22	Pine	07010105	MN
4	21	Keweenaw Peninsula	04020103	MI
5	21	Dead-Kelsey	04020105	MI
6	21	Michigamme	04030107	MI
7	21	Mississippi Headwaters	07010101	MN
8	21	Lower Missouri	10300200	MO
9	20	Leach Lake	07010102	MN
10	20	Elk-Nokasippi	07010104	MN
11	20	Crow Wing	07010106	MN
12	20	Big	07140104	MO
13	20	Spring	11010010	AR MO
14	19	St. Louis	04010201	MN WI
15	19	Black-Presque Isle	04020101	MI WI
16	19	Brule	04030106	MI WI
17	19	Cedar-Ford	04030109	MI
18	19	Tacoosh-Whitefish	04030111	MI
19	19	Thunder Bay	04070006	MI
20	19	Rum	07010207	MN
21	19	Upper Wisconsin	07070001	MI WI
22	19	Cahokia-Joachim	07140101	IL MO
23	19	Upper St. Francis	08020202	MO
24	19	Vermilion	09030002	MN
25	19	Upper Rainy	09030004	MN
26	19	Big Piney	10290202	MO
27	19	North Fork White	11010006	AR MO

Case Study—Moderate-Scoring Watershed

James River, Springfield, MO

Watershed Score for Step 3: 12 out of 30

Watershed Rank: 330 of 540

The nearly 1,400-square-mile James River watershed in southwestern Missouri is on the Ozark plateau and contains the city of Springfield, MO. Land use is roughly split between forest (31%), agricultural cover (grazing land, 37%), and other land uses. Riparian buffers are about 50 percent forested with over one-third containing agricultural land. The watershed is characterized by grazing lands and residential development dominated by large lots of 5 – 10 acres.

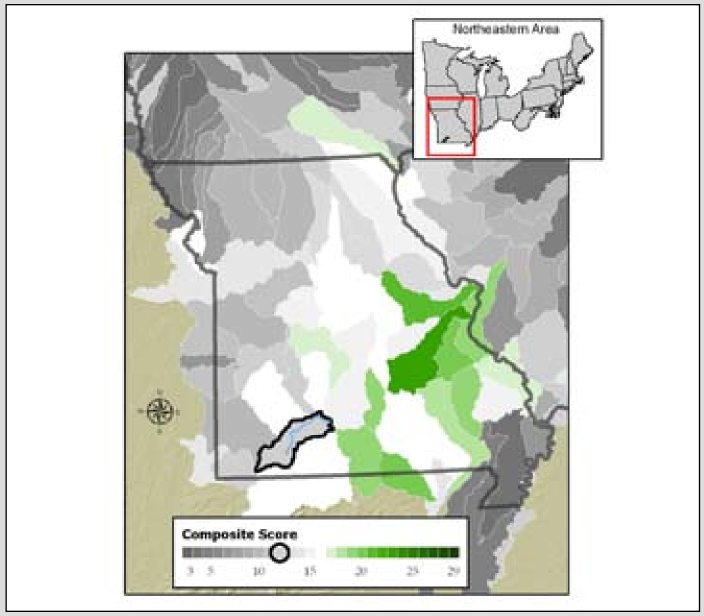
Approximately 80 percent of Springfield's drinking water comes from surface waters (lakes, rivers) and the rest from ground water (wells, springs). The Blackman Water Treatment Plant in the southeastern corner of the city receives water from Fellows Lake, Stockton Lake, and the James River. Water from a tributary of the James River fills Stockton Lake—a primary reservoir for the water supply system. Water from this lake is then pumped uphill about 460 feet into Fellows Lake. Lake water makes up two-thirds or more of the plant's intake water. At times, the plant also draws up to a third of its supply directly from the James River.

This watershed scored in the moderate importance range in the analysis. This means that in comparison to other watersheds in the study area, it has a good ability to produce clean surface water because one-third of its land base is forested. Many people rely on the surface drinking water supplies, and the water supplies are located near forest lands that are privately owned and subject to a medium level of development pressure.

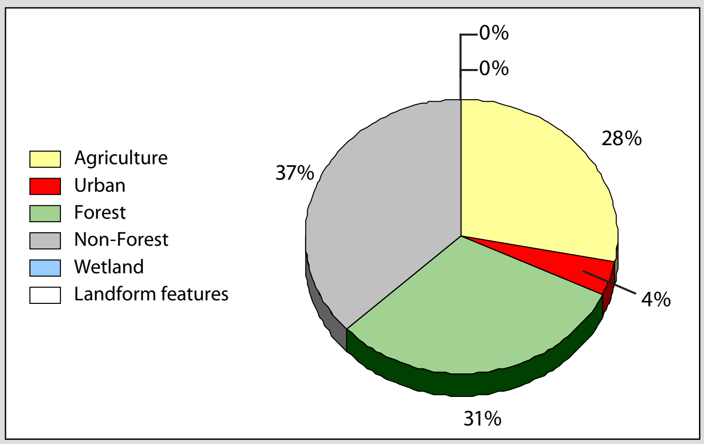
The Blackman Water Treatment Plant provides about 18 million gallons per day (MGD) of treated water to its customers with per unit chemical treatment costs of $62.20/MGD. Although water supply reservoirs have improved dramatically since the 1930s, plant operators have reported a decline in untreated water quality in recent years attributed to eutrophication from increased turbidity in the James River, sedimentation of reservoirs, and increased development of the source watershed. Failing septic systems are also seen as one of the top issues in the watershed.

County planning and zoning laws have been improved to address better watershed protection. The Watershed Committee of the Ozarks, a nonprofit that has been partnering with local stakeholders, is working to protect some property in the source watershed and to educate the public.

www.watershedcommittee.org/



Step 3 results show where the role of private forests in protecting water supplies is greatest in the James River Watershed, a moderate-scoring watershed.



Land use is divided roughly among grazing, forest, and other land uses in the James River Watershed, a moderate-scoring watershed.

Springfield, MO, receives most of its water supply from areas outside the James River basin, but some of its water comes from James River intakes. Photo by Dave Ballou, City of Springfield, MO.

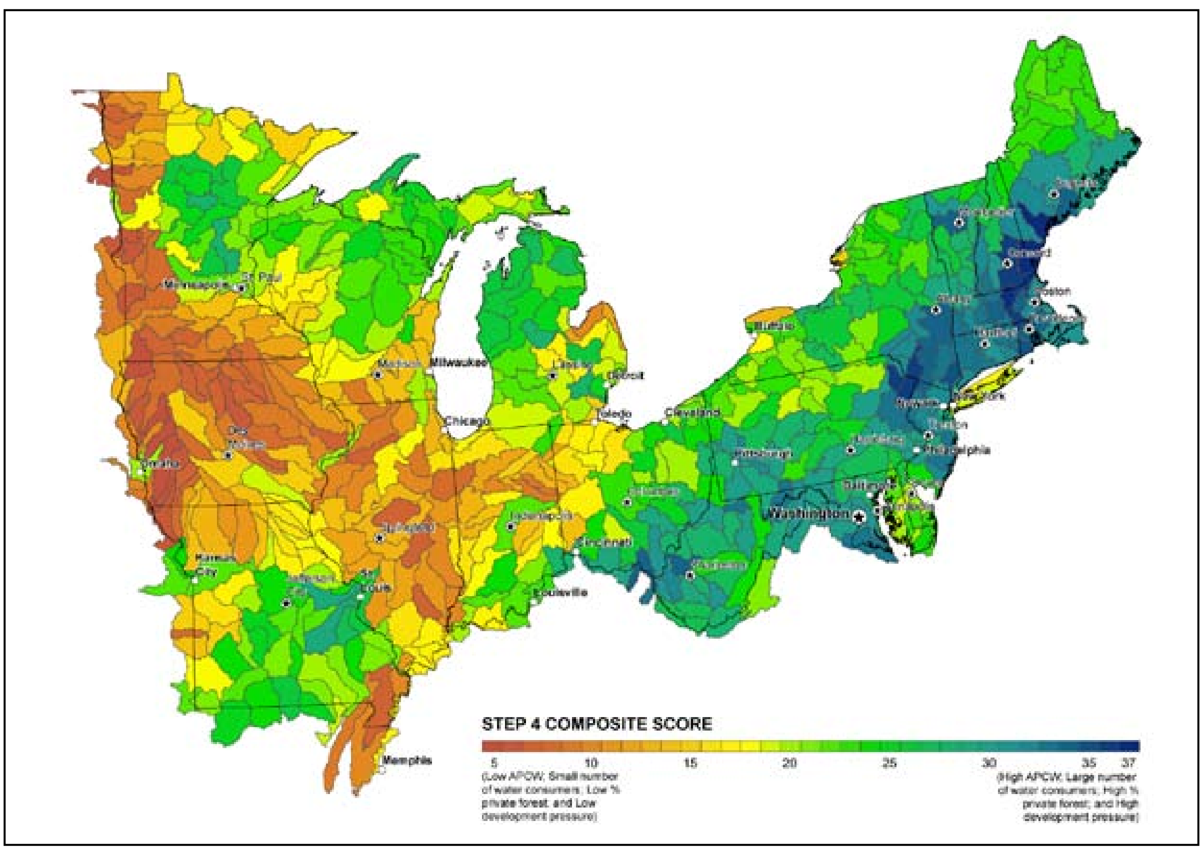
Development Pressure on Private Forests in Watersheds Important for Drinking Water Supply (Step 4)

The fact that watersheds are protected predominantly by private forest lands means that those watersheds are vulnerable to land-use change if they fall within areas of projected future growth. According to the EPA, more than 60 percent of U.S. water pollution comes from runoff from lawns, farms, cities, and highways, as well as leachate from septic systems (U.S. EPA 2007). The loss of forest lands to development affects not only the quality of drinking water, and therefore the cost of treating it, but the quantity as well. While it increases demand and water use, development also reduces the ability of water to infiltrate and recharge water supplies, and reduces supply as well.

In this analysis, housing density data, derived from U.S. Census (2000) block data, served as an indicator of development pressure. Projections of housing density change from 2000 to 2030 (Theobold 2005) that were developed as part of the Forests on the Edge project (Stein and others 2005) were combined with private land to illustrate those unprotected forest areas where housing density is likely to increase. Areas where housing density increased were extracted and reclassified as "development pressure." The acreage subject to development pressure was then calculated for each watershed and divided by the acreage of the watershed. This "development pressure per unit area" was then used to assign a value from low to high.

Map 11 combines the results of the index of Ability to Produce Clean Water, surface drinking water consumers served, percent private forest land, and housing conversion pressure to highlight environmentally important water supply protection areas that are at the highest risk for future development. Areas that ranked high are near the major cities in the Northeastern United States. Many local water supplies were established "just outside of town," and now development is encroaching upon them. In general the highest ranking watersheds in the western half of the study area fell well below those in the eastern half, with the highest ranked watersheds in northern Minnesota, northern Wisconsin, northern Michigan and the Upper Peninsula, and southern and eastern Missouri. The high scoring watersheds in the western half are near major cities or metropolitan areas, including Minneapolis – St. Paul, Lansing, Jefferson City, and St. Louis.

In general, areas scoring highest for risk of future development pressure ran along the eastern seaboard, from eastern Pennsylvania to southern Maine. Watersheds that scored highest are in southern Maine, eastern New Hampshire, central Massachusetts, and northeastern Pennsylvania. High-scoring watersheds were also found in southern Ohio, western West Virginia, northern New Jersey, southeastern New York, Rhode Island, central Massachusetts, and northern Vermont.



Map 11: *Development pressure on forests and drinking water supplies, watershed view.* *Watersheds with the highest scores and the highest risk of future development are near major cities and metropolitan areas.*

Case Study—High-Scoring Watershed

Merrimack River, Manchester, NH

Watershed Score for Step 4: 36 out of 40

Watershed Rank: 4 of 540

The 43-square-mile Merrimack River watershed provides the drinking water supply for a number of small communities as well as the residents of the city of Manchester, NH. The watershed is primarily forested (about 70%) and typical of southern New England forest, with pine, hemlock, and northern hardwoods as dominant vegetation. Most streams are well buffered by forest and wetland.

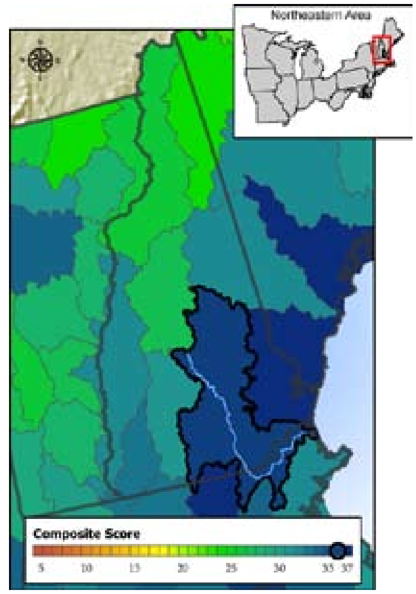
The Manchester Water Works, the State of New Hampshire's largest water utility, manages the Merrimack River intake and is responsible for providing drinking water to the City of Manchester and portions of Auburn, Bedford, Derry, Goffstown, Hooksett, and Londonderry. Located adjacent to Lake Massabesic, the Manchester Water Treatment Plant treats the water before it is distributed to homes and industries. The plant presently delivers in excess of 17.75 million gallons per day (MGD) to approximately 159,000 consumers in the greater Manchester area.

This watershed was one of the highest scoring watersheds in steps 3 and 4 of the analysis. Compared with other watersheds in the study area, this watershed had a very high ability to produce clean water because it is has such a high percent of forest; and the forests around the drinking water supplies are mainly privately owned and at great risk of development pressure.

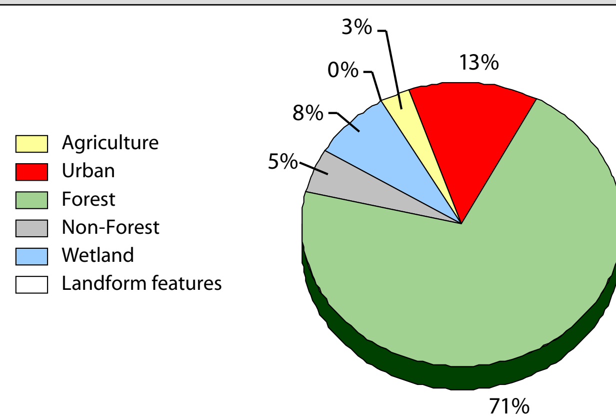
Watershed management in the source water watershed includes an active forestry program. Under the direction of a professional forester, the Manchester Water Works annually harvests about 500,000 board feet of timber. The purpose of this program is to develop the best tree cover for the forest environment and promote controlled water retention and runoff.

The Manchester area is growing substantially. The Manchester Water Treatment Plant purchased 8,000 acres, or about 3 percent of the watershed, to protect source water quality; however, the remainder of watershed forests remain privately owned. Although better-than-average water would be expected, the Manchester water plant has reported declining water quality. In recent years, the per unit water treatment cost increased from $53.26/MGD to $82.50/MGD.

www.manchesternh.gov/website/Departments/WaterWorks/WaterSupply/tabid/419/Default.aspx



Step 4 results show where development pressure on important private forest is greatest in the Merrimack River watershed, a high-scoring watershed.



Land use is primarily forest in the Merrimack River Watershed, a high-scoring watershed.

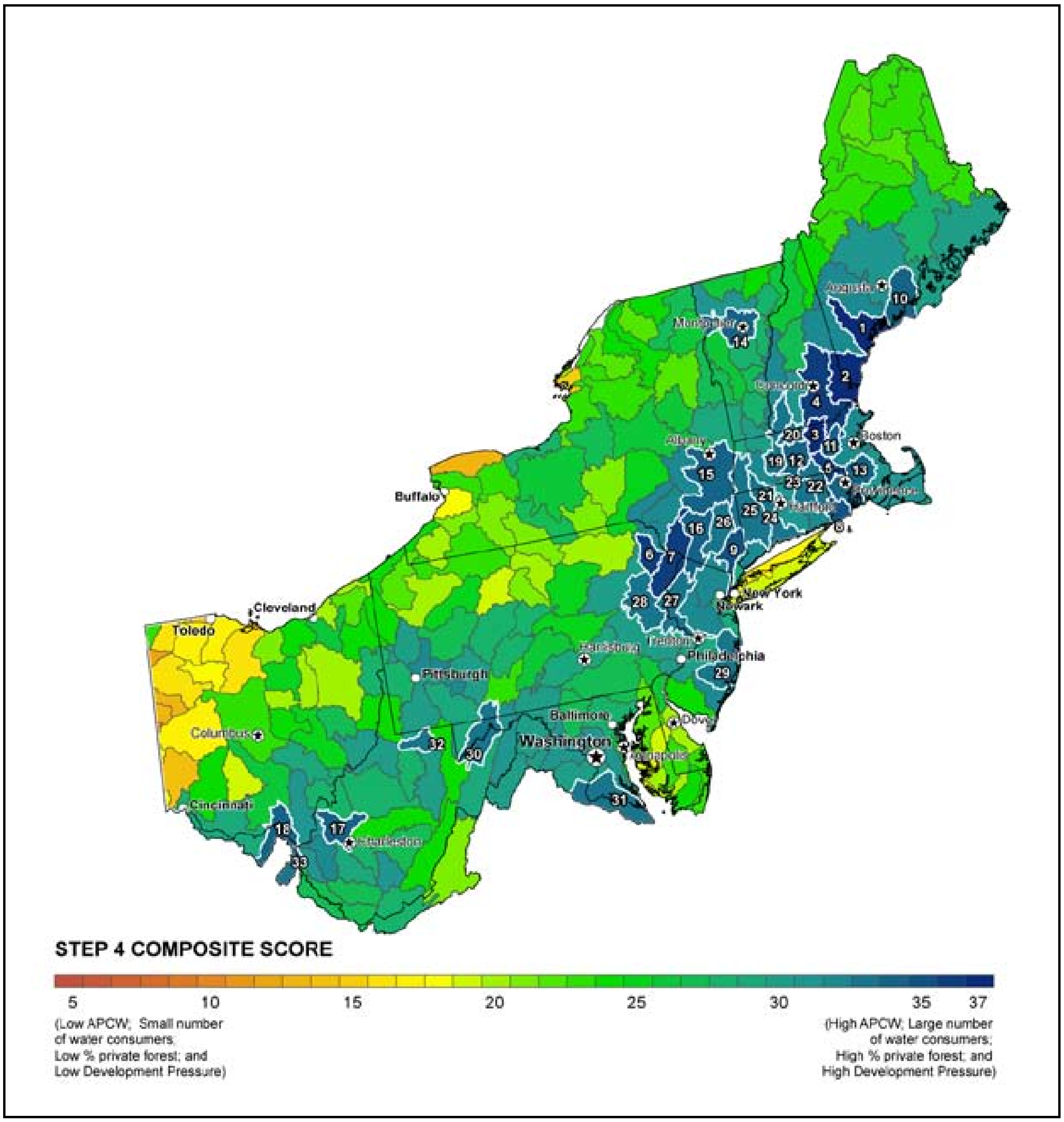
At 110 miles in length, the Merrimack River is an important regional focus in New Hampshire and Massachusetts. It flows through Manchester, the largest city in New Hampshire, and provides drinking water to the city of Nashua and surrounding towns. Photo by William Frament, U.S. Forest Service.

Top ranking watersheds—Eastern portion of the study area

The study area was divided into an eastern and western component for ease of discussion and to more easily view the geographic distribution of priority watersheds.

In the Northeast, many city water supplies were established "just outside of town," and new development is encroaching upon them. A recent study in New Hampshire showed that lands contributing to water supply made up approximately 10 percent of the State, while 75 percent of the population and most major communities relied on these lands for drinking water. The study also found, however, that these lands were four times more likely to be developed than other forest land in the State as a whole, and only 12 percent of these critical areas were permanently protected (Society for the Protection of New Hampshire Forests 1998).

Not surprisingly, those watersheds containing substantial existing forest lands and rapidly expanding towns and cities received the highest ranking. For example, the Presumpscot watershed includes the rapidly growing city of Portland, ME, while the Nashua and Merrimack watersheds are rapidly developing for commuters to Boston, MA. It is in the eastern portion of the study area along the Interstate Highway 95 corridor, where drinking water watersheds are subject to the greatest pressure.



Map 12: *Development pressure on private forests and drinking water supplies in the eastern portion of the study area, watershed view.* *In the eastern portion of the study area, forested water supply watersheds subject to the greatest development pressure are along the Interstate Highway 95 corridor. See Table 9 for more information about each watershed*

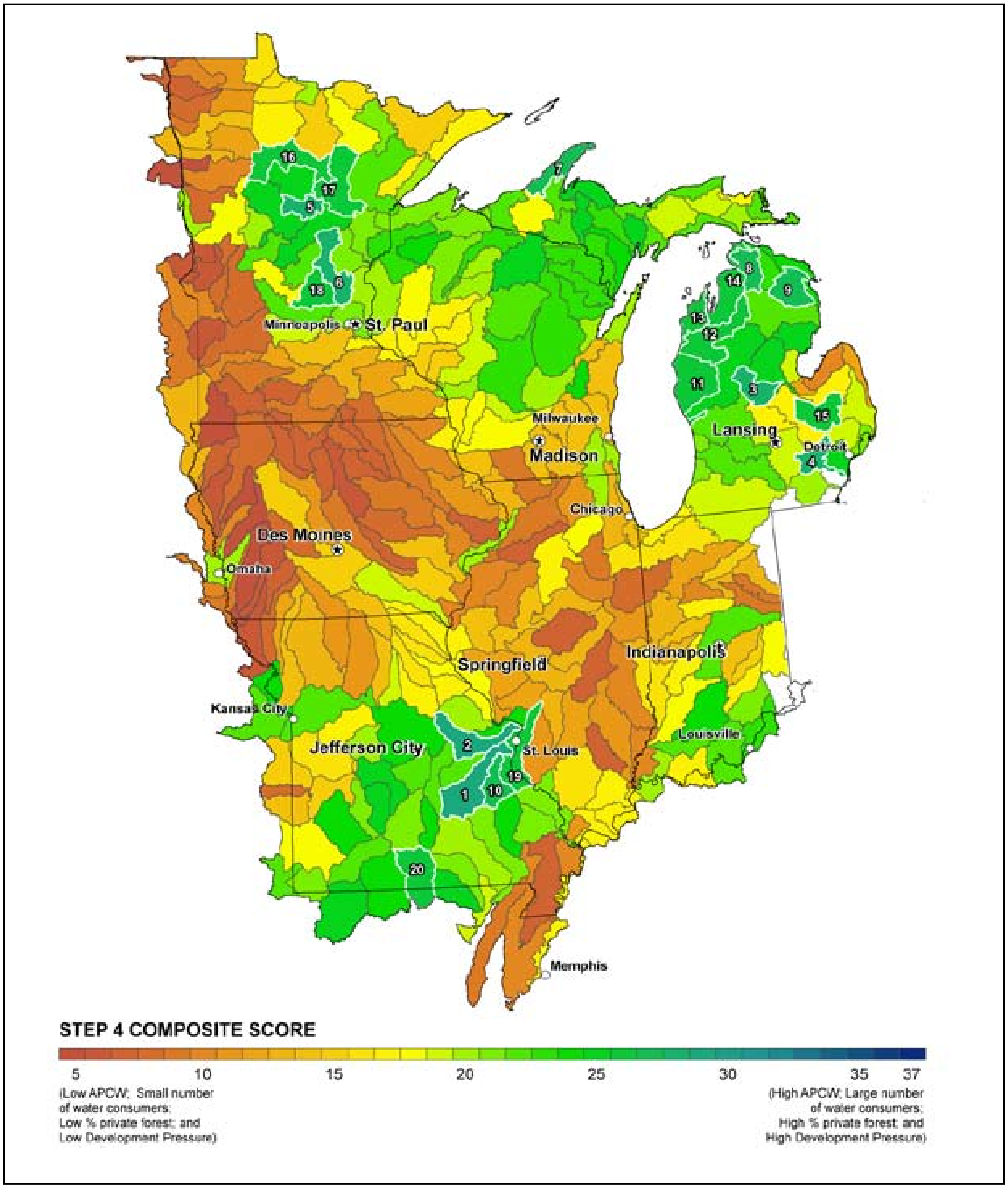
Table 9: Watersheds in the eastern portion of the study area with the greatest development pressure on private forests important for drinking water supply, by label in map 12 and composite score.

Label in map 12	Composite score	Watershed	HUC	State
1	37	Presumpscot	01060001	ME
2	37	Piscataqua-Salmon Falls	01060003	ME NH MA
3	37	Nashua	01070004	MA NH
4	36	Merrimack	01070002	MA NH
5	36	Blackstone	01090003	MA RI
6	36	Lackawaxen	02040103	PA
7	36	Middle Delaware-Mongaup-Brodhead	02040104	NJ NY PA
8	35	Pawcatuck-Wood	01090005	RI CT
9	35	Lower Hudson	02030101	CT NJ NY
10	34	St. George-Sheepscot	01050003	ME
11	34	Concord	01070005	MA
12	34	Chicopee	01080204	MA
13	34	Narragansett	01090004	MA RI
14	34	Winooski	02010003	VT NY
15	34	Middle Hudson	02020006	CT MA NY
16	34	Rondout	02020007	NJ NY
17	34	Lower Kanawha	05050008	WV
18	34	Little Scioto-Tygarts	05090103	KY OH WV
19	33	Middle Connecticut	01080201	MA NH VT
20	33	Miller	01080202	MA NH
21	33	Farmington	01080207	CT MA
22	33	Quinebaug	01100001	CT MA RI
23	33	Shetucket	01100002	CT MA
24	33	Quinnipiac	01100004	CT
25	33	Housatonic	01100005	CT MA NY
26	33	Hudson-Wappinger	02020008	NY
27	33	Middle Delaware-Musconetcong	02040105	NJ PA
28	33	Lehigh	02040106	PA
29	33	Mullica-Toms	02040301	NJ
30	33	North Branch Potomac	02070002	MD PA WV
31	33	Lower Potomac	02070011	MD VA
32	33	Upper Monongahela	05020003	PA WV
33	33	Big Sandy	05070204	KY WV

Top ranking watersheds—Western portion of the study area

Like the Step 3 analysis results, watersheds in the western portion of the study area rank lower overall than watersheds in the eastern portion, and for many of the same reasons. However, another factor in these lower rankings is the presence of less private forest land and less potential for development and impact on watersheds.

Conversely, these same conditions make it easier to identify and target those areas that are high priority in the western part of the study area. Three distinct regions stand out: the watersheds in Missouri between the growth centers of St. Louis and Jefferson City, the growing retirement and recreation-based communities along the upper portion of Lake Michigan and the suburbs of Detroit, and the "white collar" communities north of Minneapolis – St. Paul. All three regions provide challenges for future protection of water supplies. Although not ranked in the top 20, northeastern Wisconsin stands out clearly as a regional priority as well.



Map 13: ***Development pressure on private forests and drinking water supplies in the western portion of the study area, watershed view.*** *Less private forest land in the western portion of the study area means there is less development pressure on drinking water supply watersheds than in the eastern portion. See Table 10 for more information about individual watersheds.*

Table 10: Watersheds in the western portion of the study area with the greatest development pressure on private forests important for drinking water supply, by label in map 13 and composite score.

Label in map 13	Composite score	Watershed	HUC	State
1	29	Meramec	07140102	MO
2	29	Lower Missouri	10300200	MO
3	28	Pine	04080202	MI
4	28	Huron	04090005	MI
5	28	Pine	07010105	MN
6	28	Rum	07010207	MN
7	27	Keweenaw Peninsula	04020103	MI
8	27	Cheboygan	04070004	MI
9	27	Thunder Bay	04070006	MI
10	27	Big	07140104	MO
11	26	Pere Marquette-White	04060101	MI
12	26	Manistee	04060103	MI
13	26	Betsie-Platte	04060104	MI
14	26	Boardman-Charlevoix	04060105	MI
15	26	Flint	04080204	MI
16	26	Mississippi Headwaters	07010101	MN
17	26	Prairie-Willow	07010103	MN
18	26	Clearwater-Elk	07010203	MN
19	26	Cahokia-Joachim	07140101	IL MO
20	26	North Fork White	11010006	AR MO

SUMMARY OF RESULTS

Water, in all its uses and permutations, is by far the most valuable commodity that comes from the forest land that we manage, assist others to manage, and/or regulate.

–National Association of State Foresters Policy Statement, 2004

The results of this analysis confirm that forests are critically important to the supply of clean drinking water in the Northeast and Midwest. Forests protect the reservoirs and water supplies for more than 52 million people in over 1,600 drinking water supplies (U.S. Department of Agriculture, Forest Service 2005). The results provide a foundation on which protection and management strategies for water supply systems can be built.

Specifically, the results describe the magnitude and scope of forest-dependent drinking water supplies and quantify the dependence of the population on forests in these watersheds. The maps identify large-scale watersheds where strategic action and partnerships are likely needed to reduce the threat of land use change and to increase forest protection. The maps also show areas where forest management strategies aimed specifically at maintaining or enhancing the quality, quantity, and timing of water flow may be beneficial.

Of the 540 eight-digit watersheds in the Northeast and Midwest, 329 of them are surface water watersheds. Just 78 of these watersheds supply the drinking water for nearly 38 million people. The forests in these drinking water supply watersheds are overwhelmingly in private ownership and are being converted to other uses at an estimated rate of 350 acres per day. This rate of loss could increase to as much as 900 acres per day by 2030. Growth projections suggest that as many as 12 million acres of private forest land in these States may be converted to other uses by 2030.

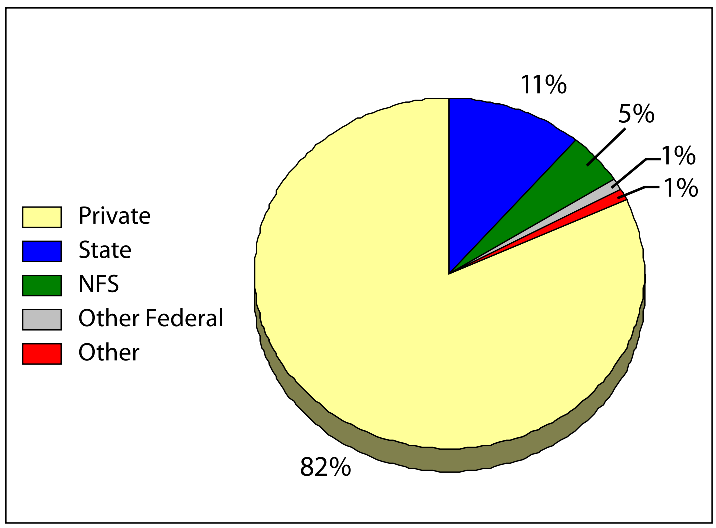


Figure 4: *Forest land ownerships in source water watersheds in the Northeast and Midwest.*

Table 11. Forest land ownership in the Northeast and Midwest, by number of surface water consumers.

Type and number of surface water consumers in the watershed	Type of land ownership (percent)				
	Private	State	National Forest System	Other Federal	Other*
No public surface water consumers	70	16	9	1	4
Small water supply systems (25 – 100,000 consumers)	80	12	6	1	1
Medium-sized water supply systems (100,001 – 1,000,000 consumers)	87	9	2	1	1
Large water supply systems (>1,000,000 consumers)	87	11	0	1	2

* Other ownerships include tribal, local, county, private-protected, joint, and unknown.

This analysis also shows significant differences between watersheds that supply drinking water. Water supply systems in the eastern half of the study area are more likely to be dominated by a dependence on surface water of high existing quality, using limited chemical treatment, and located in smaller forested watersheds—often with more numerous intakes. Water supply systems in the western half of the study area are more likely to use groundwater or be of lower existing water quality due to intense agricultural land use. These water supplies are also much more likely to draw from large rivers or lakes and rely upon extensive treatment to meet drinking water standards.

For every water supply system, there is someone who oversees it and a managing or governing entity who makes the decisions that affect its operation and its future. Throughout the study area, there is great diversity in the amount of oversight and available expertise. Many water supply systems are very small—serving only 500–3,500 people with few or no dedicated technical staff. Larger systems serving 50,000 or more may have engineers, foresters, consultants, and work crews on staff. In each case, however, the protection and management of forests play a role in the central mission—to provide reliable safe drinking water.

This analysis highlights the need to address a number of issues that water suppliers face related to protection and management of water supply systems. The issues include—

- Conservation of forest land
- Sustainable management of forests
- Understanding the forest-to-faucet connection by consumers and decisionmakers
- Appreciation of the actual cost of clean drinking water
- Communication between water providers and water consumers
- Availability of forest information and data to water providers

Figure 5: *Forest shelters this high-quality stream in Maryland. Photo by Al Todd.*

CLOSING COMMENTS

The forest is connected to the faucet: the cleanest water flows from healthy forested watersheds (Dissmeyer 2000). A watershed protection forest provides services like filtering air and water, reducing floods and erosion, sustaining stream flows and aquatic species, ensuring watershed stability and resilience, and absorbing rain and refilling groundwater aquifers. Maintaining these watershed services is essential.

Aside from the economic value of forest products like wood and paper, if forests fall into poor health or are converted to other uses, society has to invest billions in technological alternatives to replace the natural ecosystem services that the forests provided essentially for free.

The degradation of water supplies and widespread flooding and erosion, in large degree, inspired the creation of the Forest Service a century ago, along with the birth of the conservation era. When President Theodore Roosevelt and Gifford Pinchot, the first Chief of the Forest Service, set up a system of National Forests, it was primarily for "securing favorable conditions of water flows." Pinchot and Federal policymakers of the time were most concerned about preserving the forests that sustained the function of watersheds. In his Primer on Forestry, Pinchot (1903) wrote,

> *A forest, large or small, may render its service in many ways. It may reach its highest usefulness by standing as a safeguard against floods, winds, snow slides, or especially against the need of water in the streams.*

Abundant, clean drinking water is a precious resource for which there is no substitute. People can look for alternatives sources of energy, or change their diets to adjust to new sources of food. Without enough water, however, people must reduce their water use, find more water, or move. The United States has enjoyed an abundance of clean water, accessible to all of its citizens; however, drinking water scarcity is a growing concern. With projections of increasing U.S. population, competition for water is expected to grow. Water shortages, worsened by increasing demand, are becoming

A Watershed Protection Forest Is …

Based on a centuries-old concept in European and North American forestry

A living filter that protects aquatic ecosystems, drinking water supplies, and human health

Comprised of layers (overstory, midstory, and regeneration) with diverse species and ages

Growing vigorously and assimilating nutrients and sequestering carbon

Critical in protecting areas, such as riparian zones and steep slopes

Deliberately patterned across the landscape to be resistant to and resilient after natural disturbances (wildfire, storms, insects, and diseases)

Monitored to inform adaptive management

commonplace even in the humid eastern states. Climate change and its potential effects on water quantity, quality, and timing add a serious and complicated challenge to already perplexing water issues.

For natural resource agencies, a renewed focus on forests and their connection to clean and abundant water will be critical. The Forest Service—in partnership with State and local governments, nonprofits, and private landowners—has a shared responsibility to care not just for the land but for the nation's liquid assets as well.

Forested watersheds in the study area provide clean water that fills rivers, streams, lakes, and wetlands, sustains fisheries, and flows from faucets of homes and businesses. Water may be the most valuable product produced by public and private forest lands.

For more information on watershed forestry, including projects and tools linking forestry and clean drinking water, go to these Web sites:

- Northeastern Area State and Private Forestry's watershed Web site: www.na.fs.fed.us/watershed/
- Forest-to-Faucet Partnership's Web site: www.wetpartnership.org/

APPENDIX A: National Forest Lands Important for Drinking Water Supply

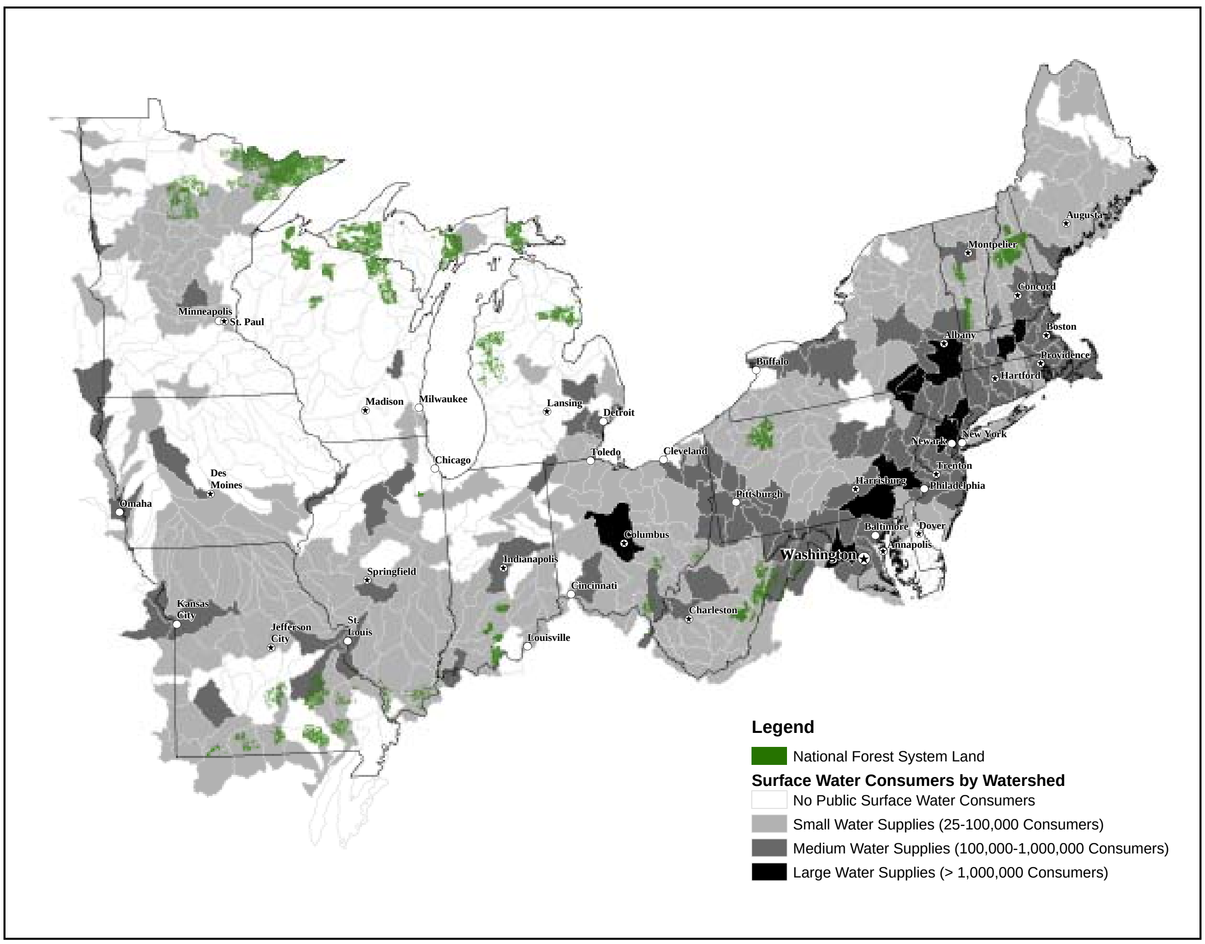
Contents

Tables

Figure

Maps

The 1897 Organic Administrative Act, which authorized the establishment of much of the National Forest System, said that the forest reserves were to protect and enhance water supplies, reduce flooding, secure favorable conditions of water flow, protect the forest from fires and other depredations, and provide a continuous supply of timber. By 1915, National Forests in the West had been established in much the form they retain today. At the time, few Federal forests were designated in the East because of the lack of public domain. Demand for eastern National Forests resulted in the passage of the 1911 Weeks Act, authorizing the acquisition of Federal lands to protect the watersheds of navigable streams. From 1911 to 1945, about 24 million acres of depleted farms, stumpfields, and burned woodlands were incorporated into the National Forest System. Map A-1 shows the National Forest System lands in the Northeast and Midwest in relation to source water watersheds and water consumers served.



Map A-1: *National Forests and important watersheds.* *National Forest System lands are near water supply systems that serve large numbers of consumers in the Northeast and Midwest.*

Maintaining supplies of clean drinking water and protecting watersheds from degradation are major reasons for management of the National Forests. Another notable issue regarding management is whether municipal watersheds should be placed under active or passive management in order to sustain supplies of high quality water. While natural resource professionals agree that active management can be compatible with or even desirable in sustaining water supplies, many people also believe that, in the interest of water quality, forests in watersheds should not be altered in any way.

Another issue is development and loss of open space. Although the vast majority of National Forest lands are unlikely to be converted to any form of developed uses, these scenic protected lands also attract development to their borders. In the Northeast and Midwest, for example, as shown in Figure A-1, the majority of forest land ownerships in the 65 source water watersheds that contain National Forest System lands are privately owned and subject to land use conversion. Moreover, the vast majority of drinking water consumers are supplied by privately owned lands, in comparison to the small percentage supplied by State and Federal lands (Table A-1). However, development adjacent to National Forest boundaries is still a serious concern in many parts of the country, including the northeast. These more intensive land uses on the fringe of public lands increase the risks for wildlife, contribute to the spread of invasive plants and pests, reduce access to recreation, fragment habitat, and impact water quality.

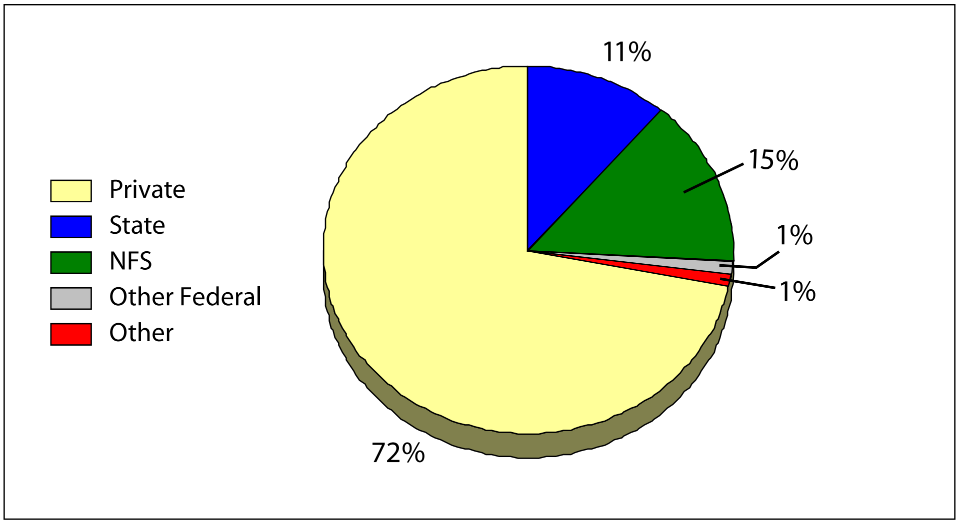


Figure A-1: *Overall percentage of all forest land ownerships in the 65 source water watersheds that contain National Forest System (NFS) lands in the Northeast and Midwest.*

Table A-1. Forest land ownerships in the 65 source water watersheds containing National Forest System (NFS) land in the Northeast and Midwest, by number of surface water consumers (percent)

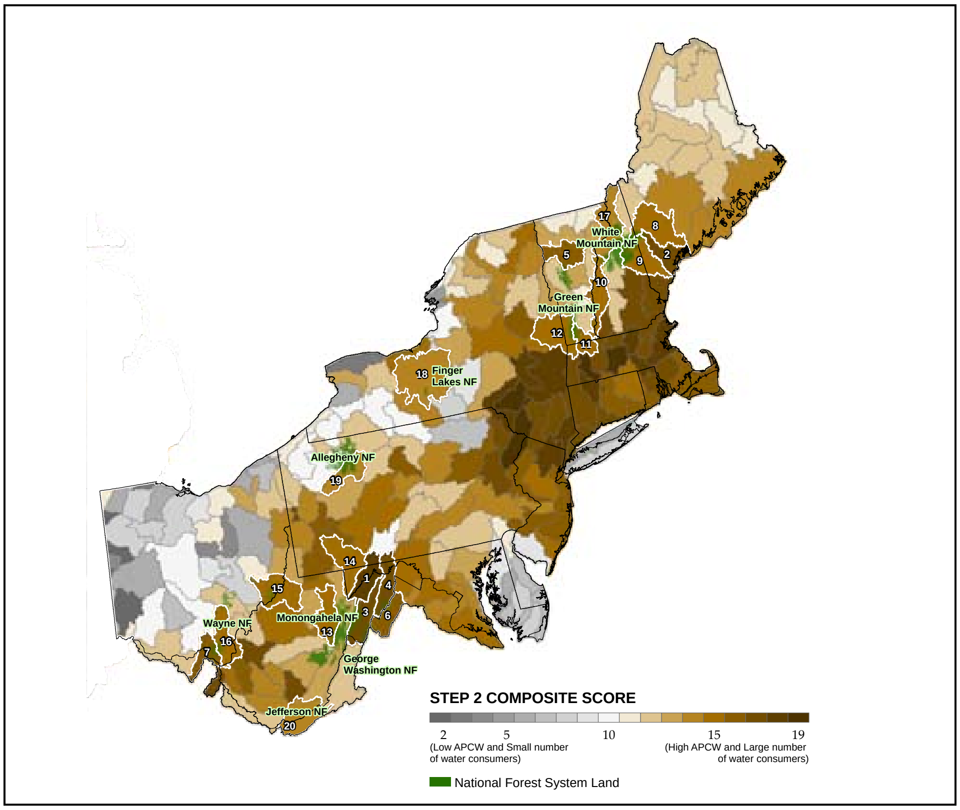
Number of surface water consumers in the watershed	Private	State	NFS	Other Federal	Other*
Small water supplies (25 –100,000 consumers)	84%	8%	7%	0%	1%
Medium-sized water supplies (100,000 – 1,000,000 consumers)	70%	12%	17%	1%	1%
Large water supplies (>1,000,000 consumers)	*There are no large water supply systems in watersheds that contain National Forest land.*				

*Other ownerships include tribal, local, county, private-protected, joint, and unknown.

Maps A-2 and A-3 show that the study area was split into eastern and western halves, displaying the National Forest boundaries overlaid on Step 2 analysis maps. In other words, these maps illustrate the relationship of National Forest lands and the relative importance of water supplies in terms of the ability to produce clean water for the greatest number of water consumers.

Overall, in the eastern portion of the study area, National Forests fall within the moderate- to high-scoring watersheds (Map A-2). In the western portion of the study area, the Chippewa and Mark Twain National Forests coincide with the highest scoring watersheds, and in general, all of the highest scoring watershed areas contain some National Forest lands (Map A-3).

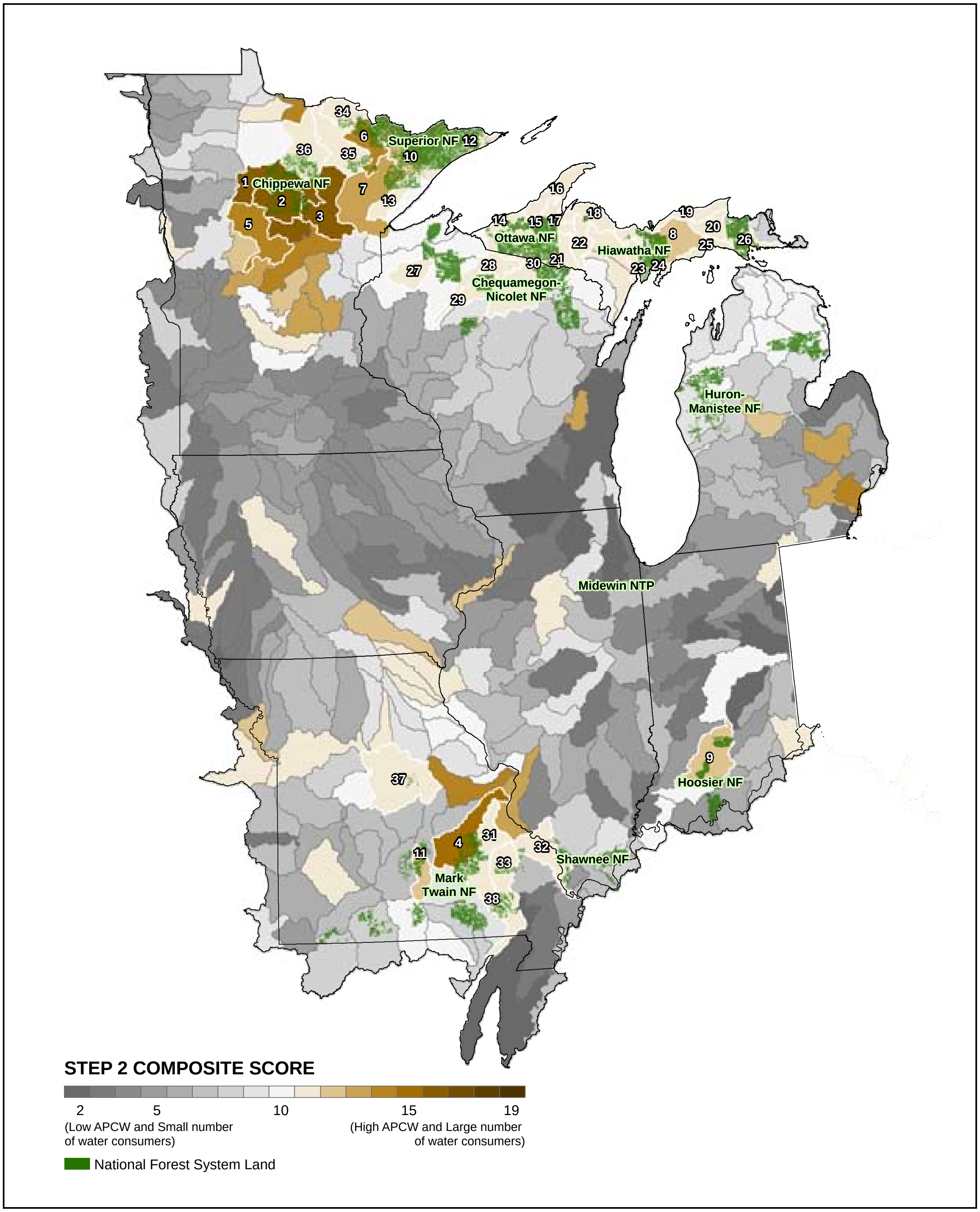
These maps help to highlight areas where National Forests are important in surface drinking water supplies and areas where this relationship is reinforced by currently unprotected forested areas. These maps also highlight areas where the collaborative management of public and private lands may benefit water consumers.



Map A-2: ***National Forests and watersheds important for drinking water supply, eastern portion of the study area, watershed view.*** *In the eastern portion of the study area, watersheds in National Forests scored moderate to high in their importance for drinking water supply. See Table A-2 for information about individual watersheds.*

Table A-2: National Forests and the top 50 percent of watersheds important for drinking water supply in the eastern portion of the study area, by label in map A-2 and composite score.

Label in Map A-3	Step 2 Composite Score	Hydrologic Unit Code	Watershed	Land Acreage	National Forest Acreage	Percent of watershed in National Forest	NFS	State(s)
1	18	02070002	North Branch Potomac	853,706	3	<1.0	Monongahela	MD PA WV
2	17	01060001	Presumpscot	635,384	8,578	1.4	White Mountain	ME
3	17	02070001	South Branch Potomac	946,664	152,164	16.1	George Washington/ Monongahela	MD VA WV
4	17	02070003	Cacapon-Town	766,584	51,778	6.8	George Washington	MD PA VA WV
5	16	02010003	Winooski	737,226	12,783	1.7	Green Mountain	VT NY
6	16	02070006	North Fork Shenandoah	655,235	3,068	<1.0	George Washington	VA WV
7	16	05090103	Little Scioto-Tygarts	637,369	54,370	8.5	Daniel Boone/Wayne	KY OH WV
8	15	01040002	Lower Androscoggin	1,264,856	60,660	4.8	White Mountain	ME NH
9	15	01060002	Saco	1,055,962	244,824	23.2	White Mountain	ME NH
10	15	01080104	Upper Connecticut-Mascoma	921,973	13,472	1.5	White Mountain	NH VT
11	15	01080203	Deerfield	416,335	67,705	16.3	Green Mountain	MA VT
12	15	02020003	Hudson-Hoosic	1,190,337	78,768	6.6	Green Mountain	MA NY VT
13	15	05020001	Tygart Valley	874,687	28,475	3.3	Monongahela	WV
14	15	05020006	Youghiogheny	1,121,664	6	<1.0	Monongahela	MD PA WV
15	15	05030201	Little Musringum-Middle Island	1,152,085	63,998	5.6	Wayne	OH WV
16	15	05090101	Raccoon-Symmes	920,885	54,337	5.9	Wayne	OH WV
17	14	01080101	Upper Connecticut	1,250,729	190,772	15.3	White Mountain	ME NH VT
18	14	04140201	Seneca	2,072,942	15,234	<1.0	Finger Lakes	NY
19	14	05010005	Clarion	797,893	132,875	16.7	Allegheny	PA
20	14	05050002	Middle New	1,067,967	1,366	<1.0	Jefferson	VA WV



Map A-3: ***National Forests and watersheds important for drinking water supply, western portion of the study area, watershed view.*** *In the western portion of the study area, all watersheds that scored high in importance for drinking water supply contain some National Forest lands. See Table A-3 for information about individual watersheds.*

Table A-3: National Forests and the top 50 percent of watersheds important for drinking water supply in the western portion of the study area, by label in map A-3 and composite score.

Label in Map A-3	Step 2 Composite Score	Hydrologic Unit Code	Watershed	Land Acreage	National Forest Acreage	Percent of watershed in National Forest	NFS	State(s)
1	16	07010101	Mississippi Headwaters	1,087,518	239,048	22	Chippewa	MN
2	16	07010102	Leach Lake	707,800	199,108	28	Chippewa	MN
3	16	07010103	Prairie-Willow	1,241,431	44,988	4	Chippewa	MN
4	15	07140102	Meramec	1,365,884	174,876	13	Mark Twain	MO
5	14	07010106	Crow Wing	1,179,214	590	0.1	Chippewa	MN
6	14	09030002	Vermilion	585,030	183,885	31	Superior	MN
7	13	04010201	St. Louis	1,830,340	139,480	8	Superior	MN WI
8	12	04060106	Manistique	882,840	190,471	22	Hiawatha	MI
9	12	05120208	Lower East Fork White	1,276,450	189,773	15	Hoosier	IN
10	12	09030001	Rainy Headwaters	1,386,415	1,175,226	85	Superior	MN
11	12	10290202	Big Piney	481,091	89,001	18	Mark Twain	MO
12	11	04010101	Baptism-Brule	952,729	579,097	61	Superior	MN
13	11	04010202	Cloquet	486,460	65,275	13	Superior	MN
14	11	04020101	Black-Presque Isle	632,267	182,131	29	Ottawa	MI WI
15	11	04020102	Ontonagan	851,254	491,647	58	Ottawa	MI WI
16	11	04020103	Keweenaw Peninsula	683,841	7,126	1	Ottawa	MI
17	11	04020104	Sturgeon	452,263	120,164	27	Ottawa	MI
18	11	04020105	Dead-Kelsey	575,108	12,963	2	Ottawa	MI
19	11	04020201	Betsy-Chocolay	717,211	50,801	7	Hiawatha	MI
20	11	04020202	Tahquamenon	517,930	67,121	13	Hiawatha	MI
21	11	04030106	Brule	657,974	216,652	33	Chequamegon-Nicolet/Ottawa	MI WI
22	11	04030107	Michigamme	438,641	4,170	1	Ottawa	MI
23	11	04030111	Tacoosh-Whitefish	401,708	86,219	21	Hiawatha	MI
24	11	04030112	Fishdam-Sturgeon	349,846	160,860	46	Hiawatha	MI
25	11	04060107	Brevoort-Millecoquins	341,555	27,373	8	Hiawatha	MI
26	11	04070002	Carp-Pine	406,330	216,357	53	Hiawatha	MI
27	11	07030002	Namekagon	599,774	31,231	5	Chequamegon-Nicolet	WI
28	11	07050002	Flambeau	678,200	9,734	1	Chequamegon-Nicolet	MI WI
29	11	07050003	South Fork Flambeau	467,663	134,914	29	Chequamegon-Nicolet	WI
30	11	07070001	Upper Wisconsin	1,276,907	127,740	10	Chequamegon-Nicolet/Ottawa	MI WI
31	11	07140104	Big	616,759	33,751	5	Mark Twain	MO
32	11	07140105	Upper Mississippi-Cape Girardeau	1,026,466	56,516	6	Mark Twain/Shawnee	IL MO
33	11	08020202	Upper St. Francis	820,394	110,996	14	Mark Twain	MO
34	11	09030003	Rainy Lake	477,779	48,796	10	Superior	MN
35	11	09030005	Little Fork	1,140,280	80,769	7	Superior	MN
36	11	09030006	Big Fork	1,234,864	181,169	15	Chippewa	MN
37	11	10300102	Lower Missouri-Moreau	2,136,106	15,352	1	Mark Twain	MO
38	11	11010007	Upper Black	1,214,146	225,267	19	Mark Twain	AR MO

APPENDIX B: Technical Information Regarding Analysis and Metadata

Contents

Tables

Introduction

The goal of the Forests, Water, and People analysis is to evaluate current and projected future conditions across the Northeast and Midwest in order to maximize the protection and enhancement of forests, drinking water supplies, public health, and aquatic ecosystems. The project involves compiling a GIS database using existing and available data to quantify the key connections between forests, land use, water, and people in the Northeastern United States. The database will permit evaluation and ranking of these connections and characteristics, to identify priority areas for forest conservation and restoration. Results are intended to help managers determine where their investments will have the greatest benefits.

This appendix is intended to serve as a technical guide to the Forests, Water, and People analysis for GIS professionals and researchers.

Definitions

Proclamation boundaries are identified in the proclamation that establishes the outer boundary within which a national forest or grassland could be established.

Administrative boundaries identify the specific lands actually owned by the Federal Government and managed by the national forest. Proclamation boundaries were used for this study because these are the only Forest Service boundary data available in a national-level database.

Private land was defined to include tribal, forest industry, and non-industrial private ownerships, excluding public lands and other private lands identified as protected through conservation easements.

Housing density is defined as the number of acres per housing unit.

Increased housing density was defined to mean shifts from rural to exurban or from rural or exurban to urban.

Rural is defined for this project as private land with greater than 20 acres per housing unit in the east (the 12 states in the study area that are east of but do not include Ohio, and including the Big Sandy watershed) and greater than 40 acres per housing unit in the west (the 8 states in the study area that are west of and include Ohio). Forest lands in this housing density can support timber, most wildlife, and water quality.

Exurban is defined for this project as private land with 5 – 20 acres per housing unit in the east (the 12 states in the study area that are east of but do not include Ohio, and including the Big Sandy watershed) and land with 5 – 40 acres per housing unit in the west (the 8 states in the study area that are west of and include Ohio) . Forest lands in this level of housing density can support many types of wildlife; however, commercial timber management is less likely.

Suburban is defined for this project as private land with 0.6 – 5 acres per housing unit. These lands are less likely to contribute to timber production, wildlife habitat, or water quality because of increased road density, infrastructure, and human population levels. Forest patches, however, are valued for their aesthetics, and noise abatement properties.

Urban is defined for this project as private land with less than 0.6 acre per housing unit. These lands are not likely to contribute to timber production, wildlife habitat, or water quality because of high road density, infrastructure, and human population levels.

Analysis Area

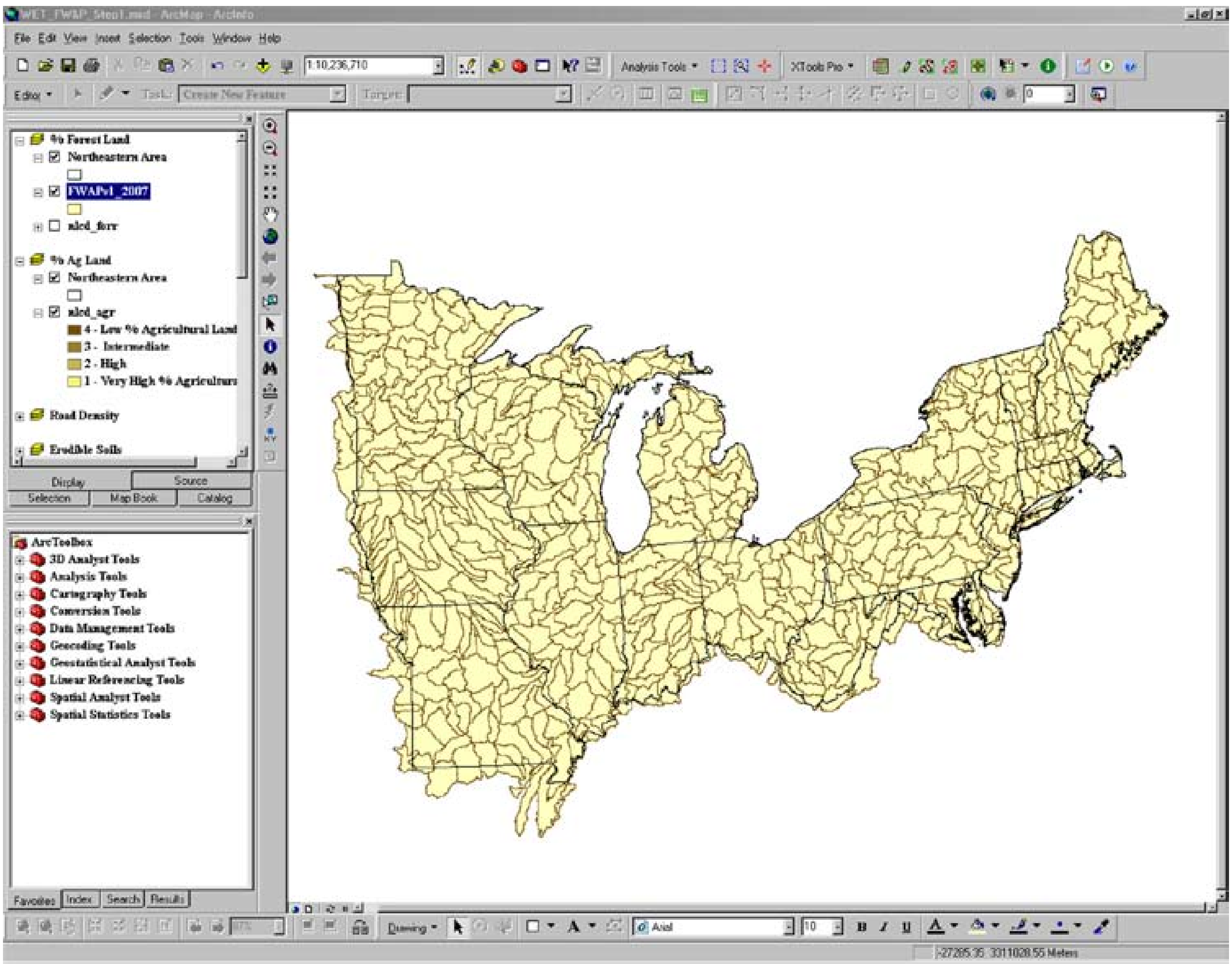
Data Source: U.S. Geological Survey. 1994. 1:250,000-scale hydrologic units of the United States. Open-File Report 94-0236. Reston, VA. http://water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml (August 10, 2007)

Description: This data set is based on the Hydrologic Unit Maps published by the U.S. Geological Survey Office of Water Data Coordination, together with the list descriptions and name of region, subregion, accounting units, and cataloging unit. The hydrologic units are encoded with an eight-digit number that indicates the hydrologic region (first two digits), hydrologic subregion (second two digits), accounting unit (third two digits), and cataloging unit (fourth two digits).

GIS Process:

1. All watersheds (HUCs) that touched the 20 states in the Northeastern United States were selected and a new polygon data layer, HUC_NA, was created. Note: Some of the HUCs only partially fall within the study area, however, for the purpose of this project, the hydrologic boundary was used rather than the administrative one. Watersheds that are considered water bodies (i.e., Great Lakes, Chesapeake Bay, and Delaware Bay) were eliminated from the final HUC data layer. A total of 540 eight-digit HUC watersheds resulted in the Analysis Area for this project.

Result: See following map.



Data projection

All data was projected into the following coordinate system prior to each of the four steps to maintain the best possible accuracy.

Projection: Albers Conical Equal Area
Standard Parallel: 29.500000
Standard Parallel: 45.500000
Longitude of Central Meridian: –96.000000
Latitude of Projection Origin: 23.000000
False Easting: 0.000000
False Northing: 0.000000
Horizontal Datum Name: North American Datum of 1983
Ellipsoid Name: Geodetic Reference System 80
Semi-major Axis: 6378137.000000
Denominator of Flattening Ratio: 298.257222

Step 1: Calculate Ability to Produce Clean Water

Step 1 characterized the biophysical conditions in each watershed. This characterization, the ability to produce clean water (APCW), is an index of water quality and watershed integrity based on six attributes: forest land, agricultural land, riparian forest cover, road density, soil erodibility, and housing density. The forest land, agricultural land, and riparian forest buffer data was summarized by watershed and converted to a 30-meter (30-m) spatial grid. The road density, soil erodibility, and housing density data were kept in their original 30-m grid format and not summarized by watershed. Each of the six attributes was scored from 1 to 4 (see Table 4 of the main report for more detail on the attribute scoring) based on scientifically accepted standards. Where standards or parameters were not available, the data was divided into quartiles.

The six attributes in step 1 were then summed, resulting in a value of 6 to 24 for each 30-m grid cell. To summarize the data by watershed, the values for all 30-m pixels in each watershed were averaged to produce a single score, with a minimum score of 6 and a maximum score of 24.

The APCW values were averaged to create a mean APCW for a watershed. This mean was divided into 10 quantiles, with the 1st quantile receiving a score of 10 (very high) and the 10th quantile receiving a score of 1 (low).

This step will generate a defensible and understandable analysis of current conditions. It also will highlight the watershed management challenges and opportunities on each site and across the entire region.

Table B-1: GIS overlay process to estimate ability to produce clean water (APCW) for eight-digit HUC watersheds in the 20-State study area.

Attribute	**Scoring for 30-meter grid cell**			
	Low (1 point)	**Moderate (2 points)**	**High (3 points)**	**Very High (4 points)**
Percent forest land (F)	0 – 24	25 – 49	50 – 75	>75
Percent agricultural land (A)	>30	21 – 30	10 – 20	<10
Percent riparian forest cover (R)	0 – 29	30 – 50	51 – 70	>70
Road density (D, quartiles)	75 – 100th percentile	50 – 74th percentile	25 – 49th percentile	0 – 24th percentile
Soil erodibility (S, k factor)	>0.34	0.28 – 0.34	0.2 – 0.28	0 – 0.2
Housing density (H, acres per housing unit in 2000)	< 0.6 acre/unit	0.6 – 5.0 acres/unit	5.0 – 20.0 acres/unit (east) 5.0 – 40.0 acres/unit (west)	> 20.0 acres/unit (east) > 40.0 acres/unit (west)
Total APCW	**F + A + R + D + S + H = APCW** Potential score 6 – 24			
Attribute	**Watershed Scoring**			
	Low (1 point)	**High/moderate (2-9 points)**		**High (10 points)**
Step 1 = Mean APCW for Watersheds	10th quantile	2nd – 9th quantile		1st quantile

Forested land

Data Source: U.S. Geological Survey (USGS). 1999. 1992 *National Land Cover Data*. Sioux Falls, SD.

http://eros.usgs.gov/products/landcover/nlcd.html. (August 10, 2007)

Description: Forested land data was extracted from the National Land Cover Data (NLCD,1992) with a spatial resolution of 30 meters. The NLCD is compiled from Landsat satellite TM imagery and supplemented by various ancillary data (where available). The analysis and interpretation of the satellite imagery was conducted using very large, sometimes multi-State image mosaics (i.e., up to 18 Landsat scenes). Using a relatively small number of aerial photographs for "ground truth," the thematic interpretations were necessarily conducted from a spatially broad perspective. Furthermore, the accuracy assessments (see below) correspond to "Federal regions" which are groupings of contiguous States. Thus, the reliability of the data is greatest at the State or multi-State level. The statistical accuracy of the data is known only for the region. The land cover data files are provided as a "Geo-TIFF" for each State.

GIS Process:

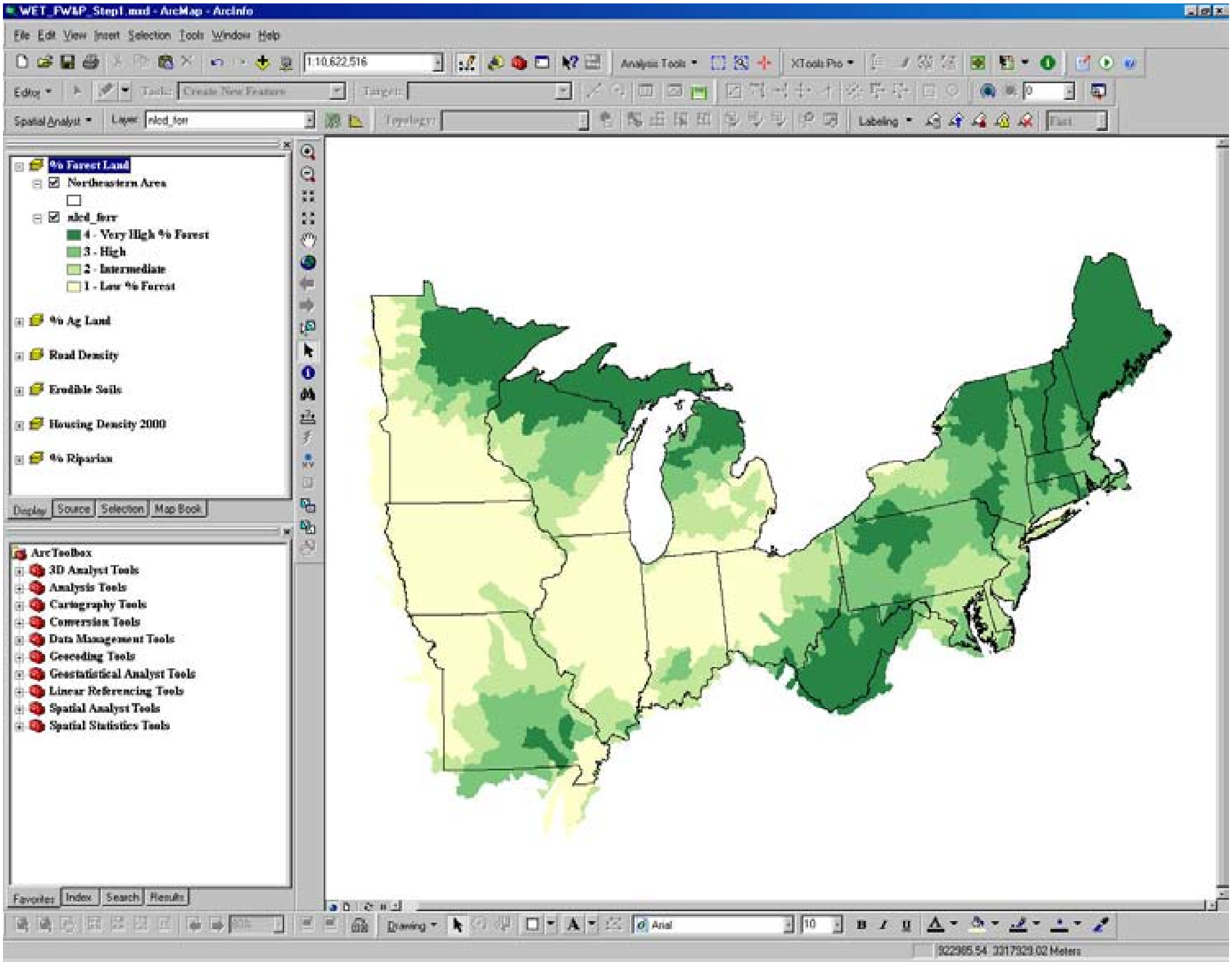
1. The raw, downloaded NLCD GeoTiffs were converted to GRID using ArcInfo workstation.
2. Once each state file was a GRID, all the GRIDs were merged to create a single GRID, nlcd92_huc.
3. Forested land was summarized using NLCD grid values 33 Transitional, 41 Deciduous Forest, 42 Evergreen Forest, 43 Mixed Forest, 51 Shrubland, 91 Woody Wetlands. The GRID was reclassified so all forested grid codes equaled "1" and all other grid codes equaled "0," nlcd_for.
4. Using the "Tabulate Areas" function, the acreage of forested land in each watershed was computed. The resulting table was then joined to the HUC_NA shapefile.
5. The percent of the watershed that is forested was calculated by dividing the acreage of forested land by the total watershed land acreage. The results were saved in the attribute field Per_FOR.
6. The percent forest was reclassified into the four categories summarized in Table B-1. The results were saved in the attribute field Per_FOR_R.

Excerpt 1 from Table B-1

Attribute	Scoring for 30-meter grid cell			
	Low (1 point)	Moderate (2 points)	High (3 points)	Very High (4 points)
Percent forest land (F)	0 – 24	25 – 49	50 – 75	>75

7. The HUC_NA shapefile was converted to a raster data set with a pixel size of 30 m and the value field set to the attribute Per_FOR_R.

Result: See following map.



WET_FW&P_Step1.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:10,622,516
Analysis Tools
XTools Pro
Editor
Task: Create New Feature
Target:
Spatial Analyst
Layer: nlcd_forr
Topology:
Labeling
% Forest Land
Northeastern Area
nlcd_forr
4 - Very High % Forest
3 - High
2 - Intermediate
1 - Low % Forest
% Ag Land
Road Density
Erodible Soils
Housing Density 2000
% Riparian
Display Source Selection Map Book
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Data Management Tools
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Spatial Analyst Tools
Spatial Statistics Tools
Favorites Index Search Results
Drawing
Arial
10
922985.54 3317929.02 Meters

Agricultural land

Data Source: Same as for percent forested land.

Description: Same as for percent forested land.

GIS Process:

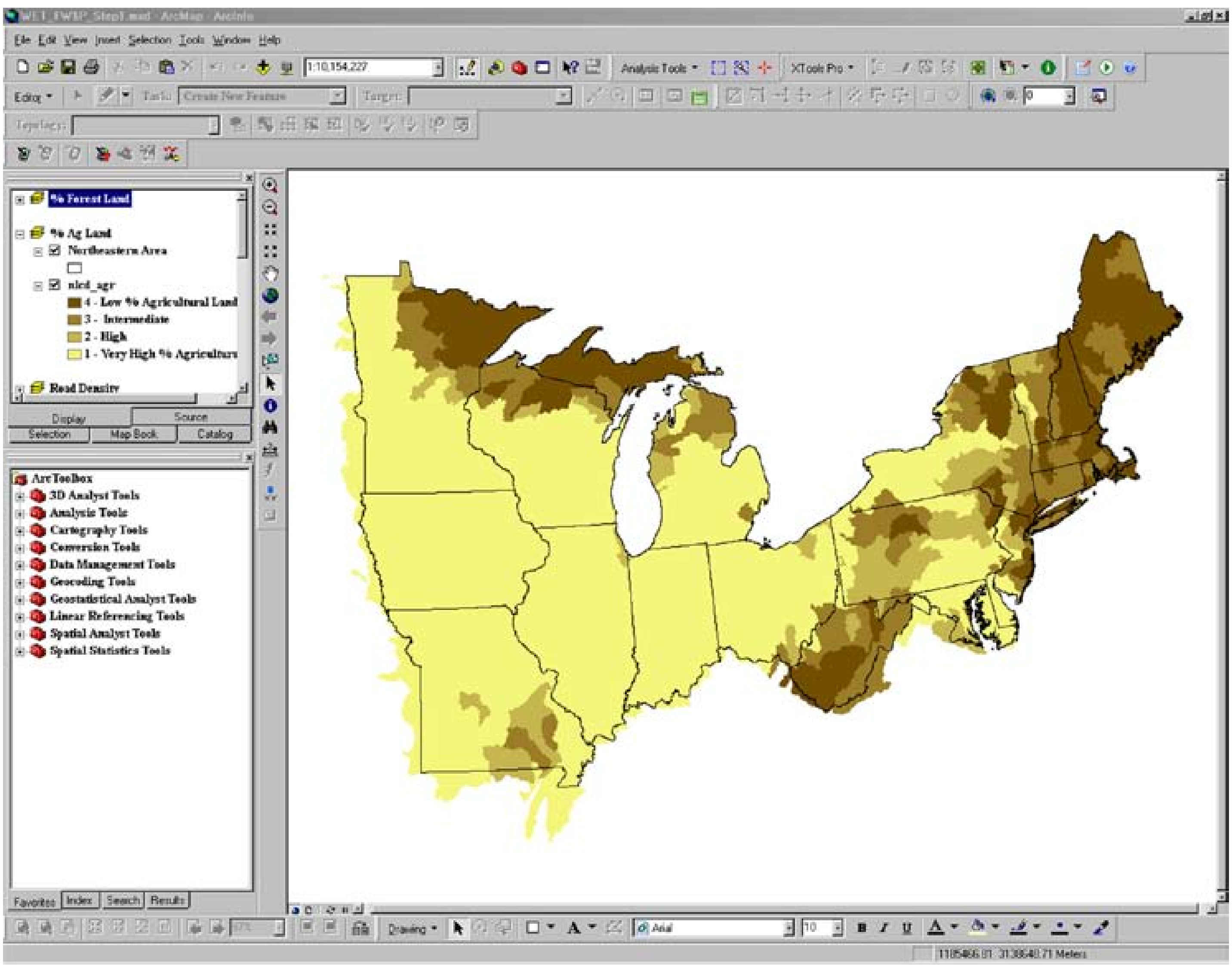
1. The raw, downloaded NLCD GeoTiffs were converted to GRID using ArcInfo workstation.
2. Once each state file was a GRID, all the GRIDs were merged to create a single GRID, nlcd92_huc.
3. Agricultural Land was summarized using grid values 61 Orchard/Vineyard; 71 Grasslands/Herbaceous; 81 Pasture/Hay; 82 Row Crops; 83 Small Grains; 84 Fallow; 85 Urban/Recreational Grasses. The GRID was reclassified so all agricultural land grid codes equaled "1" and all other grid codes equaled "0," nlcd_ag.
4. Using the "Tabulate Areas" function, the acreage of agricultural land in each watershed was computed. The resulting table was then joined to the HUC_NA shapefile.
5. The percent of the watershed that is agricultural land was calculated by dividing the acreage of agricultural land by the total watershed land acreage. The results were saved in the attribute field Per_AG.
6. The percent agricultural land was reclassified into the four categories summarized in Table 1. The results were saved in the attribute field Per_A

Excerpt 2 from Table B-1

Attribute	Scoring for 30-meter grid cell			
	Low (1 point)	Moderate (2 points)	High (3 points)	Very High (4 points)
Percent agricultural land (A)	>30	21 – 30	10 – 20	<10

7. The HUC_NA shapefile was converted to a raster data set with a pixel size of 30 m, and the value field was set to the attribute Per_AG_R.

Result: See following map.



Riparian forest cover

Data Source: Hatfield, Mark. 2005. 30m Buffer of the 1999 National Hydrography Data set (NHD). St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. [unpublished digital data]

Description: The National Hydrography Data set (NHD; USGS) comes with several different layers. Three are of interest to this project: the waterbodies, areas, and flowlines. The waterbodies layer depicts any water that has area, such as lakes, swamps, and ocean. The area layer shows features, such as rivers, that become too large to represent with only a line. The flowline layer shows all linear features, and includes information about the direction of flow through its topology. All three layers include an FCode for each feature, to describe what the feature is. Flowline features coded as "Pipeline" were deleted because they were determined to be irrelevant to the project. Using the buffer tool, a 30-m buffer was created around each feature in the Flowline and Waterbody/Area layers.

Data Source: Same as for percent forested land.

GIS Process:

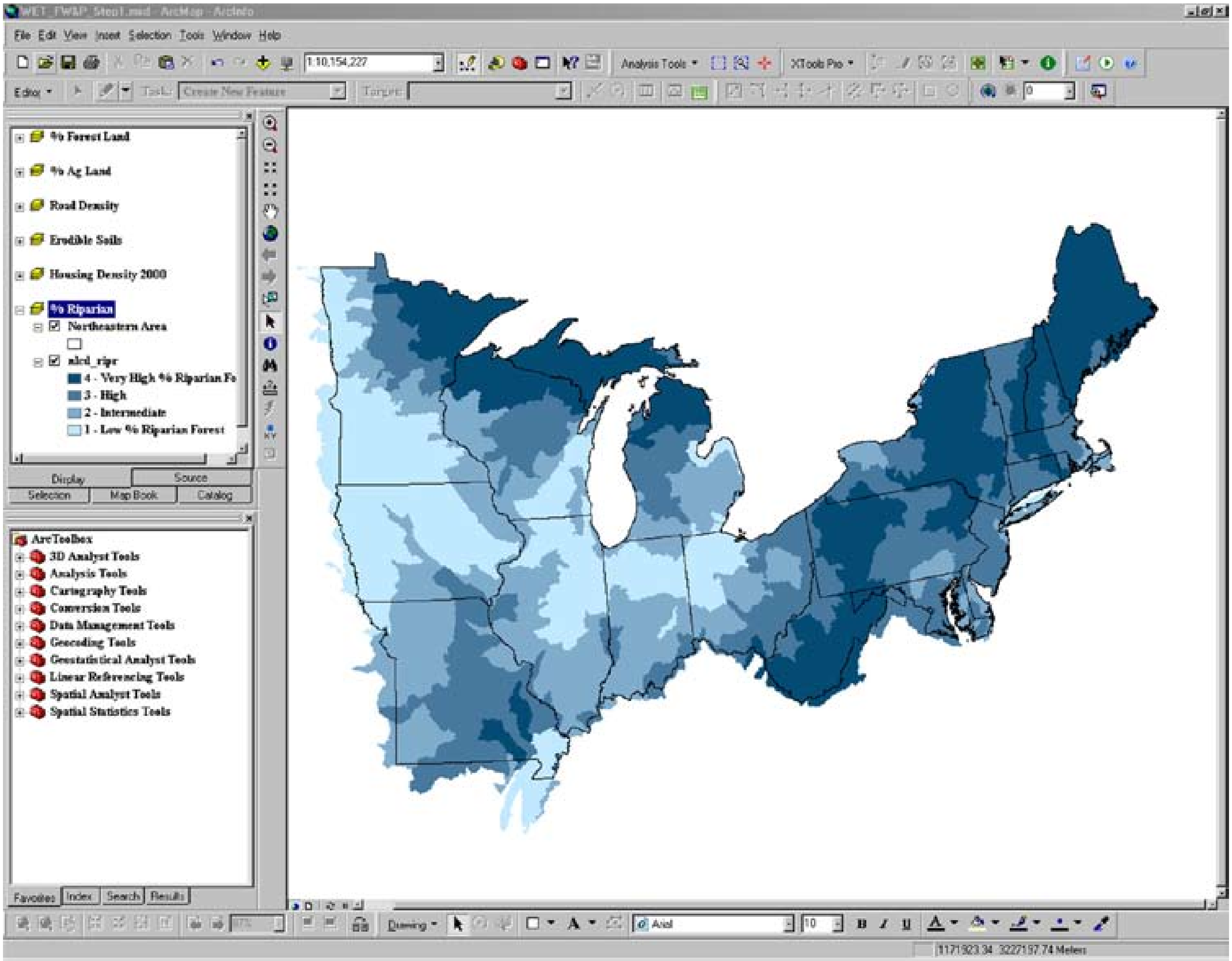
1. The raw, downloaded NLCD GeoTiffs were converted to GRID using ArcInfo workstation.
2. Once each state file was a GRID, all the GRIDs were merged to create a single GRID, <u>nlcd92_huc</u>.
3. Forested Land was summarized using NLCD grid values 33 Transitional; 41 Deciduous Forest; 42 Evergreen Forest; 43 Mixed Forest; 51 Shrubland; 91 Woody Wetlands. The GRID was reclassified so all forested grid codes equaled "1" and all other grid codes equaled "0," <u>nlcd_for</u>.
4. Using the "Extract by Mask" command in ArcInfo, the nlcd_for GRID was clipped to the 30-m NHD buffer nlcd_rip30.
5. Using the "Tabulate Areas" function, the acreage of forested land within the riparian buffer for each watershed was computed using the nlcd_rip30 GRID and HUC_NA polygon shapefile. The acreage of forested land was divided by the total acreage of riparian buffer in the watershed. The resulting table was then joined to the HUC_NA shapefile. The results were saved in the attribute field Per_RIP.
6. The percent riparian forest cover was reclassified into the four categories summarized in Table 1. The results were saved in the attribute field Per_RIP_R. See step 7.

Excerpt 3 from Table B-1

Attribute	Scoring for 30-meter grid cell			
	Low (1 point)	Moderate (2 points)	High (3 points)	Very High (4 points)
Percent riparian forest cover (R)	0 – 29	30 – 50	51 – 70	>70

7. The HUC_NA shapefile was converted to a raster data set with a pixel size of 30 m and the value field set to the attribute Per_RIP_R. See step 6.

Result: See following map.



File Edit View Insert Selection Tools Window Help
1:10,154,227
Analysis Tools
XTools Pro
Editor
Task: Create New Feature
Target:
% Forest Land
% Ag Land
Road Density
Erodible Soils
Housing Density 2000
% Riparian
Northeastern Area
nlcd_ripr
4 - Very High % Riparian Fo
3 - High
2 - Intermediate
1 - Low % Riparian Forest
Display
Source
Selection
Map Book
Catalog
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Data Management Tools
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Spatial Analyst Tools
Spatial Statistics Tools
Favorites
Index
Search
Results
Drawing
Arial
10
1171923.34 3227197.74 Meters

Road density

Data Source: U.S. Department of Transportation. 2002. Bureau of Transportation Statistics (BTS): Roads. http://seamless.usgs.gov/ (December 1, 2006)

Description: This data set portrays a Bureau of Transportation Statistics overview of the road networks for all 50 States, the District of Columbia, and Puerto Rico.

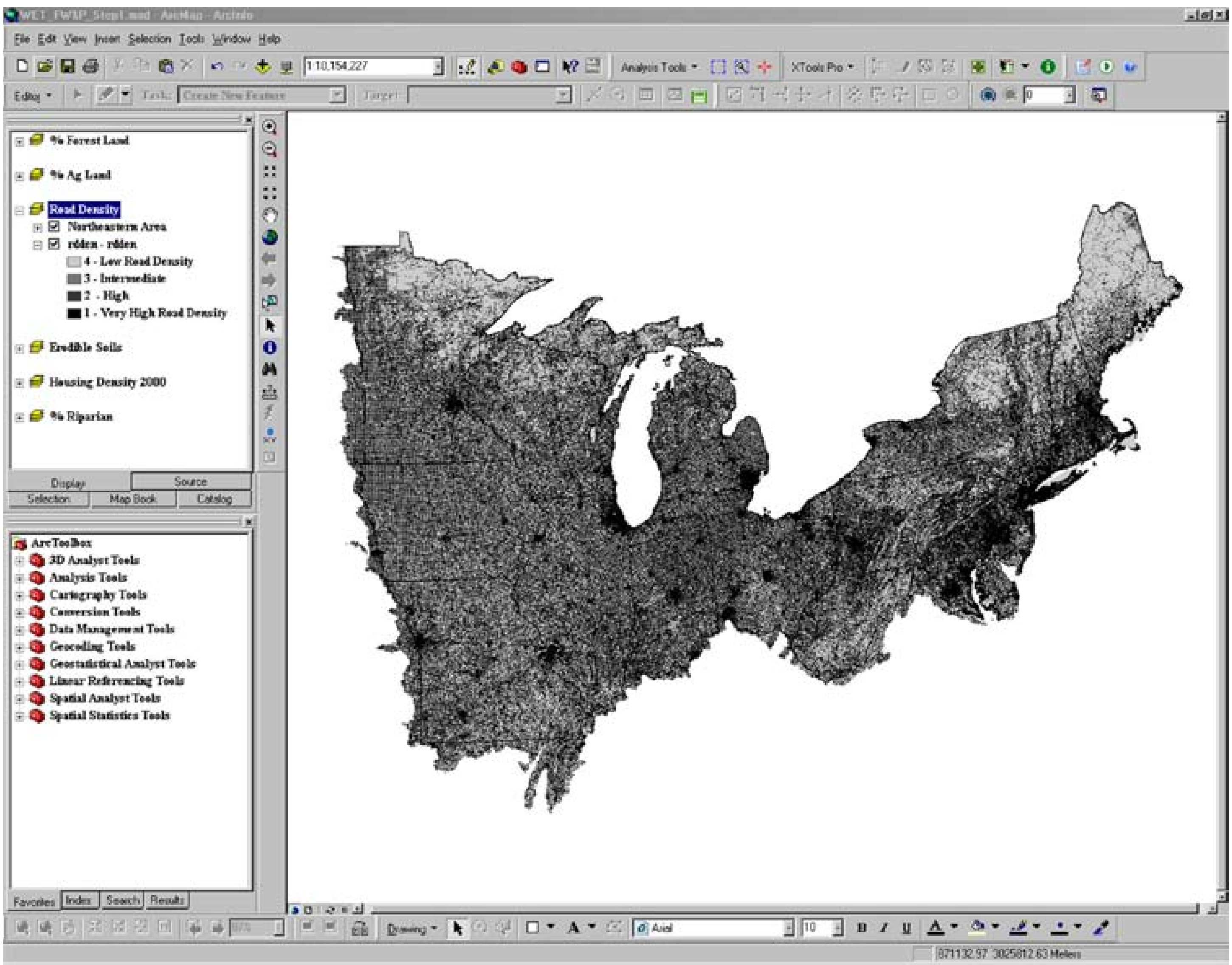
GIS Process:

1. Removed ferry routes from road layer Feature Class Code (FCC) A65, A66, A68, and A69.
2. Ran "Line Density" function in ArcInfo. Parameters were set as follows:
   Cell size = 30 m
   Search radius = 564.3326 m (to equal a search area of 1 km^2)
   Units = square kilometer
3. The line density function had to be run in sections due to file size; therefore, each final line density grid had to be merged together. Where two grids overlapped, the average line density was computed.
4. The results were sorted into four quartiles, and reclassified with values 1-4.

Excerpt 4 from Table B-1

Attribute	Scoring for 30-meter grid cell			
	Low (1 point)	Moderate (2 points)	High (3 points)	Very High (4 points)
Road density (D, quartiles)	75 – 100th percentile	50 – 74th percentile	25 – 49th percentile	0 – 24th percentile

Result: See following map.



Soil erodibility

Data Source: Miller, Douglas A.; White, Richard A. (NRCS) 1998. STATSGO: A conterminous United States multi-layer soil characteristics data set for regional climate and hydrology modeling. www.soilinfo.psu.edu/index.cgi?soil_data&conus (December 1, 2006)

GIS Process:

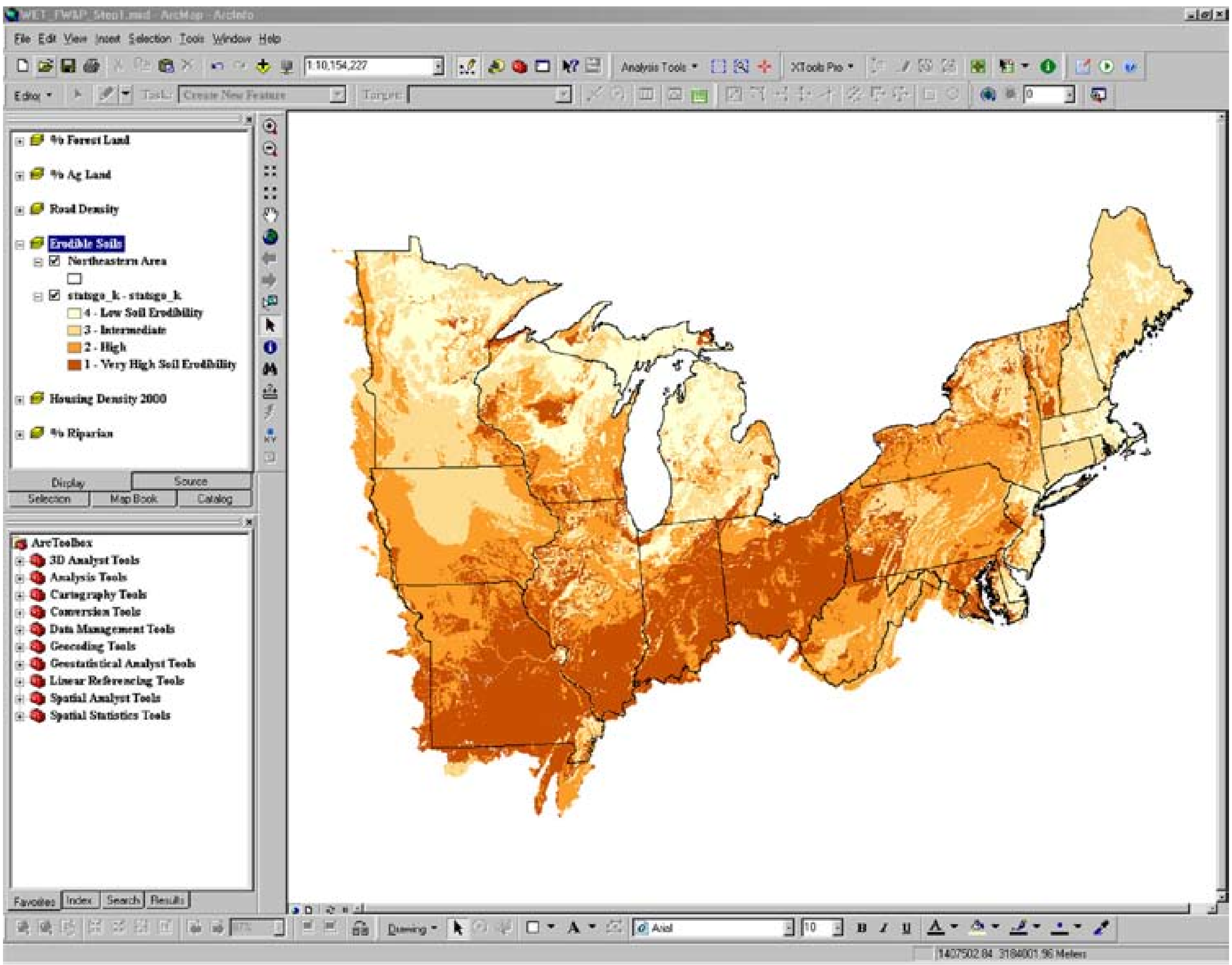
1. Clipped the STATSGO mapunit coverage to the HUC_NA boundary
2. Joined the mu_kfact table to the clipped STATSGO shapefile.
3. Converted shape to raster using the kffact field as the grid value.
4. Reclassified the grid, where

   Kffact =
   a. 0-0.2 = 4
   b. 0.2-0.28 = 3
   c. 0.28-0.34 = 2
   d. >0.34 = 1

Excerpt 5 from Table B-1

Attribute	Scoring for 30-meter grid cell			
	Low (1 point)	Moderate (2 points)	High (3 points)	Very High (4 points)
Soil erodibility (S, k factor)	>0.34	0.28 – 0.34	0.2 – 0.28	0 – 0.2

Result: See following map.



Housing density

Data Source: Theobald, David M. 2004. Housing density in 2000 and 2030. [Digital Data]. Fort Collins, CO: Colorado State University, Natural Resource Ecology Lab.

Description: This raster data set shows housing density in 2000, based on 2000 U.S. Census Bureau block (SF1) data sets developed by the Natural Resource Ecology Lab.

To reduce the overall file size, the continuous values (in units per hectare * 1,000) were reclassified into the following: Code: Units per hectare

1: ≤1
2: 2 – 8
3: 9 – 15
4: 16 – 31
5: 32 – 49
6: 50 – 62
7: 63 – 82
8: 83 – 124
9: 125 – 247
10: 248 – 494
11: 495 – 1,454
12: 1,455 – 4,118
13: 4,119 – 9,884
14: 9,885 – 24,711
15: 24,712 – 9,999,999

GIS Process:

1. The raw 2000 housing density data was clipped to the analysis area and resampled from a 100-m grid to a 30-m grid.
2. The raw grid values in units per hectare were converted to acres/unit using the following formula:

   ((units/ha)/1,000) * 1 ha/2.47 acres = units/acre (invert) = acres/unit, so the 15 classes equaled:

15 classes (acres/unit)

1: < 2,470
2: 309 – 1,235
3: 165 – 274
4: 80 – 154
5: 50 – 77
6: 40 – 50
7: 30 – 40
8: 20 – 30
9: 10 – 20
10: 5 – 10
11: 1.7 – 5
12: 0.6 – 1.7
13: 0.25 – 0.6
14: 0.1 – 0.25
15: > 0.10

3. The 15 value classes were reclassified into four housing density classes: rural, exurban, suburban, and urban, where:

West (eight States, west of and including Ohio)

Rural:	1 – 6	= 4
Exurban:	7 – 10	= 3
Suburban:	11 – 12	= 2
Urban:	13 – 15	= 1

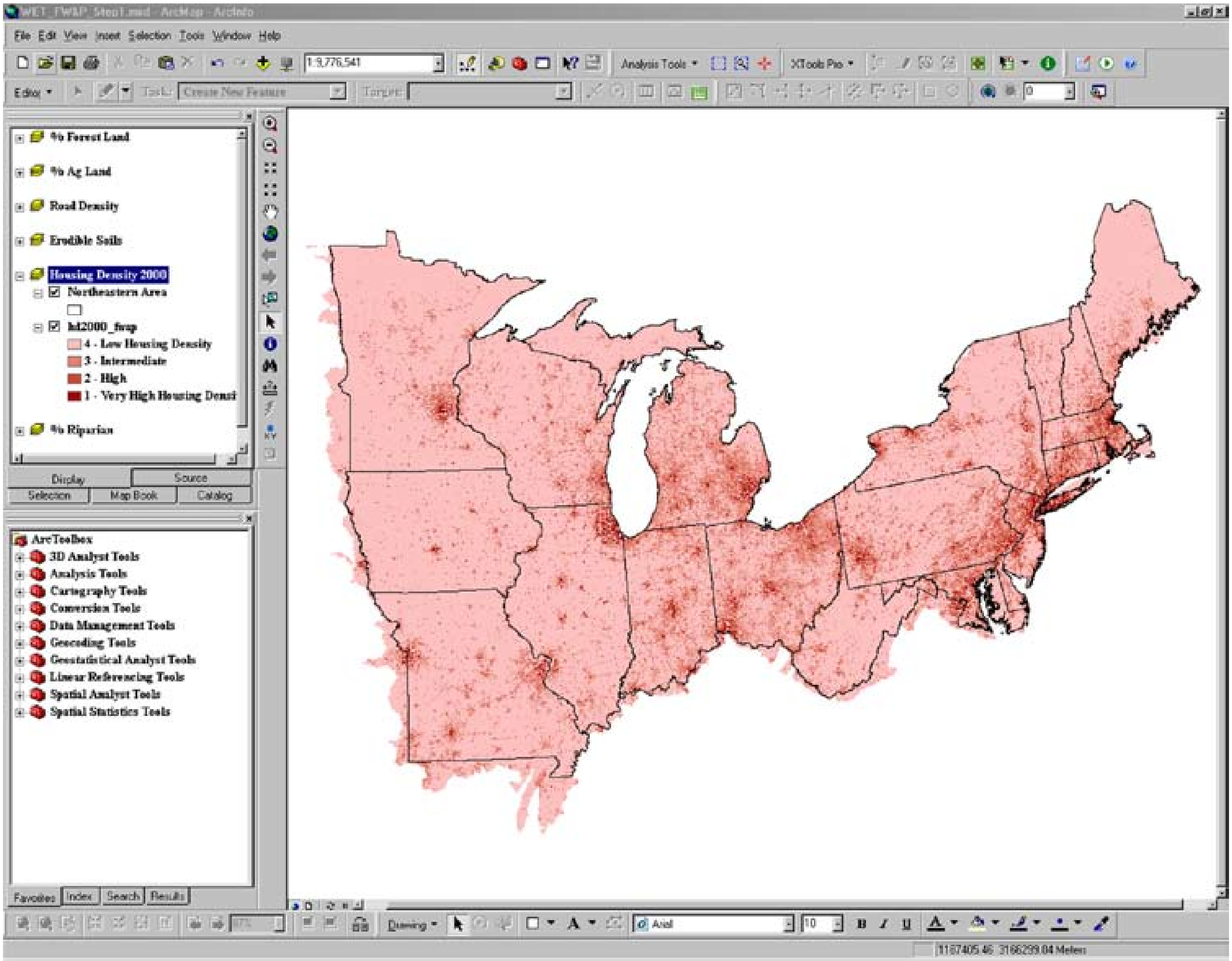
East (12 States, east of, but not including Ohio (does include the Big Sandy Watershed)

Rural:	1 – 8	= 4
Exurban:	9 – 10	= 3
Suburban:	11 – 12	= 2
Urban:	13 – 15	= 1

Excerpt 6 from Table B-1

Attribute	Scoring for 30-meter grid cell			
	Low (1 point)	Moderate (2 points)	High (3 points)	Very High (4 points)
Housing density (H, acres per housing unit in 2000)	< 0.6 acre/unit	0.6 – 5.0 acres/unit	5.0 – 20.0 acres/unit (east) 5.0 – 40.0 acres/unit (west)	> 20.0 acres/unit (east) > 40.0 acres/unit (west)

Result: See following map.


File Edit View Insert Selection Tools Window Help
Analysis Tools
XTools Pro
% Forest Land
% Ag Land
Road Density
Erodible Soils
Housing Density 2000
Northeastern Area
hd2000_fwp
4 - Low Housing Density
3 - Intermediate
2 - High
1 - Very High Housing Densi
% Riparian
Display
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Map Book
Catalog
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Data Management Tools
Geocoding Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Spatial Analyst Tools
Spatial Statistics Tools
Favorites
Index
Search
Results
Drawing
Arial

Ability to produce clean water (APCW) index by 30-m pixels

The six attributes in step 1 were summed, resulting in a value of 6 – 24 for each 30-m grid cell.

F + A + R + D + S + H = APCW

where,

F = forest land (percent)

A = agricultural land (percent)

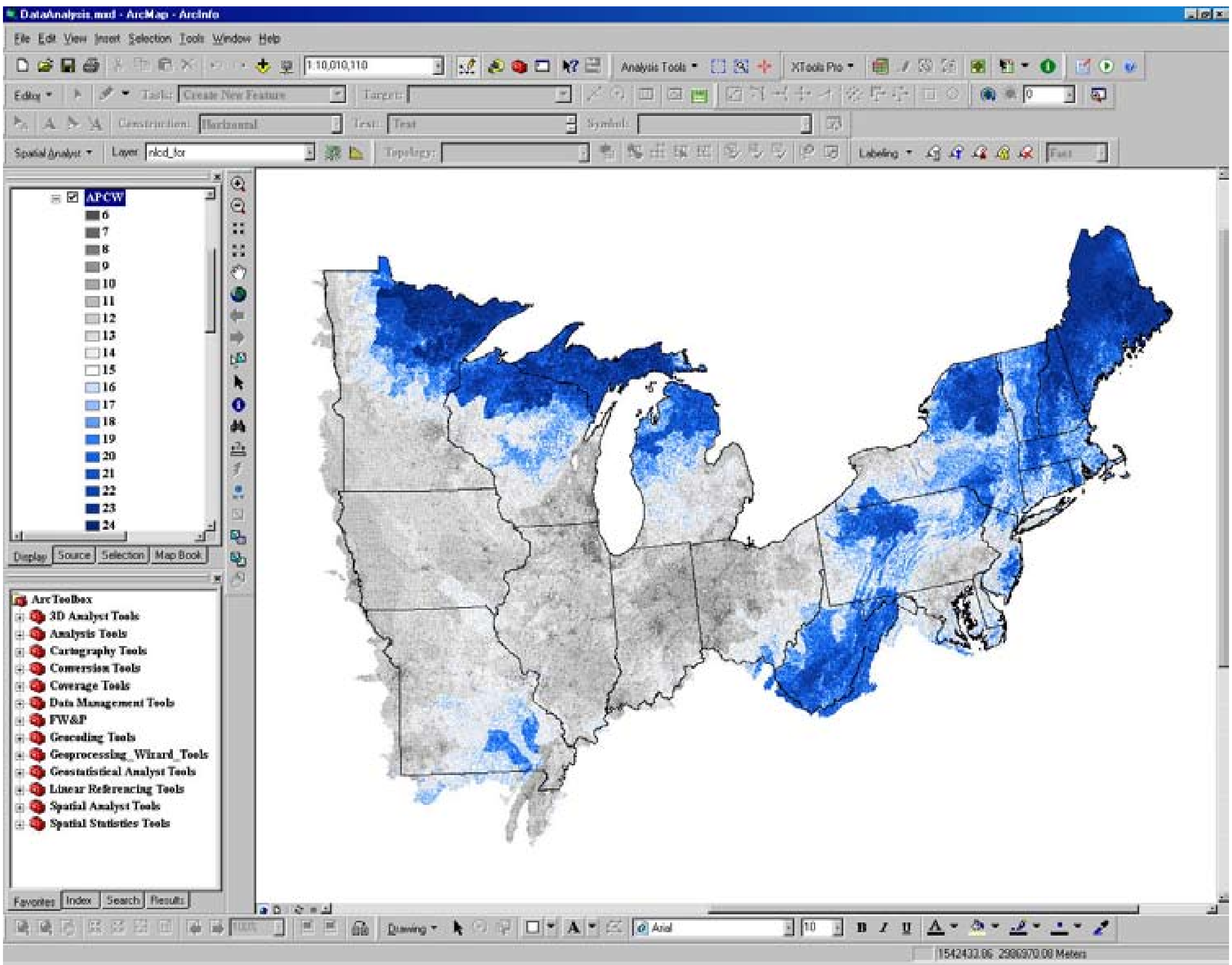
R = riparian forest cover (percent)

D = road density (quartiles)

S = soil erodibility (k factor)

H = housing density (acres per housing unit in 2000)

Result: See following map.



Step 1 composite score: Mean APCW for watersheds

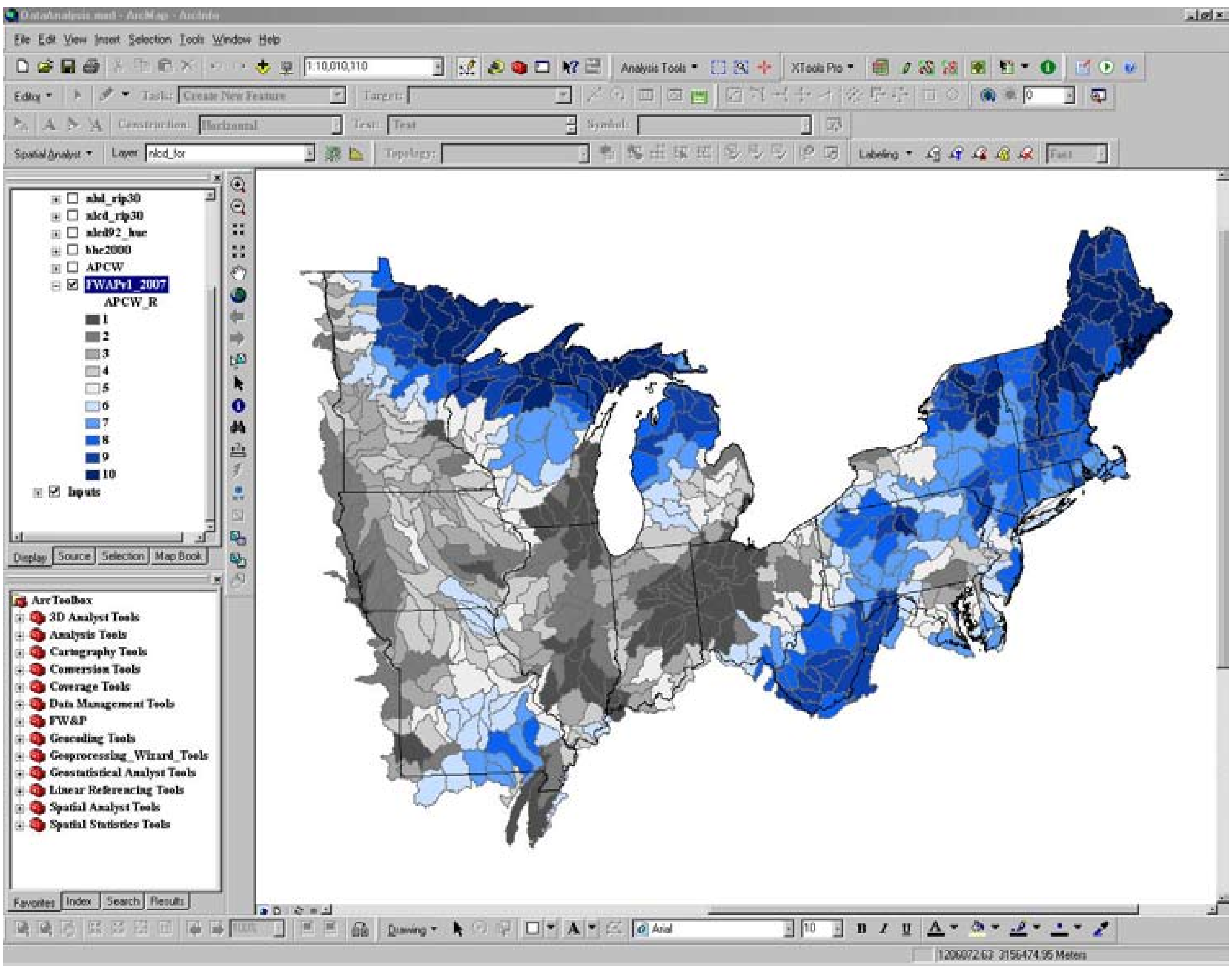
Data Source: Ability to Produce Clean Water (APCW) Index by 30-m pixels

Description: See previous step.

GIS Process

1. Using the "zonal statistics as table" function in ArcInfo, the average APCW score was computed for each watershed.
2. The average scores were split into 10 quantiles and reclassified with a value of 1 – 10, with 1 being the lowest APCW and 10 the highest (See Table B-2.)

Result: See following map.



Step 2: Add Data on Drinking Water Consumers

(See Analysis Methods section of main report)

Step 2 combined the results of Step 1, the Ability to Produce Clean Water, with water use data from the U.S. Environmental Protection Agency's (EPA) Surface Drinking Water Information System (SDWIS). The ability to produce clean water was divided into 10 quantiles, with the 1st quantile receiving a score of 10 and the 10th quantile receiving a score of 1.

Selecting only surface water consumers (reservoirs and streams), the total drinking water consumers was summed for each eight-digit watershed and divided by the watershed area. For large city watersheds that use river intakes, including Philadelphia, St. Louis, St. Paul, and Washington, DC, the drinking water consumers were redistributed among the upstream watersheds. The New York City Watershed was individually calculated using the latest drinking water consumer data from the water utility. The total number of drinking water consumers for each watershed was then divided by the watershed area. This result was divided into 10 quantiles and combined with the APCW to yield a total score ranging from 2 to 20.

Table B-2: Prioritization method for Step 2 for eight-digit HUC watersheds in the 20-State study area.

Attribute	Scoring for 30-meter grid cell		
	Low (1 point)	**Moderate/High (2-9 points)**	**Very High (10 points)**
Step 1 = Mean APCW for Watersheds	10th quantile	2nd – 9th quantile	1st quantile
DW = surface drinking water consumers per unit area	10th quantile	2nd – 9th quantile	1st quantile

(90th percentile and higher = 1st quantile = 10; 80th to 89th percentile = 2nd quantile = 9; 70th to 79th percentile = 3rd quantile = 8 …)

Step 1 composite score

See result from Step 1.

Surface drinking water consumers per unit area

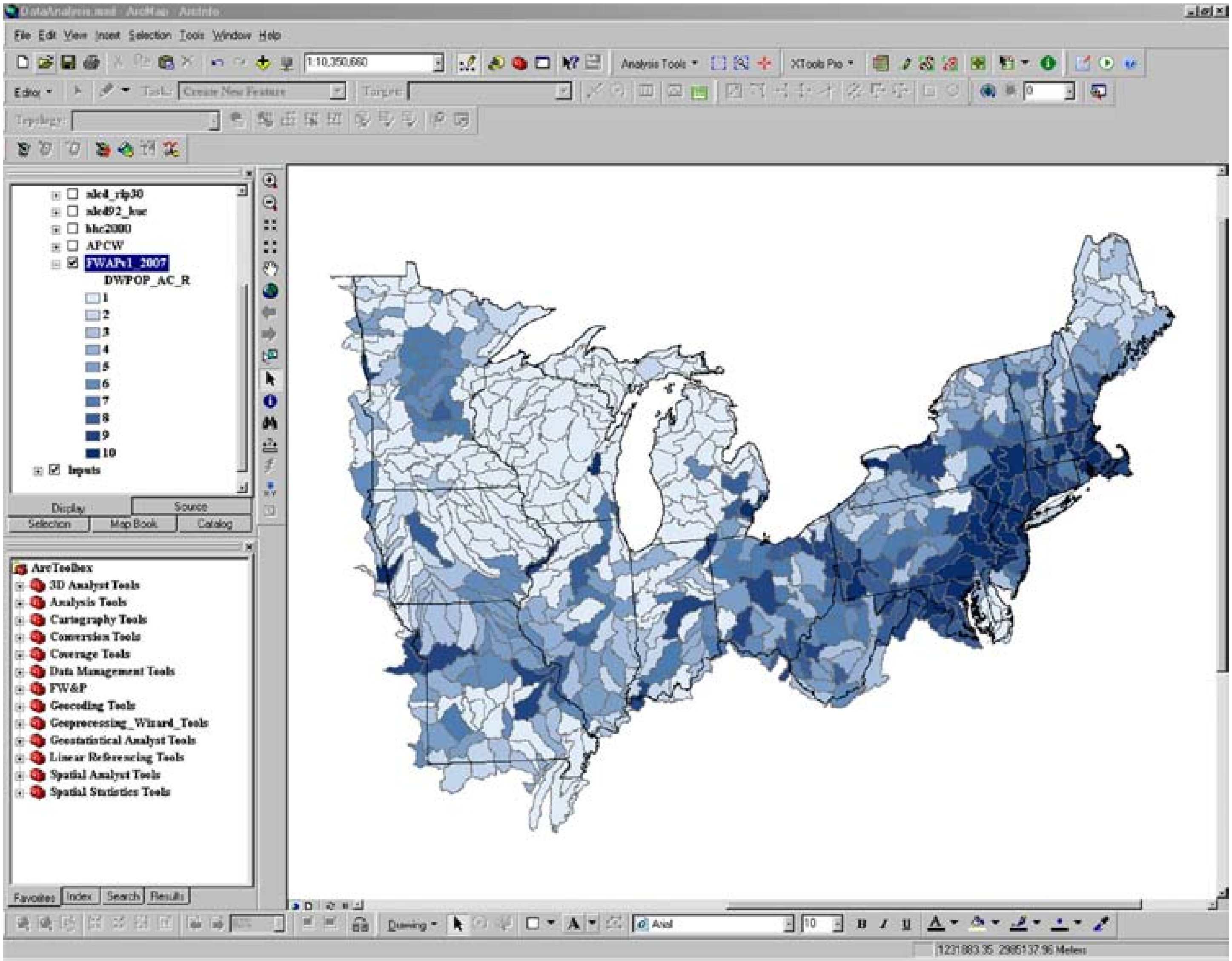
Data Source: U.S. Environmental Protection Agency. 2005. Public drinking water system (PWS) consumers by 8-digit HUC (data extracted from Safe Drinking Water Information System (SDWIS) in the 4th quarter of 2004). http://www.epa.gov/enviro/html/sdwis/sdwis_ov.html (August 10, 2007) This information is proprietary. To request access and permission to this spatial dataset, contact the U.S. EPA Office of Wetlands, Oceans and Watersheds (OWOW) at 202-566-1300.

Description: The public drinking water supply systems regulated by the EPA, and delegated states and tribes, provide drinking water to 90 percent of Americans. These public drinking water supply systems, which may be publicly or privately owned, serve at least 25 people or 15 service connections for at least 60 days per year.

GIS Process:

1. The Public Drinking Water System (PWS) data from the Safe Drinking Water Information System (SDWIS) database catalogs all drinking water intakes, including groundwater wells. Only surface water intakes (code = SW) were considered.
2. Overlaying the 540 watershed boundaries over the drinking water intakes, each intake was attributed with the proper eight-digit watershed code, in which it resides. Intakes that fell within a watershed boundary but obtain their water from the one of the five Great Lakes or the St. Lawrence River were not included.
3. The remaining intakes were evaluated by public water supply system. If a public water supply system spanned two watersheds, the total number of consumers was divided by 2 and half put in each watershed.
4. For the major cities with river intakes (Philadelphia, St. Louis, Cincinnati, St. Paul, Minneapolis, Washington, DC), their consumers were assigned to the eight-digit watershed immediately upstream, not the entire Delaware, Mississippi and Missouri, Ohio, Mississippi, or Potomac watershed above their respective intakes. In other words, it overstates the importance of the nearby watersheds while failing to "credit" the other (nested) upstream watersheds. Each city was evaluated separately:
   a. Cincinnati—The water consumers were prorated over the subwatersheds along the main stem Ohio River.
   b. St. Louis—same rationale, except the distribution of water users was limited to the Mississippi tributaries that are largely in Missouri and the Missouri River "corridor."
   c. Philadelphia and Washington, DC, were distributed on the basis of subwatershed area.
5. New York City watersheds were corrected using current NYCDEP daily drinking water supply estimates.
6. The water consumers were summed by HUC and divided by watershed land acreage.
7. The watershed results were split into 10 quantiles and given a value 1 through 10 (table B-2).

Result: See following map.


File Edit View Insert Selection Tools Window Help
Analysis Tools
XTools Pro
Editor
Task: Create New Feature
Target:
Topology:
nlcd_rip30
nlcd92_luc
hhc2000
APCW
FWAPv1_2007
DWPOP_AC_R
1
2
3
4
5
6
7
8
9
10
Inputs
Display
Source
Selection
Map Book
Catalog
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Coverage Tools
Data Management Tools
FW&P
Geocoding Tools
Geoprocessing_Wizard_Tools
Geostatistical Analyst Tools
Linear Referencing Tools
Spatial Analyst Tools
Spatial Statistics Tools
Favorites
Index
Search
Results
Drawing
Arial
10

Step 2 composite score: *Importance of watersheds for drinking water supply*

The two attributes in step 2 were summed, resulting in values of 2 to 20 for each watershed.

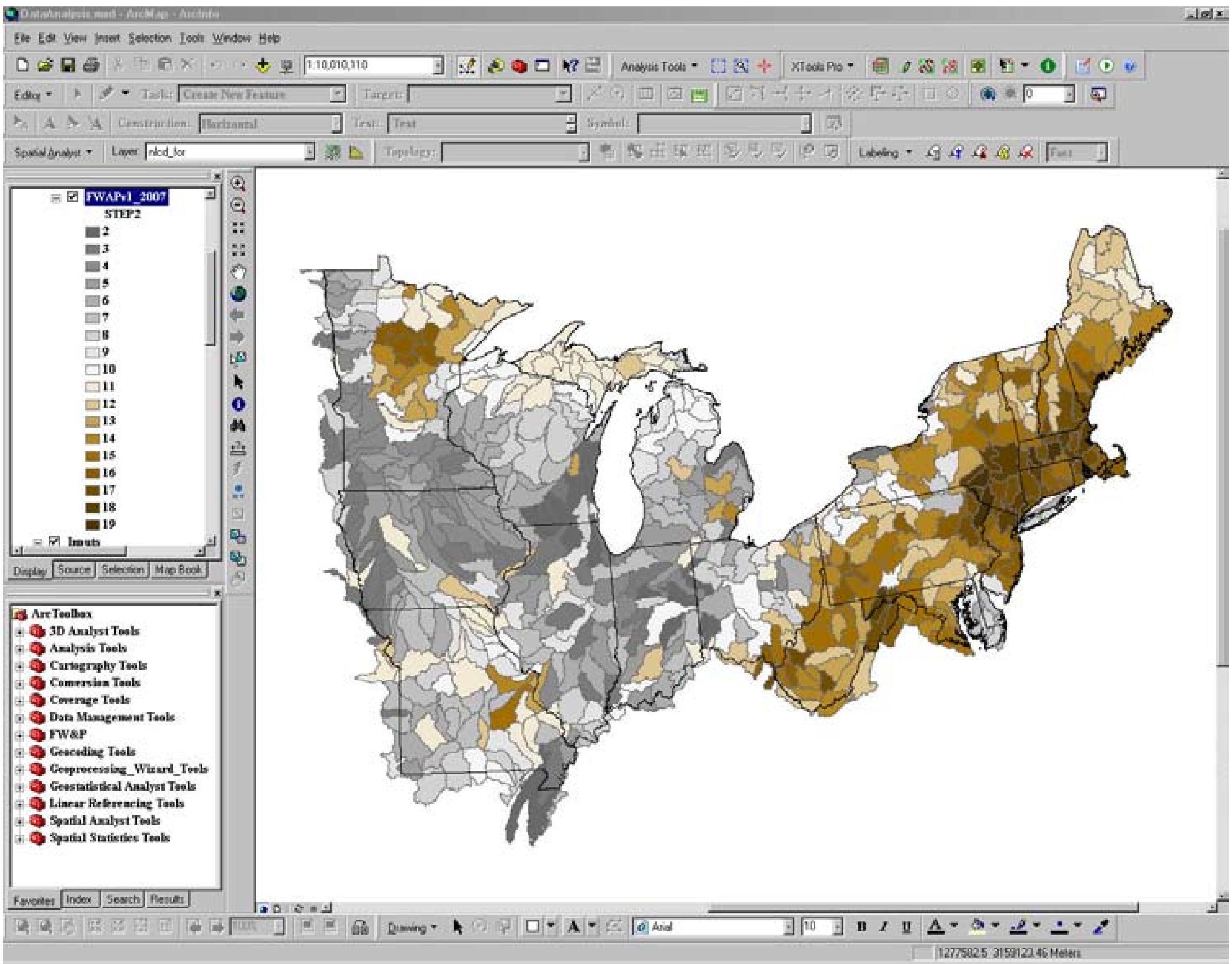
Mean APCW + DW = STEP 2

where,

Mean APCW = Ability to Produce Clean Water

DW = Surface Drinking Water consumers per unit area

Result: See following map.



Step 3: Add Data on Private Forest Land

Step 3 combines the results of Step 2 with the watershed's percent private forest to highlight those areas important for surface water drinking supply that contain private forest lands. The private forest database was derived using a subset of the Conservation Biology Institute's Protected Areas database and an updated Wisconsin data set. Only permanently protected lands (Federal, State, county, local, or permanent conservation easements) were considered "protected," all other lands were considered unprotected, having the potential to be developed. The percent private forest by watershed was divided into 10 quantiles and then combined with the results of Step 2 to yield a total score of 3 – 30.

Table B-3: Prioritization method for Step 3 for eight-digit HUC watersheds in the 20-State study area.

Attribute	Scoring for 30-meter grid cell		
	Low (1 point)	**High/moderate (2-9 points)**	**High (10 points)**
Step 2 = Importance of watersheds for drinking water supply	See results from Step 2		
PF = Private Forest (%)	10th quantile	2nd – 9th quantile	1st quantile

(For example, 90th percentile and higher = 1st quantile = 10; 80th to 89th percentile = 2nd quantile = 9; 70th to 79th percentile = 3rd quantile = 8; …)

Step 2 Composite Score

See results from Step 2.

Private forest

Data Source: Conservation Biology Institute. 2006. CBI Protected Areas Database, Version 4. [CD-ROM] Corvallis, OR. http://www.consbio.org (August 10, 2007).

U.S. Geological Survey, Upper Midwest Environmental Sciences Center. 2005. Gap Analysis Program—Wisconsin Stewardship Data. [Digital Data] La Crosse, WI.

Description: The original CBI Protected Areas Database (PAD) was the product of a collaborative effort between the Conservation Biology Institute and World Wildlife Fund, USA. The second and third versions of the PAD represent updates of the first database. This fourth version of the PAD specifically includes a complete update of 20 eastern and 5 western U.S. States. Polygons are assigned with a GAP Analysis Program (GAP) code of 1, 2, 3, or 4 and IUCN category of I through VI, N/A or Unknown. We added an additional GAP code of 5 to designate bodies of water. MN GAP has assigned some additional GAP codes, which are described in their metadata file. Additionally, the database contains information about parcel type, ownership, size, and protection level.

GAP Code 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management. Examples: national parks, nature preserves, wilderness areas.

GAP Code 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance. Examples: State parks, national wildlife refuges, national recreation areas.

GAP Code 3: An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area. Examples: national forests, most Bureau of Land Management land, wildlife management areas.

GAP Code 4: There are no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout.

Data Source: U.S. Geological Survey (USGS). 1999. 1992 National land cover data set. Sioux Falls, SD. http://edcwww.cr.usgs.gov/programs/lccp/nationallandcover.html (August 10, 2007)

Description: The National Land Cover Data set was compiled from Landsat satellite TM imagery (circa 1992) with a spatial resolution of 30 meters and supplemented by various ancillary data (where available). The analysis and interpretation of the satellite imagery was conducted using large, sometimes multi-State image mosaics (i.e., up to 18 Landsat scenes). Using a relatively small number of aerial photographs for "ground truth," the thematic interpretations were necessarily conducted from a spatially broad perspective. Furthermore, the accuracy assessments (see below) correspond to "Federal regions," which are groupings of contiguous States. Thus, the reliability of the data is greatest at the State or multi-State level. The statistical accuracy of the data is known only for the region. The land cover data files are provided as a "Geo-TIFF" for each State.

GIS Process:

1. The Protected Areas Database (PAD) contains properties that are not permanently protected; therefore, several polygons were removed before percent private forest was calculated.

   Properties retained:

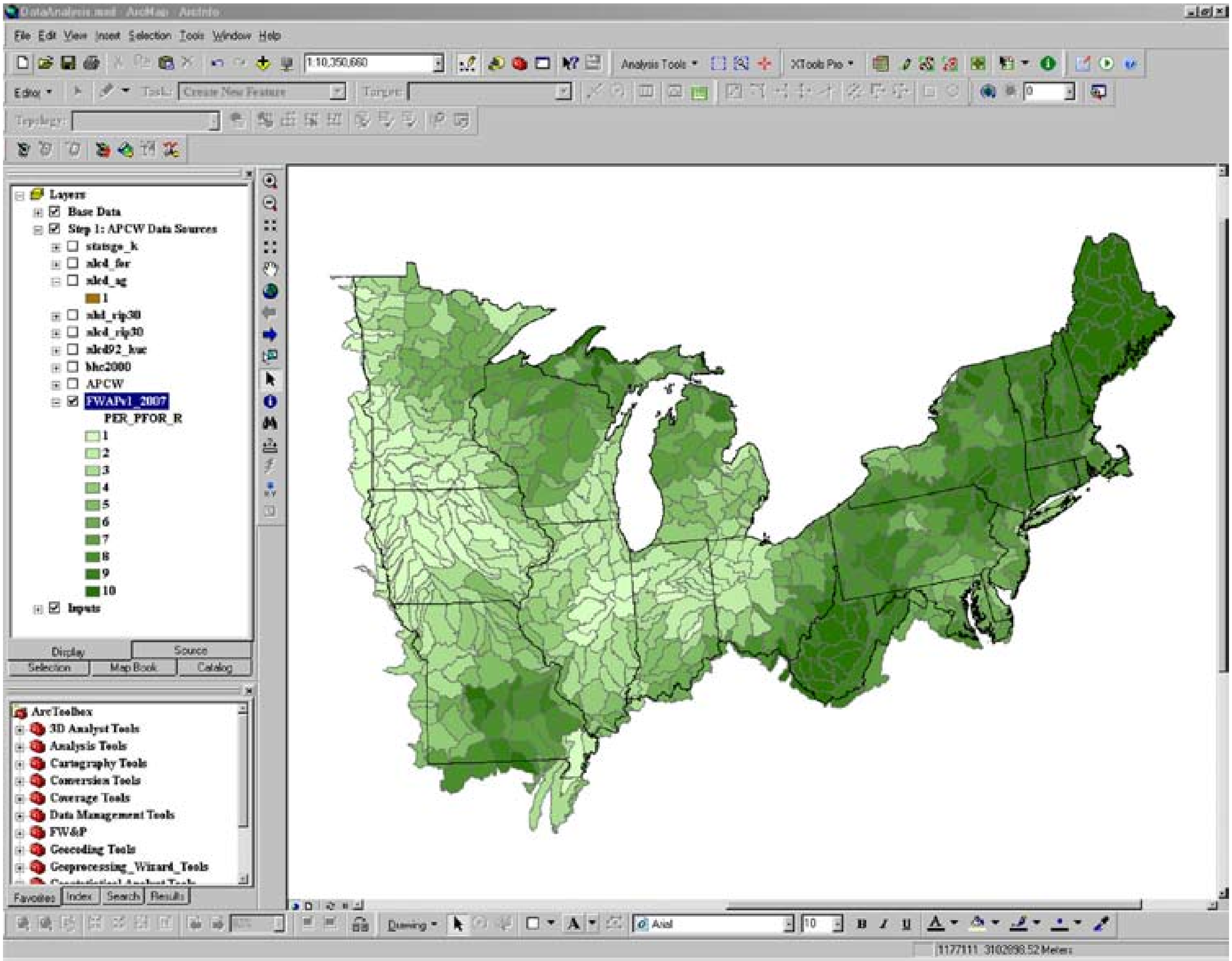
   All State, Federal, local, and county lands were considered permanently protected regardless of gap code (State and county parks and wildlife management areas are GAP code 4).

   Properties removed:

   Ownerships with a GAP code of 4 or above were removed, as were Gap codes of 3 that were designated as private industrial or private non-industrial forest.

2. Using the final edited PAD shapefile as the ERASE template, all the protected areas were erased from the analysis area resulting in a layer of private land.
3. The private land shapefile was used as a mask to clip the nlcd_for GRID (1992 forest land), to achieve a grid of private forest, pri_for.
4. To determine the acreage of private forest land in each watershed, the "tabulated areas" function was run using the pri_for GRID and HUC_NA polygon shapefile.
5. The acreage of private forest was then divided by the total land acreage of the watershed to get the percent private forest by watershed.
6. The results were split into 10 quantiles and given values of 1 through 10 (see Table B-3).

Result: See following map.


Layers
Base Data
Step 1: APCW Data Sources
statsgo_k
nlcd_for
nlcd_ag
nlcd_rip30
nlcd92_huc
hhc2000
APCW
FWAPv1_2007
PER_PFOR_R
1
2
3
4
5
6
7
8
9
10
Inputs
ArcToolbox
3D Analyst Tools
Analysis Tools
Cartography Tools
Conversion Tools
Coverage Tools
Data Management Tools
FW&P
Geocoding Tools
Geoprocessing_Wizard_Tools

Step 3 composite score: *Importance of watersheds with private forests for drinking water supply*

The two attributes in Step 3 were summed, resulting in a potential composite score of 3 to 30 for each watershed.

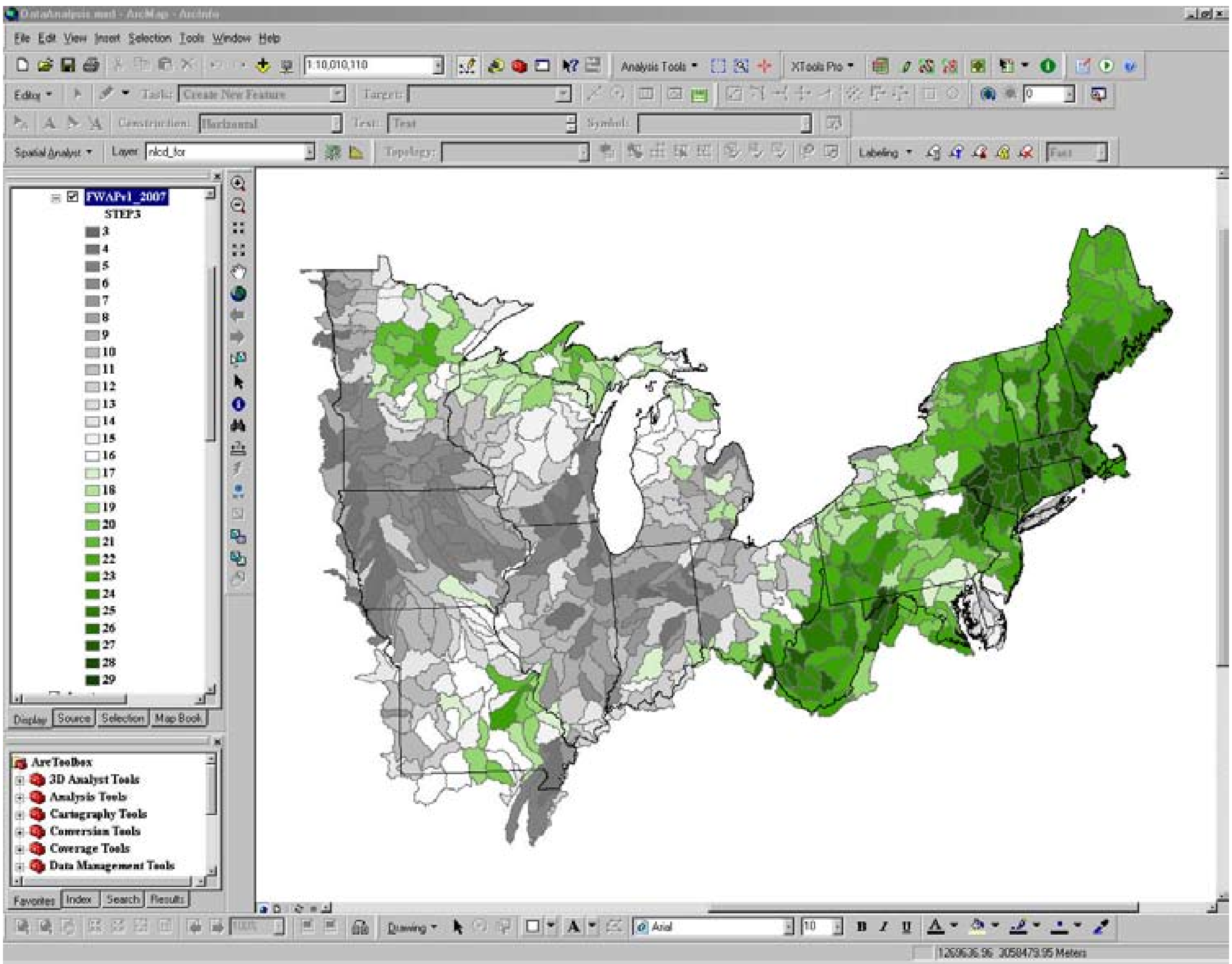
STEP 2 + PF = STEP 3

where,

Step 2 = Importance of watersheds for drinking water supply

PF = percent private forest

Result: See following map.



Step 4: Add Data on Change in Housing Density

Step 4 combines the results of Step 3 with the development pressure of future housing density change on forests. Development pressure was calculated by subtracting the housing density in 2000 from the housing density in 2030. If housing density increased between 2000 and 2030, then development pressure was said to occur. The total acreage of land under development pressure in the watershed was divided by watershed area, divided into 10 quantiles, and then combined with the results of Step 3 to yield a total score ranging from 4 to 40.

Table B-4: Prioritization method for Step 4 for eight-digit HUC watersheds in the 20-State study area.

Attribute	Score for 30-meter grid cell		
	Low (1 point)	**High/moderate (2-9 points)**	**High (10 points)**
Step 3 = Importance of watersheds and private forest for drinking water supply	See results from Step 3		
DP = Development pressure per unit area	10th quantile	2nd – 9th quantile	1st quantile

(90th percentile and higher = 1st quantile = 10; 80th to 89th percentile = 2nd quantile = 9;
70th to 79th percentile = 3rd quantile = 8; …)

Step 3 Composite Score

See the results from Step 3.

Development pressure per unit area

Data Source: Theobald, David M. 2004. Housing density in 2000 and 2030 [Digital Data]. Fort Collins, CO: Colorado State University, Natural Resource Ecology Lab.

Description: This raster data set shows housing density in 2000, based on 2000 U.S. Census Bureau block (SF1) data sets developed by the Natural Resource Ecology Lab. Housing Density in 2030 was forecasted using the Spatially Explicit Regional Growth Model (SERGoM v2).

To reduce the overall file size, the continuous values (in units per hectare * 1,000) were reclassified into the following: Code: Units per hectare

1: ≤1
2: 2 – 8
3: 9 – 15
4: 16 – 31
5: 32 – 49
6: 50 – 62
7: 63 – 82
8: 83 – 124
9: 125 – 247
10: 248 – 494
11: 495 – 1,454
12: 1,455 – 4,118
13: 4,119 – 9,884
14: 9,885 – 24,711
15: 24,712 – 9,999,999

GIS Process:

1. The raw 2000 housing density data was clipped to the analysis area and resampled from a 100 m grid to a 30 m grid.
2. The raw grid values in units per hectare were converted to acres/unit using the following formula:

((units/ha)/1,000) * 1 ha/2.47 acres = units/acre (invert) = acres/unit, so the 15 classes equaled:

15 classes (acres/unit)

1: < 2,470
2: 309 – 1,235
3: 165 – 274
4: 80 – 154
5: 50 – 77
6: 40 – 50
7: 30 – 40
8: 20 – 30
9: 10 – 20
10: 5 – 10
11: 1.7 – 5
12: 0.6 – 1.7
13: 0.25 – 0.6
14: 0.1 – 0.25
15: > 0.10

3. The 15 value classes were reclassified into four housing density classes: rural, exurban, suburban, and urban, where:

   West (eight States, west of and including Ohio)

Rural:	1 – 6	= 4
Exurban:	7 – 10	= 3
Suburban:	11 – 12	= 2
Urban:	13 – 15	= 1

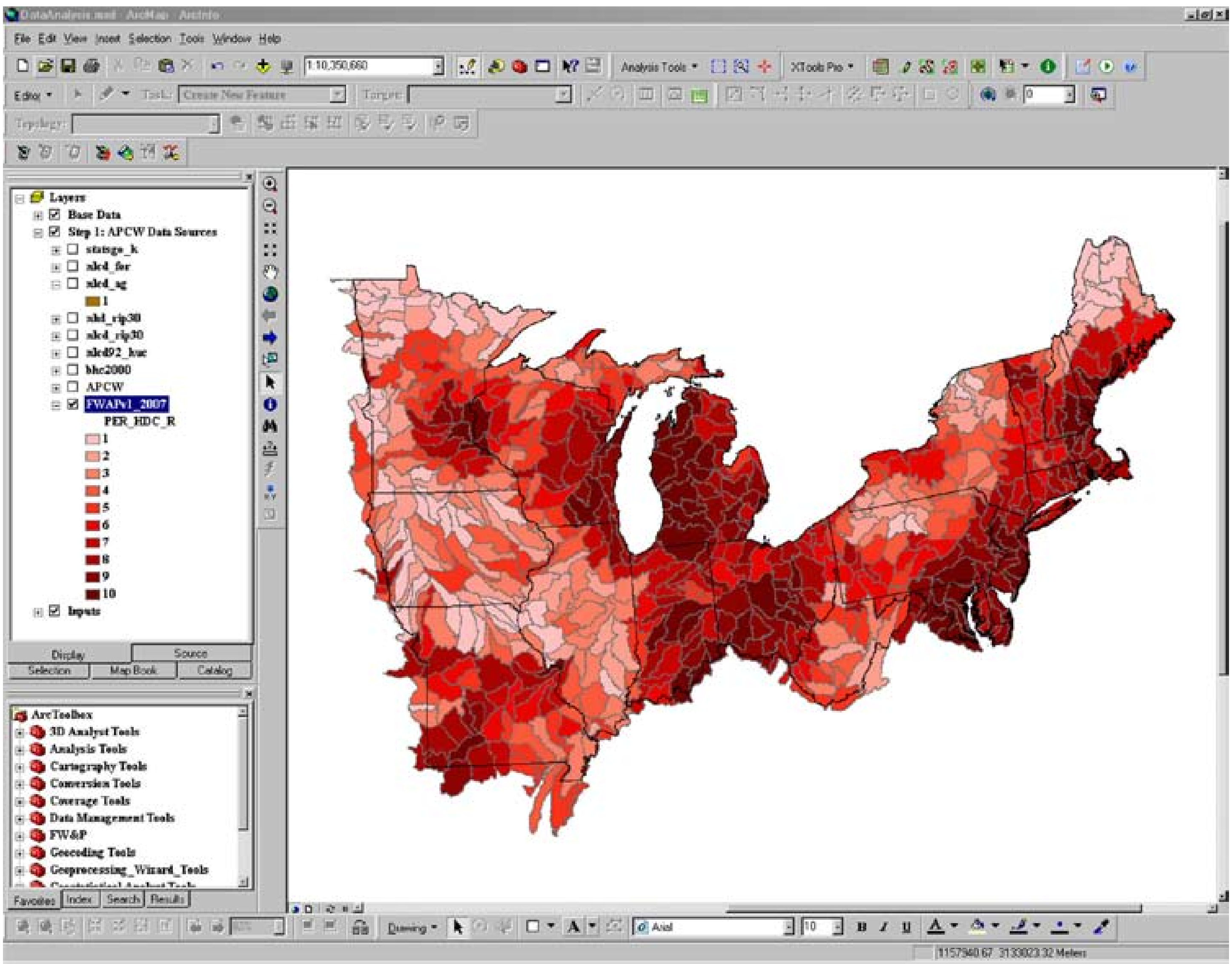
   East (12 States, east of, but not including Ohio (does include the Big Sandy Watershed))

Rural:	1 – 8	= 4
Exurban:	9 – 10	= 3
Suburban:	11 – 12	= 2
Urban:	13 – 15	= 1

4. Using the "Combine" function in ArcInfo, the values of the 2000 Housing density data set were combined with the 2030 housing density data set. Look at the output data set, areas that increased in housing density were extracted and reclassified as "development pressure." Note: Areas that increased from suburban to urban and areas where housing density was not predicted to change were not included in the final data set.

5. The acreage of areas experiencing "development pressure" was calculated for each watershed and divided the land acreage of the watershed. This "development pressure per unit area" fraction was split into 10 quantiles and given a value of 1 (low development pressure) through 10 (very high development pressure; see Table B-4)

Result: See following map.



***Step 4 composite score:** Development pressure on private forests in watersheds important for drinking water supply*

Values for the two attributes in step 4 were summed, resulting in a potential composite score of 4 to 40 for each watershed.

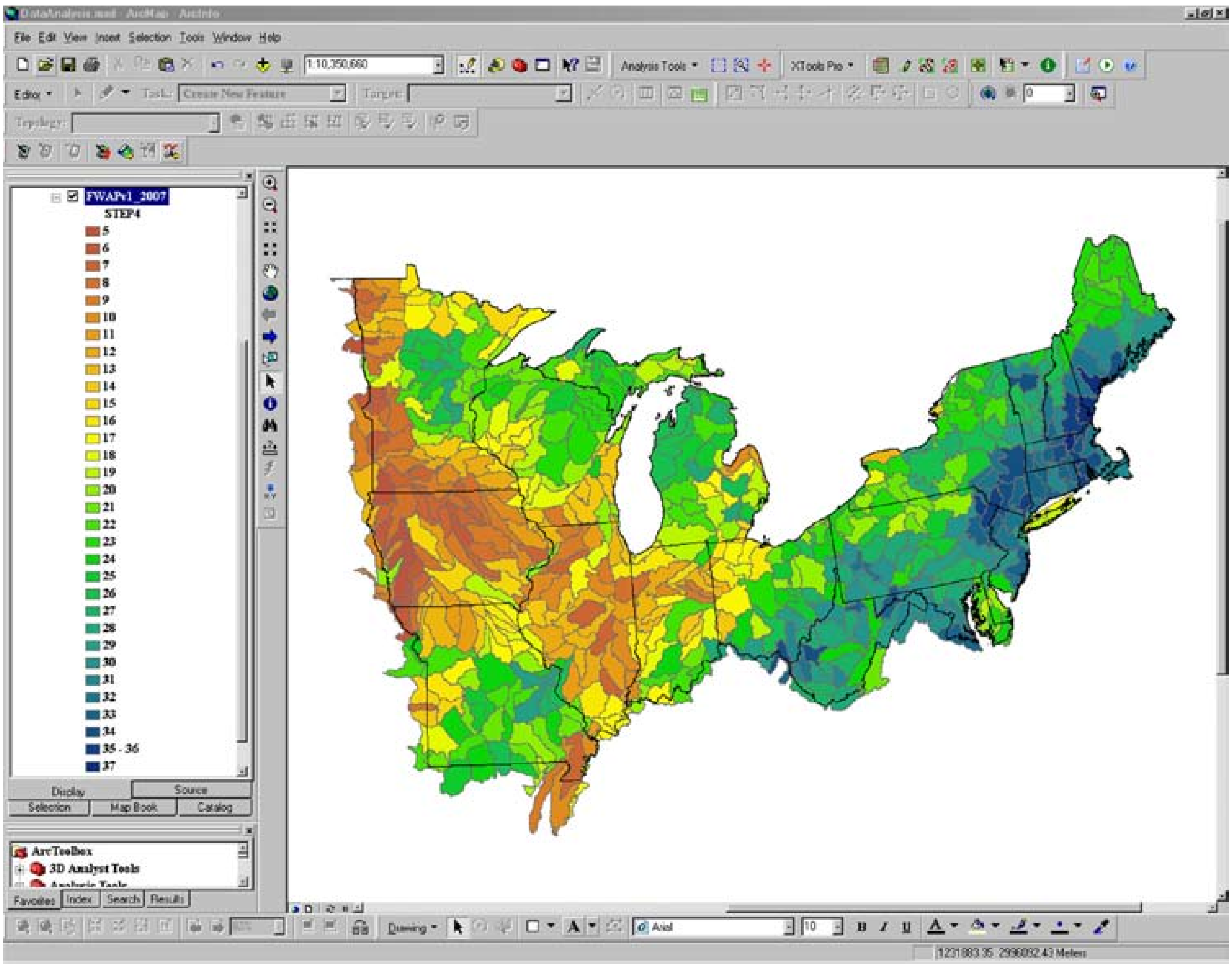
STEP 3 + DP = STEP 4

where,

Step 3 = Importance of watersheds and private forest for drinking water supply

DP = Development Pressure per unit area

Result: See following map.



For more information about the technical process, contact:

Office of Knowledge Management
Northeastern Area State and Private Forestry
USDA Forest Service
11 Campus Boulevard, Suite 200
Newtown Square, PA 19073

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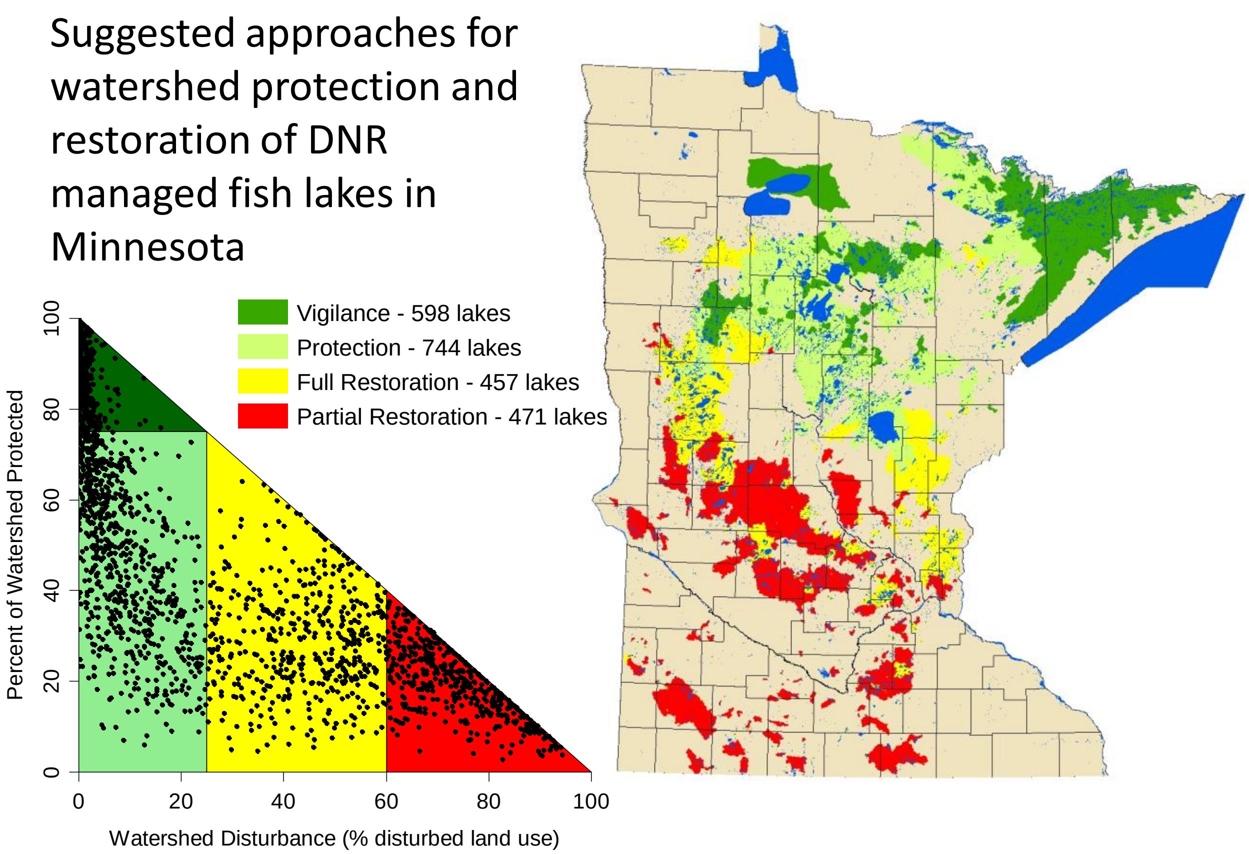
Suggested approaches for watershed protection and restoration of DNR-managed fish lakes in Minnesota.

Peter Jacobson and Michael Duval
Minnesota DNR Fisheries
March 8, 2011

Prioritization of protection and restoration efforts for water quality habitat in lakes is critically needed in Minnesota. Even though Minnesota's Clean Water, Land, and Legacy Amendment greatly increases the level of funding for watershed conservation work, it is insufficient to restore water quality habitat in every impaired lake and protect unimpacted lakes from becoming degraded. EPA has recognized this limitation for achieving Federal Clean Water Act goals and is developing tools to identify the most "restorable" systems that will allow states to cost-effectively target conservation efforts. As part of a fish habitat planning effort, DNR Fisheries has developed a recommended framework which borrows from EPA's restorability concept to guide water quality protection and restoration efforts for lakes in Minnesota.

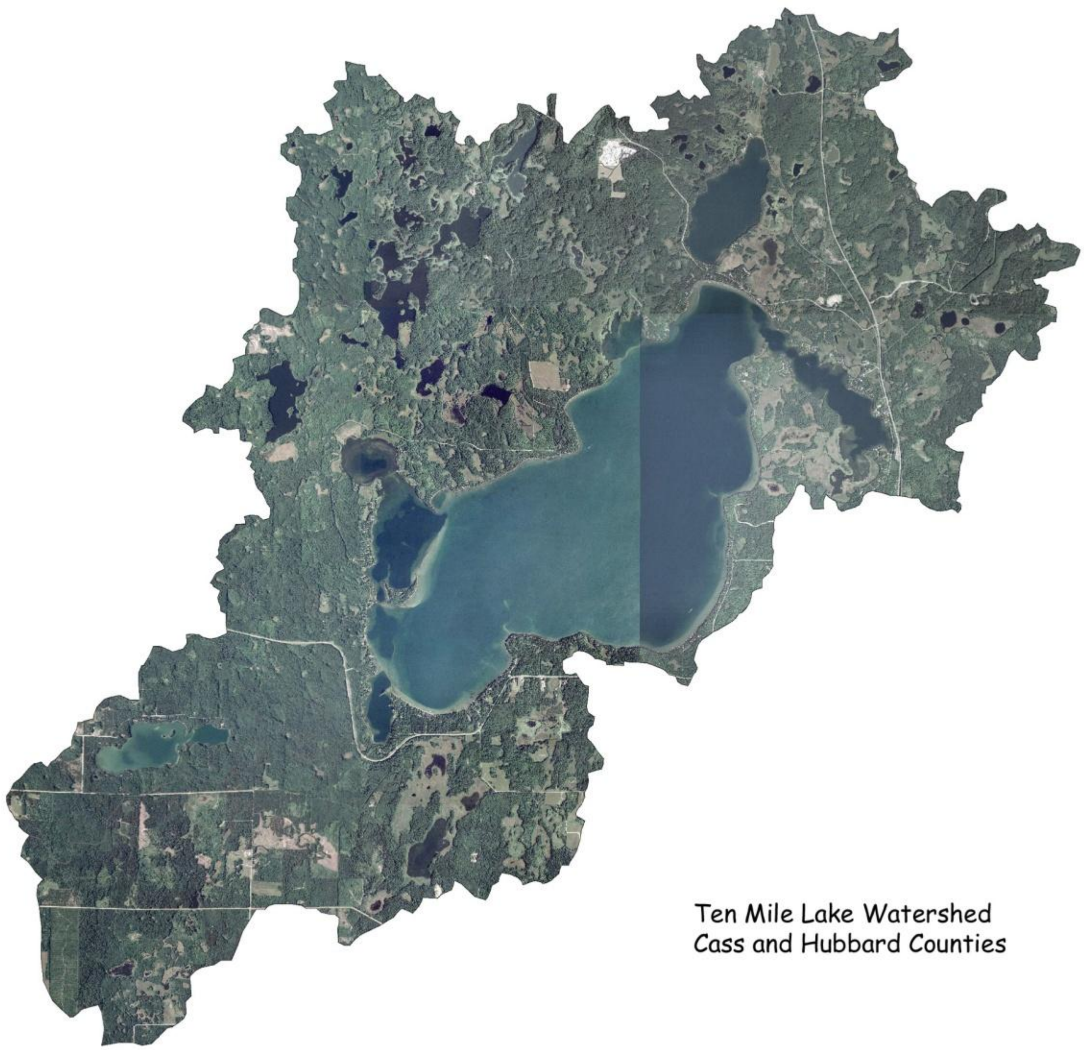


The first step in developing the framework was to delineate catchments for lakes that have watersheds completely contained within the state boundaries. Portions of the watersheds for the lakes that have watersheds shared with other states or countries (e.g. Lake Pepin, Lake of the Woods, and Lake Superior) were excluded from this assessment (lakes within their watersheds were included). A future assessment of stream habitat condition will include the entire watersheds of these border water lakes, since they contain significant contributing stream networks. But by excluding these watersheds, the geographical “footprint” of Minnesota Lakes Country is significantly narrowed which makes lake protection and restoration efforts more apparent and feasible (see map).

We developed a watershed disturbance variable (all urban, agriculture, and mining land uses) using the NLCD 2001 land use GIS data set. We then calculated the amount of protected land (publicly owned or protected by conservation easement) for each watershed using 2008 Minnesota DNR GAP Ownership data. Plotting values of each of these two components on separate axes allows for the categorization of lakes into a protection vs. restoration framework (see figure). Modeling by the DNR Fisheries Research Unit suggests that total phosphorus concentrations increase significantly over natural concentrations in lakes that have watersheds with disturbances greater than 25%. Therefore, lakes with watersheds that have less than 25% disturbance need protection and lakes with more than 25% disturbance need restoration. Restoration of lakes with intensive urbanization and agriculture in their watersheds (>60% disturbance) will be very expensive and it is probably not realistic to restore their water quality to natural levels (red). The suggested approach for these lakes is partial restoration, and possibly focusing on restoration of physical habitats at the riparian scale instead. Lakes with watersheds that have moderate levels of disturbance (25-60%) have much more realistic chances for full restoration (yellow). Lakes with watershed disturbances less than 25% and protection greater than 75% (dark green) are probably sufficiently protected and have the suggested approach of “vigilance” (keeping public lands protected). Lakes with watershed disturbances less than 25% and protection less than 75% (light green) are excellent candidates for protection efforts (primarily by keeping private lands forested).

The next step will be to prioritize lakes within each of these categories. DNR Fisheries will identify high valued fishery lakes, but other values can be included as well. Then, protection and restoration efforts can be targeted at specific systems, greatly improving chances for wise investments of Clean Water, Land, and Legacy Amendment funds.

Protecting Watersheds of Minnesota Lakes with Private Forest Conservation Easements: A Suggested Strategy



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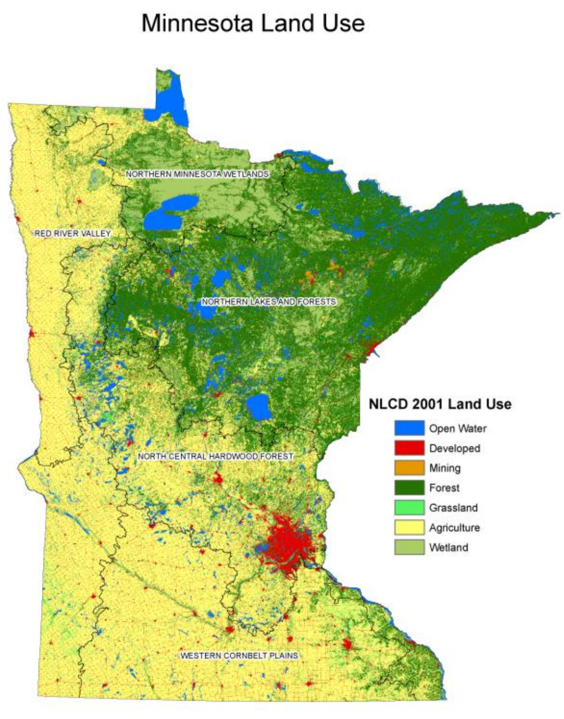
Introduction

Minnesota is fortunate to have a number of lakes that still have excellent water quality. Many of these lakes occur in the forested portion of the state where undisturbed watersheds supply clean water with low concentrations of nutrients and sediments. Protecting the forests in these watersheds from development is critical for maintaining water quality in these lakes. Large, new funding sources such as the Outdoor Heritage Fund, Clean Water Legacy, Minnesota Environmental and Natural Resources Trust Fund, and National Fish Habitat Action Plan, provide unprecedented opportunities to protect the watersheds of these systems. While land in much of the forested portion of the state is under public ownership, a considerable amount is owned by private individuals and companies. These private parcels are increasingly being "split up" and sold for development. Private forest conservation easements are a promising tool for preventing the detrimental ecological consequences of forest parcelization and development. These "working land" easements are purchased from willing landowners and allow sustainable timber harvesting, but protect the land from development. Targeting forest easements at land within the watersheds of high water quality lakes will provide the permanent protection necessary to sustain the important ecological services that these systems provide to the citizens of Minnesota.



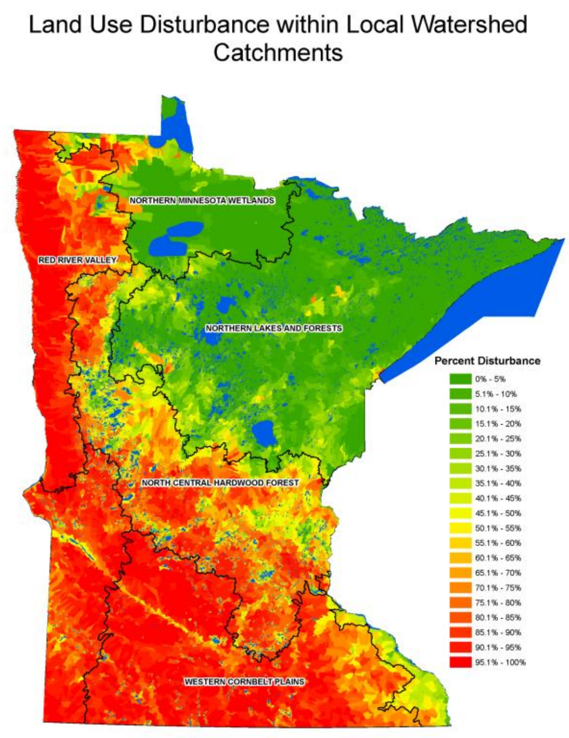


Figure 1. NLCD 2001 land use (left panel) and percent disturbed land use (agriculture, developed, and mining) by DNR catchment (right panel), with Omernik EPA/PCA ecoregions.

Land Use in Minnesota

The largest land use in Minnesota is agriculture (40.9%). Urban and developed rural areas comprise 4.9% of the land within the state. The forested portion of the state (30.5%) is largely confined to the Northern Lakes and Forests Ecoregion and contains many lakes with good water quality (also manifested within Minnesota PCA's ecoregional nutrient standards). Lake watersheds with extensive agricultural and urban land uses have appreciably poorer water quality (and many times designated as impaired under the

Federal Clean Water Act). Lakes with good water quality (such as those with forested watersheds) also receive protection under antidegradation provisions within the Federal Clean Water Act.

The water quality effects of land use can be captured by calculating the relative amount of disturbed land within the watersheds of lakes. A simple measure such as the percent of a local catchment with disturbed land uses (agricultural, develop, and mining) is useful for visualizing watershed disturbance (Figure 1) on a regional scale. Lakes with predominately undisturbed watershed land uses will likely have good water quality (the lowest disturbance values are in the Northern Lakes and Forest and Northern Minnesota Wetlands ecoregions). Catchments within agricultural ecoregions have the highest disturbance (largely represented by red in the figure). Catchments in the North Central Hardwoods Ecoregion that represents the transition from forest to prairie have intermediate disturbance values (and represented by the highest amount of yellow in the figure).

Preliminary modeling by the Minnesota DNR Fisheries Research Unit suggests that total phosphorus concentrations remain near natural background levels when less than 25% of a lake's watershed is disturbed (a lake's watershed is the sum of all local catchments upstream from the pour point of that lake). Therefore, lakes with watersheds consisting of primarily green catchments in Figure 1 are likely good candidates for watershed and water quality protection. Lakes with watersheds consisting primarily of yellow catchments are likely good candidates for watershed and water quality restoration. Lakes with watersheds consisting of primarily red catchments are also likely candidates for restoration, although full restoration to natural background levels might be difficult.

Geographical Extent of Lake Watersheds in Minnesota

The left hand panel of Figure 2 presents lake watersheds that are completely contained within the boundaries of the State of Minnesota. Although border lakes such as Lake Superior, Lake of the Woods, and Lake Pepin are important resources and warrant individual attention (such as Great Lakes Restoration Initiative, Lake of the Woods International Water Quality Forum, and Lake Pepin TMDL), the State of Minnesota has more direct control over what happens to the lakes that have watersheds entirely contained within the state. A noteworthy aspect of Figure 2 is the greatly diminished geographical extent of "Minnesota Lakes Country". The watershed boundaries in the left panel of Figure 2 illustrate the large watershed sizes of Lake of the Woods, Lake Superior, and Lake Pepin (which includes contributions from the Minnesota, Mississippi, and St. Croix river watersheds).

The right hand panel of Figure 2 illustrates lakes that have watersheds with less than 25% disturbed land uses and are good candidates for protection. As expected, the protection candidate lakes are primarily within the forested portion of the state.

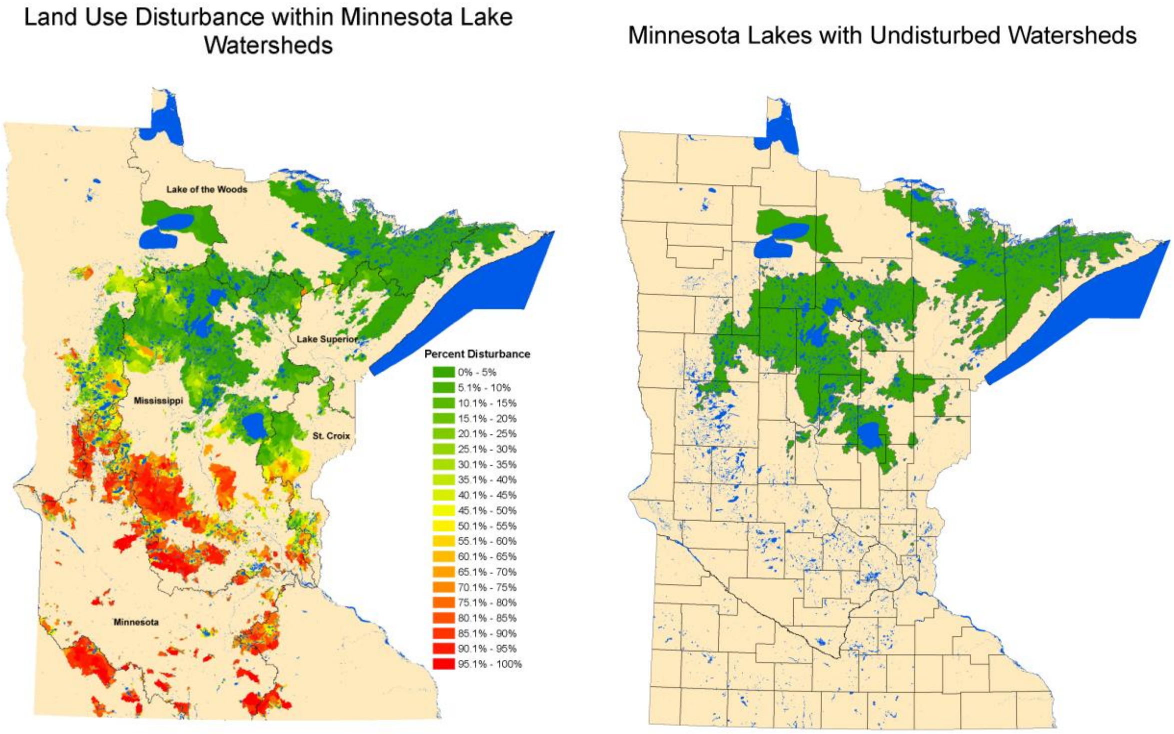


Figure 2. Land use disturbance in lake watersheds totally contained within the boundary of Minnesota (left panel) and lake watersheds with less than 25% disturbance (right panel) for Minnesota DNR Fisheries surveyed lakes >100 acres. Boundaries for large watersheds are also included in the left panel.

Ownership Status of Candidate Watersheds for Protection

The mosaic of ownership status throughout the state illustrates that protection of watersheds in Minnesota is incomplete (Figure 3). The majority of protective public ownership and existing conservation easements lies primarily in the forested portion of the state. “Filling in” the gaps in forest land protection would have great benefits for protecting water quality in Minnesota.

Some lakes with undisturbed watersheds already have a level of protection sufficient to maintain good water quality (Figure 4). These lakes lie primarily in the northeast part of the state where extensive public holdings exist within the Superior National Forest, in addition to state and county owned land. Other watersheds with adequate protection are scattered across north central Minnesota. Some of these watersheds are located in the Chippewa National Forest. Others are composed primarily of state and county forests in Becker, Mahnomen, Clearwater, and Beltrami counties.

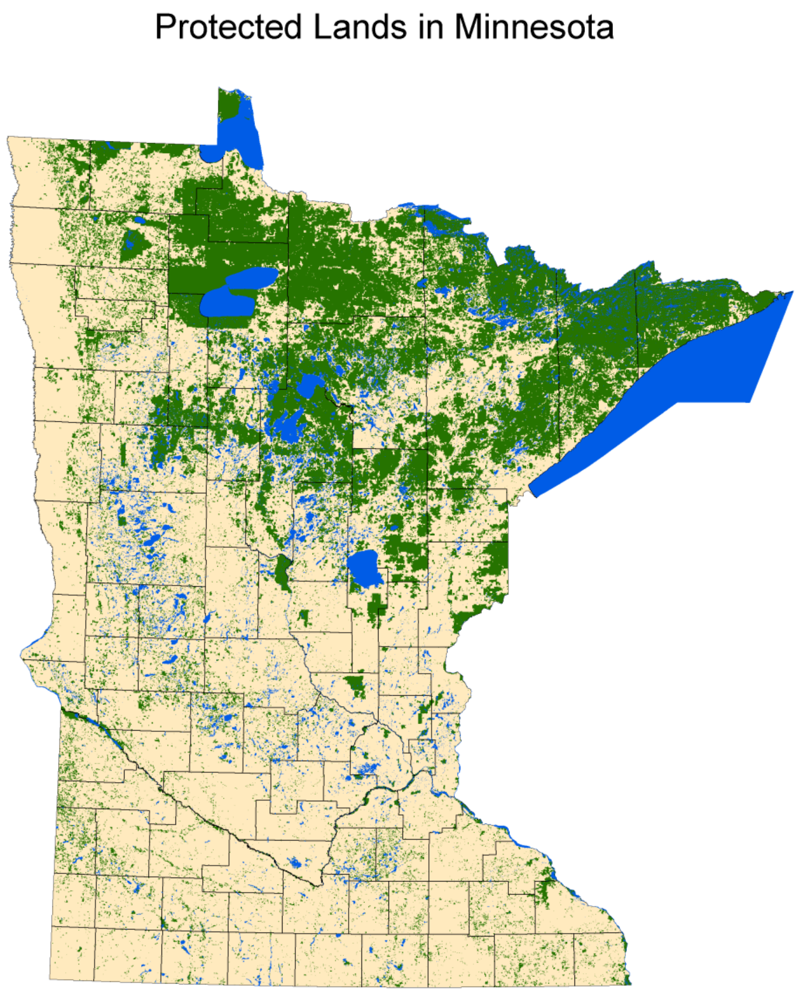


Figure 3. Lands with some form of protective status (public ownership or conservation easement). Data from DNR standard GIS layer GAP Stewardship 2008 (NEW_MANAGE codes =1, 2, or 3).

The right panel of Figure 4 presents lakes with undisturbed watersheds that do not yet have adequate protection. These lakes lie primarily in the north central Minnesota counties of Becker, Beltrami, Hubbard, Cass, Crow Wing, Aitkin, and Itasca. In addition, there is a considerable part of the northeast portion of the state that does not have adequate protection of watersheds (primarily on the western side of the Superior National Forest in St. Louis County). Note, there is some overlap in the two figures because many lake watersheds are nested and share some local catchments (some downstream lakes might not have the same level of protection as upstream lakes).

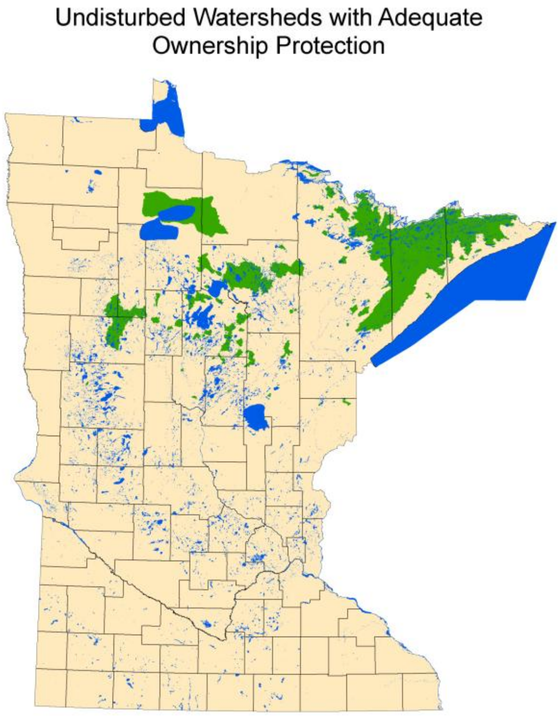


Figure 4. Lake watersheds with less than 25% disturbance and >75% protected land ownership (left panel) and with less than 25% disturbance and <75% protected land ownership (right panel) for Minnesota DNR Fisheries surveyed lakes >100 acres.

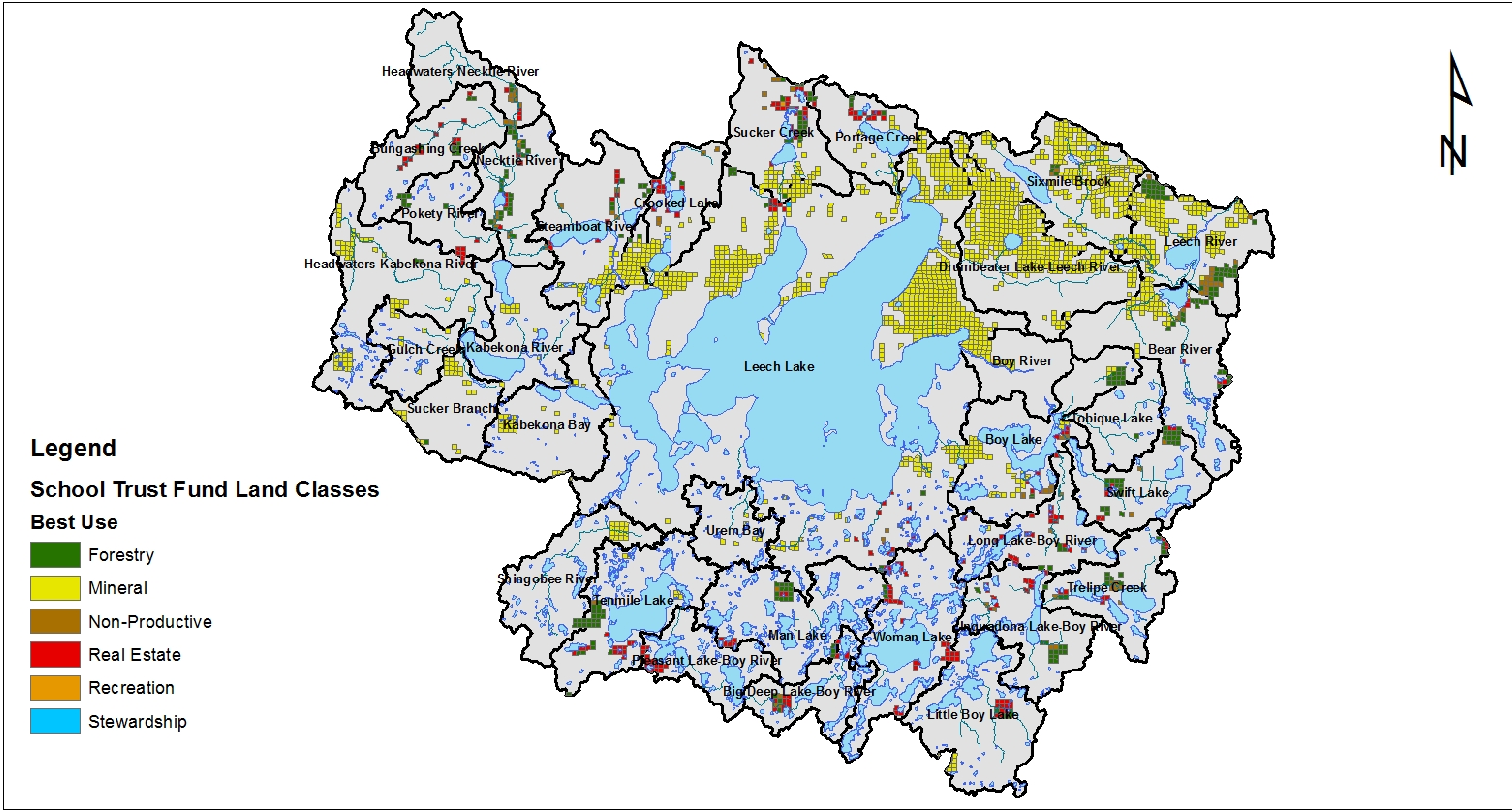
Conservation easements targeted at private forests within the watersheds of lakes identified in the right half of Figure 4 would be an effective strategy for protecting the water quality. Of the 7.09 million acres within the right half of Figure 4, 58% are in some form of protection status. An additional 1.26 million acres would be required to adequately protect the water quality of lakes within that region. If that were to occur, water quality would be permanently protected in 1,342 lakes in Minnesota.

Development of a Protection Strategy

The development of a strategy for protecting watersheds of high water quality lakes with private forest conservation easements will need to involve several state, county and possibly federal agencies. Although substantial fiscal resources are now available for funding conservation easements, significant structural limitations exist that need to be addressed. Perhaps most important is the lack of a large scale infrastructure for development and management of private easements. Considerable resources are required to develop relationships with private landowners, negotiate easement terms, file legal documents, and maintain and enforce easement conditions. The most likely candidate for developing such an infrastructure is DNR Forestry. Area Private Forest Management personnel are well versed in private landowner relationships, but private easement infrastructure within the Division is rather limited at this time. Any buildup of DNR Forestry infrastructure would require funding external to traditional sources. Also, given that DNR Fisheries does not have the infrastructure to manage a large scale easement program, the following suggestions are made to initiate the development of a protection strategy:

- Initiate discussions with DNR Forestry staff (e.g. the Forests for the Future program) on how a private forest conservation easement program could be developed. DNR Fisheries could play a role in advocating and securing funding for infrastructure development.
- Explore the use of private forest conservation easements as a tool for developing protection strategies under the antidegradation provisions of the Federal Clean Water Act with PCA, DNR Waters, DNR Ecological Resources.
- Engage other divisions and agencies (e.g. BWSR, USFS, and county land departments) for their possible involvement in such an effort.
- Measure the interest in private conservation groups such as the Trust for Public Land, The Nature Conservancy, and others for partnering with possible administrative aspects of a protection effort.
- Develop a proposal for external funding (e.g. LCCMR, Clean Water Legacy, or National Fish Habitat Action Plan) to fund an effort to begin developing a protection strategy.
- Further prioritize lakes within the suggested protection portion of the state. For example, high priority lakes could include very deep lakes that have exceptional water quality and support robust coldwater fish populations.
- Explore other options beyond forest conservation easements. Although forest conservation easements have excellent potential as a protection strategy, a number of other tools are available as well. BWSR and county water planning, local zoning ordinances, DNR environmental review and permitting, shoreland ordinance development and rules oversight, reducing the loss of public lands (including land in tax forfeit status and school lands), forest stewardship planning, and individual lake management planning all have potential for further developing lake protection strategies and should be used in combination with forest conservation easements.

In any case, DNR Fisheries should play a role in assisting with the development of a strategy to protect the watersheds of high quality lakes with private forest conservation easements. Water quality is a fundamental fish habitat and warrants significant effort in protecting it. Although DNR Fisheries is not a primary water quality or forest manager, it can play an important role advocating for funding and assisting with the development of water quality protection strategies.



Leech Lake River Watershed - Local Catchment Strategies

DNR Catchment with Lake Protection and Restoration Strategies based on Local Catchments (Includes all upstream catchments)

WATERSHED RESTORATION ACTION PLAN FORM
STEP C WATERSHED CONDITION FRAMEWORK

1. Summary

Region, Forest: Region 9, Chippewa NF	Fiscal Year Priority Identified: 2011
Watershed Name: Leech Lake	6th Level HUC: 070101020507
Condition Class: 2	% NF Land In Watershed: 22
General Location: The watershed is in the north central portion of the Mississippi River Headwaters basin (3rd level HUC), encompassing the towns of Walker, Whipholt, and Federal Dam, Minnesota.	
Land Use: Primary land uses consist of forestland management, recreation, and traditional hunting and gathering by the Leech Lake Band of Ojibwe. Chippewa NF Plan management direction consists primarily of long-rotation timber harvest and recreation uses in a scenic landscape.	
Important ecological values: The watershed contains Research Natural and Candidate Research Natural areas, Riparian Emphasis Area, State Wildlife management areas, and State areas of High Biodiversity. Its location within the Mississippi River Headwater Basin makes it an important ecological feature of the Mississippi River headwaters for several public land managers.	

2. Watershed Condition Attributes in Fair or Poor Condition

Attributes	Reason for Fair or Poor Rating
1.1, 1.2, 6.1, 6.2, and 6.3	Impaired waters and water quality issues related to road density, road maintenance, and road proximity to water: Leech Lake is a listed 303(d) impaired water and has fish consumption advisories due to high mercury content; however no action would be taken until an efficient means to remove the mercury is developed. The density of roads and the lack of maintenance on some road segments have also affected water quality in the watershed through introduction of sediment to adjacent waterbodies. Particularly, roads in close proximity to water are direct sources of runoff and displace native riparian/wetland vegetation.
2.1, 3.1, and 3.3	Aquatic habitat fragmentation and changes to water quantity and channel form and fucntion: Leech Lake Dam in Federal Dam, MN, is an aquatic organism passage barrier and has altered the natural hydrograph on Leech Lake. Hydrology and channel form and function of river systems flowing into and out of Leech Lake have also been altered as a result of dam management; issues with Federal Dam would not be addressed in the foreseeable future in light of public controversy with lake levels. Stream crossings and impoundments in other portions of the watershed are also having similar but less significant impacts affecting the overall watershed condition.
3.2	Large woody debris: By the early 1900s, much of the watershed had been logged; forests have since recovered under more sustainable management, yet input of large wood into aquatic ecosystems remains altered. Conifer and older trees, both long-term sources of large woody debris recruitment to aquatic ecosystems, are less common today than they were prior to the logging boom.
4.2, 4.3, and 11.1	Native and exotic/invasive terrestrial and aquatic species: Past land use within the watershed has impacted native terrestrial and aquatic species through habitat disturbance and alteration of natural hydrology. Some species have recovered, yet others remain threatened or endangered. Exotic/invasive terrestrial and aquatic species have been introduced into the watershed as a result of past land use as well. In some circumstances they've colonized portions of the watershed and replaced native species.
8.1	Fire regime condition: Lands within the watershed were primarily developed for logging, agriculture, and homesteading, which were located mostly in ecosystems adapted to dry conditions with frequent fire disturbance. Wetlands were largely ignored by development; however much was still impacted by establishment of roads and impoundments. These land use patterns, along with decades of fire suppression, have altered natural fire disturbance processes that shaped native plant communities.

3. Restoration Projects That Would Improve Watershed Condition Attributes in Fair/Poor Condition

Attributes	Potential/Priority Restoration Projects
1.1, 1.2, 6.1, 6.2, and 6.3	· Overall, decommission # miles of roads. · Decommission # miles of roads within within 300 feet of a waterbody. · Stabilize and restore eroded and compacted soils at # campsites near waterbodies. · Stabilize lakebed scour and lakeshore erosion at # boat accesses.
2.1, 3.1, and 3.3	· Remove or replace # culverts or impoundments that currently restrict surface flow or aquatic organism passage. · Fill or plug # miles of ditches draining wetlands or bypassing native stream channels.
3.2	· Increase the basal area of riparian forestland less than 60 BA/acre. · Convert # acres of riparian forestland, currently dominated by short-lived tree species, to conifer and other long-lived species when and where ecological site conditions warrant. · Introduce # acres of conifer and other long-lived tree species to sites through diversity seeding or planting when and where ecological site conditions warrant.
4.2, 4.3, and 11.1	· Restore native terrestrial and aquatic habitat: - On # acres through vegetation management. - Along # miles of stream or lakeshore through vegetation management and restoration of natural hydrology. · Treat # acres of terrestrial and aquatic habitat infested with exotic/invasive species using a range of control methods.
8.1	· Restore natural fire disturbance to # acres of fire dependent/fire tolerant landscape ecosystems through prescribed fire. · Mimic natural fire disturbance on # acres through harvest and fuels reduction activities.

4. Watershed Characteristics and Conditions

a. General Context/Overview of the Watershed: The watershed is located within two distinct landtype associations; the Itasca Moraine (Im) is located in the southern portion of the watershed and the Guthrie Till Plain (Gtp) in the north. Topography and soils in the Im are quite complex. The Landscape may range from relatively flat to some of the steepest grades across the Chippewa National Forest. Soils consist primarily of coarse-loamy till, but gravely outwash sands are found frequently as well and often mixed in with the till. Vegetation growth rapid enough that soil erosion is typically not a concern when soils are exposed; however moderate to heavy textured soils, particularly near the numerous small lakes and wetlands pitting the landscape, are a concern for soil compaction. Historically the dominant vegetation was mixed pine and oak; however years of logging, fire suppression, and population growth have shifted vegetation more toward aspen and mixed northern hardwoods.

Topography is the Gtp tanges from flat to rolling with very few lakes but many wetlands and small streams connecting them. Soils consist of loams and clay loams with a sandy cap formed from glacial lake wave wash. Flat topography and rapid vegetation growth control erosion, but compaction is a concern in much of the landscape due to heavy saturated soils, particularly near the numerous wetlands and small streams. Vegetation is and has been dominated by mixed northern hardwoods with infrequent fire disturbance. Years of logging have increased the amount of short-lived tree species such as aspen and paper birch.

b. Watershed Conditions: The watershed is considered functioning but at risk. Infrastructure such as roads and administrative sites are sources of sediment to adjacent waterbodies and alter natural hydrology. Past logging and fire suppression have had a role in changing native plant communities and large woody debris recruitment near lakes and streams. Past and current land use has affected native terrestrial and aquatic species, and in some areas introduced exotics/invasives. Current impacts have not significantly altered the health and function of the watershed but if unchecked may do in the future.

5. Partnership Opportunities and Alignment with Agency Priorities

a. Partnership Involvement: The Leech Lake watershed has an active lake association on Leech Lake and broad landscape management groups in the Leech Lake Watershed Foundation and Leech Lake Pines Collaborative, a subgroup of the North Central Landscape Committee. These groups have been and continue to be actively engaged with the Chippewa National Forest, Minnesota Department of Natural Resources, and Cass County Environmental Services agencies. Natural resource management projects have already been completed within the watershed through collaborative efforts amongst these groups and multi-level government land managers.

b. Alignment with other National, Regional, or Forest Priorities: Restoration in the Leech Lake watershed is aligned with Forest Plan management area direction for Riparian Emphasis Area, Unique Biological Area, and Pine Point Research Natural Area. Restoration, particularly in the State's areas of high biodiversity, is also in line with Minnesota Department of Natural Resource goals and objectives in the Chippewa Plains and Pine Moraines Subsection Management Plan.

6. Essential Projects

a.
b.
c.

7. Outcomes/Outputs

a. Improved WCC rating/s as a result of implemented restoration:
b. Performance Measure Accomplishment:
c. Job Creation or Stabilization:

8. Monitoring

The forest will monitor:

a.
b.
c.

Monitoring will be done in cooperation with

a.
b.
c.

9. Estimated costs to complete all essential projects

Source	Planning	Design	Implementation	Monitoring	Totals
FS Contribution					
Partner Contribution (both in kind and $)					
Totals					

10. Timelines and Scheduling

Fiscal Year	Task	FS Cost	Partner cost

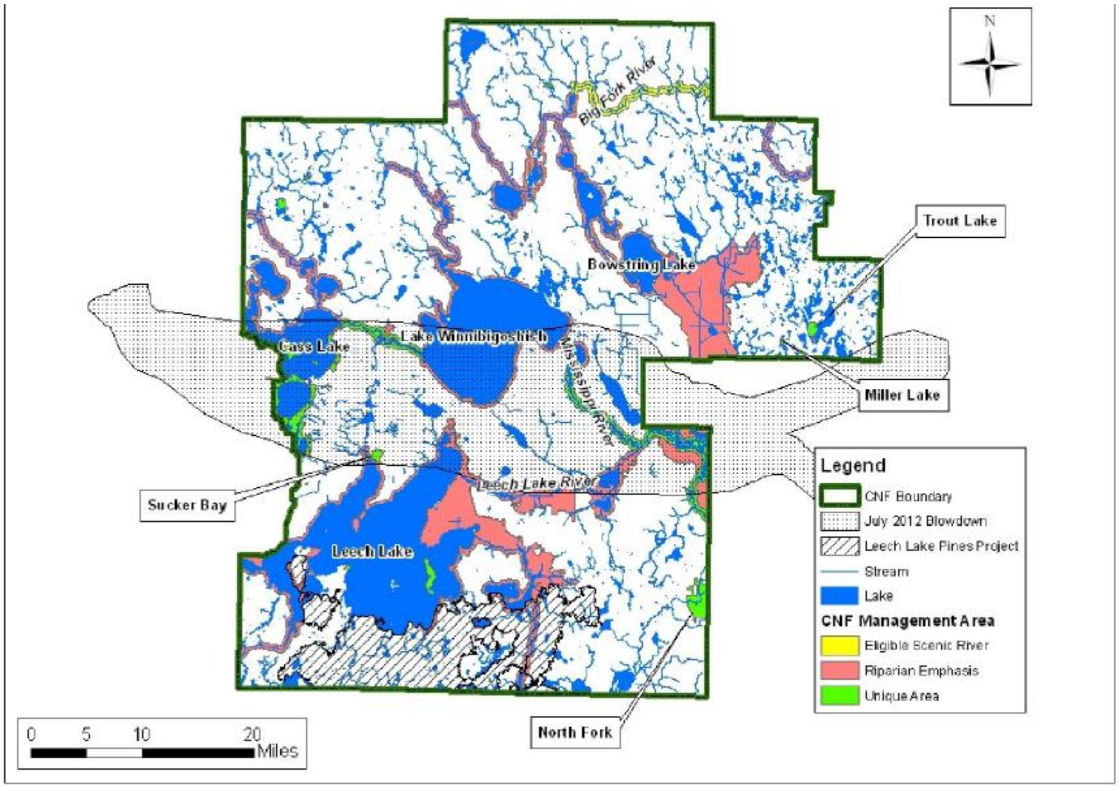


Figure 3. The map above shows potential areas within the CNF to focus riparian management activities.

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

MNDNR

Fisheries Management Plan for Leech Lake

2016-2020

Matt Ward, Large Lake Specialist

December 2015

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Matt Ward, Leech Lake Specialist, Walker

Leech Lake Fisheries Input Group

Organization/Affiliation	Representative
City of Walker	Jed Shaw
Leech Lake Association	Pat Mortale
Leech Lake Band of Ojibwe	Steve Mortensen
Leech Lake Fishing Task Force	Larry Jacobson
Leech Lake Area Watershed Foundation	Jim Bedell
Statewide Bass Work Group	Scott Peterson
Statewide Northern Pike and Muskellunge Work Group	Greg Kvale
Statewide Walleye Work Group	Tom Neustrom
Resort owner	Tim Anderson
Resort owner	Frank Alianello
Local business owner	Chip Leer
Local business owner	Jeff Arnold
Local guide	Al Maas
Local angler	John Dainsberg
Statewide angler	Doug Strecker
Academic, Bemidji State University	Dr. Andrew Hafs

Executive Summary

Purpose

Update the 2011-2015 Leech Lake Fisheries Management Plan for another five years.

Background and Current Status

Declines in Walleye and Yellow Perch populations during the early to mid-2000s prompted the development of a 2005-2010 Fisheries Action Plan for Leech Lake (Rivers 2005a). This plan was developed with input from concerned citizens at several open house style meetings. A more formal process using a citizen based fisheries input group was used to prepare the 2011-2015 management plan (Schultz 2010). Management efforts have focused primarily on increasing Walleye abundance using conservative regulations, cormorant management, Walleye fry stocking, and increased habitat protection.

Walleye abundance improved during 2005-2007 in response to combined management actions and has remained relatively stable since. Gill net catch rates of Walleye, female spawner abundance, Walleye recruitment, and targeting angler catch rates have been at or above long-term averages and/or objective ranges for several years. Overall, the Walleye population has fully recovered. The protected slot limit on Walleye was relaxed (from 18-26 inches to 20-26inches) effective on the 2014 Walleye opener to increase angler harvest opportunity and to relieve predatory pressure on Yellow Perch.

Although the Yellow Perch population initially responded positively to the management actions employed in 2005, the population began declining by 2008. Yellow Perch abundance in the three most recent gill net catches was at or near the historical low. Similarly, recruitment has also been declining since 2007 and size-structure (abundance of fish $\geq$8 inches) has been below the 25^{th} percentile two of the past three years. Elevated predation by juvenile and adult Walleye and increases in winter harvest are both suspected as primary causes of these trends. A strong negative relationship exists between Yellow Perch recruitment and total Walleye fry densities from the same year, and record Yellow Perch harvest was documented during the 2010-11 and 2014-15 winter angling seasons. Although many anglers perceive cormorant consumption of Yellow Perch as a significant influence on recruitment, consumption by cormorants has been reduced by 90% relative to 2004 levels and has been similar to pre-2000 levels for several years.

The Minnesota Department of Natural Resources (DNR) continues to work with a group of 16 stakeholders which comprise the Leech Lake Fisheries Input Group (LLFIG). This group provides diverse local and statewide perspectives and makes recommendations on Leech Lake fisheries management. The LLFIG provided input to the DNR while establishing the 2016-2020 Leech Lake Fisheries Management Plan. This plan builds upon the successes of and knowledge gained from previous plans by recommending specific goals, objectives, and management actions aimed at preserving a high-quality, species-diverse fishery on Leech Lake. New to the 2016-2020 management plan is the use of 3-year moving averages (most recent three observations) for most of the objectives. Moving averages are used to smooth the year to year variability to more closely reflect current trends. The DNR will continue to hold annual update meetings with the LLFIG and other interested stakeholders to review the previous year's information and status with regards to the management plan. A weight of evidence approach will be used annually to assess if deviations from the management plan are necessary and appropriate.

Sportfish Population Goals and Objectives

Walleye Goal: Support a self-sustaining Walleye population that balances harvest opportunity, with the opportunity to catch quality-sized fish, while meeting reproductive needs.

Walleye Objectives:

- *Abundance:* Maintain gill net catch rate (3-year moving average) of 7-10 fish/net (40^{th}-90^{th} percentiles).
- *Reproductive Potential:* Maintain mature female biomass (3-year moving average) between 1.5-2.0 pounds/acre (50^{th}-80^{th} percentiles).
- *Size Structure:* The percentage of Walleye sampled in gill nets (3-year moving average) ≥20 inches should be between 10 and 20% (50^{th}-80^{th} percentiles).
- *Recruitment:* Maintain year class strength index (3-year moving average) greater than 1.1 (25^{th} percentile).
- *Angler Catch Rate:* Maintain a targeting angler summer catch rate of 0.30 fish/hour or higher (50^{th} percentile).
- *Angler Harvest:* Sustain an annual total Walleye harvest within a target range of 130,000 and 190,000 pounds (50^{th}-80^{th} percentile).
- *Condition:* Maintain condition factor (3-year moving average) between 82 and 86 (25^{th}-75^{th} percentiles).

Yellow Perch Goal: Support a self-sustaining Yellow Perch population that provides both a stable prey base for sportfish and harvest opportunities for anglers.

Yellow Perch Objectives:

- *Abundance:* Maintain gill net catch rate (3-year moving average) of ≥16 fish/net (25^{th} percentile).
- *Size Structure:* The percentage of Yellow Perch sampled in gill nets (3-year moving average) ≥8 inches should exceed 30% (25^{th} percentile).
- *Recruitment:* Maintain gill net catch rate (3-year moving average) of age-4 Yellow Perch ≥3.2 fish/net (25^{th} percentile).
- *Angler Harvest:* The annual total Yellow Perch harvest should be less than 98,000 pounds.
- *Maturity:* Female length at 50% maturity exceeds 5.5 inches.

Northern Pike Goal: Support a self-sustaining Northern Pike population that balances harvest opportunity with catch quality.

Northern Pike Objectives:

- *Abundance:* Maintain gill net catch rate (3-year moving average) between 4.2 and 5.3 fish/net (25^{th} and 75^{th} percentiles).
- *Size Structure:* The percentage of Northern Pike sampled in gill nets (3-year moving average) ≥22 inches should exceed 30% (25^{th} percentile).
- *Recruitment:* Maintain gill net catch rate (3-year moving average) of age-3 Northern Pike between 1.0 and 1.6 (25^{th} and 75^{th} percentiles).

Management Actions

Fisheries assessments

- Conduct standardized annual assessments, including seining, trawling, electrofishing, gill netting, zooplankton, water quality and temperature monitoring.
- Conduct summer and winter creel surveys 2 of every 6 years. The next scheduled surveys are summer of 2016-2017 and 2017-2018, and the winters of 2015-2016 and 2016-2017.
- Continue to improve upon young-of-the-year predictors of potential Walleye year class strength.
- Continue to conduct lakewide Bluegill, Black Crappie, Largemouth Bass, and Smallmouth Bass spawner assessments every three years, standardizing gears, locations, and timing prior to 2018. Monitor for potential changes in size structure and catch rates. Assess the use of trap nets to sample Bluegill and Black Crappie prior to 2018. Establish Smallmouth Bass electrofishing stations prior to 2018. The next scheduled survey is in 2018.
- Insert Passive Integrated Transponder (PIT) tags in all Muskellunge adults sampled during spawn take operations and all fingerlings stocked during spawn take years on Leech Lake.
- Annually collect data from a subsample of cisco and whitefish in coordination with the Leech Lake Band of Ojibwe, Division of Resource Management commercial fishery.
- Annually collect and analyze data from a subsample of burbot registered at the Leech Lake Eelpout Festival.

Stocking & related activities

- Stock 7.5 million Boy River Strain Walleye fry (OTC marked) if the 3-year moving average (year class strength index values) falls below the 25th percentile.
- Stock sufficient numbers (low density) of Walleye fry (Boy River strain) to estimate wild fry production when mature female density falls below 1.25 or exceeds 2.75 pounds/acre. The purpose of this stocking is to expand on the existing range of total fry density observations. Information gained from these stocking events will increase understanding of the relationship between total fry density and recruitment. Stocking should not occur if Walleye condition and Yellow Perch abundance remain low.
- Conduct Muskellunge spawn take operations every four years in Miller's Bay to maintain genetic diversity in statewide brood stock lakes. Return 600 Muskellunge fingerlings to Leech Lake during spawn take years. The next scheduled spawn take is 2017.

Regulations

- The existing Walleye regulation (20-26 inch protected slot limit, possession limit of 4, one over 26 inches allowed in possession) will be continued. Adjustments to the existing 20-26 inch protected slot limit will be considered if mature female biomass continues to exceed the objective range of 1.5-2.0 pounds/acre and other key population metrics indicate signs of an unbalanced Walleye population. The DNR will review the status of key population metrics with the Leech Lake Fisheries Input Group annually.
- The existing bag limits of 50 Cisco (Tullibee) and 25 Lake Whitefish within the Leech Lake Indian Reservation will be continued. Daily and Possession limits are the same.
- The Leech Lake Fisheries Input Group requested DNR consider and evaluate bag limit reductions on panfish species to maintain the existing size quality of the populations.
- If changes to statewide regulations occur, implement regulations consistent with statewide recommendations and evaluate angler and fish population responses through standardized creel and gill net surveys.

Habitat

Note: many of these initiatives will only be possible with additional resources (funding and staff)

- Continue to partner with and/or provide support to government and non-government organizations to acquire via fee title or conservation easement key shore land areas within the Leech Lake watershed with the intent to protect key habitats and to implement best management practices (BMPs) where appropriate.
- Explore options for inventorying nearshore aquatic habitat in Leech Lake, including use and condition.
- Explore options for performing an inventory of aquatic vegetation stands to identify potential long-term trends in species composition, abundance, and distribution.
- Explore options for performing a telemetry study to identify additional Muskellunge spawning locations to guide future priorities for shoreland protection.
- Coordinate with DNR Ecological and Water Resources staff and Cass County Environmental Services to assist with aquatic invasive species prevention, education, and management efforts by DNR Ecological and Water Resources Division and other agencies.

Other Considerations

- Continue to provide financial and technical support to the Leech Lake Band of Ojibwe, Division of Resource Management for Double-Crested Cormorant control and evaluation efforts on Leech Lake.
- Continue to monitor potential effects of climate change on Walleye populations, specifically the length and intensity of the growing season (i.e. growing degree days).
- Evaluate the potential of collecting additional data from annual Muskellunge tournaments.
- Explore options for determining Largemouth Bass re-redistribution needs following tournaments if the number of tournaments increases to pre-2014 levels.
- DNR will hold annual meetings to update the LLFIG and other interested stakeholders to share the previous year’s information and track status with regards to the management plan.

Table of Contents

Fisheries Management Plan for Leech Lake, 2016-2020

Minnesota Department of Natural Resources Mission Statement

The mission of the Minnesota Department of Natural Resources (DNR) is to work with citizens to conserve and manage the state's natural resources, to provide outdoor recreation opportunities, and to provide for commercial uses of natural resources in a way that creates a sustainable quality of life.

Purpose

Management plans describe goals, objectives, and actions that support the DNR mission statement. The purpose of this plan is to guide fisheries management on Leech Lake. It is written for use by both the DNR and citizens that are interested in the management of the fishery resource. This plan is based on a fish community approach to fisheries management and highlights why this approach is important. This plan is designed to guide effective and efficient allocation of staff and fiscal resources to protect the fish community and provide for its sustained use. The goals, objectives, and actions identified in this plan will focus the work of the DNR over the next five years. Although this plan contains clearly defined goals, objectives, and actions, it is written to be flexible and deviations can occur based on changes to the fishery or the citizens that utilize it. Citizen participation is major component in the development of this plan and will continue to be critical throughout its life. The success of the plan will ultimately be determined by its benefits to the resource and users.

Lake Characteristics

Leech Lake has approximately 112,000 surface acres. In its original state the lake covered about 106,000 acres. In 1884 a dam was built on the Leech River, raising the water level about two feet and increasing the surface area to its present size (Wilcox 1979). The maximum depth of the lake is near 150 feet; however, nearly 80 percent of the lake is less than 35 feet deep. Leech Lake has approximately 58,000 littoral acres (≤15 feet).

Leech Lake is located in three glacial zones and has an irregular shape with many large and small bays. The lake varies considerably from a morphological perspective. Some large bays, such as Steamboat, Boy, and Headquarters, display eutrophic water characteristics (high in productivity) whereas other large bays, such as Walker, Kabekona, and Agency have properties more congruent with oligotrophic lakes (low in productivity). The main portion of the lake (including Sucker, Portage, and Traders bays), is mesotrophic (moderate in productivity). Shoreline length based on remote sensing technology is 201 miles. Approximately 23% of the shoreline consists of a windswept gravel-rubble-boulder mixture, nearly all of which is suitable Walleye spawning habitat (Wilcox 1979), and numerous off-shore gravel-rock-boulder reefs are also available.

The diversity of the shoreline and substrate, as well as its extensive littoral zone, provides excellent spawning and nursery habitats for a number of species. Walleye *Sander vitreus*, Northern Pike *Esox lucius* and Muskellunge *E. masquinongy* are the principal predators and are common throughout the lake. Although most fish species are found in every portion of the lake, Walleye and Muskellunge abundances are highest in the mesotrophic areas. Northern Pike are most prominent in vegetated eutrophic bays. Yellow Perch *Perca flavescens* are abundant throughout the lake and are the primary forage for most predators. Cisco *Coregonus artedi* and Lake Whitefish *C. clupeaformis* are an important forage species for larger predators and are typically found in the mesotrophic and oligotrophic areas. Juvenile Cisco also comprise larger proportions of predator diets when large year classes are present. Other species present in the lake include: White Sucker *Catostomus commersoni*, Burbot *Lota lota*, Rock Bass *Ambloplites rupestris*, Bowfin *Amia calva*, Shorthead Redhorse *Moxostoma macrolepidotum*, Bullheads *Ameiurus spp.*, Pumpkinseed *Lepomis gibbosus*, Bluegill *L. macrochirus*, Largemouth Bass *Micropterus salmoides*, Smallmouth Bass *M. dolomieu*, and Black Crappie *Pomoxis nigromaculatus*.

Survey History

DNR:

Prior to the inception of the large lake program in 1983, unstandardized gill netting, seining, trawling, and creel survey assessments were infrequently conducted by the DNR. Gill net assessments were completed during 1943, 1944, 1950, 1976, and 1982. Seining assessments were completed from 1965-1968, 1970-1982. Trawling assessments were completed from 1965-1968, and in 1976. Summer creel surveys were conducted in 1965, 1966, and 1967, while a winter creel survey was conducted in 1965-66. Gear and locations used during these surveys were not consistent with the standardized protocols established with the inception of the Large Lake Program in 1983 (Wingate and Schupp 1984).

Annual Large Lake Program surveys initiated in 1983 included seining in mid-July and gill netting in mid-September; additional gears targeting specific species and age classes have been added over the past 32 years. Currently annual surveys include water quality in mid-July (1986-present), trawling in mid-August (1987-present), hourly water temperature loggers (2006-present), electrofishing in mid-September (2007-present), and monthly zooplankton sampling (2012-present). Summer creel surveys have been conducted in 1984-1985, 1991-1992, 1998-1999, 2004-2005, 2008-2011, and 2014, and winter creel surveys were conducted in 1984-85, 1990-91, 1991-92, 2004-05, 2005-06, 2010-11, and 2014-15. Spring bluegill, black crappie, largemouth bass, and smallmouth bass assessments were initiated in 2012 and are conducted every three years.

1965-68: The first extensive Walleye population survey was completed on Leech Lake from 1966-1968 by Schupp (1978) as part of a broader status update of the State's flagship Walleye fisheries. The first creel survey was also conducted from 1965-1967 and estimated annual fishing pressure to be 785,905 angler-hours/year, a harvest rate of 0.183 Walleye/hour, and total Walleye harvest of 208,120 pounds of Walleye per year (Schupp 1972).

1979-80: A Muskellunge telemetry study was conducted to identify spawning areas, seasonal distribution, and movement throughout 1979 and 1980 (Strand 1986). Six spawning locations were determined lakewide through the tracking of 14 females. Spawning sites were characterized as being approximately 3-6 feet deep with *Chara* spp. as the dominant vegetation type.

2002-2005: The first lakewide survey of aquatic vegetation distribution and assemblage (Perleberg and Loso 2010).

2005-2010: Double-crested cormorant studies assessed cormorant diets (Göktepe 2008; Hundt 2009; Göktepe et al. 2012) and estimated cormorant population size, associated fish consumption, and trends in fish population metrics in response to culling efforts (Schultz et al. 2013).

2007: A critical review of young-of-the-year Walleye sampling (Schultz et al. 2007). Concluded Walleye year class strength was most accurately predicted using mid-August bottom trawling data, when compared to mid-July seining data. However, mid-September electrofishing data may serve as an additional tool to predict Walleye year class strength.

2012: Compared genetic variation in Leech Lake and Woman Lake Walleye populations (Miller 2012). No declines in genetic diversity in Leech Lake were detected between the pre-stocking (pre-2005) and stocking (2005-present) time periods. Additionally, no signs of increased relatedness or inbreeding depression were observed and no increases in genetic diversity are needed.

2012: Compared variation in juvenile Walleye growth rates in Leech Lake (Ward et al. 2012). Growth rates for both age-0 and age-1 Walleye for both stocked and naturally produced year classes were compared and no statistically meaningful differences were observed. Growth was negatively associated with higher fry densities and positively associated with longer and warmer growing seasons.

Other Management Agencies:
1978-79: The Army Corps of Engineers completed an assessment evaluating nearshore habitat and the effect of various water level regimes on fish production in the Leech Lake (Wilcox 1979). It was recommended that water levels should be rising from April 15-May 15 to prevent exposure of Walleye and Northern Pike eggs, or limit the accessibility to or potentially strand Northern Pike in spawning areas.

1988-91: A hydrology and groundwater quality study was conducted from 1988-1991 (Lindgren 1996).

1992: The Leech Lake Band of Ojibwe completed a report evaluating water quality and productivity of Leech Lake (LLBO 1992). The report indicated good water quality was present and recommended alternatives for maintenance.

1993: Leech Lake River Basin Study Report: A watershed report and plan was sponsored by the Leech Lake Band of Ojibwe and the Cass, Hubbard, and Beltrami Soil and Water Conservation Districts (USDA 1993).

1997: A Water Quality Assessment of the Leech Lake Watershed: A watershed report sponsored by the Leech Lake Division of Resource Management and the Minnesota Chippewa Tribe (LLDRM 1997).

2010-Present: Watershed Restoration and Protection (WRAP) strategies outlined under the guidance of MN Pollution Control Agency (unpublished).

Invasive Species:
A number of invasive species have been identified in Leech Lake. These species and first record of presence include: rusty crayfish (Helgen 1990); heterosporosis (unknown); curly-leaf pondweed (unknown); Eurasian watermilfoil (Rivers 2005b); purple loosestrife (unknown), and banded mystery snail (2006; G. Montz, DNR, unpublished data).

Recent Fisheries Trends and Status

Walleye is currently the only species of sportfish in Leech Lake with special regulations (20-26 inch protected slot limit, possession limit of 4, one of which can be over 26”). Reduced daily and possession limits on Cisco and Lake Whitefish are in place on all waters within the Leech Lake Indian Reservation, which includes most of Leech Lake. Statewide regulations apply to all other species.

Walleye:
Walleye abundance in the mid-2000s was low relative to the historical time series. Relatively high angler pressure and harvest in the late 1990s and into the 2000s (Sledge 1999, 2000) combined with increasing cormorant abundance and predation during 2000-2004 to produce five of the weakest seven Walleye year classes observed since 1983 (Schultz et al. 2013). Starting in 2005, conservative regulations, cormorant management, Walleye fry stocking, and increased habitat protection were implemented concurrently to improve the Walleye population.

Walleye abundance improved rapidly in response to combined management actions and has remained relatively stable since 2007. Gill net catch rates have exceeded the long-term average during 2007-2014, female spawner abundance has been within or above the management objective range since 2010, average or stronger year classes were produced during 2010-2014, and targeting angler catch rates have been at or above the long-term average since 2008. Overall, the Walleye population has fully recovered. Mature female density exceeded the management objective range for several years prompting the relaxation of the protected slot limit from 18-26 inches to 20- 26 inches in 2014 to allow for increased angler harvest.

Yellow Perch:
Increased predation by double-crested cormorants resulted in low abundances of Yellow Perch during the early to mid-2000s (Schultz et al. 2013). Yellow Perch gill net catch rates were below the 25th percentile in 2005 when cormorant culling commenced, and by 2007 catch rates exceeded the 75th percentile. This rapid change was attributed to predation relief in conjunction with fast growth and high survival rates of Yellow Perch. However, as Walleye abundance continued to increase at both the juvenile and adult levels, predation pressure on Yellow Perch by Walleye also increased and indices of Yellow Perch abundance again declined. Yellow perch are the primary prey species for Walleye and most other predatory sportfish in the lake.

Yellow Perch gill net catch rates have had a decreasing trend since 2007 as the Walleye population recovered and active Walleye management activities continued through 2014. Yellow Perch gill net catch rates have fallen below the 25th percentile the past three years (2012-2014) and reached a historic low in 2013. The abundance of age-4 Yellow Perch recruiting to the fishery has also had a declining trend since 2007 while the percentage of Yellow Perch in gill nets ≥8 inches has been below the 25th percentile two of the past three years (2012-2014). Elevated predation by juvenile and adult Walleye and increases in total harvest of Yellow Perch by winter anglers are both suspected as primary causes of the most recent decline. A strong negative relationship exists between Yellow Perch recruitment and total Walleye fry density estimates from the same year class (Appendix B, Figure 4), and record Yellow Perch harvest was documented during the 2010-11 and 2014-15 winter angling seasons (Schultz and Vondra 2011, Stevens and Ward 2015). Due to record harvest of Yellow Perch the past two winter creel surveys, additional surveys will be conducted in both the winters of 2015-16 and 2016-17 to continue to monitor and evaluate harvest. Although some perceive cormorant consumption of Yellow Perch continues to have a significant influence on Yellow Perch recruitment, consumption by cormorants has been reduced by 90% relative to 2004 levels and are similar to pre-2000 levels (Schultz et al. 2013).

Northern Pike:
All metrics indicate the population is stable and low to moderate in abundance. The lakewide abundance continues to remain stable, with an average gill net catch rate of 4.7 fish/net over the past five years (1983-2014 average = 4.8 fish/net). The gill net catch rate of age-3 fish/net has remained between the 25th and 75th percentiles five of the past five years, indicating stable lakewide abundance of smaller individuals surviving to catchable sizes (i.e. stable recruitment). Additionally, the percentage of Northern Pike sampled in gill nets ≥22 inches has exceeded 30% for ten years in a row, indicating a stable abundance of mid-size and larger fish.

Other Sportfish Species:
Limited long-term data is available to review trends and status for other sportfish species, such as Black Crappie, Bluegill, Muskellunge, and Largemouth and Smallmouth Bass; these data sets are currently building.

Social considerations

The DNR recognizes the economic base supported by Leech Lake and the role fishing quality in Leech Lake has on the local quality of life. Communication and cooperation between the DNR and stakeholders, and the need for an adaptive management framework that provides context for framing biological and social questions and goals with stakeholder involvement is critically important. Adaptive management promotes flexible decision making that can be adjusted over time as outcomes from management actions and other events become better understood (i.e. learning by doing).

The DNR requested 16 stakeholders with diverse local and statewide interests provide input to the DNR on proposed management goals, objectives, and actions as the Leech Lake Fisheries Management Plan was updated for 2016-2020. The Leech Lake Fisheries Input Group (LLFIG) was formed in February 2015 and is represented by eight organizations: Leech Lake Association, Leech Lake Fishing Task Force, City of Walker, Leech Lake Area Watershed Foundation, Leech Lake Band of Ojibwe, Statewide Walleye Work Group, Statewide Northern

Pike and Muskellunge Work Group, and the Statewide Bass Work Group. In addition, eight members were selected from a statewide web-based application process. Open seats include two resort owners, two local business owners, a local guide, local angler, statewide angler, and a Fisheries professor from Bemidji State University. The LLFIG built upon the successes of the previous plan by providing input and recommendations on specific goals, objectives, and/or actions aimed at preserving a quality fishery on Leech Lake. The DNR will hold annual update meetings with the LLFIG and other interested stakeholders with the previous year's information and status with regards to the management plan. A weight of evidence approach will be used annually to assess if deviations from the management plan are appropriate.

Sportfish Population Goals, Objectives, and Actions

Outlining population goals, objectives, and associated management actions are important, as they are the tools for evaluating results that can be applied to future decision-making processes. Goals are broad qualitative statements encompassing what the management plan hopes to achieve for a particular species and objectives are specific quantitative statements that contribute to achieving the goal. Management actions are specific activities implemented either to build long-term data sets or when an objective is exceeded or fails to be met. Placing proposed objectives within their proper historical context (1983-present) and relative to 2011-2015 objectives is necessary for an expectation of what is either realistic or sustainable. For example, a Walleye gill net catch rate of 20 Walleye/net in Leech Lake is neither realistic nor sustainable as the Walleye gill net catch rate has never exceeded 14 Walleye/net and has only exceeded 9 Walleye/net seven times in the past 32 years. New to this management plan is the use of 3-year moving averages (most recent three observations) for most of the objectives. Moving averages are used to smooth the year to year variability and more closely reflect current trends. This management plan also attempts to be more representative of all sportfish species within the fish community, as Leech Lake supports a very strong and diverse multi-species fishery.

Walleye Goal:

Support a self-sustaining Walleye population that balances harvest opportunity with the opportunity to catch quality-sized fish while meeting reproductive needs.

Walleye Objectives:

Abundance. *Maintain Walleye gill net catch rate (3-year moving average) of 7-10 fish/net (40th-90th percentiles).*

Maintaining a stable abundance of Walleye benefits anglers and stabilizes recruitment. Walleye gill net catch rates have ranged from 4.6 fish/net (1993) to 13.4 fish/net (1988) during 1983-2014. The objective range of 7 to 10 fish/net represents the 40th and 90th percentiles. The objective under the 2011-2015 management plan was to maintain a gill net catch rate of ≥8.5 fish/net, the 75th percentile at the time. Maintaining a gill net catch rate at or above the 75th percentile is not realistic due to annual variability in the number of juvenile Walleye surviving to catchable sizes (i.e. recruitment) and relaxation of the protected slot limit (PSL) to allow for increased harvest opportunity (shift from 18-26 inch PSL to 20-26 inch PSL). For these same reasons, the upper end of the 2016-2020 objective range is aggressive, and will not be exceeded on a regular basis.

Peaks in gill net catch rates (i.e. catch rates ≥10 fish/net) have been attributed to a disproportionately large number of age-0 and/or age-1 fish being sampled relative to other years (1988, 1989, 1998, and 2007). Thus, gill net catch rates can be strongly influenced by recruitment variability, and the highs and lows in gill net catch rates tend to be driven by the frequency of unusually strong or weak year classes moving through the age-1 through age-6 age classes. Gill net catch rates can also be influenced by the growth rate of a particular cohort (gill net capture efficiency is related to the size of fish, particularly smaller and larger ones), and angler harvest which is typically correlated with pressure (angler hours). The objective range of 7 to 10 fish/net should accommodate for variability in catch rates over the duration of this plan, as gill net catch rates have remained within this range eight of the past ten years.

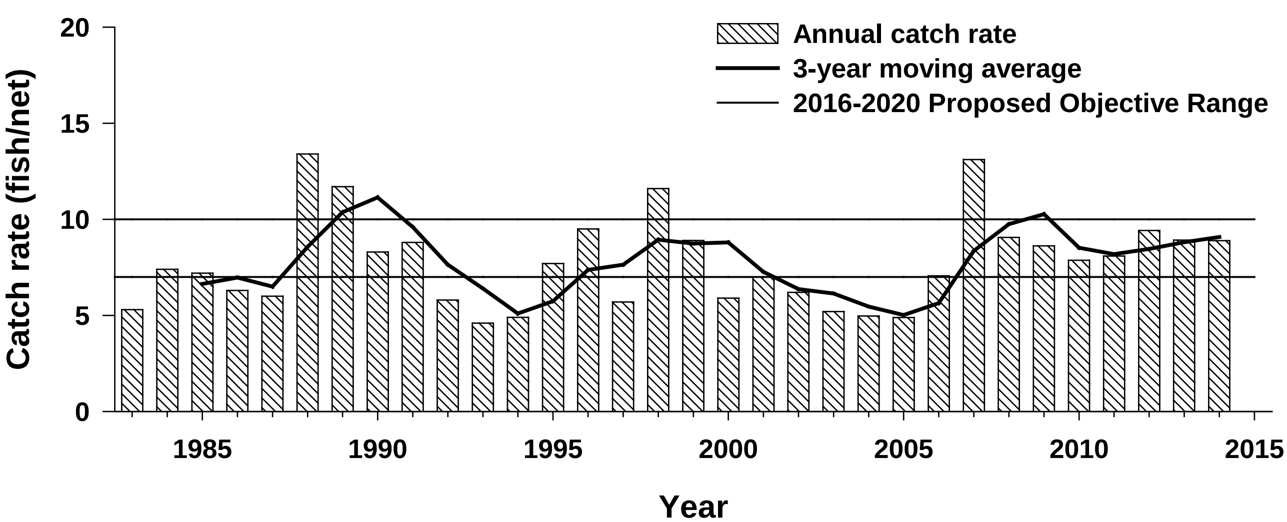

Figure 1. Gill net catch rates (fish/net) of Walleye in Leech Lake, 1983-2014. Horizontal lines represent the 40th and 90th percentiles. The darker line represents the 3-year moving average.

Reproductive Potential. *Maintain Walleye mature female biomass (3-year moving average) between 1.5-2.0 pounds/acre (50th-80th percentiles).*

Maintaining an adequate density of mature females (i.e. spawners) reduces recruitment variability and increases the relative abundance of subsequent year classes. Uncontrollable factors, such as weather, growing conditions, forage availability, density-dependence, and others, also influence year class strength. The density of mature females has ranged from 0.7 pounds/acre (1997) to 2.5 pounds/acre (2014) during 1989-2014. The values of 1.5 to 2.0 pounds/acre represent the 50th and 80th percentiles through this time series. Prior to 1989, maturity observations were not recorded for Walleye. The recruitment potential objective under the 2011-2015 management plan was to maintain a mature female density between 1.5 and 2.0 pounds/acre, the 60th to 90th percentiles at that time.

During 2005-2014 mature female density ranged from 1.0-2.5 pounds/acre, and overall Walleye fry densities during this time ranged from 61 to 779 wild fry/littoral acre and 237 to 908 total fry/littoral acre, respectively. Total fry densities were estimated by stocking known quantities of marked fry during 2005-2014 per the methods described by Logsdon (2006), and wild fry density was estimated by subtracting stocked fry density from total fry density. Stocking densities ranged from 129-391 fry/littoral acre (acres ≤15 feet deep).
For the seven years that mature female density exceeded 1.5 pounds/acre since 2005, wild fry densities have averaged 348 fry/littoral acre. The three years in which mature female densities were less than 1.5 coincided with the only three years subsequent Walleye year class strength index values were below average. Wild fry densities are expected to average between 270-370 fry/littoral acre relative to the mature female density range of 1.5-2.0 pounds/acre. Growth, survival, and recruitment of age-0 fish to the fishery increase as fry density decreases, and fry densities of 500 fry/littoral acre or higher have consistently resulted in lower recruitment. Given these observations over the past ten years, the current target range for spawner biomass is expected to be appropriate for supporting consistent fry production.

Spawner density is influenced by the strength of year classes reaching maturity, fishing pressure, and angler harvest. Walleye harvest regulations are an important tool for managing the Reproductive Potential objective. Adjustments to the existing 20-26 inch protected slot limit will be considered if mature female biomass continues to exceed the objective range of 1.5-2.0 pounds/acre and other key population metrics (Walleye and Yellow Perch gill net catch rates, the percentage of Walleye within the protected slot, lower than anticipated fishing pressure and Walleye harvest, and Walleye density dependence) indicate signs of an unbalanced Walleye population. Signs of density dependence include maturation at longer lengths and older ages, and below average growth and condition. The DNR will review the status of these metrics annually with the Leech Lake Fisheries Input Group. Regulation adjustment(s) over time should be used cautiously to avoid compulsive responses to short-term dynamics common to and frequent in Walleye populations, as over-reactive modifications could be detrimental to population balance and, in particular, the fishery it supports. Summer and winter creel surveys scheduled for 2016 and 2017 will provide critical information for considering potential Walleye regulation changes.

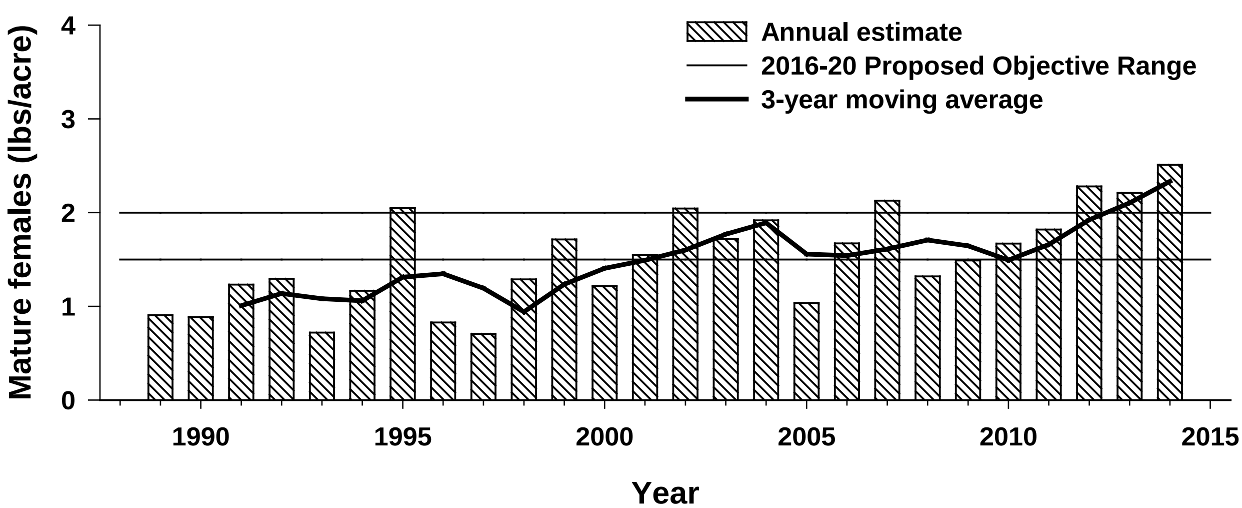

Figure 2. Estimated biomass (pounds/acre) of mature female Walleye in Leech Lake, 1989-2014. Horizontal lines represent the 50th and 80th percentiles. The darker line represents the 3-year moving average.

Size Structure. *Maintain the percentage of Walleye sampled in gill nets (3-year moving average) ≥20 inches between 10 and 20% (50th-80th percentiles).*

Maintaining a balanced size distribution of Walleye in a population ensures there are both fish available for angler harvest, and allows anglers the opportunity to catch larger sized individuals. Angler dissatisfaction with protective size regulations is often in response to the portion of their catch that they are required to release; this objective is intended to address that concern. The percentage of Walleye sampled in gill nets ≥20 inches has ranged from 2% (1984) to 26% (2006) during 1983 - 2014. The range of 10 to 20% represents the 50th to the 80th percentiles. The size structure objective under the 2011-2015 management plan stated that the proportion of Walleye sampled in gill nets ≤15 inches remain between 45-65%, the 25th - 75th percentiles at the time. The intent of this objective was to quantify the abundance of smaller fish entering the population that would be available for angler harvest. The Walleye recruitment objective accomplishes this also. The new size structure objective better reflects the effects of special harvest regulations on angler harvest.

Peaks in the percentage of larger Walleye sampled in gill nets (exceeding 20%) have occurred twice. The peak from 2005-07 was attributed to increased cormorant predation on juvenile Walleye shifting size structure to primarily larger individuals, and the peak from 2012-2014 was attributed to overshooting the management objective goal for female spawner abundance and triggered the relaxation of the protected slot limit (PSL). Cormorant control measures, angler pressure and harvest, and the current regulation play a key role in accomplishing this objective. If this management objective continues to be exceeded the weight of evidence approach will be used to assess if further modification of the PSL is appropriate.

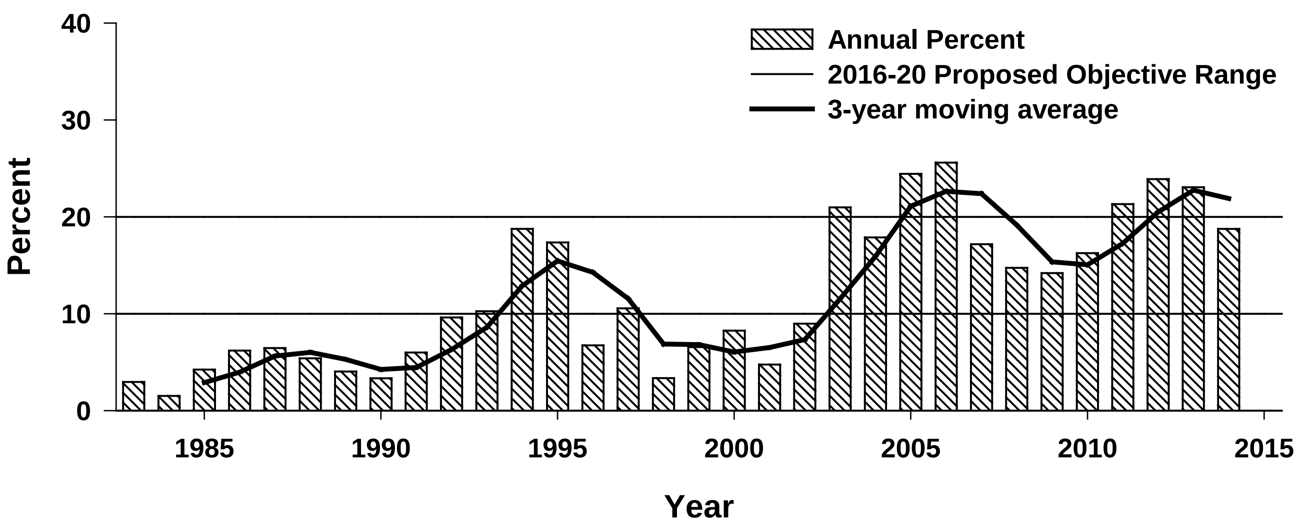

Figure 3. The percentage of Walleye in gill nets ≥20 inches in Leech Lake, 1983-2014. Horizontal lines represent the 50th and 80th percentiles. The darker line represents the 3-year moving average.

Recruitment. *Maintain Walleye year class strength index (3-year moving average) greater than 1.1 (25th percentile).*

Maintaining a stable number of juvenile Walleye surviving to catchable sizes (i.e. recruitment) ensures there are both fish available for angler harvest and sexually mature individuals entering the spawning population. Recruitment variability, or the variability in the size or strength of a year class, is influenced by a number of factors. These include spawner abundance, spawning conditions, juvenile density, length and intensity of growing season, predation, and prey abundance among others. Most recruitment concerns center on consecutive years where the year class strength index (i.e. the relative abundance of Walleye produced in an individual year) is below the 25th percentile. The 25th percentile is a threshold below which year class strength is defined as poor. Year class strength values have ranged from 0.30 (1993) to 2.30 (1988) during 1983-2014. The threshold of 1.1 refers to the 25th percentile for the 1983-2014 time series. The recruitment objective under the 2011-2015 management plan stated that year classes should have a measured strength at or above the long-term average (1983-2009 = 1.35) during two of four consecutive years. This objective was exceeded and the result was elevated predation pressure on the prey base, specifically Yellow Perch, and corresponding reductions in Yellow Perch recruitment.

Since 1983, the year class strength index has dropped below the 25th percentile for two consecutive years on two occasions, from 1992-1993 and from 2000-2004. The low experienced in 1992 and 1993 was attributed to those summers being several of the coldest on record since 1983 (i.e. having the fewest days with average air temperatures ≥50°F). Lower water temperatures result in reductions in growth, survival, and recruitment of Walleye, and this pattern was prominent throughout Minnesota (Schupp 2002). Year class strength values below the 25th percentile from 2000-2004 were attributed to increased cormorant predation (Schultz et al. 2013).

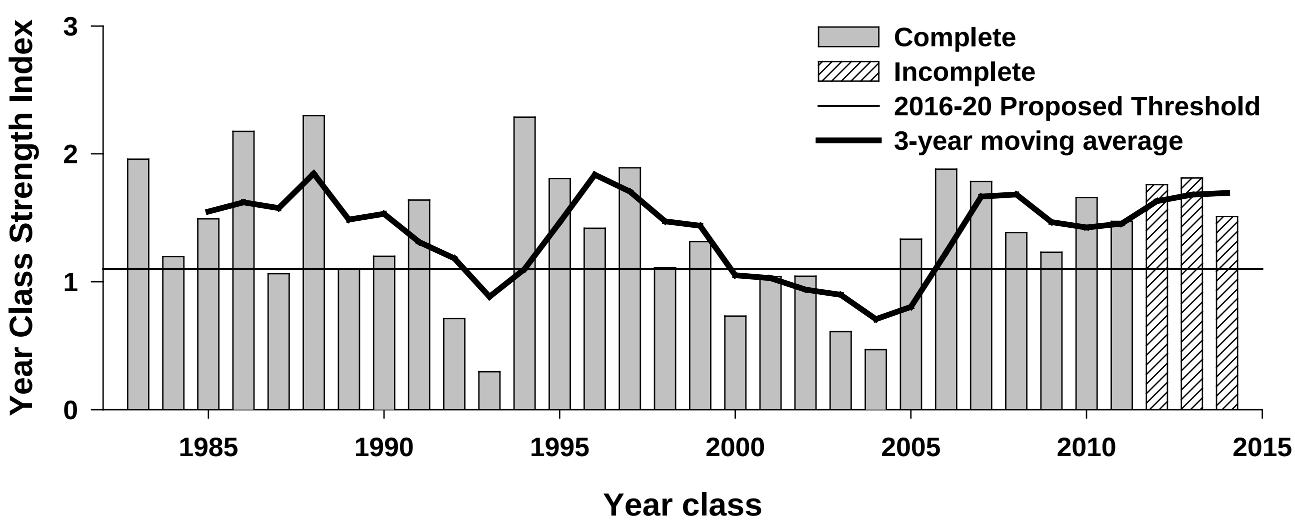

Figure 4. Year class strength index of Walleye in Leech Lake, 1983-2014. Both year classes fully recruited to the fishery and those still incomplete are indicated. The horizontal line represents the 25th percentile. The darker line represents the 3-year moving average.

Angler Catch Rate. *Maintain a targeting angler summer catch rate of 0.30 fish/hour or higher (50th percentile).*

Maintaining stable abundance of Walleye for anglers to catch and harvest is important, as Walleye are the species most frequently targeted by summer and winter anglers. Length limits, such as protective slot limits (PSLs), are intended to reduce or eliminate harvest of a particular size group of fish, improve size structure and/or improve the quality of fishing with higher catch rates and larger fish. Uncontrollable factors such as weather, forage availability, and others also influence angler catch rates

Targeting angler summer catch rates have ranged from 0.05 (2005) to 0.41 (2009) during 1991-2014. Prior to 1991, anglers were not asked what species they were fishing for and this metric could not be calculated. Targeting angler statistics are a more precise measure of fishing quality for a particular species than statistics generated across all anglers, as targeting anglers only fish for that particular species. The threshold of 0.30 represents the 50th percentile for the 1991-2014 time series. This threshold tracks well with good fishing experienced throughout the 1990s and 0.30 is an above average catch rate compared to the nine other 'large Walleye lakes' in Minnesota (Wingate and Schupp 1984).

The only angler oriented Walleye objective in the 2011-2015 management plan was harvest oriented. The angler oriented objective in the 2011-2015 management plan stated that the targeting angler summer harvest rate should be 0.25 fish/hour or higher. This objective was acknowledged as likely unachievable in light of the regulation change that was intended to reduce harvest. This objective also exceeded the 90th percentile for the 1991-2009 time series, which included pre-protected slot limit fishing seasons.

The two objectives in the 2016-2020 management plan (Angler Catch Rate and Angler Harvest) are intended to recognize catch and release anglers, the harvest oriented anglers, and the contribution of fish that are released due to the protected slot limit.

This objective is only applicable during years creel surveys are conducted.

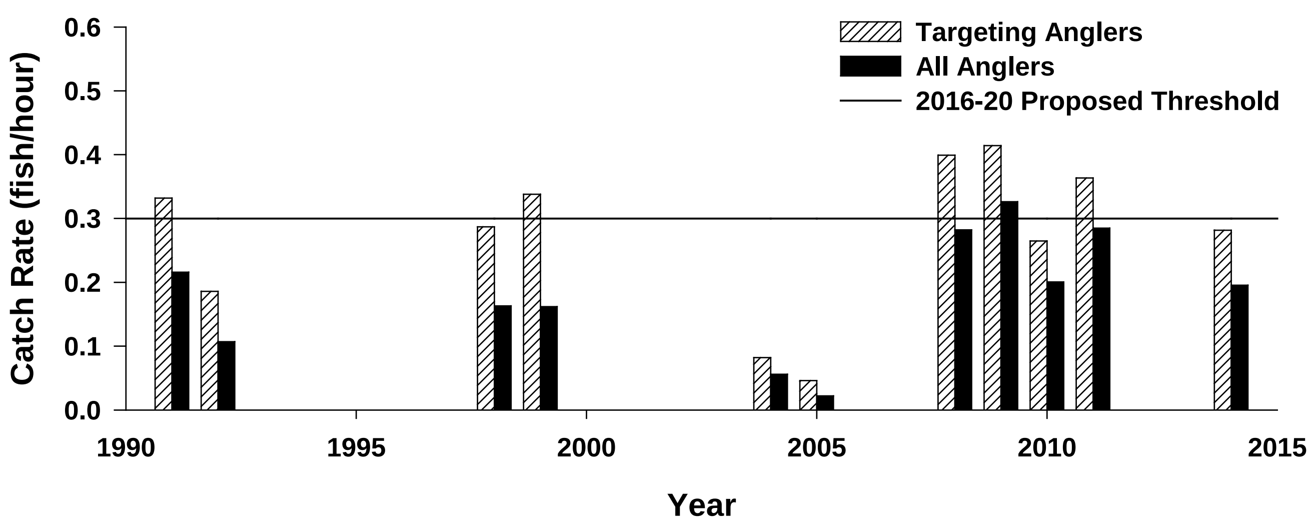

Figure 5. Angler catch rates of Walleye in Leech Lake, 1991-2014. Catch rates for targeting anglers and all anglers are indicated. The horizontal line represents the 50th percentile.

Angler Harvest. *Maintain annual total Walleye harvest between 130,000 - 190,000 pounds (50th-80th percentiles).*

Maintaining an angler oriented Walleye harvest objective is important, as it is a measure of fish returned to the angler. Walleye are the 1st and 3rd most harvested species by pounds in summer and winter, respectively. The total annual pounds of Walleye harvested have ranged from 6,881 (2005) to 224,310 (1966) during 1965-2014. The objective range from 130,000 to 190,000 pounds represents the 50th and 80th percentiles for the 1965-2014 time series. This range demonstrates that additional harvest is currently available and management steps have been taken to provide additional harvest opportunity (i.e. the relaxation of the protected slot effective 2014 Walleye opener). The total annual fishing pressure and regulation type will have strong influences on this objective.

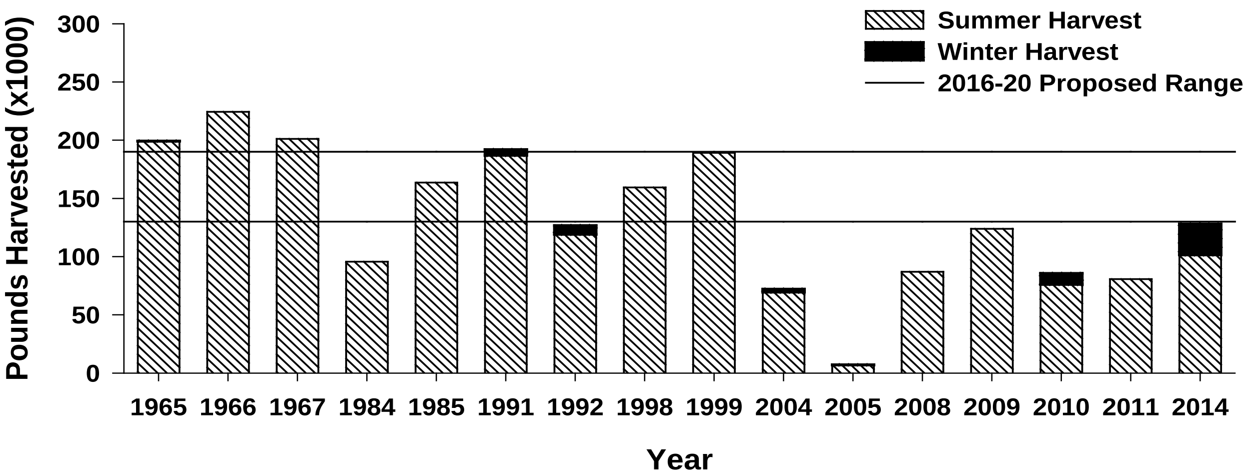

Figure 6. Total harvest (pounds x 1,000) of Walleye by Leech Lake anglers throughout summer and winter seasons, 1965-2014. Horizontal lines represent the 50th and 80th percentiles.

Condition. *Maintain Walleye condition factor (3-year moving average) between 82 - 86 (25th-75th percentiles).*

Walleye condition is assessed using relative weight (*Wr*), which is a ratio of individual weight versus its length (Murphy et al. 1990). Condition can be used as a surrogate to assess prey availability. If an individual has to increase the amount of energy expended to locate preferable prey or if it has to opt for less desirable prey, its condition values are lower. Lower Walleye condition values over the past several years coincide with the time period Yellow Perch gill net catch rates were below the 25th percentile. Walleye condition values have ranged from 78 (2011) to 90 (2004) during 1983-2014. Values of 82 and 86 are the 25th and 75th percentiles for the 1983-2014 time series. There was not a condition objective for Walleye in the 2011-2015 management plan.

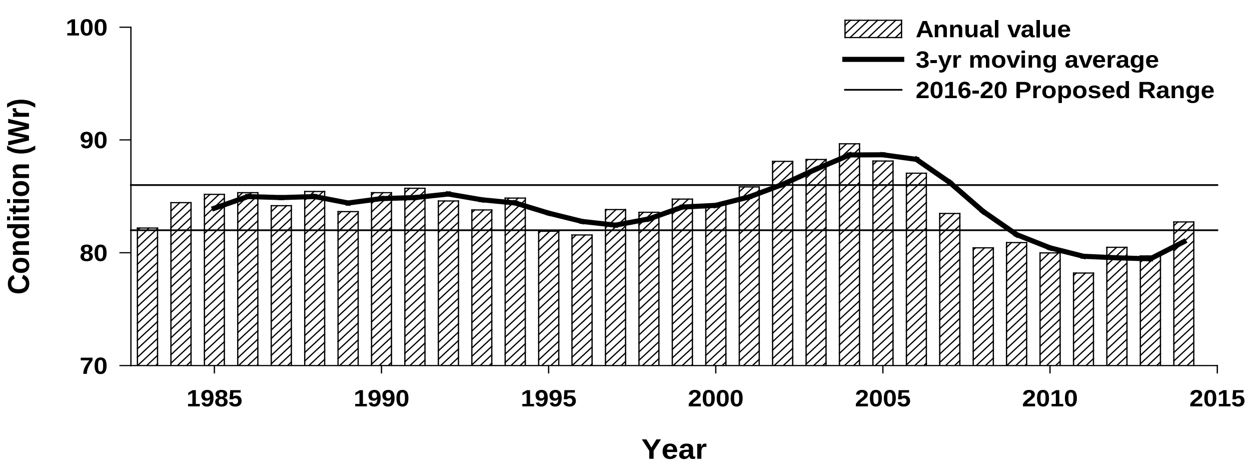

Figure 7. Annual mean condition (Wr) of Walleye in gill nets in Leech Lake, 1983-2014. Horizontal lines represent the 25th and 75th percentiles. The darker line represents the 3-year moving average.

Yellow Perch Goal:

Support a self-sustaining Yellow Perch population that provides both a stable prey base for sportfish and harvest opportunities for anglers.

Yellow Perch Objectives:

Abundance. *Maintain Yellow Perch gill net catch rate (3-year moving average) ≥16 fish/net (25th percentile).*

Yellow Perch are the primary prey species for most predator sportfish. Anglers also harvest more Yellow Perch (by number) than any other species throughout the year. Yellow Perch gill net catch rates have ranged from 12.1 fish/net (2013) to 37.7 fish/net (1995) during 1983-2014. The objective threshold of 16.0 fish/net is the 25^{th} percentile for the time series. The abundance objective under the 2011-2015 management plan was to maintain a gill net catch rate ≥16.3 fish/net, the 25^{th} percentile for that time series.

Although some variability in catch rates can be attributed to fluctuations in recruitment, the decline in perch catch rates from 1997-2005 occurred concurrently with marked increases in the cormorant population. Cormorant diet studies indicated that Yellow Perch were the principal prey of cormorants at that time (Schultz et al. 2013). Elevated predation by juvenile and adult Walleye and increases in total harvest of Yellow Perch by winter anglers are both suspected as primary causes of recent declines. In particular, a strong negative relationship exists between Yellow Perch recruitment and total Walleye fry density (Appendix 2, Figure 4). Recent steps taken to reduce predation pressure on Yellow Perch include reductions in Walleye fry stocking and expanded Walleye harvest opportunity for anglers. Based on the time series, 25^{th} percentile represents a threshold below which Yellow Perch recruitment and Walleye growth and condition are negatively impacted. From the perspective of sportfish management, maintaining Yellow Perch abundance above the 25^{th} percentile is necessary.

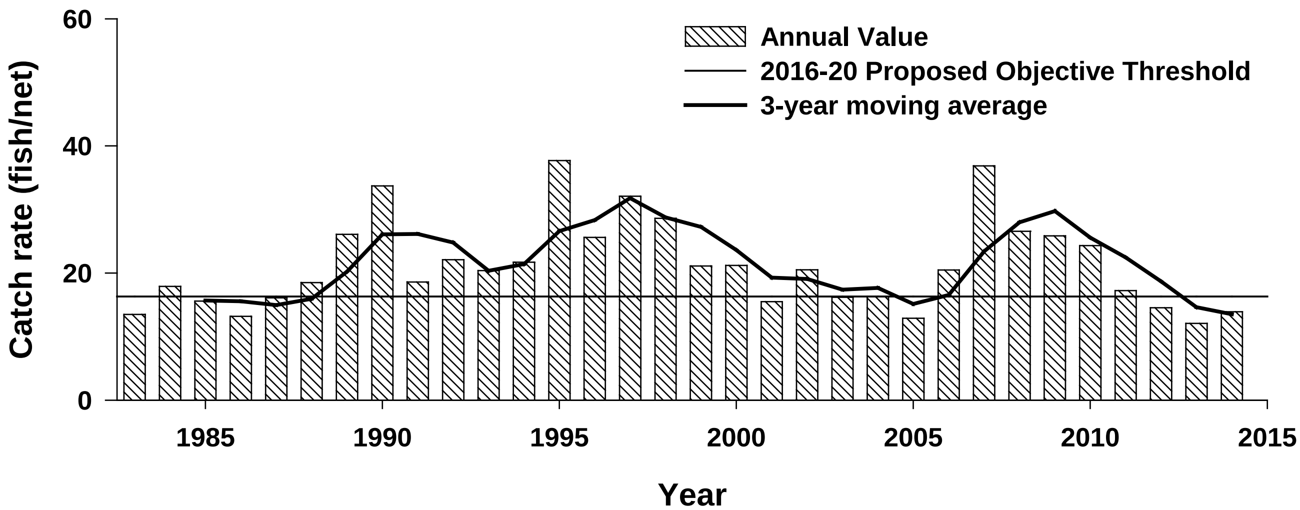

Figure 8. Gill net catch rates (fish/net) of Yellow Perch in Leech Lake, 1983-2014. The horizontal line represents the 25th percentile. The darker line represents the 3-year moving average.

Size Structure. *The percentage of Yellow Perch sampled in gill nets (3-year moving average) ≥8 inches should exceed 30% (25th percentile).*

Summer and winter anglers start harvesting Yellow Perch on Leech Lake at 8 inches. It is important to maintain a certain percentage of the Yellow Perch population that is of a size anglers elect to harvest. Acknowledging that Yellow Perch are managed as both a primarily prey species and as for a species angler harvest, we have established the 25th percentile (30%) for this time series as the management objective.

The percentage of Yellow Perch sampled in gill nets ≥8 inches has ranged from 20% (2014) to 49% (1999) during 1983-2014, and the threshold of 30% represents the 25th percentile for the time series. The size structure objective under the 2011-2015 management plan stated that the percentage of Yellow Perch sampled in gill nets ≥8 inches (PSD-8) and ≥10 inches (RSD-10) exceed the 25th percentile thresholds for the 1983-2009 time series, which were 30% and 7%, respectively (Murphy and Willis 1996). Although the previous objectives did quantify length-frequency data and the portion of the population that was sexually mature and large enough for anglers to catch, the method was complex.

The time periods where the metric fell below the 30% threshold for multiple years included the early to mid-2000s and two of the three years from 2012-2014. Reductions in the early to mid-2000s were attributed to elevated cormorant predation of juvenile Yellow Perch, which resulted in lower numbers of fish reaching harvestable sizes. Reductions in recent years are suspected to be attributed to elevated Walleye predation of juvenile Yellow Perch and elevated winter angler harvest of adults.

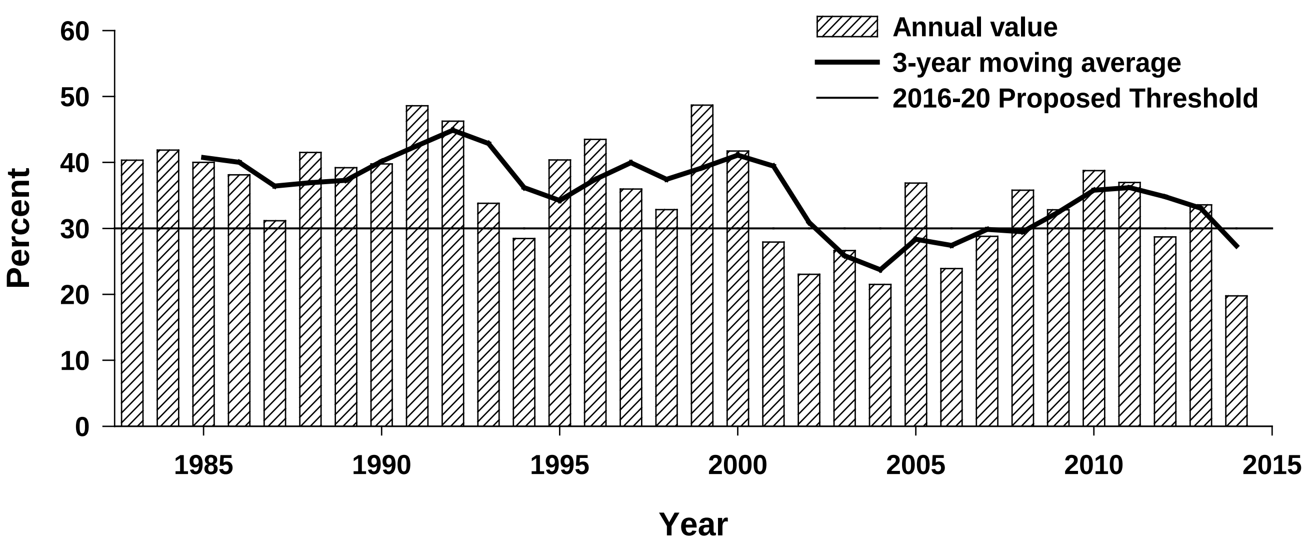

Figure 9. The percentage of Yellow Perch in gill nets ≥8 inches in Leech Lake, 1983-2014. The horizontal line represents the 25th percentile. The darker line represents the 3-year moving average.

Recruitment. *Maintain gill net catch rate (3-year moving average) of age-4 Yellow Perch ≥3.2 fish/net (25th percentile).*

Maintaining stable Yellow Perch recruitment ensures fish are both available for consumption by sportfish and angler harvest. Monitoring Yellow Perch recruitment is important as it is a metric that indicates increased mortality of juvenile Yellow Perch or declines in producion. Although young-of-the-year and age-1 Yellow Perch are annually sampled via seine in mid-July and bottom trawl in mid-August, there are no statistical relationships between the relative abundance of juvenile Yellow Perch sampled with standardized gears at standardized locations and the number of individuals sampled in gill nets. Likely reasons include the numerous bottlenecks present between juvenile life stages and maturity or gear type and sampling locations. Bottleneks include, but are not limited to climate shifts, consumption by predators, and abundance of alternative prey such as cisco for predators. Age-4 Yellow Perch are a size (approximately 7 inches on Leech Lake) at which all individuals in a year class are large enough to be sampled in a gill net yet are smaller than most anglers elect to harvest. Therefore, age-4 gill net catch rates are a good index of recruitment.

Yellow Perch gill net catch rates for age-4 individuals have ranged from 2.1 (2006) to 9.0 (2007) during 2001-2014. Yellow Perch were aged with scales prior to 2001 and sample sizes were small and not distributed around the lake; consequently, the data set used to calculate this metric is limited to 2001 and later. The threshold of 3.2 fish/net refers to the 25th percentile. Suspected reasons for the precipitous decline in gill net catch rates since 2007 include increased predation pressure by Walleye in response to aggressive Walleye management actions in previous plans. There was not a recruitment objective for Yellow Perch in the 2011-2015 management plan.

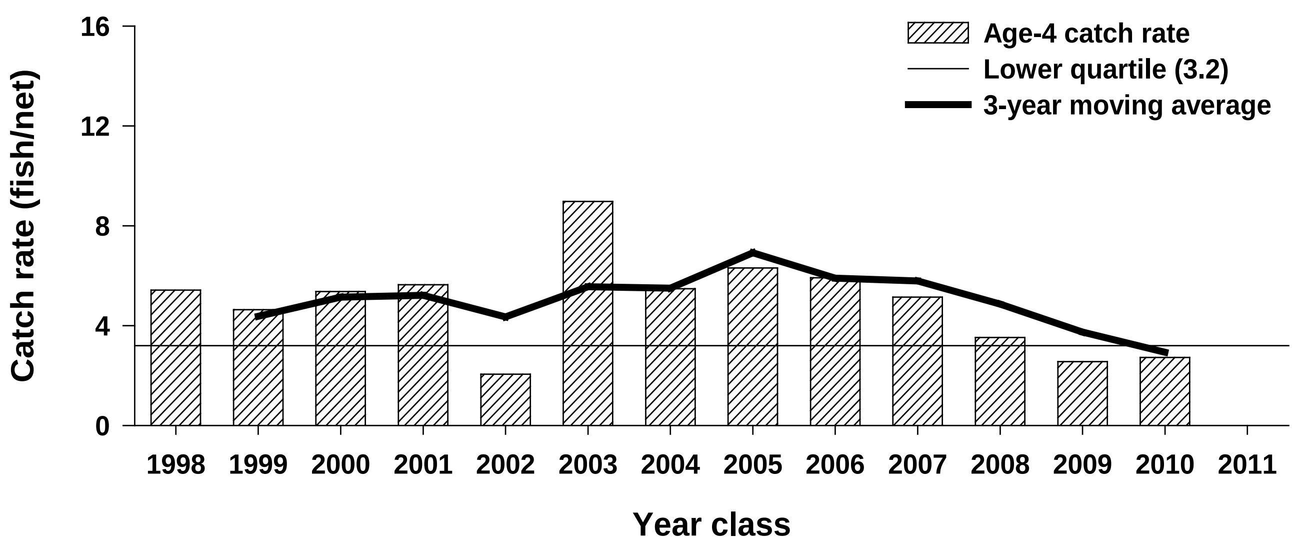

Figure 10. Gill net catch rates (fish/net) of age-4 Yellow Perch by year class in Leech Lake, 1998-2010. The horizontal line represents the 25th percentile. The darker line represents the 3-year moving average.

Angler Harvest. *The annual total Yellow Perch harvest should be less than 98,000 pounds.*

An angler oriented objective focused on Yellow Perch harvest is important, as it is a measure of fish returned to the angler. Yellow Perch are the 3rd and 1st most harvested species by pounds, by summer and winter anglers, respectively. The total annual pounds harvested (summer + following winter) have ranged from 28,909 (2004) to 160,217 (2010) between 1965 and 2014. The threshold of 98,000 pounds represents harvest levels below which angling quality is protected or enhanced (DNR 1997). If the annual pounds harvested exceeds the threshold on an infrequent basis, changes to population metrics (e.g. abundance, growth, age at maturity, etc.) will not likely be observed. Although the threshold can be exceeded in an individual year, sustained exceedance may result in changes to population metrics. For example, if annual total harvest consistently and significantly exceeds the objective, then growth rates may increase and maturity rates may decrease in response to elevated mortality. If harvest is driving this effect, then a noticeable decline in Yellow Perch ≥8.0 inches should also occur. Therefore, if annual harvest routinely exceeds the threshold and changes to population metrics similar to those described above are observed, then the weight of evidence approach should be used to determine if regulation modifications are appropriate. There was not an angler harvest objective for Yellow Perch in the 2011-2015 management plan.

Lower angler harvest in the mid-2000s corresponded with the declines in angler pressure at that time. Reductions in angler pressure and harvest in the mid-2000s was attributed to declines in Walleye and Yellow Perch abundance which corresponded with increases in cormorant abundance. Increases in angler pressure and harvest over the past five years, specifically in the winter, have resulted in unprecedented winter harvest of Yellow Perch. As a result, harvest and other population metrics (e.g. abundance, growth, and length at maturity, size structure) will be closely monitored during the life of this plan.

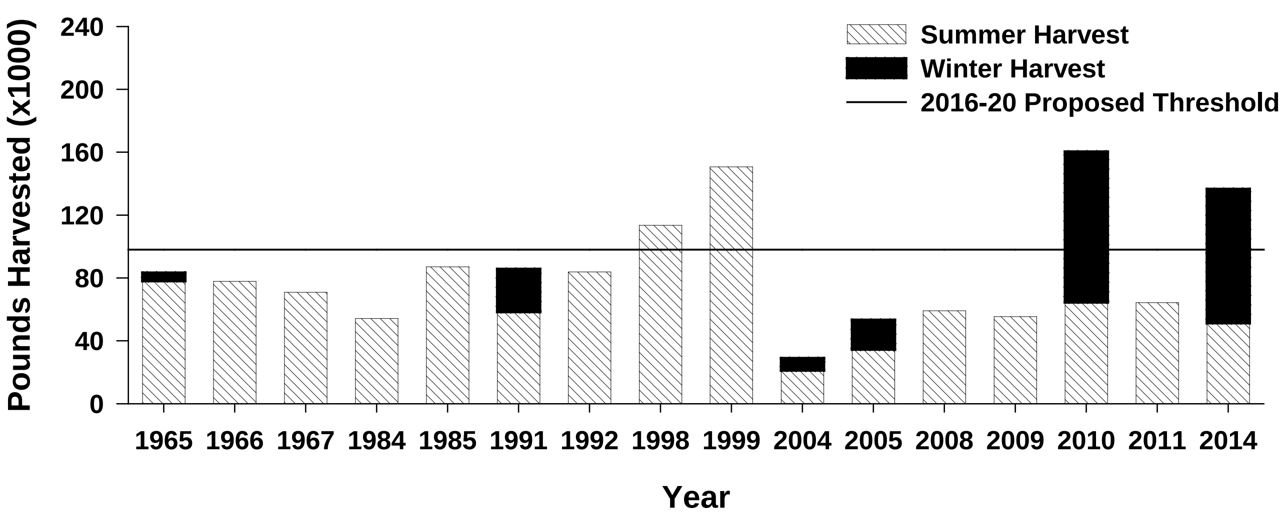

Figure 11. Total harvest (pounds x 1,000) of Yellow Perch by Leech Lake anglers throughout summer and winter seasons, 1965-2014. The horizontal line represents the harvest level below which angling quality is protected or enhanced (DNR 1997).

Maturity. *Female length at 50% maturity exceeds 5.5 inches.*

The length at which individuals become sexually mature is one of several metrics that can indicate overharvest or, more precisely, increased mortality. As mortality increases, populations respond by shifting more energy to reproduction than growth, resulting in maturation at shorter lengths. Changes in growth rate and recruitment patterns are two additional metrics that can indicate increased mortality.

Female length at 50% maturity refers to the length at which females have a 50% chance of being mature. That length was 6.2 inches in 2014. Therefore, individuals less than 6.2 inches had less than a 50% chance of being mature, while individuals greater than 6.2 inches had greater than a 50% chance of being mature. Prior to 2000, maturity observations were not recorded for Yellow Perch. Two distinct time periods exist within this time series, 2000-2005 and 2007-2014. From 2000-2005 when cormorant predation was excessive, female length at 50% maturity never exceeded 5.4 inches. Specifically, in 2002, 2004, and 2005, less than four immature individuals were sampled in gill nets, while no immature fish were sampled in 2006. However, from 2007 through 2014 the length at 50% maturity had an average of 6.3 inches (range 6.1-6.5), and greater than 65 immature individuals were annually sampled.

The differences in these metrics across the two respective time periods indicates the expected population responses by Yellow Perch to changes in mortality as cormorant abundance increased and was then reduced and maintained by control efforts (Schultz 2013). There was not a maturity objective for Yellow Perch in the 2011-2015 management plan.

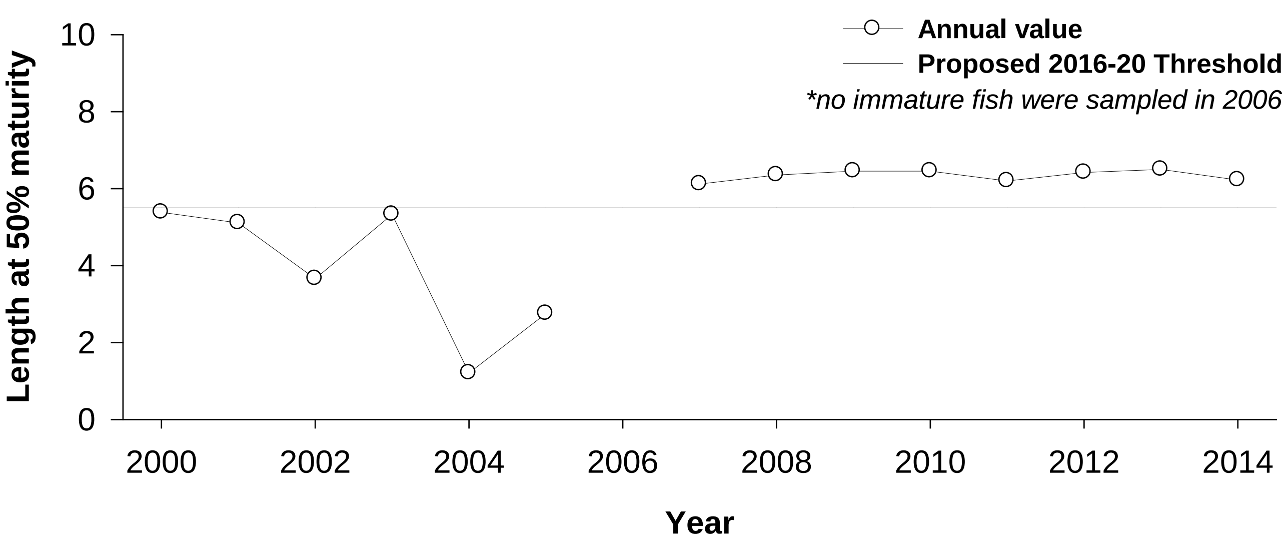

Figure 12. Total length of female Yellow Perch at 50% maturity in gill nets in Leech Lake, 2000-2014. The horizontal line represents the mortality threshold below which Yellow Perch matured at shorter lengths.

Northern Pike Goal:

Support a self-sustaining Northern Pike population that balances harvest opportunity with catch quality.

Northern Pike Objectives:

Abundance. *Maintain a gill net catch rate (3-year moving average) between 4.2 - 5.3 fish/net (25th and 75th percentiles).*

Maintaining a stable abundance of Northern Pike is important as they are the 2nd most harvested species (pounds) annually and comprise 5-10% of angling trips. Overall, gill net catch rates have varied little since 1983, ranging from 3.6 fish/net (1993) to 6.2 fish/net (1995) during 1983-2014. The objective range of 4.2 to 5.3 fish/net represents the 25th and 75th percentiles, respectively. The abundance objective under the 2011-2015 management plan was to maintain a gill net catch rate of 4.1 fish/net or higher, the 25th percentile for the 1983-2009 time series. Although catch rates exceeded the 25th percentile 9 of the past 10 years, having a threshold at the 25th percentile does not account for statewide concerns of increasing pike abundance. Therefore a range instead of a threshold is more appropriate. If gill net catch rates above the 75th percentile are sustained for consecutive years, then the weight of evidence approach should be used to determine if regulation modifications are appropriate. Growth and maturity rates, recruitment, and harvest statistics are additional metrics to monitor for determining the appropriateness of regulation changes.

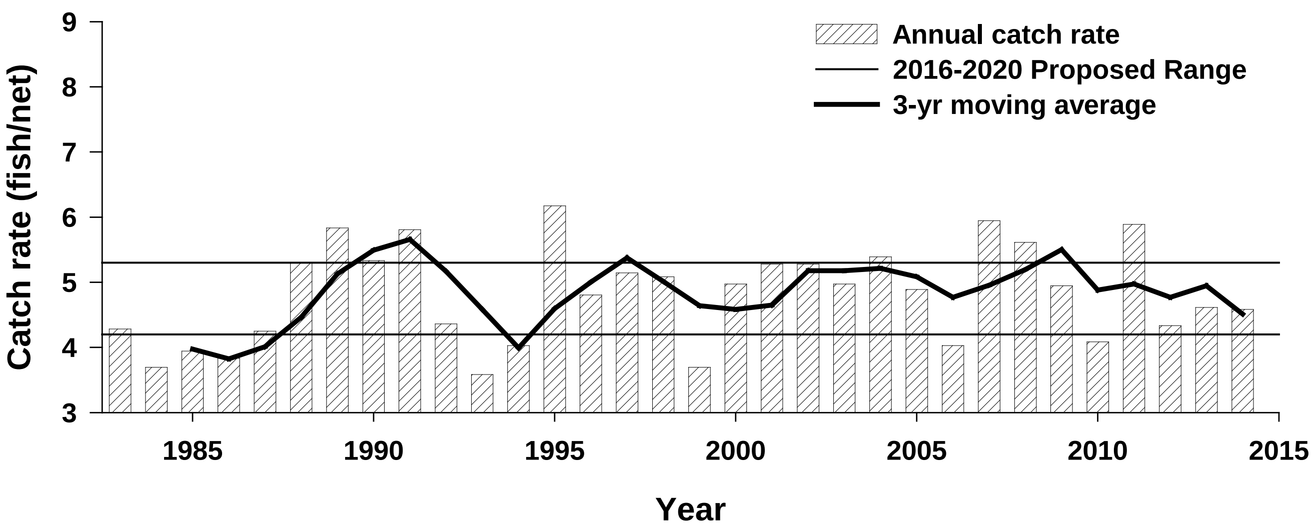

Figure 13. Gill net catch rates (fish/net) of Northern Pike in Leech Lake, 1983-2014. Horizontal lines represent the 25th and 75th percentiles. The darker line represents the 3-year moving average.

Size Structure. *The percentage of Northern Pike sampled in gill nets (3-year moving average) ≥22 inches should exceed 30% (25th percentile).*

Increases in the abundance of small Northern Pike can result in poor size structure, slow growth, increases in consumption of prey (Yellow Perch and Walleye), and lower harvest potential. Therefore, maintaining a balanced size structure of Northern Pike reduces the likelihood these conditions will occur and maintains the catch quality and harvest potential for anglers.

Anglers on Leech Lake begin harvesting Northern Pike at lengths of 22 inches. It is important to maintain a certain percentage of the Northern Pike population that is of a size anglers elect to harvest. The percentage of Northern Pike sampled in gill nets ≥22 inches has ranged from 22% (2001) to 62% (2007) during 1983-2014. The threshold of 30% represents the 25th percentile throughout the time series, and provides perspective on mid-size and larger individuals. The size structure objective under the 2011-2015 management plan stated the percentage of Northern Pike sampled in gill nets ≥21 inches (PSD-21) and ≥28 inches (RSD-28) exceed the 25th percentiles for the 1983-2009 time series, which were 43% and 5% respectively (Murphy and Willis 1996). Although the previous objectives did quantify length-frequency data and the portion of the population that was sexually mature and large enough for anglers to catch, the metric was overly complex.

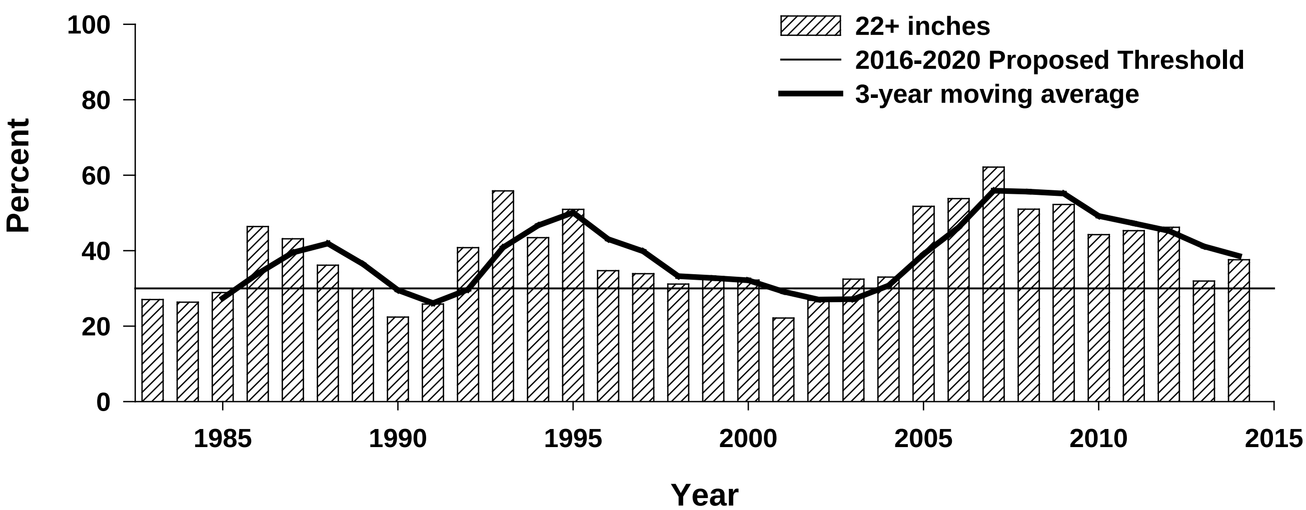

Figure 14. The percentage of Northern Pike in gill nets ≥22 inches in Leech Lake, 1983-2014. The horizontal line represents the 25th percentile. The darker line represents the 3-year moving average.

Recruitment. *Maintain gill net catch rate of age-3 Northern Pike (3-year moving average) between 1.0 - 1.6 fish/net (25th and 75th percentiles).*

Maintaining a stable number of juvenile Northern Pike recruiting to the fishery ensures there are both fish available for anglers and sexually mature individuals continually entering the spawning population. Most Northern Pike concerns center on the elevated abundances of small pike and this objective provides perspective on smaller sized individuals. Age-3 Northern Pike are a size (approximately 18-19 inches) at which all individuals in a year class are large enough to be sampled by gill nets, yet are smaller than most anglers elect to harvest. Therefore, age-3 gill net catch rates are a good index of recruitment.

Northern Pike gill net catch rates for age-3 individuals have ranged from 0.4 (1993) to 2.4 (2004) during 1990-2014. Northern Pike were aged with scales prior to 1990; consequently, the data set is limited to when cleithera have been used as the aging structure. The ranges of 1.0 and 1.6 refer to the 25th and 75th percentiles, respectively. Maintaining gill net catch rates between 1.0 and 1.6 fish/net indicates stable lakewide recruitment. There was not a recruitment objective for Northern Pike in the 2011-2015 management plan.

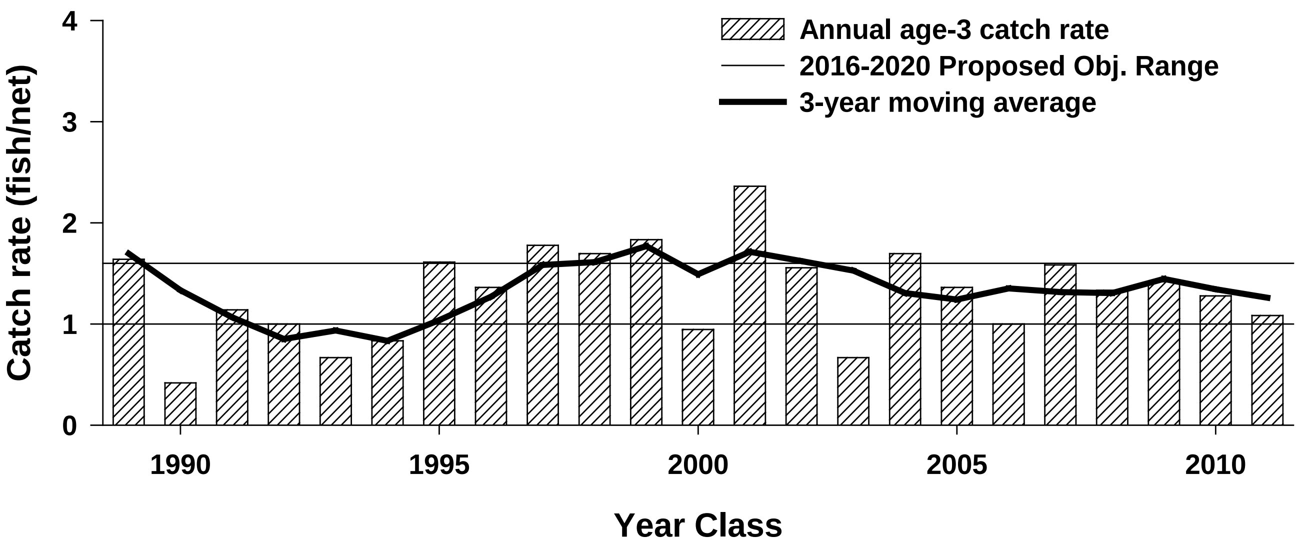

Figure 15. Gill net catch rates (fish/net) of age-3 Northern Pike by year class in Leech Lake, 1998-2011. Horizontal lines represent the 25th and 75th percentiles. The darker line represents the 3-year moving average.

Management Actions

Fisheries Assessments

Annual Large Lake surveys

Annual surveys will continue to include water quality and seining in mid-July, trawling in mid-August, electrofishing in mid-September, gill netting in mid-September, water temperature loggers (recording hourly year round), and monthly zooplankton sampling (mid-May through mid-October).

Creel surveys

Summer and winter creel surveys will be conducted two of every six years. The next scheduled creel surveys on Leech Lake are for the summer of 2016 and 2017, and the winters of 2015-2016 and 2016-2017. Angler satisfaction surveys will be incorporated into future creel surveys at the request of the Leech Lake Fisheries Input Group.

Fall Electrofishing for YOY Walleye

To date, a combination of trawl and gill net catch rates at age-0 have been used to predict year class strength. The estimated year class strength at age-1, age-2, and age-3 is determined based solely on gill net catch rates. Age-3 Walleye are considered fully recruited to the fishery. The multivariate (multiple years) method for predicting age-0 year class strength has greater precision over the trawl-only prediction model (Schultz 2007), though both are subject to the high uncertainty surrounding young-of-year catch rates and first-year survival. These methods will continue to be refined as additional years and new gears are assessed. Electrofishing in mid-September was initiated in 2007 and appears to be a more accurate predictor of age-0 Walleye year class strength. If this relationship holds up over the next several years, we will consider switching from trawling to electrofishing as the primary indicator of year-class strength.

Bluegill, Black Crappie, Largemouth Bass, and Smallmouth Bass Sampling

Continue to conduct lakewide bluegill, black crappie, largemouth bass, and smallmouth bass assessments every three years, and standardize sampling methodology, locations, and timing by 2018. Monitor for potential changes in size structure and catch rates. The next scheduled survey is in 2018.

Muskellunge Sampling

Insert Passive Integrated Transponder (PIT) tags in all Muskellunge adults sampled during spawn take operations in Miller's Bay and all fingerlings returned to Leech Lake under the traditional DNR put-back policy during spawn take years. Leech Lake is the source stock for the statewide Muskellunge propagation program and tagging adults and fingerlings facilitates the opportunity for:

1) Tracking individuals mated during spawn take operations
2) Point observations of length-at-age and growth rates for repeat captures
3) Known-age fish for eventual validation of anal fin rays as an ageing technique, or to better describe the limitations of this method

While marking adults and fingerlings is necessary to determine adult population estimates, the sample size will potentially be limiting to assess survival and recruitment of stocked fish and to estimate natural reproduction.

Cisco and Whitefish Sampling

Coordinate with the Leech Lake Band of Ojibwe, Division of Resource Management to collect additional Cisco and Lake Whitefish data from the commercial fishery.

Burbot Sampling

Annually collect data from a subsample of Burbot registered at the Leech Lake Eelpout Festival. Burbot are a cold-water sensitive species that are poorly understood. Interest in Burbot has increased in recent years with numerous anglers inquiring why this species is not a sportfish. The collection of biological information to better understand population characteristics and dynamics is necessary.

Stocking & related activities

Walleye Fry Stocking

The DNR recognizes stocking is a valuable management tool when used to meet specific management objectives. In general, stocking has not been necessary for maintenance of Walleye populations in Minnesota's large natural Walleye lakes. However, a policy of returning a percentage of fry back to the source waters where spawn take operations are conducted exists.

Stocking OTC-marked Walleye fry (i.e. oxytetracycline-marked) was one of four tools used to increase Walleye abundance in Leech Lake following a decline in the fishery during the early to mid-2000s. Annual fry stocking densities during 2005-2014 ranged from 7.5 to 22.5 million fry. The use of variable densities of marked fry facilitated a thorough evaluation of total fry density effects on first-year growth and eventual recruitment to the fishery (Appendix 2, Figures 1-4).

These analyses have determined that:

- higher fry stocking rates have not resulted in more Walleye surviving to catchable sizes.
- higher fry stocking rates have resulted in slower growth rates for young-of-the-year Walleye.
- slower growth rates of young-of-the-year Walleye result in fewer Walleye surviving to catchable sizes.
- higher Walleye fry densities have increased predation on young-of-the-year Yellow Perch, resulting in lower abundances of Yellow Perch surviving to age-4.
- as Yellow Perch are the primary prey of Walleye, lower Yellow Perch abundances have resulted in below average adult Walleye condition (plumpness) and growth rates (see Walleye Condition objective).

Although annual stocking of Walleye fry is not necessary at this time on Leech Lake, it is important to outline circumstances when it would be an appropriate and/or an informative management action. Most recruitment concerns center on consecutive years where the year class strength index (i.e. the relative abundance of Walleye produced in an individual year) is below the 25th percentile. The 25th percentile is a threshold below which year class strength is defined as poor, and the most recent occurrence of this was during the early 2000s when cormorant predation was later determined to be excessive (Schultz et al. 2013). Cormorant control, Walleye stocking, and restrictive Walleye harvest regulations were all simultaneously implemented in 2005 to improve the Walleye population. Research indicates the current level of cormorant control is appropriate, and the stocking evaluation indicates wild fry production is sufficient to sustain a robust Walleye population. Discontinuation of walleye stocking as an annual management action in 2015 was based on strong empirical evidence indicating negative impacts of supplemental fry stocking. Thus, this management plan is testing the validity of the current cormorant control target in the absence of walleye fry stocking. Close monitoring of Walleye recruitment in the absence of fry stocking is the next step in fully evaluating cormorant impacts on the fishery.

This plan includes two scenarios when Walleye fry will be stocked. The first is directly related to the Walleye Recruitment objective (see figure on page 15). The action states that if the 3-year moving average (of year class strength index values) falls below the 25th percentile (for the 1983-2014 time series) 7.5 million Walleye fry will be stocked the following year. This stocking density has performed similarly to higher densities and minimizes the potential for negative effects on first-year Walleye growth, survival, and recruitment to the fishery as well as minimizing predation pressure on the Yellow Perch. Furthermore, failing to meet the recruitment objective one or more years would suggest revisions to the cormorant target may be warranted.

The second scenario when Walleye fry stocking action would be implemented would be for research purposes to expand on the range of total fry density observations (currently 237-908 fry/littoral acre) when yearly mature female density is below 1.25 pounds/acre or above 2.75 pounds per acre. The action states if the mature female density estimate observed in a single year is below 1.25 or above 2.75 pounds/acre, a low-density fry stocking will be considered the following year. A weight of evidence approach will be used to determine if implementing this action will pose low risk to Walleye or other sportfish populations, particularly Yellow Perch.

Any stocked Walleye fry will originate from the Boy River (Cass County) and will be marked with OTC prior to stocking. This genetic stocking strategy is based on recommendations from the University of Minnesota which determined that the Boy River strain is the most similar and appropriate strain to use in Leech Lake (Miller 2007). Other recommended strategies for reducing the risk for adverse population impacts at the genetic level include stocking early life stages (fry instead of fingerlings), stocking fewer fish, stocking less often, and not stocking from multiple sources (e.g. other strains).

Muskellunge Spawn Take and Fingerling Stocking

Conduct Muskellunge spawn take operation every four years in Miller's Bay to maintain genetic diversity in brood stock lakes. To compensate for removing gametes during the Muskellunge spawn take operation, approximately 600 fingerlings will be returned to Leech Lake under the traditional DNR put-back policy on systems with spawn take operations. The next scheduled spawn take is in 2017.

Regulations

Walleye regulations

The existing Walleye regulation (20-26 inch protected slot limit, possession limit of 4, one over 26 inches allowed in possession) will be continued. If mature female biomass remains outside of the target range for several consecutive years, more liberal or restrictive regulations may be considered.

Whitefish and Cisco regulations

The existing bag limits (25 daily and 50 in possession) on Cisco (Tullibee) and Lake Whitefish within the Leech Lake Indian Reservation will be continued.

Potential Sunfish and Black Crappie regulations

The Leech Lake Fisheries Input Group requested DNR consider and evaluate bag limit reductions on panfish species to maintain the existing size quality of the populations.

Other species managed with statewide regulations

If changes to statewide regulations occur, implement regulations consistent with statewide recommendations and evaluate angler and fish population responses through standardized creel and gill net surveys.

Habitat

Protection

Many of the proposed habitat management actions will require additional funding and/or staff, or rely heavily on partner agencies or non-governmental organizations (NGOs) and will only be possible when specific opportunities present themselves (Appendix C). DNR Fisheries will make recommendations or support actions with other non-government organizations and/or government agencies as appropriate to protect the aquatic resource.

DNR will continue to cooperate and partner with NGOs to identify and acquire critical shoreland habitat through fee title and conservation easements. Five Mile Point and Miller's Bay (Whipholt) have been identified as high priority areas for acquisition because they are Muskellunge spawning areas and potentially sensitive to anthropogenic disturbance. Prioritizing additional areas for acquisition can be accomplished using findings from the Cass County Sensitive Shorelands project, Minnesota Pollution Control Agency's WRAPS program (Watershed Restoration and Protection Strategy), and other habitat-oriented evaluations.

DNR will continue to thoroughly review project proposals requiring a permit within the context of short- and long-term environmental impact.

Nearshore Habitat Inventory
Explore options for performing an inventory of nearshore aquatic habitat in Leech Lake, including substrate, vegetation, fish species presence, and human use.

Aquatic Vegetation Inventory
Explore options for performing an inventory of lakewide aquatic vegetation stands to identify potential long-term trends in species composition, abundance, and distribution.

Muskellunge Spawning Habitat Assessment
Explore options for performing a telemetry study to identify additional Muskellunge spawning locations to guide future priorities for shoreland protection.

Aquatic Invasive Species (AIS) management & education
Coordinate with DNR Ecological and Water Resources staff and Cass County Environmental Services to assist with aquatic invasive species prevention, education, and management efforts by DNR Ecological and Water Resources Division and other agencies.

Other Considerations

Double-crested cormorant control & evaluation
The Leech Lake Band of Ojibwe, Division of Resource Management (DRM) has jurisdiction over the double-crested cormorant control policy on tribal lands and waters on Leech Lake. The DNR supports maintaining the population at 500 reproducing pairs which equates to a total fall population at or below 2,000 cormorants. The annual removal of most birds earlier in the year will continue to be supported as this reduces total fish predation and is included under the existing federal Public Resource Depredation Order. The DNR will continue to support DRM's efforts to secure funding sources and provide technical assistance for continued cormorant control and research evaluating cormorant impacts on Leech Lake sportfish populations as requested by DRM.

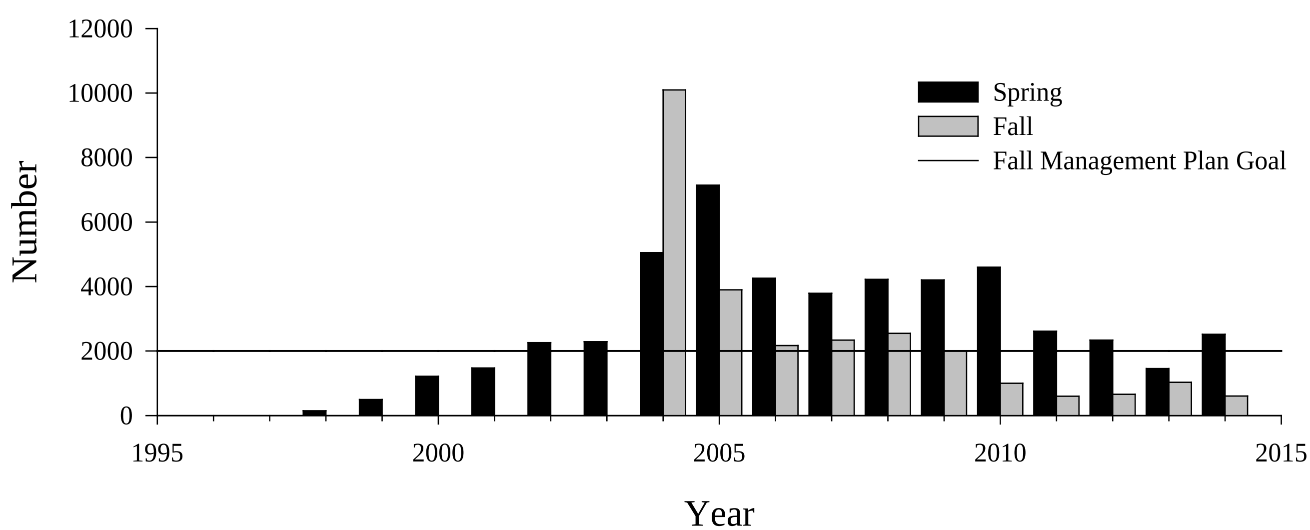

Figure 16. Spring and fall Double-Crested Cormorant numbers on Leech Lake, 1998-2014. The line depicts the current fall population goal of 2,000 birds ([500 nesting pairs x 2 adults] + 2 offspring/nest). (S. Mortensen, Division of Resource Management, Leech Lake Band of Ojibwe, personal communication).

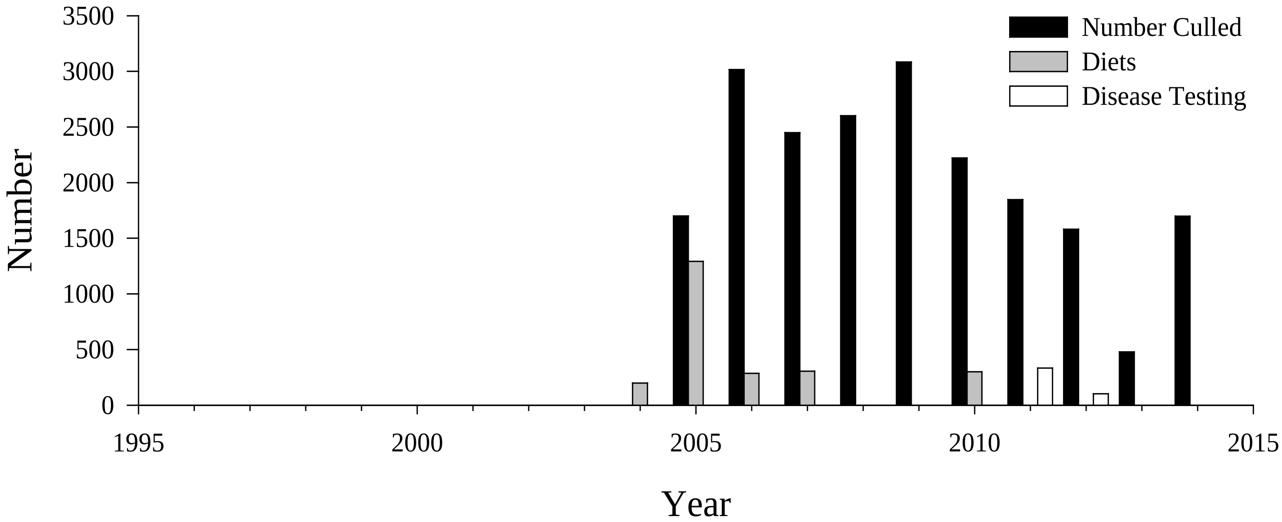

Figure 17. The number of Double-Crested Cormorants culled on Leech Lake, 2000-2014. The number of additional birds culled for diet and disease testing is also indicated. (S. Mortensen, Division of Resource Management, Leech Lake Band of Ojibwe, personal communication).

Climate effects on Walleye populations

Continue to evaluate climate effects on Walleye recruitment, specifically length and intensity of the growing season (i.e. growing degree days; GDD_{50}=GDD ≥50°F). Annual GDD_{50} values were calculated using water temperature data from loggers deployed in Leech Lake by the DNR. Growing season length and intensity have a strong influence on Walleye first-year growth and eventual recruitment (Appendix 2 Figures 5 and 6).

Muskellunge Tournament Data

Evaluate the potential for collecting additional data from participants during various Muskellunge tournaments. Options to consider include diaries, "creel forms", and others to monitor catch rates, size structure, etc.

Largemouth Bass Tournaments

The Leech Lake Fisheries Input Group requested DNR explore options for determining bass re-redistribution needs following tournaments if the number of tournaments increases to pre-2014 levels.

Annual stakeholder meetings

Annual update meetings with the LLFIG will occur in March. The purpose of these meetings during will be to share current data and information with the LLFIG and other interested stakeholders. Management objectives and actions delineated in this document are intended to provide the framework for management for the next five years. Most management objectives and actions outlined here are directed at fish populations. Consequently, time is required for these populations to respond via metrics, such as recruitment, growth, and maturity rates, to the effects any management actions may be having. While adaptive management relies upon "learning by doing", appropriate timelines are needed to ensure the outcomes of management actions can be accurately assessed and lessons learned can be applied to future decision-making processes.

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Appendix A.

A comparison of the 2005-2010, 2011-2015, and 2016-2020 Fisheries Management Plan objectives for Leech Lake.

	Management Plan		
Walleye	*2005 – 2010*	*2011 – 2015*	*2016 – 2020*
Female spawner abundance (pounds/acre)	1.25 – 1.75 (50^{th} - 80^{th} percentiles)	1.5 – 2.0 (60^{th} - 90^{th} percentiles)	3-year running average between 1.5 – 2.0 (50^{th} - 80^{th} percentiles)
Abundance (fish/gillnet)	≥7.4 (60^{th} percentile)	≥ 8.5 (75^{th} percentile)	3-year running average between 7-10 (40^{th} - 90^{th} percentiles)
Gillnet size distribution	50% < 15” (40^{th} percentile)	45 – 65% ≤ 15” (25^{th} - 75^{th} percentiles)	3-year running average between 10-20% ≥20" (50^{th} - 80^{th} percentiles)
Year class strength (recruitment)	Two strong year classes by 2009 (≥75^{th} percentile)	Average or stronger year classes produced 2 out of 4 years (50^{th} percentile)	3-year running average >1.1 (>25^{th} percentile)
Age 1 abundance	Age-1 trawl catch rate 45 fish/hour (50^{th} percentile)	None	None
Angler catch (fish/hour)	None	None	Targeting angler summer catch rate ≥0.30 (50^{th} percentile)
Angler harvest	None	Targeting angler summer harvest rate 0.25 (fish/hour) (90^{th} percentile)	Annual pounds harvested between 130,000 and 190,000 (50^{th} and 80^{th} percentiles)
Natural reproduction	None	Natural reproduction alone can maintain population	None
Condition	None	None	3-year running average between 82 and 86 (25^{th} and 75^{th} percentiles)
Yellow Perch			
Abundance (fish/net)	None	≥16.3 (25^{th} percentile)	3-year running average ≥16 (25^{th} percentile)
Gillnet size distribution	None	Proportion ≥8 inches (PSD-8) and ≥10 inches (RSD-10) (25^{th} percentiles)	3-year running average ≥8 inches exceeds 30% (25^{th} percentile)
Year class strength (fish/net; recruitment)	None	None	3-year running average age-4 perch ≥3.2 (25^{th} percentile)
Angler harvest	None	None	Harvest should be ≤98,000 pounds annually[1]
Maturity	None	None	Female length at 50% maturity >5.5"
Northern Pike			
Abundance (fish/net)	None	≥4.1 (25^{th} percentile)	3-year running average between 4.2 and 5.3 (25^{th} and 75^{th} percentiles)
Gillnet size distribution	None	Proportion ≥8 inches (PSD-21) and ≥10 inches (RSD-28) (25^{th} percentiles)	3-year running average ≥22 inches exceeds 30% (25^{th} percentile)
Year class strength (fish/net; recruitment)	None	None	3-year running average age-3 catch rate between 1.0 and 1.6 (25^{th} and 75^{th} percentiles)

[1]Threshold established in MNDNR 1997; Special Publication 151

Appendix B.

Relationships observed thorough the evaluation of total Walleye fry density effects on first-year growth and eventual recruitment to the fishery.

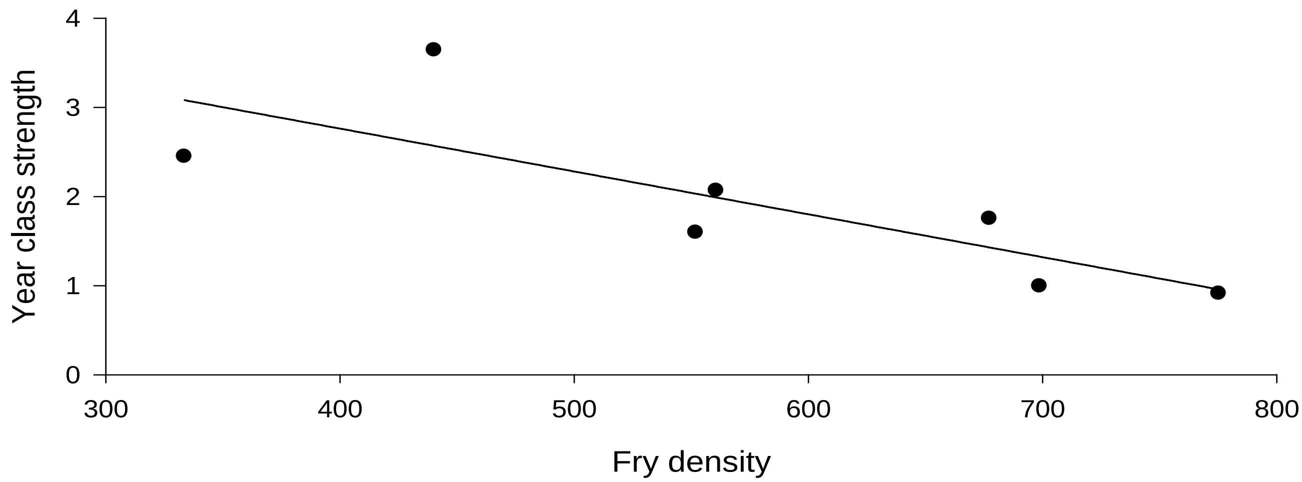


Figure B1. Estimated total Walleye fry density (fry/littoral acre, i.e. depths ≤15 feet) and the resulting strength of stocked year classes, 2005-2011. Year classes are considered fully recruited at age-3.

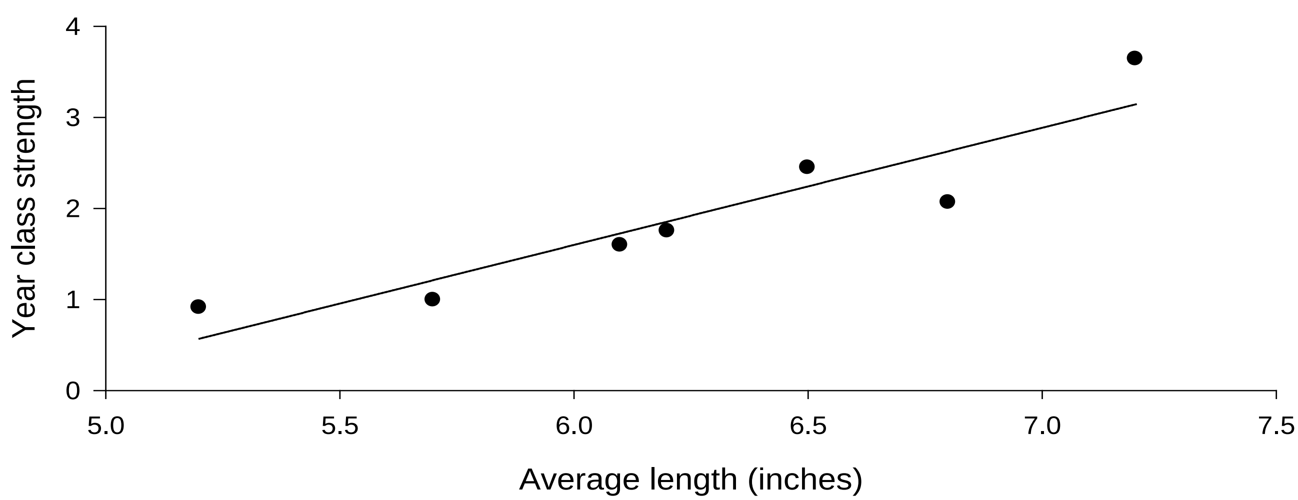


Figure B2. Estimated total Walleye fry density (fry/littoral acre, i.e. depths ≤15 feet) and the average length (inches) of young-of-the-year Walleye sampled by electrofishing in mid-September, 2005-2014.

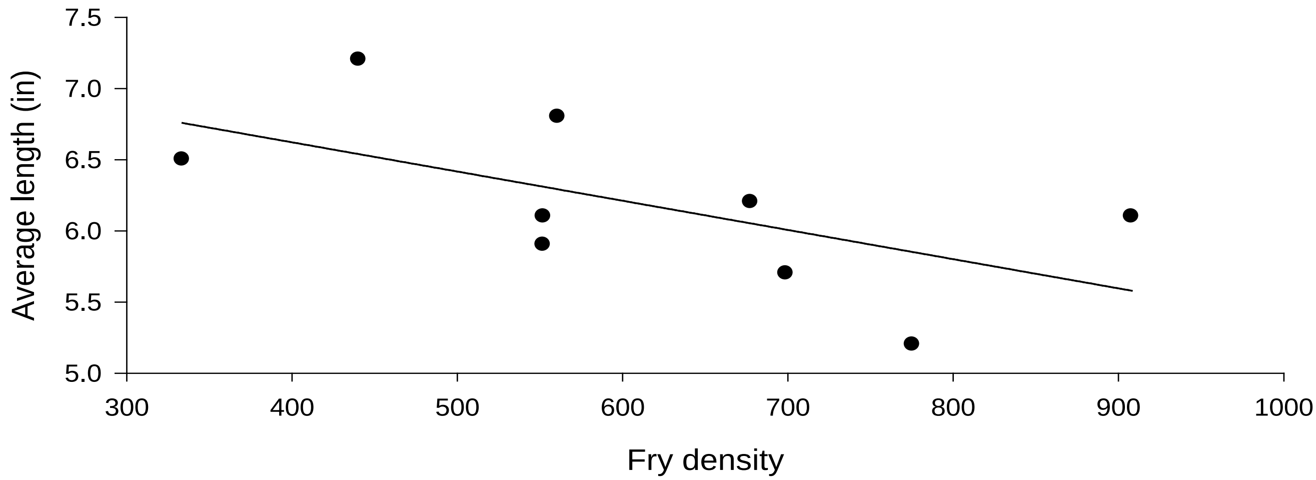


Figure B3. The average length (inches) of young-of-the-year Walleye sampled in mid-September and the resulting strength of stocked year classes, 2005-2011. Year classes are considered fully recruited at age-3.

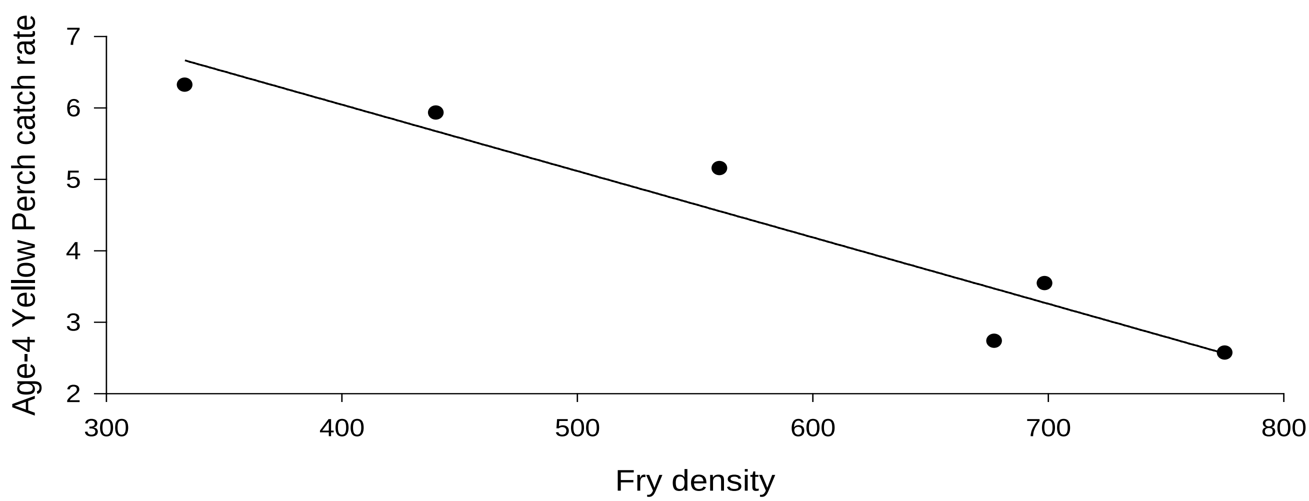


Figure B4. Estimated total Walleye fry density (fry/littoral acre, i.e. depths ≤15 feet) and the resulting strength of Yellow Perch year classes (age-4 gill net catch rate) produced the same year, 2005-2010.

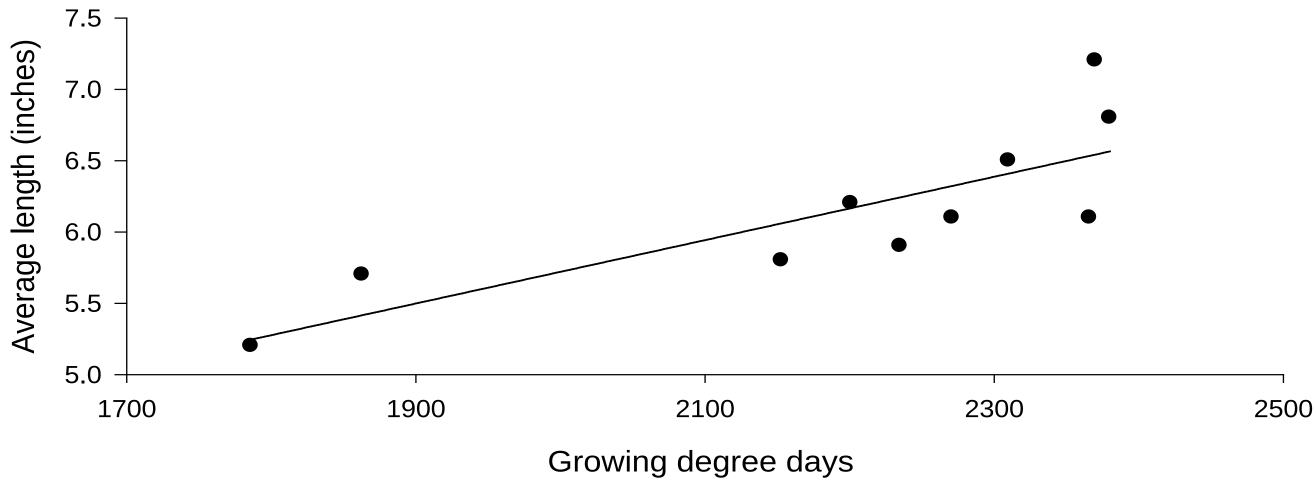


Figure B5. Growing degree days (GDD_{50}) and the average length (in) of young-of-year Walleye sampled by electrofishing in mid-September, 2005-2014.

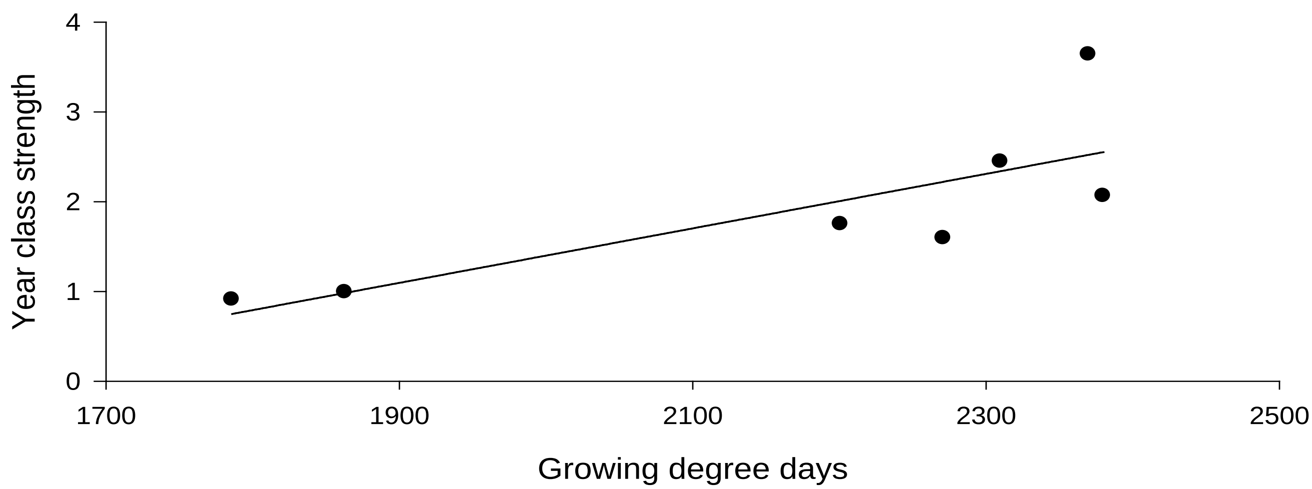


Figure B6. Growing degree days (GDD_{50}) experienced by young Walleye during their first growing season and the resulting strength of stocked year classes, 2005-2011.

Appendix C.

Habitat and aquatic invasive species initiatives outlined by the LLFIG to pursue throughout the life of the 2016-2020 fisheries management plan. Some of these recommendations are enveloped under annual DNR operating responsibilities and associated budgets. In other instances, staff and funding limitations necessitate that much of this work will only be accomplished with supplemental funding and collaboration among the many partners interested in a healthy ecosystem.

Habitat	Related Recommendations	Lead Agency/Partners	Relative Priority (1 = high, 2 = moderate, 3 = low)	Funding
1	Inventory nearshore aquatic habitat	FAW[1], partners	2	External funding
2	Lakewide inventory of aquatic vegetation	FAW, partners	2	External funding
3	Inventory and evaluate spawning areas	FAW, partners	2	External funding
4	Continue Environmental Review	FAW, EWR[2], COE[3], ESDCC[4]	1	Agency base funding
5	Protect vegetation beds including wild rice	EWR, ESDCC	1	Agency base funding
6	Enforce shoreland rules, vegetation removal, and invasive species	DOE, EWR, ESDCC	1	Agency base funding
7	Acquire important shoreland	FAW, LLAWF[6], LLA[7], partners	1	External funding
8	Continue shoreland development rulemaking	EWR, ESDCC	1	Agency base funding
9	Continue invasive species prevention and treatment	EWR, ESDCC, partners	1	Agency base funding
10	Continue tournament watercraft inspections, enforcemnt and education	EWR, ESDCC, partners	1	Agency base funding
11	Continue invasive species and vegetation management education and outreach for guides, resorts, law enforcement and industries	EWR, ESDCC, partners	1	Agency base funding

FAW[1] DNR Division of Fish and Wildlife

EWR[2] DNR Division of Ecological and Water Resources

COE[3] Army Corps of Engeneers

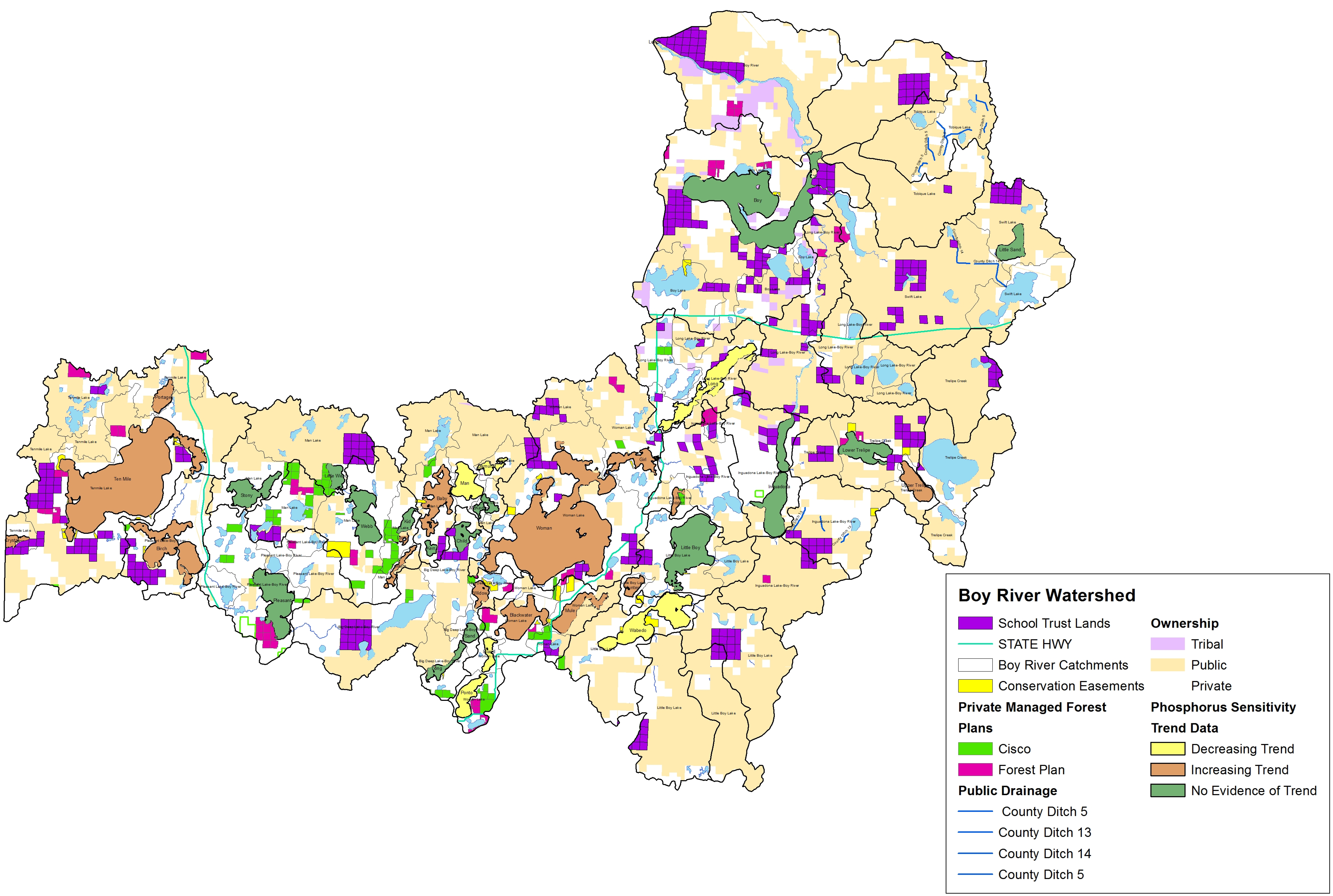
ESDCC[4] Environmental Services Division, Cass County

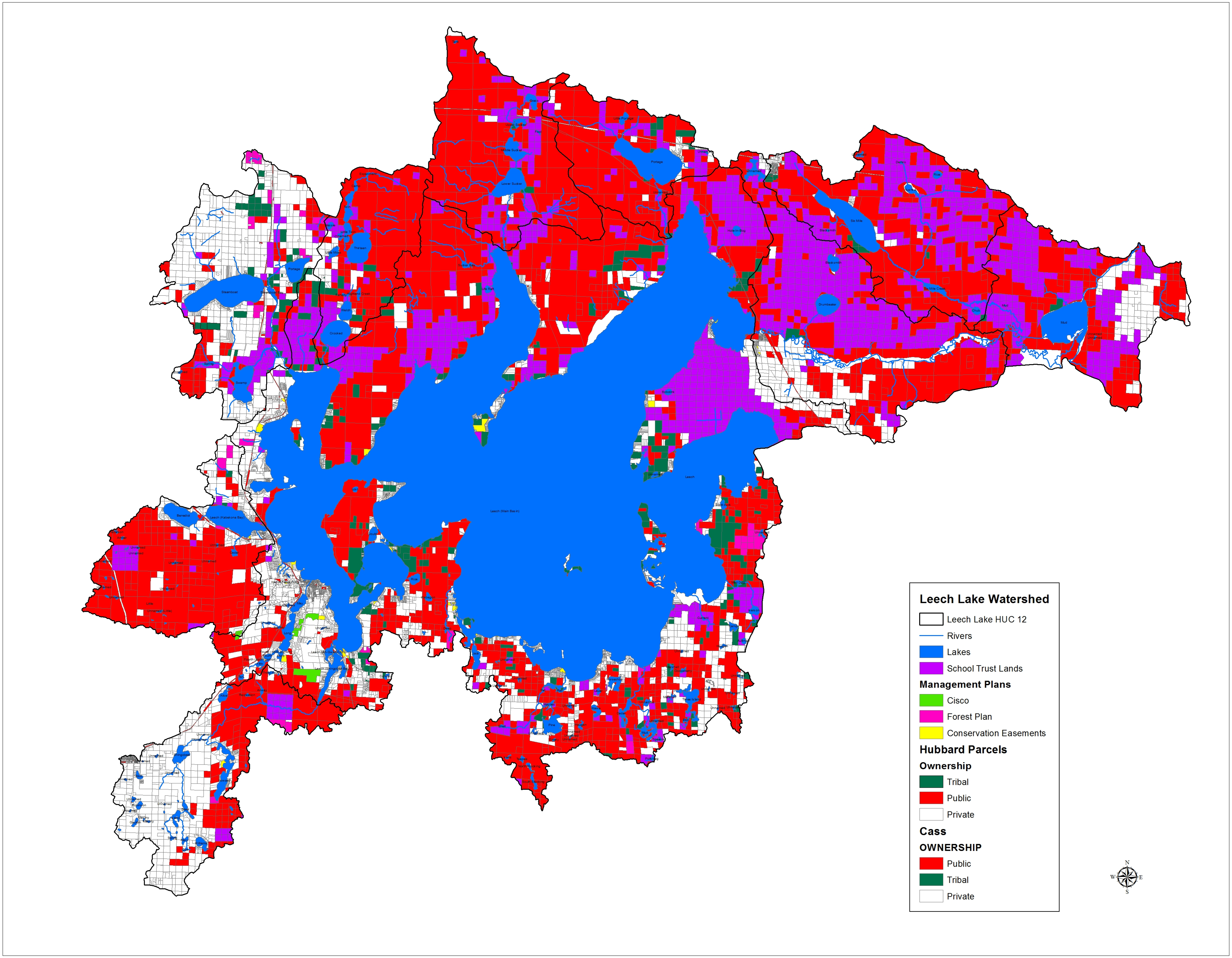
DOE[5] DNR Division of Enforcement

LLAWF[6] Leech Lake Area Watershed Foundation

LLA[7] Leech Lake Association

Boy River Watershed




Leech Lake Watershed
Leech Lake HUC 12
Rivers
Lakes
School Trust Lands
Management Plans
Cisco
Forest Plan
Conservation Easements
Hubbard Parcels
Ownership
Tribal
Public
Private
Cass
OWNERSHIP
Public
Tribal
Private
N
S
E
W