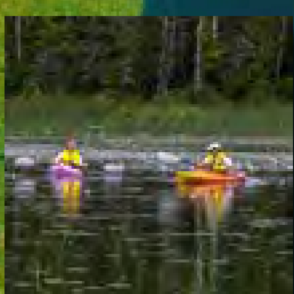
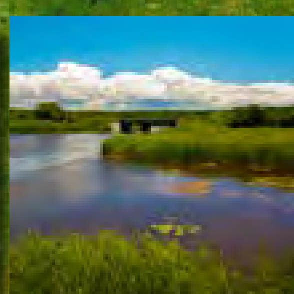
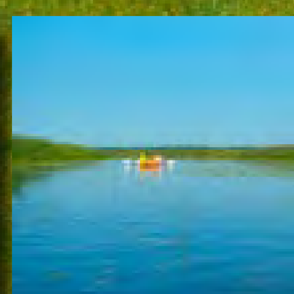
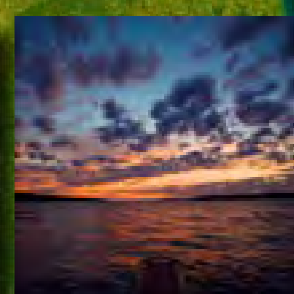
Betsie River / Crystal Lake

Watershed Management Plan



2016 – 2026

Program Partners

Acknowledgements

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DEQ

2016

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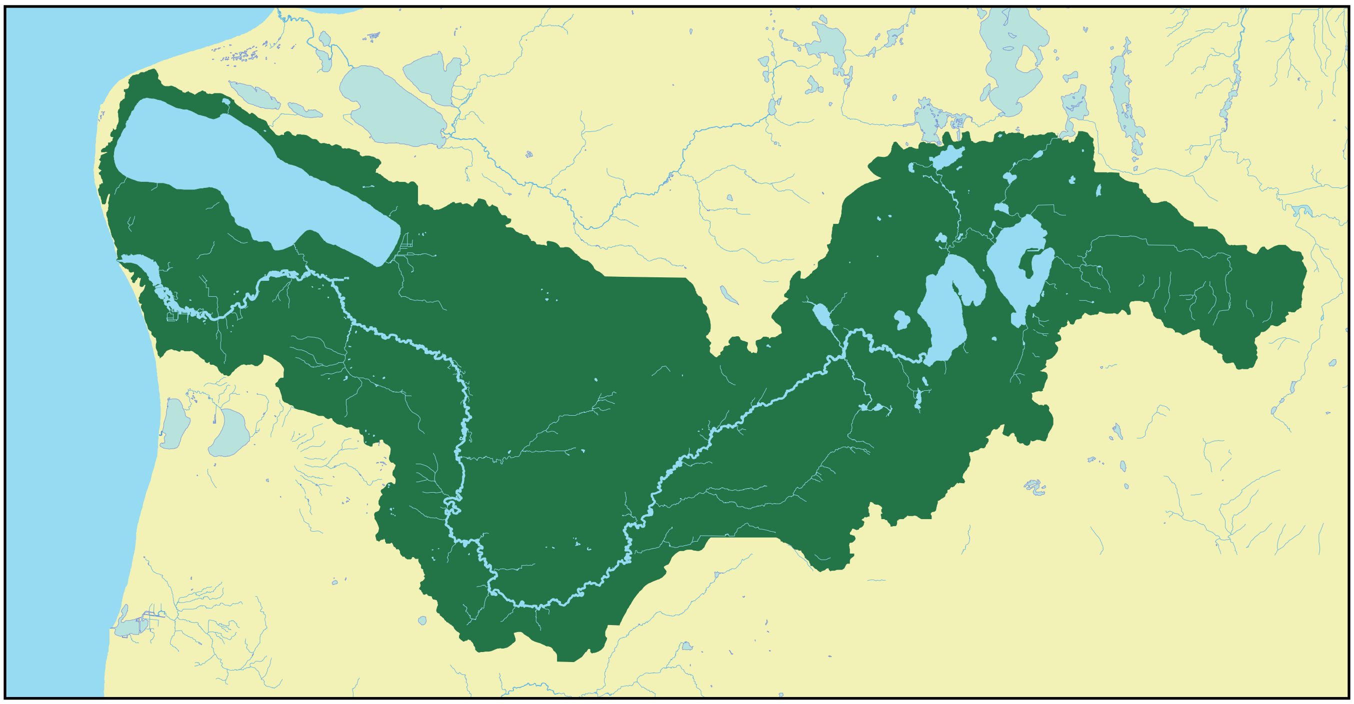


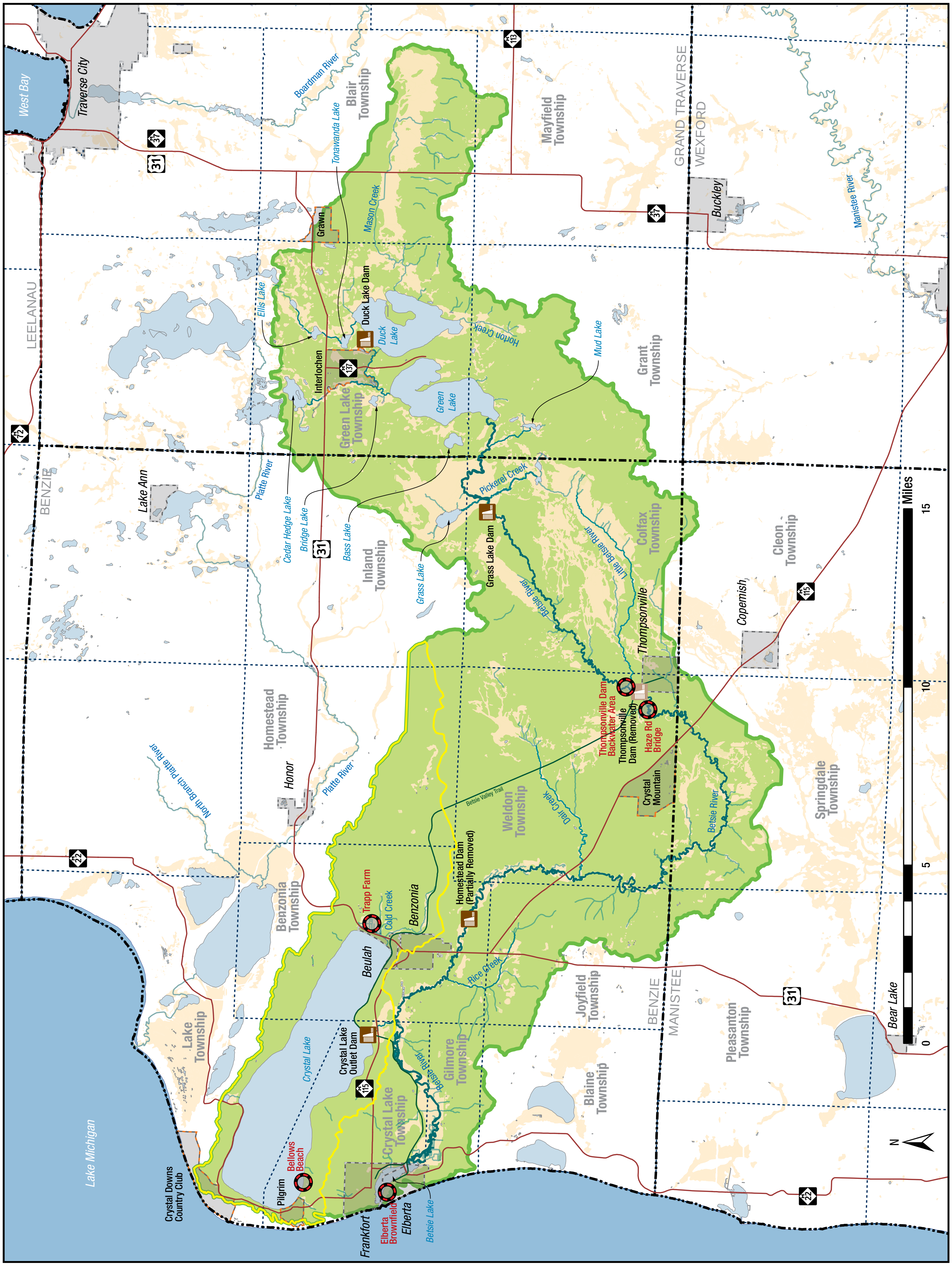
Betsie River Watershed

Notes on this document:

This document was prepared by the Betsie River / Crystal Lake Watershed Management Plan Steering Committee. The work was supported by a multi-year grant from the Michigan Department of Environmental Quality to Networks Northwest. Content, including submissions from project partners, was assembled by Networks Northwest and the Crystal Lake & Watershed Association. The full document was reviewed by the MDEQ and approved under guidelines of the Clean Michigan Initiative on July 19, 2016. It was subsequently submitted to the United States Environmental Protection Agency. On August 31, 2016 the US-EPA approved the document as meeting the "nine-element" requirements of Section 319 of the Clean Water Act.

Website link to online content: nwm.org/brclwmp

Please direct comments to the Planning Department of Networks Northwest: nwm.org/planning


West Bay
Traverse City
Boardman River
Tonawanda Lake
Blair Township
Mayfield Township
GRAND TRAVERSE
WEXFORD
Buckley
Manistee River
Mason Creek
Grawn
LEELANAU
BENZIE
Ellis Lake
Duck Lake Dam
Duck Lake
Horton Creek
Mud Lake
Grant Township
Interlochen
Green Lake Township
Green Lake
Lake Ann
Platte River
Cedar Hedge Lake
Bridge Lake
Bass Lake
Pickerel Creek
Grass Lake
Grass Lake Dam
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Colfax Township
Cleon Township
Betsie River
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Copemish
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Honor
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Weldon Township
Springdale Township
Benzonia Township
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Cold Creek
Benzonia
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Rice Creek
Joyfield Township
BENZIE
MANISTEE
Pleasanton Township
Bear Lake
Lake Township
Crystal Lake
Crystal Lake Outlet Dam
Gilmore Township
Crystal Lake Township
Blaine Township
Lake Michigan
Crystal Downs Country Club
Pilgrim
Bellows Beach
Frankfort
Elberta Brownfield
Elberta
Betsie Lake
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Crystal Lake Watershed

Lake Michigan

Lakes and Water Bodies

Rivers

Major Tributaries

MDOT Roads 31 115 22 137

Local Roads 700

Wetlands (NWI)

Dam Location

Major Watershed Lake

CITY OR VILLAGE

TOWNSHIP

COUNTY

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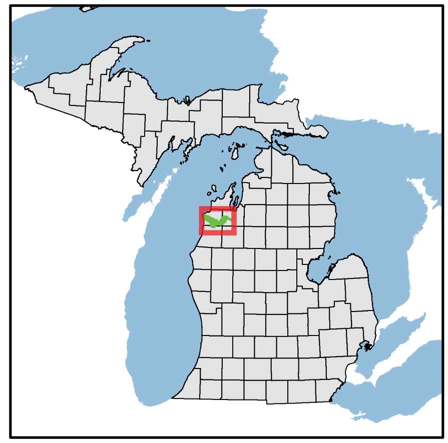

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Platte Lake Improvement Association
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Betsie Valley District Library
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Interlochen Public Library
Manistee County Library
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Executive Summary

The Watershed Management Plan for the Betsie River / Crystal Lake Watershed is the result of a multi-year effort by a Steering Committee of Northwest Michigan partners, supported by a grant from the Michigan Department of Environmental Quality.

The grantee for the project is Networks Northwest (formerly, the Northwest Michigan Council of Governments). The Crystal Lake & Watershed Association served as subcontractor for portions of the Plan. The Grand Traverse Regional Land Conservancy, the Conservation Resource Alliance and the Benzie Conservation District also contributed material and/or paid staff time.

The complete list of partners and Steering Committee members is included in the introductory material to the document.

The Plan is intended to protect surface water quality by preventing or reducing non-point source pollution during the 10-year period from 2016 through 2026. It is constructed as a living document which may be amended – or extended into additional years – by a permanent Watershed Protection Committee.

The Betsie River Watershed, including the Crystal Lake Subwatershed, is designated by the United States Geologic Survey's 10-digit Hydrologic Unit Code, 0406010403. The overall watershed encompasses 242 square miles in Benzie, Grand Traverse and Manistee counties of Northwest Michigan.

Watershed population is estimated at 17,500, concentrated primarily near the lakes, within several villages, and in the city of Frankfort. The regional economy is significantly related to tourism and outdoor recreation. Predominant land covers are forest, open rangeland and wetlands, which together account for nearly 75 percent of the land in the watershed. Soils are mostly well-drained sands.

Watershed residents rely entirely on groundwater for drinking water supplies. The Betsie River and tributaries are popular recreational waterways that support boating and fishing. The Betsie was designated in 1973 as a Michigan Natural River. The shores of Crystal Lake, Duck Lake and Green Lake together have more than 1,000 dwellings, in addition to public beaches and access sites. Betsie Lake is a busy harbor with boating access to Lake Michigan and facilities for vessels up to 145 feet in length.

The first two chapters of the WMP contain general information about the planning process and the characteristics of the watershed. Chapter 3 presents a general pollution inventory, including estimates of pollutants in stormwater runoff and on-site wastewater systems.

The Steering Committee approved a set of goals and objectives, which are presented in Chapter 5 of the document. The goals specify that the plan is to protect and improve water quality to meet the "designated uses" promulgated by the State of Michigan (e.g. full-body contact recreation in summer months), as well as desired uses expressed by the local community. (Designated and desired uses are shown in Chapter 4.)

Many of the surface waters in this watershed are of such high quality that they exceed state and federal clean-water standards. A primary focus of the Plan is to preserve that situation through a long-term program of monitoring water quality indicators and responding rapidly to any emerging threats.

Chapter 4 describes the specific pollutants of greatest concern in this watershed.

Potential threats include: sediment; excess nutrients; invasive species; bacterial and parasitic pathogens; runoff from impervious surfaces; and to a lesser extent agricultural chemicals and oil and gas products. These potential pollutants must be monitored and in some cases managed or reduced in order to protect the water.

The Steering Committee considered relevant water quality data, public input and the results of the social indicators survey to identify six primary environmental stressors in the Betsie River / Crystal Lake Watershed. The stressors were assigned priority levels from (1) to (3), with (1) denoting the level of greatest significance in this Watershed:

Level 1 – Biological Pathogens: E. coli

Level 1 – Sediments

Level 2 – Excessive nutrients

Level 2 – Invasive Species

Level 2 – Biological pathogens: Swimmer's Itch cercariae

Level 3 – Elevated Temperatures

Level 3 – Other unspecified pollutants

In addition to an overall monitoring strategy, the Plan designates seven critical sites where water quality is currently impaired or likely to be threatened by non-point source pollution in the near future.

The critical areas described in Chapter 4 are: Bellows Park and Bellows Creek on Crystal Lake; the historic Thompsonville Dam backwater area; road-stream crossings, including the failed Haze Road crossing; severely eroding streambanks on the Betsie River; the Elberta brownfield site; The Interlochen development area in Green Lake Township; and the Beulah Beach and Cold Creek subwatershed at the eastern end of Crystal Lake.

The Bellows Park and Beulah Beach sites are considered to be impaired, due to intermittently high levels of *E. coli* bacteria, which on some occasions exceeded Michigan standards for full- and partial-body contact recreation. Physical Improvements underway at Bellows Park may mitigate past issues at that site. At the Beulah site, the Plan envisions an engineering study and changes in management of storm water and Cold Creek outflows to the beach area.

The remaining critical areas currently meet standards for the "designated uses" defined by MDEQ. However the sites are considered to be at risk of deterioration unless careful management is applied.

The Plan also cites eight priority areas for protection (Chapter 4). These are areas in which long-term management is recommended in order to preserve exceptional sites or conditions.

The priorities for protection are: Lake shorelines; headwaters and small tributary streams; groundwater; the Grass Lake Flooding; steep and forested slopes; the Crystal Lake Outlet; the Betsie Rivermouth at M-22; Frankfort Outer Harbor.

Chapter 6 of the document lists 14 categories of implementation tasks necessary to reach the goals and objectives of the plan. The overall cost of implementation over the 10-year period is estimated to be approximately $17.4 million. More than $10 million that total would be required to correct critical transportation, erosion and fish-passage issues that result from the aging infrastructure of bridges and culverts on the Betsie River and tributaries.

Other major anticipated costs include $1.85 million for long-term land protection activities and $1.7 million to address the Beulah / Cold Creek critical area. The listed costs are considered to be broad estimates. Accomplishing the tasks will require some combination of local funding and grant support.

The WMP creates a long-term monitoring strategy with 20 specific sites to be sampled for water quality on a regular schedule (Chapter 7). As part of the monitoring strategy, the Plan calls for creation of a permanent Watershed Protection Committee to coordinate monitoring and information sharing. The committee will include representation from plan partners and other stakeholders and will operate through the auspices of the Benzie Conservation District as a subcommittee of the Benzie Watersheds Coalition.

A final element of the WMP is the continuing information and education component (Chapter 8). A social indicators survey conducted at the start of the planning process indicated that property owners in the watershed place a high value on water quality, but often are unaware of management practices such as septic system maintenance or native vegetation plantings that can help preserve that water quality.

The information and education component is designed to disseminate specific information to target groups.

The Betsie River / Crystal Lake Watershed is somewhat unusual in that it has at least four active community organizations supporting water-quality efforts on various water bodies – but no one speaking for the watershed as a whole. In addition, the watershed has benefited from the work of regional non-profits such as CRA and GTRLC, and governmental agencies such as local planning commissions and the Benzie Conservation District.

All of those stakeholders have taken a role in creation of the WMP. They will continue to work together to preserve the Watershed's outstanding resources as members of the Watershed Protection Committee.

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Chapter 1

Background and Introductory Information

The Betsie River / Crystal Lake Watershed in Northwest Michigan retains excellent water quality and significant natural features which support both a quality of life and a local economy heavily reliant upon tourism and outdoor recreation. This water quality persists despite the fact that humans have been altering the region's landforms and watercourses for more than 150 years.

Map 1 - Betsie River / Crystal Lake Watershed Satellite Image

Though it is of modest size, the watershed is exceptionally diverse, extending from unpeopled wetlands and remote trout streams in inland forests to the busy Lake Michigan recreational harbor at Frankfort.

Within its 242 square miles, the Watershed contains: Part or all of four villages and one city; miles of pine and hardwood forests; glacial moraines; a dozen lakes; remote natural areas; golf courses; a four-season resort; campgrounds; trails; orchards; cropland; and much more.

Near the headwaters of the Betsie River, in Grand Traverse County, hundreds of homes cluster around the community of Interlochen and the shores of Duck and Green lakes. Also here are the Interlochen State Park, The Interlochen Center for the Arts, Northwest Michigan Fairgrounds, and a growing residential area populated by families who work locally or in Traverse City.

As the river flows west into Benzie County, it passes through forests and wetlands near Grass Lake, which is maintained by a low-head dam as an important waterfowl habitat. Near the village of Thompsonville, the mainstream is joined first by the Little Betsie River and then a bit further west by Dair Creek, two prime coldwater streams. Also near this segment of river is the Crystal Mountain Resort and Spa, where golf courses, ski slopes and other amenities provide local employment and attract thousands of visitors.

The river dips into remote, forested sections of northern Manistee County, then flows back into Benzie before discharging into Betsie Lake and ultimately Lake Michigan.

The Betsie River is noted for its steelhead, brown trout and salmon fishery. It was designated as a Michigan Natural River in 1973, the second stream to receive that distinction.

The Crystal Lake and Crystal Lake Outlet subwatershed – including the 9,850-acre Crystal Lake and its associated drainage area – occupies the northern margin of the overall Betsie/Crystal Watershed, including the village of Beulah and part of Benzonia village. This deep lake has exceptional water clarity and 21 miles of shoreline with some of the highest shoreline property values in Northern Michigan. A small segment of the Sleeping Bear Dunes National Lakeshore lies in the Crystal Lake Watershed. The Crystal Lake Outlet joins the Betsie River five miles before the river reaches Betsie Lake.

Betsie Lake – which is officially designated as an inland lake, but is colloquially known as “Betsie Bay” – has a history as an industrial and commercial harbor. It was homeport for the Ann Arbor Rail Road’s Lake Michigan carferries for 90 years, ending in the early 1980s. Today, it is a picturesque harbor, linked by a short channel to Lake Michigan and sited between the city of Frankfort on the north and the village of Elberta on the south. The harbor supports a Lake Michigan fishing fleet, a public boat launch site and permanent boat slips for vessels up to 145 feet in length.

At the harbor mouth, the water from the river flows between concrete piers and past the historic Frankfort Light before merging with Lake Michigan.

This diverse area is, of course, not without challenges.

Potential threats to water quality include: sediment; excess nutrients; invasive species; bacterial and parasitic pathogens; runoff from impervious surfaces; elevated water temperatures; and to a lesser extent agricultural chemicals and oil and gas products. These potential pollutants must be monitored and in some cases managed or reduced in order to protect the water.

That is the essence of this document: To identify threats to water quality and develop a plan for protecting the water for the benefit of property owners, residents, visitors, and the environment.

Many of the surface waters in this watershed presently are of such high quality that they exceed state and federal clean-water standards. A primary focus of the plan will be to preserve – and potentially improve – that situation through a long-term program of monitoring water quality indicators and responding rapidly to any emerging threats.

In simplest terms, the Watershed Steering Committee and planning team asked three questions about our waters:

- **A** *What do we have?*
- **B** *What do we want?*
- **C** *How we get from A to B?*

Creating the Watershed Plan:

The federal Clean Water Act, adopted by Congress and signed into law in 1975, envisions watershed planning as a vital tool in controlling and reducing "nonpoint source" contamination of surface waters.

The Michigan Department of Environmental Quality (MDEQ) defines nonpoint source (NPS) pollution as "pollution caused when rain, snowmelt, or wind carry pollutants off the land and into lakes, streams, wetlands, and other water bodies."

At the time the Clean Water Act was adopted, the majority of known pollution came from so-called point sources such as municipal wastewater plants and industrial discharges. After decades of hard work, point source pollution has been reduced to the extent that today most pollution enters the water from nonpoint sources.[1]

Michigan's Nonpoint Source Program, a section of the MDEQ, assists local units of government, non-profit entities, and numerous other state, federal, and local partners to reduce nonpoint source pollution statewide.

With Grant Funds awarded in 2012 through the MDEQ, the Betsie River and Crystal Lake community embarked upon a multi-year process of creating this Watershed Management Plan, which will guide efforts to protect the community's outstanding water resources.

The grant process was initiated as a cooperative effort by: The Grand Traverse Regional Land Conservancy; Crystal Lake & Watershed Association; Conservation Resource Alliance; Benzie Conservation District; Green Lake and Duck Lake Association, Friends of Betsie Bay, and the Northwest Michigan Council of Governments.

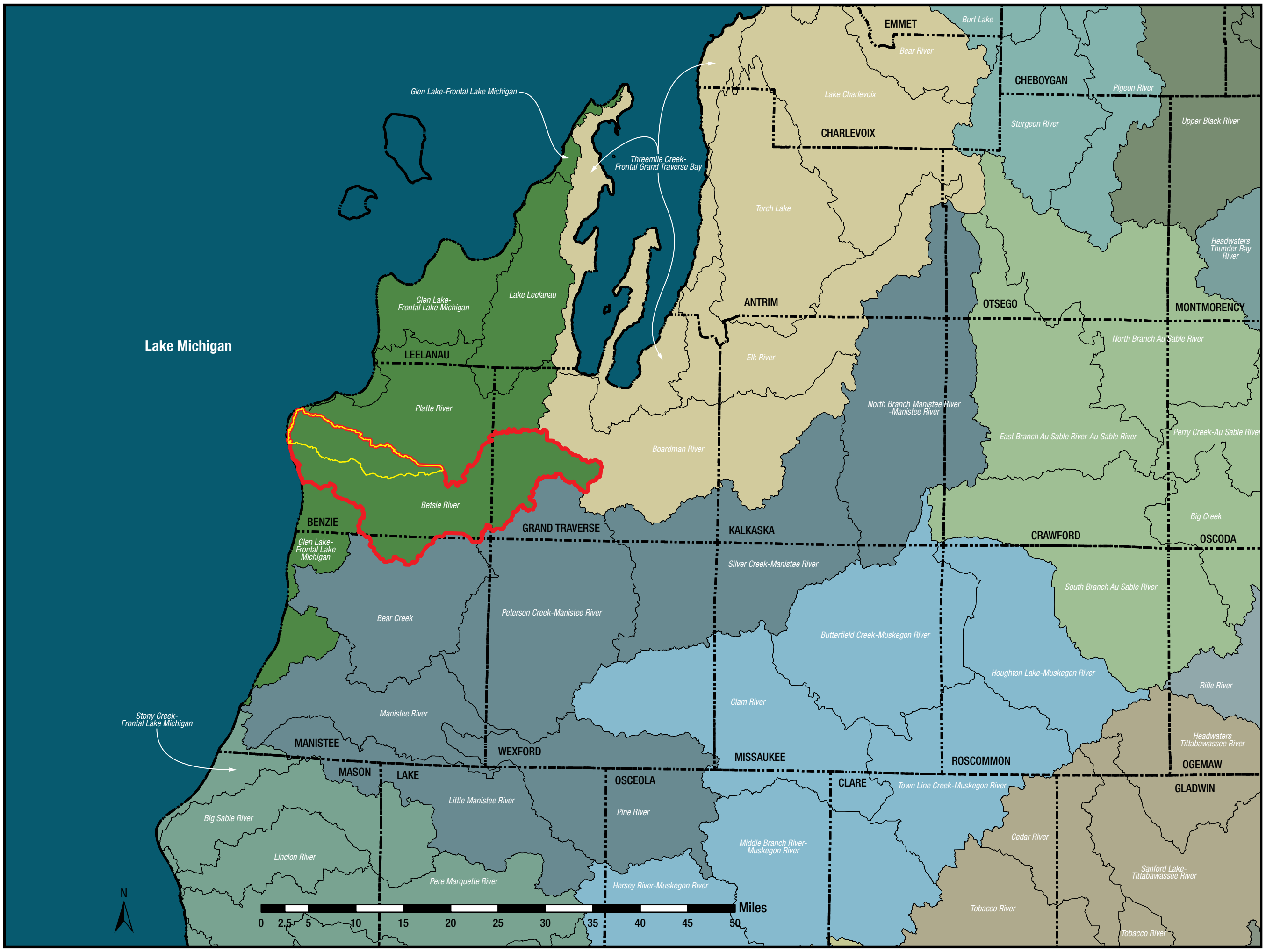
Local governments, tribes, individuals and stakeholder groups were invited to participate in the project by serving on the Watershed Management Plan Steering Committee and a permanent Watershed Protection Committee.

Hydrologic Unit Codes

Watersheds and subwatersheds throughout the United States are identified through a unique set of numerical “Hydrologic Unit Codes” or HUCs.

Under this system, the Betsie River and Platte River watersheds in Northwest Lower Michigan are identified by the HUC: 04060104.

Map 2 - HUC 8 and 10 Watersheds



KEY | HYDROLOGICAL UNITS

- Au Gres-Rifle
- Au Sable
- Betsie-Platte
- Black
- Boardman-Charlevoix
- Cheboygan
- Kawkawlin-Pine
- Lake Michigan
- Manistee
- Muskegon
- Pere Marquette-White
- Pine
- Thunder Bay
- Tittabawassee
- Betsie River Watershed
- Crystal Lake Watershed

The Betsie River Watershed (10-digit HUC: 0406010403) includes seven subwatersheds designated by 04060104 plus the following four digit suffixes:

0301 — Duck Lake area

0302 — Green Lake area

0303 — Upper Betsie River and Little Betsie River

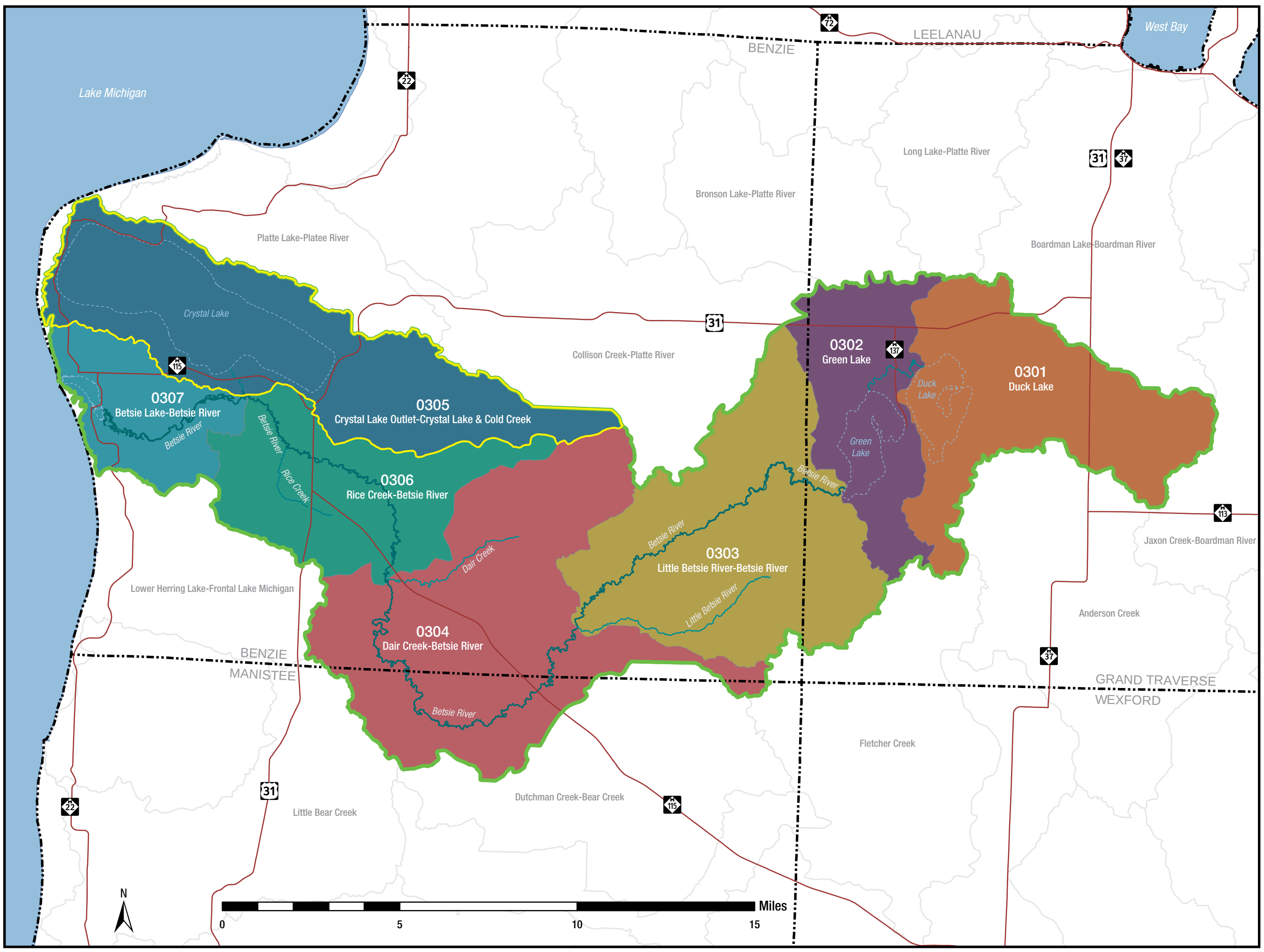
0304 — Betsie River and Dair Creek

0305 — Crystal Lake Outlet, Crystal Lake, Cold Creek

0306 — Lower Betsie River and Rice Creek

0307 — Betsie Rivermouth, Betsie Lake and Frankfort Harbor

Map 3 - HUC 12 Subwatersheds



KEY | HUC 12 SUBWATERSHEDS

- Betsie Lake-Betsie River
- Crystal Lake Outlet-Crystal Lake & Cold Creek
- Dair Creek-Betsie River
- Duck Lake
- Green Lake
- Little Betsie River-Betsie River
- Rice Creek-Betsie River

This plan is focused on the above seven subwatersheds. As part of the plan preparation, the WMP team consulted plans developed previously for adjacent watersheds.

Project Team and Planning Process

As grantee, the Northwest Michigan Council of Governments (NWMCOG) has overall responsibility for development of the plan. NWMCOG retained the Crystal Lake & Watershed Association as a contractor to share in fieldwork and other tasks in writing the plan.

(Subsequent to the award of the WMP grant, NWMCOG redefined its scope of operation and adopted a new name: Networks Northwest. In addition to other activities, the agency continues to function as a regional planning agency, and in that role continues as grantee for this project.)

The Watershed Steering Committee met quarterly during the grant period. All Steering Committee meetings were held within the watershed, and were open to the public. In addition, staff provided periodic reports to lake associations and governmental bodies within the watershed.

This document includes the product of input from multiple sources.

The Michigan Department of Environmental Quality oversaw many technical details, and provided invaluable advice. The Conservation Resource Alliance updated its earlier inventories of road-stream crossings and Betsie River streambank conditions. Grand Traverse Regional Land Conservancy developed a "Priority Parcel" analysis for land-protection purposes. The Northwest Michigan Invasive Species Network developed and provided maps of terrestrial invasives. Michigan Department of Natural Resources completed and explained fishery status reports and other wildlife information. Lake associations contributed volunteer assistance and historic water quality data. And Watershed Steering Committee members gave of their time and expertise to propose, critique, and revise elements of the final plan.

While much of the data presented herein has been gleaned from pre-existing records, the plan also required the development of new information, including the following:

- Shoreline condition inventories of Crystal, Duck and Green lakes, which involved cruising the entire shoreline of the three bodies of water to assess development levels, greenbelts, shoreline hardening, etc.
- Kayak inspections of small segments of the watershed, including Cedar Hedge, Ellis, Grass and Bass lakes and upstream river segments.
- A hydrologic assessment, performed by Great Lakes Environmental Center of Traverse City, under an arrangement with MDEQ.
- Inspection and analysis of 40 road stream crossings, conducted by a team from Conservation Resource Alliance, to complete gaps in earlier road-stream crossing analyses.
- An updated inventory of streambank erosion conditions on the Betsie River, conducted by Conservation Resource Alliance staff in the summer of 2015.
- Sampling for *Escherichia coli*, conducted for MDEQ, at several inlet points on Crystal Lake.
- Sampling for *E. coli* on public beaches during the summers of 2013, 2014 and 2015, funded by local governments, MDEQ and CLWA.
- A social indicators survey mailed to 1,000 property-owners in the watershed, with statistically significant results analyzed through the state's Social Indicators Data Management and Analysis (SIDMA) software.

Water Quality Standards and the "Integrated Report"

Michigan has determined that surface waters must be of sufficient quality to support certain "designated uses" such as navigation, agricultural and industrial uses, and body contact recreation. Waters that do not support those uses are considered "impaired." The Watershed Management Plan must include provisions to ensure that water quality will be protected or improved to allow the public to engage in these uses. In addition, the WMP may also include provisions to support locally desired uses – for example, recreational enjoyment and/or economic benefits.

In the Betsie River / Crystal Lake Watershed, the known impairments relate to bacterial pollution during and after heavy rains at two Crystal Lake beaches, and fish-consumption limits caused by mercury and PCB pollution. There are no watershed-wide impairments. The status of the "designated uses" and "desired uses and conditions" for the watershed are discussed in Chapter 4 of this document.

Michigan's water quality standards, and the overall status of pollution control efforts within the state, are detailed in the Department of Environmental Quality publication: **"Water Quality and Pollution Control in Michigan 2014 Sections 303(d) 305 (b) and 314 Integrated Report."**[2]

The document, generally known as the "Integrated Report," is published every second year. Where appropriate, this Watershed Management Plan relies on the 2014 Integrated Report as a source for information on standards and the known status of our waters relative to those standards.

"At a minimum," the report states, "all surface waters of the state are designated and protected for all of the following designated uses: agriculture, navigation, industrial water supply, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation, and fish consumption … In addition, all surface waters of the state are designated and protected for total body contact recreation from May 1 to October 1 ... Specific rivers and inland lakes as well as all Great Lakes and specific Great Lakes connecting waters are designated and protected for coldwater fisheries."

According to the Integrated Report, Michigan's standards "establish minimum water quality requirements by which the waters of the state are to be managed, and provide the primary framework that guides the MDEQ's water quality monitoring/assessment and water protection activities."

The 2014 Integrated Report provides the following general assessment of the status of Michigan waters:

> "Michigan is blessed with a wealth of surface water resources, including Great Lakes and their connecting channels, inland lakes, rivers, and wetlands. Most of Michigan also has an abundant supply of high quality groundwater.
>
> In general, the open waters of the Great Lakes have good to excellent water quality. The inland waters of Michigan's Upper Peninsula and the northern half of the Lower Peninsula support diverse aquatic communities and are commonly found to have good to excellent water quality. Many lakes and rivers in this mostly forested area of the state support coldwater fish populations.
>
> Lakes and rivers in the southern half of Michigan's Lower Peninsula generally have good water quality and support warmwater biological communities as well as some coldwater fish populations. The southern portion of the state contains Michigan's major urban areas with much of the rural land in agricultural production.
>
> Many of Michigan's rivers and lakes receive direct discharge of treated effluent from municipal and industrial sources as well as runoff from urbanized areas, construction sites, and agricultural areas. Sedimenta-

tion, nutrient enrichment, and toxic pollutant loading are problems associated with runoff that can impact surface water quality.

Surface water quality is generally showing improvement where programs are in place to correct problems and restore water quality."

The 2014 edition of the Integrated Report lists three locations in the Betsie River / Crystal Lake Watershed as "Not Supporting" one or more of the designated uses.

Green Lake is listed as not meeting the fish consumption standard, due to mercury and PCB in fish tissue. Crystal Lake falls short of the same standard because of PCB in fish tissue; and Bellows Park on Crystal Lake is listed as not meeting the full- and partial body contact standards because of *E. coli* bacteria contamination.

The fish consumption issue is of considerable concern in the Betsie-Crystal watershed, because recreational fishing is important to the local economy and quality of life. It is noted that, while only two lakes are listed as "not supporting" this use, other waters are listed as "not assessed" or having "insufficient information." In addition, fish species from Lake Michigan, which is listed as "not supporting," migrate annually into Betsie Lake and the Betsie River.

The pollutants cited in fish-consumption advisories – mercury and PCB – originate outside the watershed. They reach local waters through atmospheric deposition or other vectors that are beyond local control. Advisories and/or consumption limits for certain species of fish have been instituted for all Michigan waters.

For purposes of this Watershed Management Plan, fish consumption will be treated as an issue requiring public education and continued monitoring. However there is a recognition that the causes of this impairment are external to the Betsie/Crystal Watershed and must be addressed on a state and regional basis, not through elements of this plan.

The *E. coli* finding at Bellows Park is based on sampling from 2004, which indicated the water at this public beach exceeded the numerical standard for full body contact recreation. That finding had not been replicated at the time this WMP planning process began in 2013.

Concurrent with the development of the WMP, additional sampling was accomplished at Bellows Park and the small Bellows Creek that discharges near the beach. Sampling was also initiated at another Crystal Lake public beach at the village of Beulah. (Bellows Park, on the south shore, is owned and operated by the City of Frankfort. Beulah Beach, at the east end of the lake, is owned and operated by the Village of Beulah. The sites are approximately six miles apart. Both are heavily used by the public in summer.)

Beulah Beach

Weekly samples of lake water at Bellows Park in the summers of 2013, 2014 and 2015 were all well within the health standard for both full- and partial-body contact.

However, tests sponsored by MDEQ during rain events in both years found elevated levels, above the health standard, in Bellows Creek.

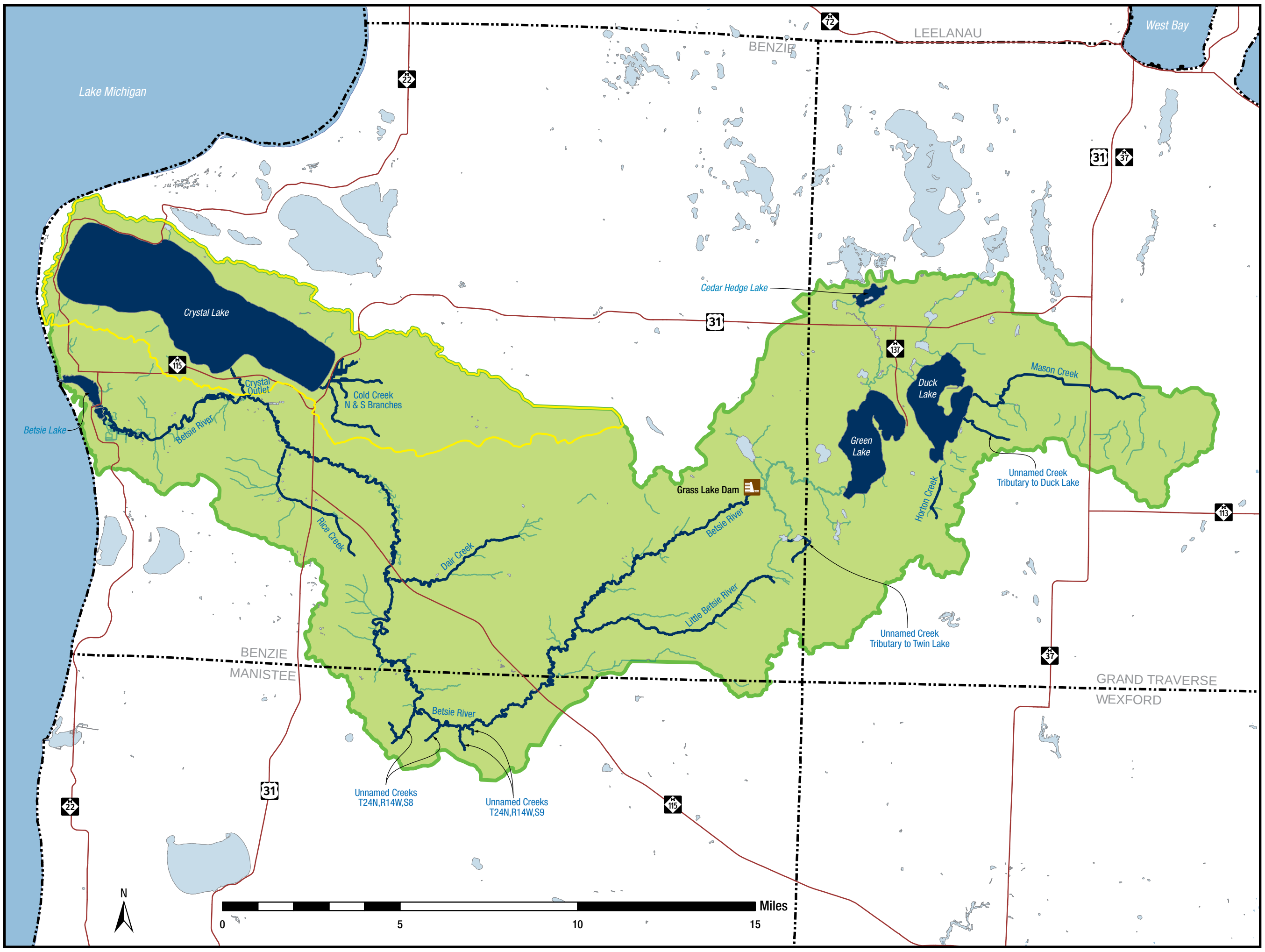
At Beulah Beach, three dates in 2013 and one each in 2014 and 2015 exceeded full body contact recreation standards. Additional testing by MDEQ during rain events in 2014 found elevated levels of *E. coli* in Cold Creek, which discharges at Beulah Beach, and in storm sewer outfalls on or near Beulah Beach.

According to the draft of the 2016 Integrated Report (not released in final form at the time of this Plan's submission) Bellows Beach and Bellows Creek are listed as impaired for both Total Body Contact and Partial Body Contact Recreation. Beulah Beach and Cold Creek are listed as impaired for Total Body Contact Recreation.

Table 1 - Michigan Surface Water Quality Standards (Partial list)

<table>
<tr><th>Designated Use</th><th colspan="12">Standard</th><th>Applies to</th></tr>
<tr><td>Total Body Contact Recreation</td><td colspan="12">E. coli counts of 130 CFU or less per 100 ml as a monthly average, or 300 or less on any daily sampling event</td><td>All water bodies, May 1 to October 1</td></tr>
<tr><td>Partial Body Contact Recreation</td><td colspan="12">E. coli count of 1,000 CFU or less in daily sampling event</td><td>All water bodies</td></tr>
<tr><td>Warmwater Fishery</td><td colspan="12">Dissolved oxygen not less than 5.0 ppm in epilimnion of lake</td><td>All water bodies not designated as coldwater lakes or streams</td></tr>
<tr><td rowspan="4">Coldwater Fishery</td><td colspan="12">Dissolved oxygen not less than 6.0 ppm during summer low flow period; not less than 7.0 ppm at other times</td><td rowspan="4">Designated coldwater streams and trout lakes (see list below)</td></tr>
<tr><td colspan="12">Monthly averages for cold water inland streams in this watershed (F°):</td></tr>
<tr><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>Jun</td><td>Jul</td><td>Aug</td><td>Sep</td><td>Oct</td><td>Nov</td><td>Dec</td></tr>
<tr><td>38°</td><td>38°</td><td>43°</td><td>54°</td><td>65°</td><td>68°</td><td>68°</td><td>68°</td><td>63°</td><td>56°</td><td>48°</td><td>40°</td></tr>
<tr><td>Other Indigenous Aquatic Life and Wildlife</td><td colspan="12">Limits on permitted discharges to prevent nuisance algae blooms and protect wildlife.</td><td>All water bodies</td></tr>
<tr><td>Fish Consumpton</td><td colspan="12">Advisories triggered if mercury level in fish tissue exceeds 0.35 mg/kg; or PCB's exceed 0.026 ng/L in water column.</td><td>All water bodies</td></tr>
</table>

Map 4 - Coldwater Lakes & Streams



KEY | COLDWATER DESIGNATIONS

COLDWATER LAKE — COLDWATER RIVER OR STREAM — GRASS LAKE DAM (Coldwater Below)

Table 2 - Coldwater Lakes & Streams in the Betsie River Watershed

Lakes	Location	Streams	Location
Betsie Lake	Crystal Lake & Gilmore Twp	Betsie River	EXCEPT: Upstream of Grass Lake Dam
Cedar Hedge Lake	Green Lake Twp	Crystal Lake Outlet	T26N, R15W, S29
Crystal Lake	Benzonia, Crystal Lake, & Lake Twp	Cold Creek	T26N, R15W, S26
Duck Lake	Green Lake Twp	North Branch Cold Creek	T26N, R15W, S23
Green Lake	Green Lake & Grant Twp	Rice Creek	T26N, R15W, S34
		Dair Creek	T25N, R14W, S19
		Two Unnamed Creeks	T24N, R14W, S8
		Two Unnamed Creeks	T24N, R14W, S9
		Little Betsie River	T25N, R14W, S25
		Unnamed Creek - Tributary to Twin Lake	T25N, R13W, S12
		Mason Creek	T26N, R12W, S23
		Unnamed Creek - Tributary to Duck Lake	T26N, R12W, S26
Source: MDNR		Horton Creek upstream from Youker Road	T25N, R12W, S3

Social Indicators Survey

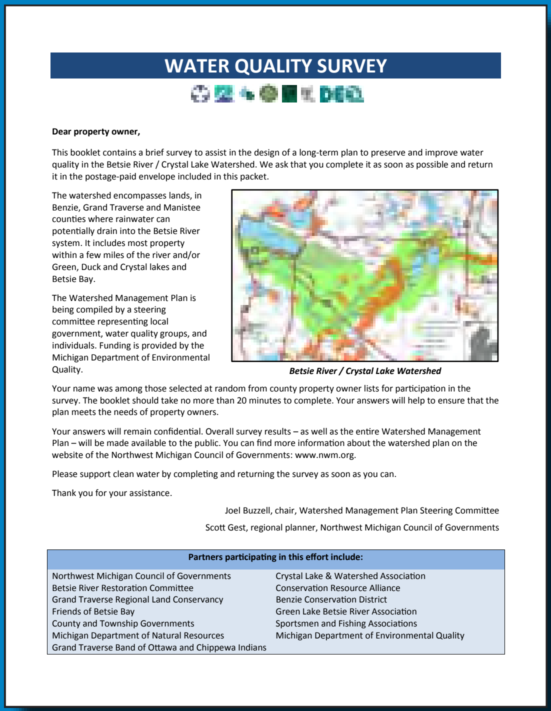
The Betsie River Crystal Lake Watershed "Social Indicators Survey" was conducted in the spring and summer of 2014 to provide information on the opinions and watershed knowledge of property owners within the watershed.

Authorities in Grand Traverse, Manistee and Benzie counties used property ownership data and geographic information system software to identify all properties within the watershed. The list of property owners was provided in digital spreadsheet data, and filtered to remove duplicate ownerships.

The resulting spreadsheet included approximately 12,000 individual properties in the Watershed. The mailed survey consisted of a 12-page questionnaire and cover letter, mailed to 1,000 property owners, selected at random from the list. The goal, based on the experience of similar survey methods in other watersheds, was to receive a minimum of 372 responses, which would yield results with a 5 percent margin of error. That goal was reached and exceeded, with a final response of 407 valid surveys.

Survey responses were entered into the Social Indicators Data Management software provided by Michigan State University and the Michigan Department of Environmental Quality. Results were considered in the development of goals and objectives for the WMP and in the development of the education and information component (Chapter 8)

Below are some general results. Survey results are discussed more extensively in the education and information section of Chapter 8. Detailed survey response tables are included as Appendix A to the WMP.


WATER QUALITY SURVEY

Dear property owner,

This booklet contains a brief survey to assist in the design of a long-term plan to preserve and improve water quality in the Betsie River / Crystal Lake Watershed. We ask that you complete it as soon as possible and return it in the postage-paid envelope included in this packet.

The watershed encompasses lands, in Benzie, Grand Traverse and Manistee counties where rainwater can potentially drain into the Betsie River system. It includes most property within a few miles of the river and/or Green, Duck and Crystal lakes and Betsie Bay.

The Watershed Management Plan is being compiled by a steering committee representing local government, water quality groups, and individuals. Funding is provided by the Michigan Department of Environmental Quality.

Betsie River / Crystal Lake Watershed

Your name was among those selected at random from county property owner lists for participation in the survey. The booklet should take no more than 20 minutes to complete. Your answers will help to ensure that the plan meets the needs of property owners.

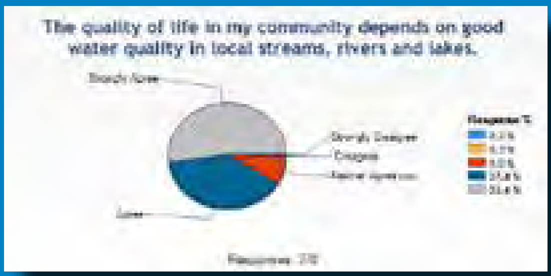
Your answers will remain confidential. Overall survey results – as well as the entire Watershed Management Plan – will be made available to the public. You can find more information about the watershed plan on the website of the Northwest Michigan Council of Governments: www.nwm.org.

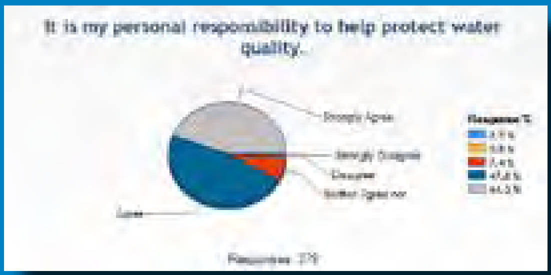
Please support clean water by completing and returning the survey as soon as you can.

Thank you for your assistance.

Joel Buzzell, chair, Watershed Management Plan Steering Committee
Scott Gest, regional planner, Northwest Michigan Council of Governments

Partners participating in this effort include:	
Northwest Michigan Council of Governments	Crystal Lake & Watershed Association
Betsie River Restoration Committee	Conservation Resource Alliance
Grand Traverse Regional Land Conservancy	Benzie Conservation District
Friends of Betsie Bay	Green Lake Betsie River Association
County and Township Governments	Sportsmen and Fishing Associations
Michigan Department of Natural Resources	Michigan Department of Environmental Quality
Grand Traverse Band of Ottawa and Chippewa Indians	





Sample of Results

Q: Overall, how would you rate the quality of the water in your area?

	Poor	OK	Good
For canoeing, kayaking other boating	0.3	6.8	86.3
For eating locally caught fish	1.4	18.2	60.1
For swimming	4.5	28.2	62.0
For picnicking and family activities	1.0	10.3	84.2
For Fish Habitat	1.4	23.5	52.9
For Scenic Beauty	0.0	4.1	94.6

Q: Of the following activities, which is most important to you?

For canoeing, kayaking other boating:	15.8 %
For eating locally caught fish:	10.7 %
For swimming:	24.0 %
For picnicking and family activities:	6.1 %
For Fish Habitat:	13.3 %
For Scenic Beauty:	30.1 %

Q: Indicate your level of agreement or disagreement with the following statements:

> *"I would be willing to pay more to improve water quality (for example through local taxes or fees)." Agree or strongly agree: 47.6 percent*

> *"The quality of life in my community depends on good water quality in local streams, rivers and lakes." Agree or strongly agree: 89.7 percent*

When asked to rate the severity of 15 potential "water impairments" such as sediment, algae, etc.: Swimmer's itch and invasive species were ranked as the most severe in this watershed.

Asked which information sources are most trusted for information about soil and water, local government, environmental groups and Farm Bureau scored lowest; the local conservation District, MSU extension and the "local watershed project" scored highest.

EPA Nine Elements

The overriding goal of the Watershed Management Plan is to protect the quality of the watershed. The Plan responds to the desires of the local community, and to the guidelines of the Michigan Department of Environmental Quality and United States Environmental Protection Agency. The plan is intended to meet MDEQ requirements under the Clean Michigan Initiative, as well as EPA requirements for approved watershed management plans under section 319 of the Clean Water Act.

As part of the EPA approval process, the plan must include these "Nine Elements:"

a. Identify causes and sources of pollution

b. Estimate pollutant loading into the watershed and the expected load reductions

c. Describe management measures that will achieve load reductions and targeted critical areas

d. Estimate amounts of technical and financial assistance and the relevant authorities needed to implement the plan

e. Develop an information/education component

f. Develop a project schedule

g. Describe interim, measurable milestones

h. Identify indicators to measure progress

i. Develop a monitoring component

According to the EPA, **"The elements are labeled (a) through (i) to reflect how they are presented in the 319 guidelines. The first three elements (a through c) are considered during the characterization and goal-setting phases to address the primary sources of pollution in the watershed and to determine the management strategies needed in specific areas to reduce the pollution to meet water quality goals. The remaining six elements (d through i) are used to develop a specific plan of action with measureable targets and milestones, as well as the necessary financial and technical resources needed to restore the waterbody."**[3]

For this WMP, elements (a) and (b) are addressed in Chapters 3 and 4. Management measures related to element (c) are described in the Critical Areas and Priority Issues sections of Chapter 4.

A multi-page graphic describing Implementation Tasks, in Chapter 6, details the schedules, milestones, costs, monitoring, and progress measurements required in elements (d), (f), (g), (h) and (i). The monitoring and evaluation program is further discussed in Chapter 7.

Chapter 8 describes the Information/Education component (element e).

Because the majority of the Watershed meets and exceeds standards for the designated and desired uses (described in Chapter 4), the WMP adopts a non-degradation standard – requiring that the present high water quality is maintained.

Past and Ongoing Water Quality Efforts

Efforts to protect and improve water quality in the Betsie River / Crystal Lake Watershed have been ongoing for many years. While this WMP is the first document specifically developed to address water quality in the overall watershed (HUC 0406010403), it must be recognized that efforts undertaken in the past have had significant positive impact toward achieving the same water quality goals.

Many of those past and ongoing successes are the result of work sponsored by the partners who came together to develop this plan. In a sense, this plan may be seen as both a way to coordinate the efforts of the partner agencies, and as a vehicle to address additional issues.

The following list highlights some of the major accomplishments of recent decades:

- The Michigan DNR and the Crystal Lake & Watershed Association settled a contentious dispute over public access to Crystal Lake in 2011 with an agreement that incorporated a privately financed boat-washing station as part of a new boating access site on the lake. The agreement also reduced wetland loss at the site while ensuring safe access to the lake.
- The Betsie River Watershed Restoration Committee – a partnership of government and private stakeholder groups – formed in the 1990s to restore the river after the catastrophic failure of a former hydroelectric dam. BRWRC has remained active and provided the leadership for more than $700,000 in streambank and habitat restoration over the years.
- Conservation Resource Alliance completed inventories of road stream crossings and streambank erosion sites in the 1990s. Those inventories were updated for this WMP. CRA also serves as staff for the BRWRC and administers a Website, Northernmichiganstreams.org, with information on the Betsie and other area rivers.
- The Benzie County Road Commission, working with CRA, reduced sedimentation by improving or replacing several road crossings.
- The Green Lake and Duck Lake Association worked with professional limnologists to compile annual reports on the status of the lakes, including chemical parameters, weed surveys and monitoring of *E. coli* at selected sites
- The Benzie County communities around Crystal Lake worked with The Crystal Lake & Watershed Association to incorporate The Crystal Lake Watershed Overlay District into local zoning ordinances. The CLWOD regulates land uses in such sensitive areas as shoreline buffers and steep slopes. Benzie County also adopted one of the nation's first provisions requiring upgrades of substandard septic systems, and inspection/repair of all on-site wastewater systems at time of property sale or transfer.
- Grand Traverse Regional Land Conservancy has protected thousands of acres in the watershed, through purchase, donation and conservation easements. Significant recent additions include the Railroad Point Natural Area on Crystal Lake; Misty Acres, on the Betsie River in Benzie and Manistee counties; and a large parcel of frontage on Dair Creek.
- The Friends of Betsie Bay won modifications in a proposed residential development on the east end of Betsie Bay. Through the FOBB's efforts, the amount of wetland impacted by the project was reduced in the final approved plan.
- Benzie Conservation District took the lead in creating the Benzie Watersheds Coalition, with representation from the Betsie, Platte, Herring Lakes and adjacent watersheds. Local voters approved a property tax millage to support Conservation District activities, and the district received a grant to

purchase a boat and motor. The district now assists with water quality monitoring on several water bodies, including Crystal and Betsie lakes.

- Crystal Lake & Watershed Association funded an automated lake-level monitoring system which assists the Benzie County Drain Commissioner in management of the Crystal Lake Outlet dam. CLWA has partnered with local schools on an annual educational field day, "The Crystal Lake Walkabout." CLWA also joined with other large Northern Michigan lakes in 2015 to form the Michigan Swimmer's Itch Partnership as a way to foster combined research into Swimmer's itch.

2000 Betsie River Watershed Plan

A Watershed Management Plan for the Betsie River was completed in 2000, as a cooperative venture of the Betsie River Watershed Restoration Committee and the Conservation Resource Alliance.

The document was developed in cooperation with the Clean Michigan Initiative, through the Michigan Department of Environmental Quality, and was not submitted for USEPA approval under section 319.

The 2000 WMP was concerned primarily with needed actions to protect and restore the Betsie River mainstem and flowing tributaries, rather than the lakes within the larger watershed. It identified the major threats as sedimentation, nutrient inflows and thermal pollution. Those issues continue to be major concerns in the watershed.

Many of the 2000 plan's objectives were met through grant and local funding for more than $700,000 in projects to stabilize streambanks and improve road stream crossings on the mainstream and major tributaries.

The 2000 WMP was consulted as an important resource in the development of the current plan. Elements of the current Betsie River / Crystal Lake Watershed Management Plan document, where they relate to the river and tributaries, may be seen as updates and expansion of the work that was included in the 2000 Betsie River WMP.

Michigan Ecoregions

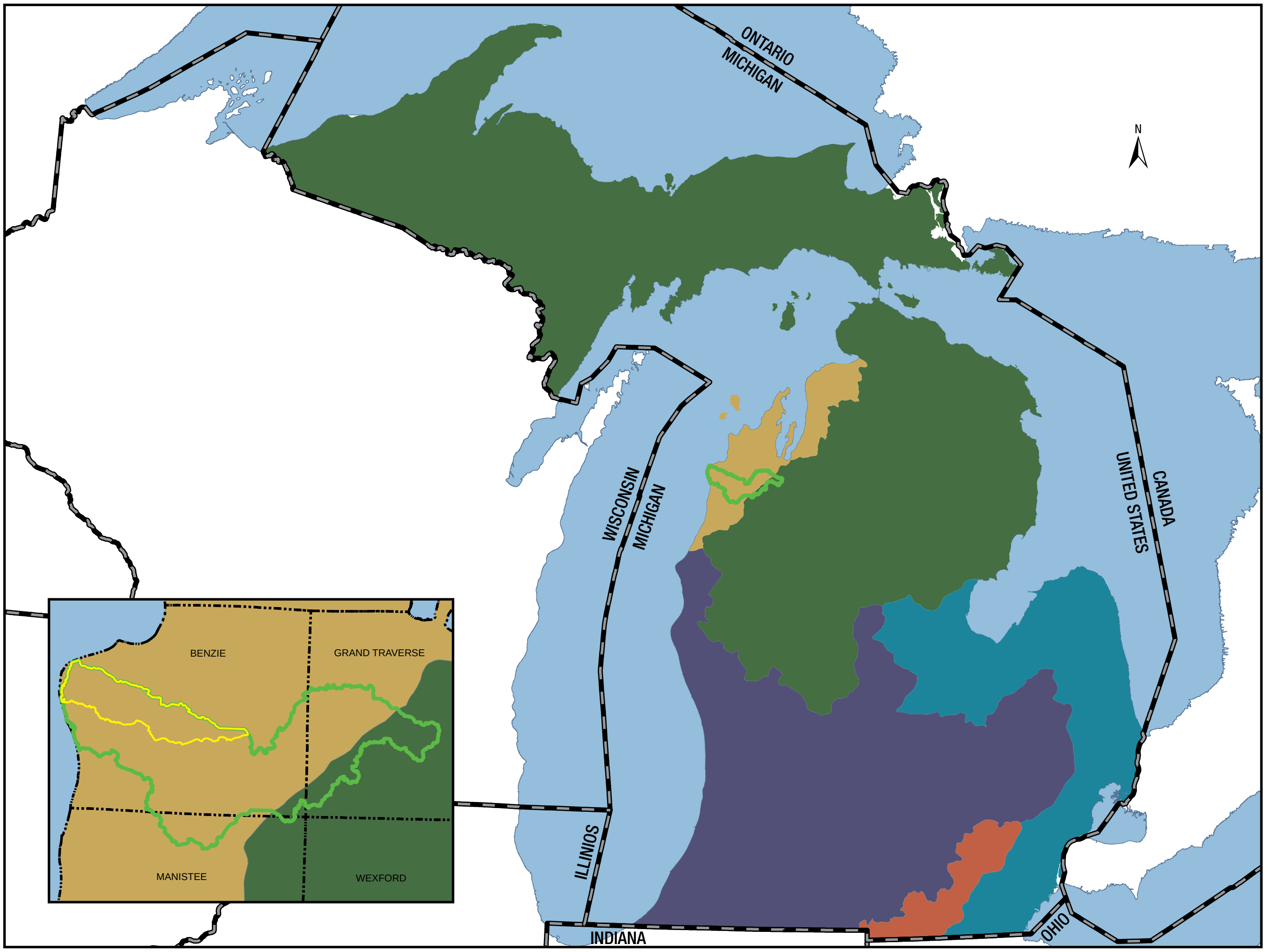
Michigan's rivers are grouped into five distinct ecoregions, based upon the character of the land through which they flow. Most of the Betsie River Crystal Lake Watershed is in the North Central Hardwood Forests ecoregion, which encompasses most of the northwest Lower Peninsula. A small segment of the watershed along with the northeastern Lower and all of the Upper Peninsula are in the Northern Lakes and Forest ecosystem.

According to the Integrated Report:

"Each of the five ecoregions in Michigan consists of areas that exhibit relatively similar geological landform characteristics (Omernik and Gallant, 1988). Factors used to delineate ecoregions include climate, soils, vegetation, land slope, and land use. This framework provides information on the environmental characteristics that tend to occur within each ecoregion. In order by size (largest to smallest area), the five ecoregions in Michigan are Southern Michigan/Northern Indiana Till Plains, Northern Lakes and Forests, North Central Hardwood Forests, Huron-Erie Lake Plains, and Eastern Corn Belt Plains.

Rivers in the Northern Lakes and Forests and North Central Hardwood Forests ecoregions tend to support coldwater fish within at least a portion of their systems. These rivers commonly have relatively small watersheds, high relief topography, substantial groundwater inputs, and are naturally low in productivity. … In the North Central Hardwood Forests ecoregion, river flow is highly variable. Flow is entirely intermittent in some portions of the ecoregion and entirely perennial in other areas. These rivers typically drain soils with much poorer nutrient content than in bordering ecoregions to the south."

Map 5 - Ecoregions of Michigan



KEY | LEVEL III ECOREGIONS

- Eastern Corn Belt Plains
- Huron/Erie Lake Plains
- North Central Hardwood Forests
- Northern Lakes and Forests
- Southern Michigan/Northern Indiana Drift Plains

Chapter 2

Watershed Overview

The Betsie River / Crystal Lake Watershed is a small but exceptionally diverse watershed, occupying parts of three counties in the northwestern Lower Peninsula of Michigan.

Great Lakes with the Betsie River Watershed

Within the 242 square miles of the watershed are four large inland lakes, a Great Lakes harbor, several smaller named lakes, and significant acreage of wetlands

The local economy is heavily oriented toward tourism and recreation, and dependent upon the quality of surface water and groundwater. The Watershed arises with small tributary streams in Grand Traverse County, six miles south of Traverse City. From there it meanders south and west through southern Benzie County and a section of northern Manistee County before reaching Betsie Lake and the harbor of Frankfort, which connects to Lake Michigan.

The Watershed extends a maximum of 32 miles east to west, and 12 miles north to south. Adjacent watersheds include Platte River to the north; Boardman River to the east; Manistee River, Bear Creek and Herring Creek to the south; and Lake Michigan to the west.

The predominant land use is forested or open land. Population and development are concentrated near lakes and in the one city and several villages within the watershed.

The eastern segments of the watershed are largely forested, with mixed agricultural and residential areas. In the western portion, a microclimate within 12 miles of Lake Michigan supports a number of commercial orchards, growing cherries and apples.

Crystal Lake, at approximately 9,850 acres, is Michigan's ninth largest inland body of water. The community of Interlochen – including Interlochen State Park and the Interlochen Center for the Arts – is on the shores of Green Lake and Duck Lake, which together total nearly 4,000 acres.

Total area of the watershed is 155,032 acres, including 28,145 acres in the Crystal Lake subwatershed.

In Grand Traverse County, the watershed includes portions of Blair, Grant, Green Lake and Mayfield townships. Prominent features include headwater streams, Duck Lake, Green Lake, the Interlochen village area and several smaller lakes: Cedar Hedge, Bass, Bridge, Tullers, Ellis and Mud.

Ellis Lake Lily Pads

In Benzie County, the Watershed covers portions of 10 townships: Benzonia, Blaine, Colfax, Crystal Lake, Gilmore, Homestead, Inland, Joyfield, Lake and Weldon; as well as the city of Frankfort and part or all of four villages: Benzonia, Beulah, Elberta and Thompsonville. Major Benzie County features include: The Grass Lake wildfowl flooding; Crystal Lake; Cold Creek; Betsie Lake and Frankfort Harbor; much of the mainstem of the river and major tributaries such as the Little Betsie River, Dair Creek and Rice Creek.

The Manistee County segment of the Watershed includes parts of Cleon, Pleasanton and Springdale townships. Features include a segment of the mainstream of the river, small tributaries, and the Misty Acres preserve of the Grand Traverse Regional Land Conservancy.

Significant Public Lands

Betsie River State Forest (part)

Fife Lake State Forest (part)

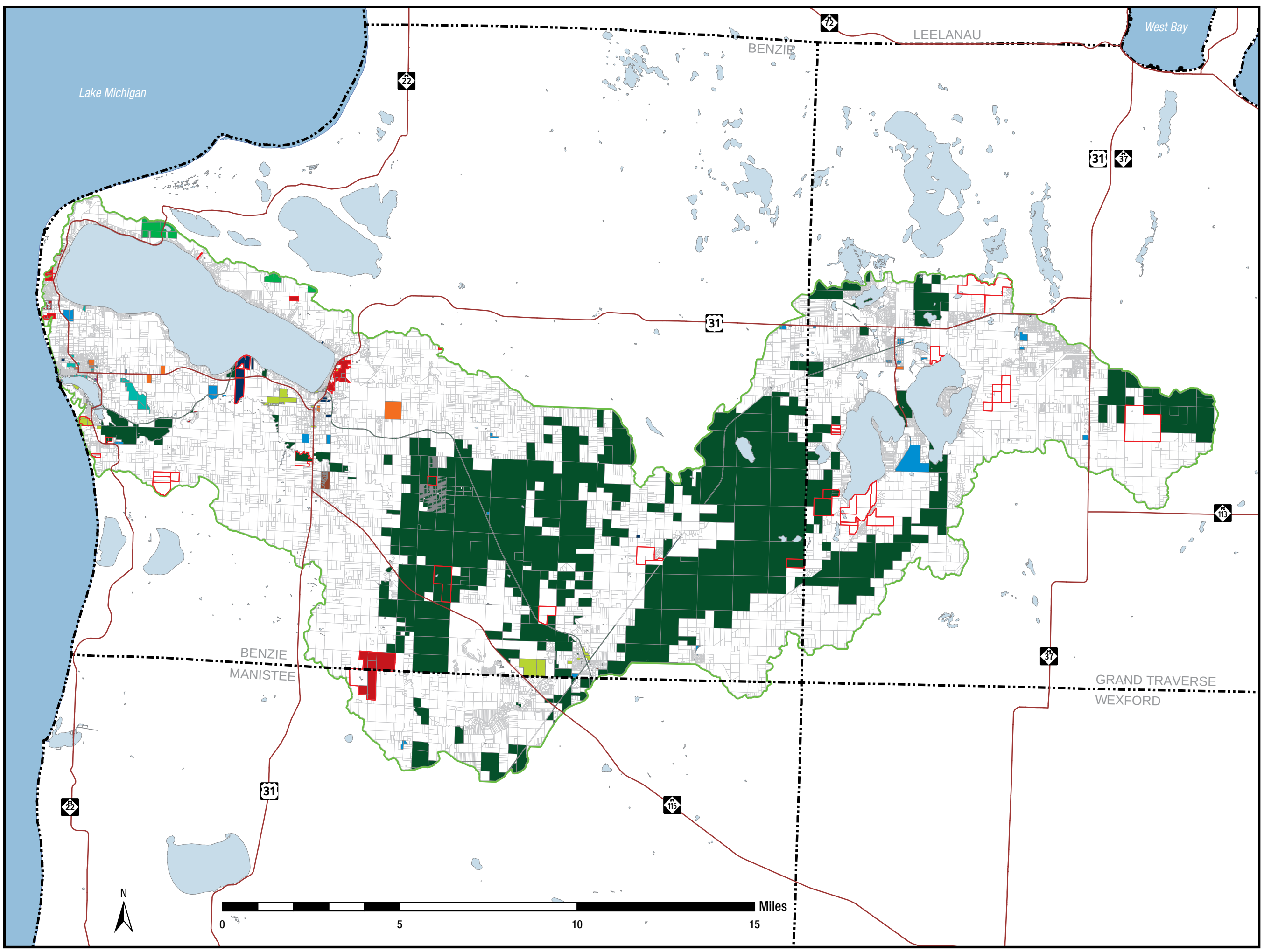
Betsie River State Game Area

Railroad Point Natural Area

Interlochen State Park

(*continued next page*)

Map 6 - Public Lands



KEY | LAND OWNERSHIP CLASSIFICATION

- National Park Service
- Federal
- State of Michigan
- Counties
- Townships
- Cities
- Villages
- Local Governmental
- Schools Districts
- Conservancy
- Private
- GTRLC Protected Lands

Sleeping Bear Dunes National Lakeshore (part)

Beulah Memorial Park and Beach

MDNR Crystal Lake Boating Access Site

MDNR Homestead Dam Lamprey Barrier and Fishing Site

MDNR Betsie River Pathway

Frankfort Open Space and Mineral Springs Park

Elberta Historic Waterfront Park

Bellows Park / Seventh Street Beach

Betsie Valley Trail

Grass Lake State Forest Campground

Thompsonville Day Use Area

Climate (and Climate Change)

The Betsie River / Crystal Lake Watershed is located in a temperate "four-season" region of the Northwest Lower Peninsula of Michigan. Daily average high temperatures are 75 to 80 degrees in July and August; nightly average lows are in the teens in January and February.

Climate in this watershed is significantly moderated by proximity to Lake Michigan. Western sectors of the Watershed, near the Great Lake, are generally snowier than the eastern sectors, with warmer winters and cooler summers. The lake water acts as a heat "sink" in warm weather, and releases some of that warmth in winter.

As a result, shoreline areas are included in the U.S. Department of Agriculture's Plant Hardiness Zone 6 (likely annual lowest temperature of zero to minus 10 degrees, Fahrenheit) while sectors away from the lake are in Zone 5, indicating annual coldest temperature of -10 to -20 degrees.

Western sectors also receive somewhat more precipitation, which is measured in Frankfort at an annual average of 34.87 inches; and at 33.12 inches in Traverse City.

Table 3 - Frankfort Climate

Month	Jan	Feb	March	April	May	June	July	Aug.	Sept	Oct	Nov	Dec
Avg. High	28	31	39	52	63	73	77	75	68	56	44	32
Avg. Low	18	19	25	35	44	53	59	60	53	42	33	23
Avg. Precip.	2.24	1.85	1.89	2.68	3.03	3.19	2.91	3.54	4.25	3.58	3.07	2.64

Table 4 - Traverse City Climate

Month	Jan	Feb	March	April	May	June	July	Aug.	Sept	Oct	Nov	Dec
Avg. High	28	30	40	54	66	76	80	78	70	57	44	32
Avg. Low	15	15	22	32	42	52	58	57	50	39	30	21
Avg. Precip.	2.83	1.50	1.85	2.80	2.60	3.15	3.03	3.39	3.54	3.23	2.72	2.48

The microclimate near Lake Michigan allows for commercial orchards in the strip of land up to about 12 miles inland. Cooler spring temperatures in that area tend to delay the blossoming of fruit trees and reduce the likelihood that the crops will be harmed by late frosts.

Snowfall throughout the region averages more than 100 inches per winter: About 140 inches in Benzie County and 100 to 120 inches in the Manistee and Grand Traverse county portions of the Watershed.

Much of the snowfall is related to the “lake effect,” which results when cold winds absorb moisture while crossing Lake Michigan, and then release that moisture as snow over land.

The four-season climate is important to the local economy. While summer is clearly the busiest tourist time, the region also draws visitors for skiing, snowmobiling and ice fishing in winter; steelhead fishing in spring; leaf-color viewing, deer hunting and salmon runs in autumn, and general touring year round.

In planning for future water quality it is important to consider the potential impacts of climate change. “Greenhouse gases” such as carbon dioxide have the physical effect of trapping a portion of the sun’s heat in the atmosphere. Global data indicate that increases in atmospheric CO_2 have been occurring in line with burning of fossil fuels since the beginning of the industrial revolution.

Impacts such as rising sea levels, decreasing arctic ice cover and higher average global temperatures have been documented over recent decades, lending strong support to models that show a link between atmospheric CO_2 levels and increasing climate change.

While the global issue seems clear, climate predictions are considerably more difficult for a small area such as the Betsie/Crystal Watershed. As the earth retains more of the sun’s heat energy, it is likely that air and sea currents will be impacted, making some areas wetter, some dryer, and possibly even pushing cold air into some areas.

Specific local impacts of those complex interactions remain very much in doubt. There is no consensus, for example, on the question of Great Lakes water levels. Warmer air holds more moisture, so precipitation may increase, potentially raising lake levels. On the other hand, more warmth also means less winter ice cover and more evaporation, which could result in lower levels.

Add those opposing forces to the natural variability of Lake Michigan, and it’s impossible, given our current knowledge, to accurately forecast lake level changes.[4]

There does, however, appear to be high probability of several local impacts resulting from climate change.

A 2014 report by the Rocky Mountain Climate Organization found that the probability of severe rainstorms – defined in the report as a rainfall of 2 inches or more in a single day – increased by 89 percent from 1965 to 2010.[5]

The finding comports with most climate models: Warmer air holds more energy and more moisture and is thus capable of producing stronger storms.

In another 2014 study, the United States Geological Survey found that over the next 30 years, Northern Michigan will likely see an increasing percentage of winter precipitation in the form of rain, rather than snow. That, combined with a higher likelihood of midwinter thaws, will have the dual effect of reducing the size of the late winter snowpack, and decreasing the number of days each year when the ground is snow-covered.[6]

That will tend to moderately increase stream flows during the normally low-flow winter months, and decrease the rise of streams in the spring. While the change may appear to be modest, the USGS report stated, it may “appreciably alter ecosystem functions … that depend on seasonal dynamics at subannual time periods, such as fish spawning.”

The USGS report further notes that a decrease in days of snow cover would be expected to increase rates of evapotranspiration which could lead to drier soils in late summer and increased reliance on groundwater for irrigation.

These potential changes reinforce the desirability of meeting the central goals of this Watershed Management Plan.

Best management practices such as native plantings, properly sized stream culverts, stormwater catchment and wetland preservation are important to preserving water quality under present climate conditions. They become even more vital as climate changes.

Likewise, as climate uncertainty rises, the need for consistent monitoring of water parameters also increases.

Hydrology

The Betsie River Hydrologic and Hydraulic Study was completed in May, 2014, by the Great Lakes Environmental Center, Inc. (GLEC) under a contract with the Michigan Department of Environmental Quality. (The full report is included as Appendix B to this WMP.)

The purpose of the study was to use data on land cover, impervious surfaces, soil types, topography and related factors to estimate hydraulic response and peak water flows that will result from a "design storm event." The design storm for this effort is a "50 percent probability" rain storm event, or a rainfall which, based on past climate

Storm Water Erosion on Beulah Beach

records, can be expected to occur on average once every two years.

For this region of Michigan, that is a rainfall of 2.09 inches in a 24-hour span.

For purposes of the modeling effort, MDEQ and GLEC defined 48 subwatersheds in the Betsie River Watershed, and used GIS mapping, soil maps, and other techniques to estimate infiltration, runoff and other hydraulic parameters for each area. Those figures were then applied to segments of the river system to estimate peak flows.

Runoff volumes calculated as part of the Hydrologic Study were also used to estimate nutrient loads as part of the pollution Source Inventory in Chapter 3 of this WMP. The subwatersheds are delineated primarily by topographical features or by the streams to which they contribute runoff. There was no attempt in this exercise to characterize governmental units such as the City of Frankfort or the Village of Beulah.

The study considered watershed land cover as it existed in three time periods: 1800 (presettlement); 1978; and 2006.

For the 1800 map, conditions were estimated from original surveyors' data and land descriptions created prior to 1856.

The 1978 map was created from aerial imagery and county records, using the Michigan Resource Inventory System (MIRIS) framework. The 1800 and 1978 maps were accessed through the Michigan Center for Geographic Information Geographic Data Library.

Since no current land cover map exists for the entire watershed, the GLEC hydrologists used the National Land Cover Dataset from 2006 as the most recent data to represent current conditions.

The major land cover classes for the three time periods are shown in the following table.

Table 5 - Land Cover

Major Landcover Classes	1800 Conditions Percent of Total Area	1978 Conditions Percent of Total Area	2006 Conditions Percent of Total Area
Agricultural Land	0%	6%	8%
Forest Land	76%	51%	46%
Rangeland	0%	19%	13%
Urban and Built Up	0%	5%	8%
Water	10%	10%	10%
Wetlands	14%	9%	15%

The tabular data show that agricultural and urban land increased over time, while forested land decreased. Unforested rangeland increased during the pre-1978 time period but has since decreased.

The table reports an increase in wetland acreage from 1978 to 2006. The report authors speculate that the reported increase may stem from the use of a different dataset for the 2006 land cover. Further study may be indicated to determine whether the figures represent an actual increase in wetlands, or an anomaly in the data.

According to the GLEC analysis, the percentage of impervious surfaces in the watershed grew from zero in 1800 to approximately 3 percent currently, with individual subbasins varying from 0 percent to 6 percent imperviousness.

The impervious cover model developed by The Center for Watershed Protection indicates that stream quality degradation is likely when impervious surfaces exceed 5-10 percent of total land area.[7]

The Betsie River / Crystal Lake Watershed overall is well below those levels, but urban areas and the busy US31 corridor north of Duck Lake have significant amounts of impervious surfaces. As the GLEC report notes: "While the percent imperviousness is still relatively low, the trend over time shows steady increases in imperviousness that, if left unmitigated, may significantly impact the water quality of the Betsie River and its tributaries in the future."

Overall, runoff volumes in the watershed have increased about 5 percent since development of the region began.

The largest increase calculated for any of the delineated subbasins was about 33 percent, in the region that includes the US31 corridor north and east of Duck Lake.

"In most subbasins, runoff volume increases over time due to the effect of development," the report states. It notes that nearly 100 percent of rain falling on pavement will be classed as runoff, while a two-inch rain falling on forest or sandy grassland may not run off at all.

A major finding is that the Betsie River actually rises and falls less rapidly after a rainfall than do many other river systems. That is the result of the large lakes (Green, Duck, Crystal, Grass and Betsie) that act as reservoirs, storing water and releasing it gradually downstream.

"Peak rates are significantly attenuated by the reservoirs and lakes in the Betsie River Watershed," the report noted. For example, peak flow into Duck Lake following a 2.09 inch rainfall is estimated to be at least 300 cubic feet per second, while the outflow peaks at about 35 cfs.

"Similar predictions are made at the outflow of each of the lakes," according to the study.

The following table shows the calculated peak flow rates for key points on the Betsie system, based on the design rainfall event of 2.09 inches over a 24-hour period.

Table 6 - Peak Flow rates at key hydraulic points in the Betsie River System

	Location	Baseflow (cfs)	1800 Peak Flow (cfs)	1978 Peak Flow (cfs)	2006 Peak Flow (cfs)
1	Mainstem below Duck Lake	26	32	33	35
2	Mainstem below Green Lake	44	45	46	46
3	Mainstem below Grass Lake	58	71	68	67
4	Little Betsie River before confluence with Betsie River	7	19	22	29
5	Mainstem below Little Betsie River	79	109	103	116
6	Dair Creek before confluence with Betsie River	10	10	10	10
7	Mainstem below Dair Creek	119	151	143	159
8	Rice Creek before confluence with Betsie River	7	7	7	12
9	Crystal Lake outlet before confluence with Betsie River	34	60	60	60
10	Betsie River mainstem below connection to Crystal Lake	171	229	222	237
11	Mouth of Betsie River at Betsie Lake	183	232	227	239

The authors note that the calculations are based on accepted hydrologic principles and the best available data. Since no long-term stream gage data exists for the Betsie, the results cannot be correlated with documented stream flows. The report recommends that actual stream flow data should be collected on the river. The WMP supports that recommendation.

Fishery

Fishing is a very popular activity throughout the watershed. The Betsie River is a renowned salmon and steelhead stream, hosting large runs of salmon and steelhead. In particular the Betsie River sees very heavy fishing pressure in the fall for Chinook salmon, and in the spring for the steelhead spawning run. While the Chinook salmon run is supported entirely through natural reproduction, the steelhead run includes a mix of both wild and stocked fish. MDNR stocks 20,000 steelhead annually into the Betsie River. In addition, the Betsie River supports a modest fishery for resident brown trout, which is enhanced by MDNR, through the stocking of 18,000 brown trout annually.

From the Grass Lake Dam downstream to Kurick Road, the Betsie River is regulated as a Type 1 trout stream. This means that it can only be fished during the "regular" trout season, or the last Saturday in April through September 30. The daily bag limit is 5 trout or salmon per day, with no more than three greater than 15 inches. The minimum size limits are 7 inches for brook trout, 8 inches for brown trout, and 10 inches for rainbow trout. All Betsie River tributaries are also regulated as Type 1 trout streams.

Below Kurick Road, the Betsie River is regulated by MDNR as a Type-4 trout stream, meaning that the river is open to year-round fishing. The size limits are 7 inches for brook trout, and 10 inches for all other salmonid species. The daily bag limit is 5 trout or salmon per day, with no more than three greater than 15 inches.

One issue with the Betsie River fishery is the lack of thoughtfully spaced public access sites, particularly in the reach between Thompsonville and Homestead Dam. The lack of appropriate parking and restroom facilities sometimes leads to conflict with private landowners, and also creates erosion issues when watercraft are launched at makeshift launches up and down the corridor. A comprehensive access plan for the Betsie River would go a long way toward alleviating these concerns.

The Betsie River has a number of smaller tributaries, most of which are designated as Trout Streams by MDNR. One issue is that many of these streams have not been surveyed by MDNR in decades.

The inland lakes of the watershed also host outstanding fishing opportunities, both in open water seasons and through the ice. Duck and Green Lakes are very heavily fished for a variety of species, including panfish, largemouth and smallmouth bass, lake trout, rainbow smelt, and yellow perch. Interlochen State Park, which provides excellent access to both lakes, is a destination for many campers who also like to fish. Both lakes are stocked annually with lake trout by MDNR. Crystal Lake is also one of the more popular fishing lakes in the northwestern Lower Peninsula, with anglers pursuing smallmouth bass, yellow perch, rainbow smelt, lake trout, rainbow trout, coho salmon, and burbot. Crystal Lake is stocked by MDNR with lake trout and rainbow trout. Betsie Lake is also very popular for fishing, in particular for migratory species like steelhead, Chinook salmon, and coho salmon. MDNR annually stocks 31,000 brown trout in the Frankfort Harbor, many of which are also caught in Betsie Bay. Other lakes with public access in the watershed include Cedar Hedge and Ellis lakes. These lakes host populations of largemouth bass, bluegill, pumpkinseed sunfish, northern pike, yellow perch, and rock bass. Cedar Hedge Lake also has a documented population of lake herring (cisco).

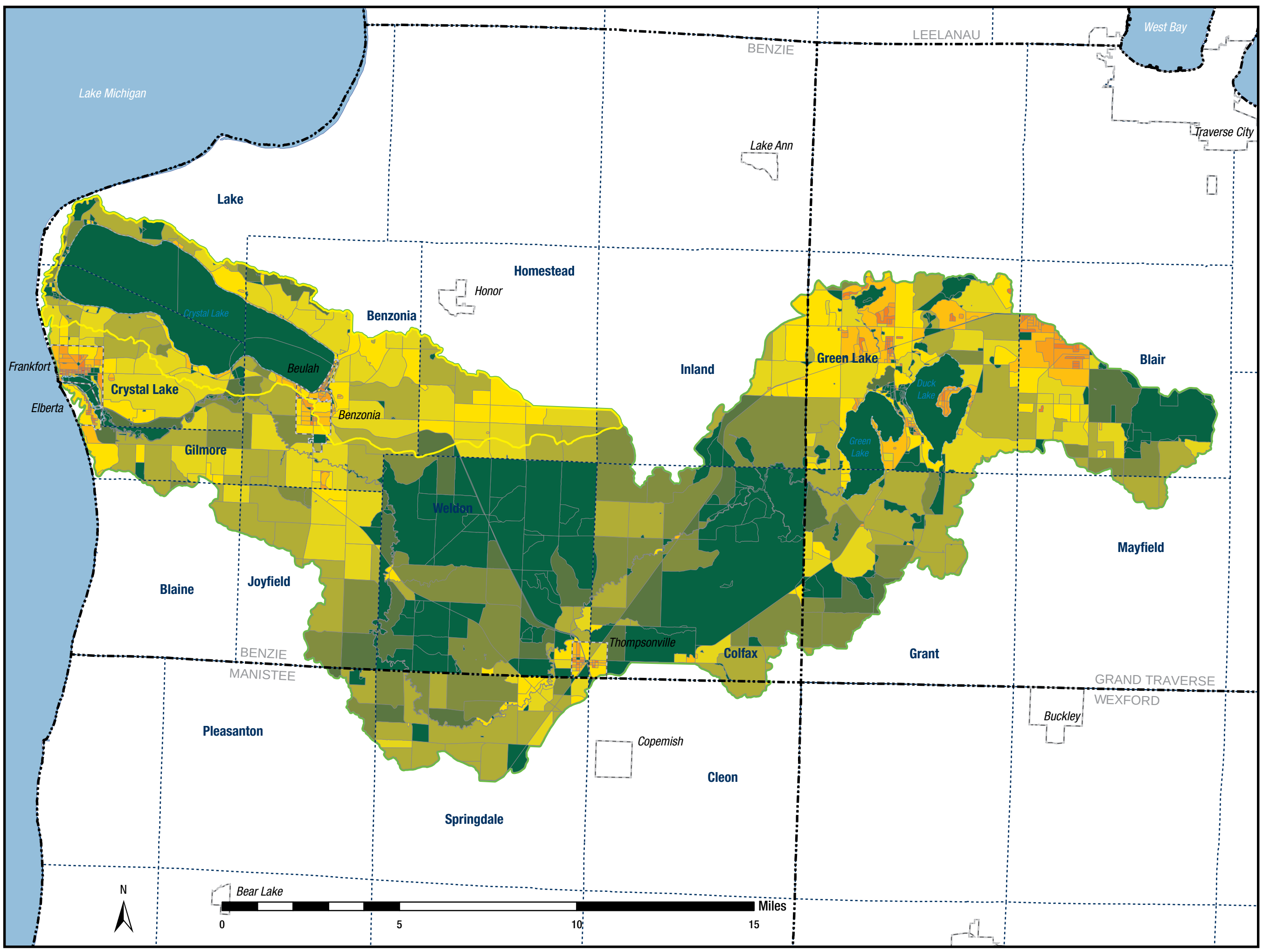
Duck and Green Lakes are designated as Type B trout lakes, meaning that they can be fished all year long, and all trout and salmon species may be harvested all year. Possession limits are five trout per day, but no more than three over 15 inches. The minimum size limit for lake trout in these lakes is 15 inches, while brook trout, coho salmon, and Chinook salmon must be 10 inches, and brown and rainbow trout must be 12 inches. Crystal Lake is a Type E lake, so it can be fished year-round. The daily limit is three trout or salmon, with the minimum size limit being 15 inches on all trout species, and 10 inches on coho and Chinook salmon. Betsie Lake is a Type E lake, meaning that it can be fished year-round. Harvest of trout and salmon is legal year-round, except for lake trout, which can only be harvested between January 1 and September 30. In Betsie Lake, the minimum size limit for all trout and salmon species in 10 inches.

There are four lakes in the Betsie River watershed that historically had populations of lake herring (cisco), which is designated as a State-threatened species. The four lakes are Crystal Lake, Green Lake, Duck Lake, and Cedar Hedge Lake. However, recent MDNR fisheries surveys of Crystal, Duck, and Green Lakes have failed to capture any cisco. Cedar Hedge Lake has not been surveyed by MDNR since 1976. Fishery Status Reports compiled by the MDNR for the Betsie River and Crystal, Duck, Green and Betsie lakes are included as Appendix C to the WMP.

Demographics

The year-round population of the watershed is estimated at 17,482, living in the city of Frankfort and portions of 17 townships. Of the total population, about 9,000 live in Grand Traverse County, 8,150 in Benzie County and fewer than 400 in Manistee County.

Map 7 - Population Density



KEY | POPULATION DENSITY (GEOMETRIC)

People per Acre
- 0.000 - 0.005
- 0.005 - 0.015
- 0.015 - 0.035
- 0.035 - 0.085
- 0.085 - 0.200
- 0.200 - 0.500
- 0.500 - 1.500
- 1.500 - 3.000
- 3.000 - 10.00
- 10.00 - 20.00

CITY OR VILLAGE
TOWNSHIP
COUNTY

The 2010 census showed significant growth in the eastern half of the watershed – especially in the areas nearest to Traverse City. Meanwhile, the western sections, closer to Lake Michigan, saw slow growth or actual population declines.

The most populous area in the watershed is Grand Traverse County's Green Lake Township, which had a 2010 population of 5,784. More than 75 percent of the township is in the Betsie River Watershed. (Blair Township actually has a higher total population, but the majority of Blair is in the Boardman River Watershed.)

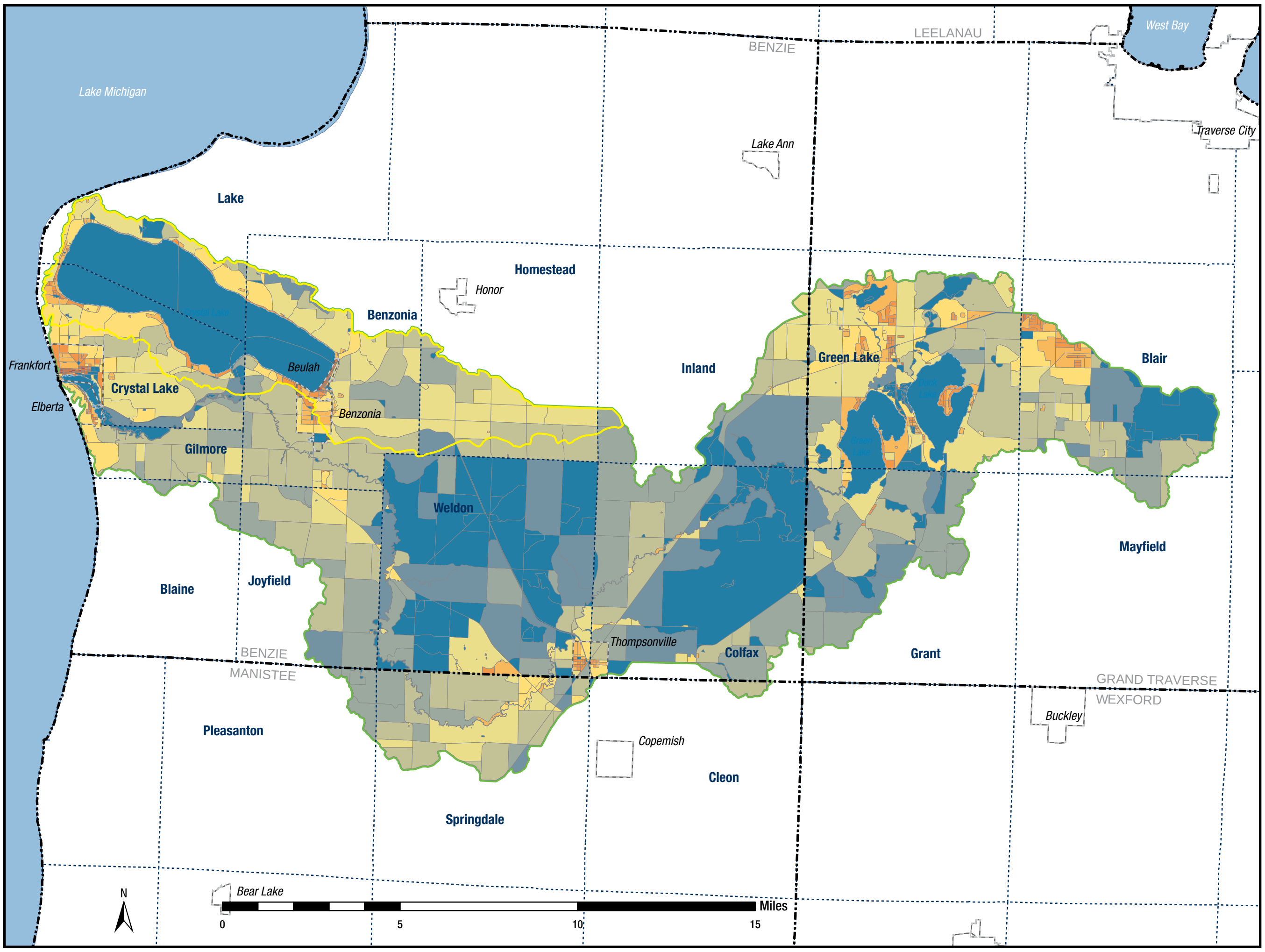
Table 7 - Watershed Population Estimates

Township/City/County		Total Population (2010 Census)	Percent of Jurisdiction Area Inside Watershed	Estimated Population within Watershed
Benzie	Benzonia Twp	2,727	71%	1,931
	Blaine Twp	551	5%	28
	Colfax Twp	657	92%	604
	Crystal Lake Twp	957	97%	932
	Gilmore Twp	821	93%	761
	Homestead Twp	2,357	35%	828
	Inland Twp	2,070	26%	543
	Joyfield Twp	799	64%	509
	Lake Twp	759	30%	231
	Weldon Twp	542	100%	542
	Frankfort City	1,286	96%	1,241
	Benzie Subtotal	17,525	47%	8,150
Grand Traverse	Blair Twp	8,209	43%	3,506
	Grant Twp	1,066	46%	495
	Green lake Twp	5,784	86%	4,966
	Mayfield Twp	1,550	2%	36
	Grand Traverse Subtotal	86,986	13%	9,003
Manistee	Cleon Twp	957	1%	12
	Pleasanton Twp	818	4%	29
	Springdale Twp	781	37%	288
	Manistee Subtotal	24,733	3%	329
Three County Total		129,244	17%	17,482

In each of the three counties, the 2010 census found that the overall population had a higher median age and a lower poverty rate than did Michigan as a whole.

The townships around Crystal Lake and in the sparsely populated interior of the watershed showed very high housing vacancy rates, indicating a high percentage of dwellings in those areas are used as second homes or cottages. For all of Benzie County, the 2010 count showed 40 percent of homes were vacant on the census day in April 2010. The figure for Grand Traverse County was much lower, at 15.1 percent, just slightly above the state average of 14.6 percent vacancy.

Map 8 - Housing Density



KEY HOUSING DENSITY (GEOMETRIC)

Housing Units per Acre

- 0.0000 - 0.0025
- 0.0025 - 0.0100
- 0.0100 - 0.0250
- 0.0250 - 0.0650
- 0.0650 - 0.1500
- 0.1500 - 0.4000
- 0.4000 - 1.0000
- 1.0000 - 2.5000
- 2.5000 - 6.0000
- 6.0000 - 15.000

CITY OR VILLAGE

TOWNSHIP

COUNTY

A long term trend of some concern in the region is the loss of city and village population, with most growth occurring in unincorporated townships. From 1970 to 2010, Benzie County's city and villages lost 8 percent of their population, while unincorporated areas gained 194 percent.

The Local Economy

The Betsie River and Crystal Lake areas are known primarily as destinations for outdoor recreation, boating, golf, winter sports and general tourism. While those amenities are certainly key to a large part of the local economy, there is somewhat more diversity.

Large year-round employers within the watershed include: Two fruit processing operations (Graceland Fruit in Frankfort and Cherry Growers Inc. in Green Lake Township); Magna International, an auto-industry supplier in Benzonia; The Crystal Mountain Resort and Spa in Thompsonville; Interlochen Center for the Arts in Interlochen; and Paul Oliver Memorial Hospital in Frankfort.

There is a significant population of retirees, who live in the area either year-round or seasonally. Public and private campgrounds provide more than 1,000 tent and RV sites, which help to swell the summer population and increase demand for seasonal employment.

Fishing is an important component of the economy. A number of fishing guides run trips on the Betsie River. Out-of-town anglers during salmon and steelhead runs support campgrounds, hotels, restaurants and other businesses. The Frankfort charter fleet fishes for the Chinook salmon and steelhead that are produced by the outstanding habitat provided by the Betsie River.

The area benefits from a large number of small tourist-oriented retail and dining establishments, many of which close or reduce operations in winter.

Census figures indicate that many residents in the eastern townships work outside the watershed, largely for employers in and around Traverse City. For example, the census found that more than 70 percent of workers in Benzie County's Colfax and Inland townships crossed the county line to go to work.

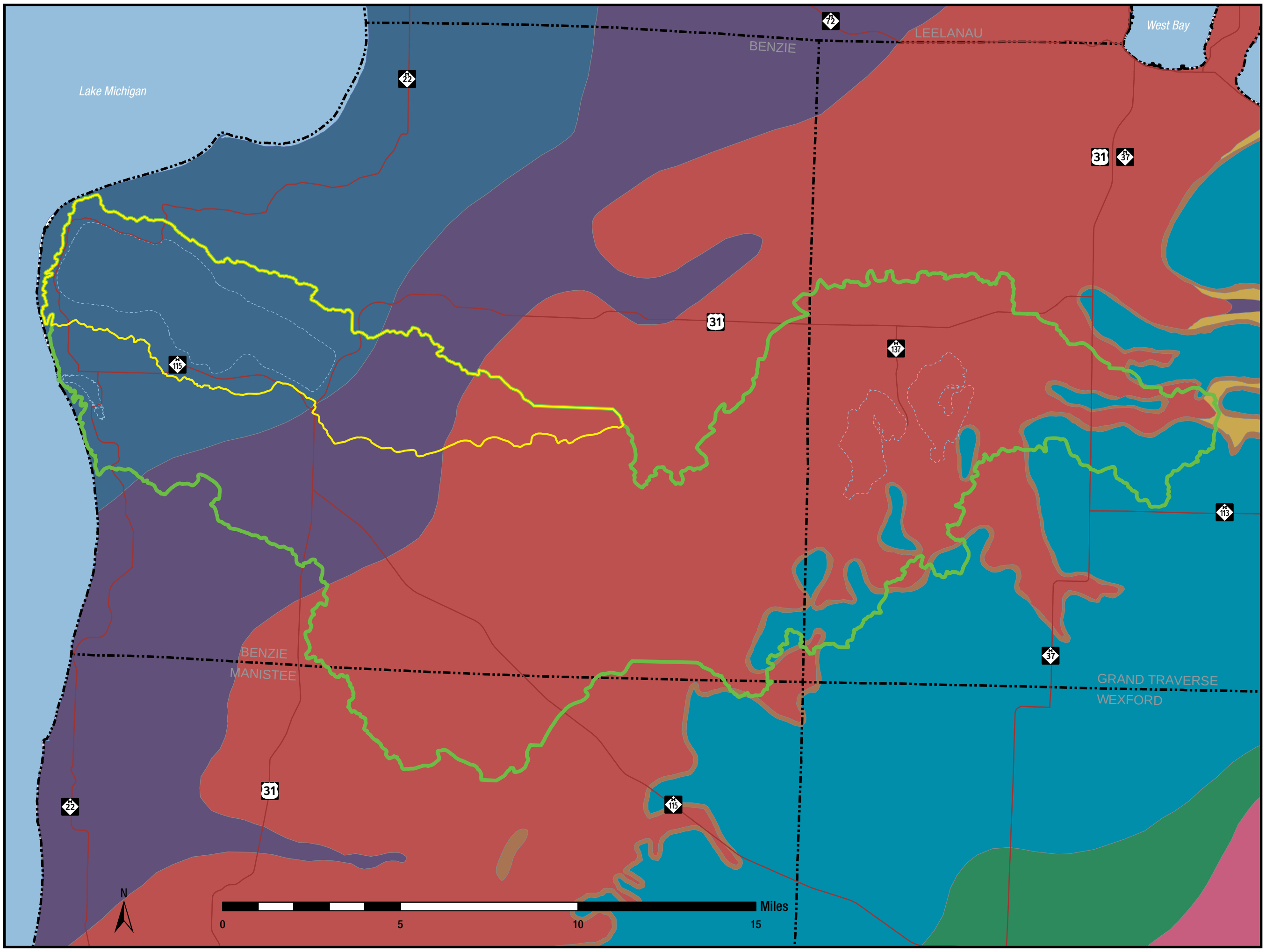
The agricultural economy is limited to fruit orchards in the climate-favored areas near Lake Michigan, and scattered small farms. The region once had considerable acreage in Christmas tree plantations, but most of that was phased out in the 1990s as a result of changing market conditions.

Betsie Lake Boating Activity

Geology and Soils

The surface geology of the watershed is dominated by glacial features, including moraines, outwash plains and kettle lakes. Soils within the watershed largely reflect the glacial history of the region, with deep course-grained deposits over the underlying bedrock. Organic wetland soils have developed in some lowland areas during the post-glacial period.

Map 9 - Bedrock Geology



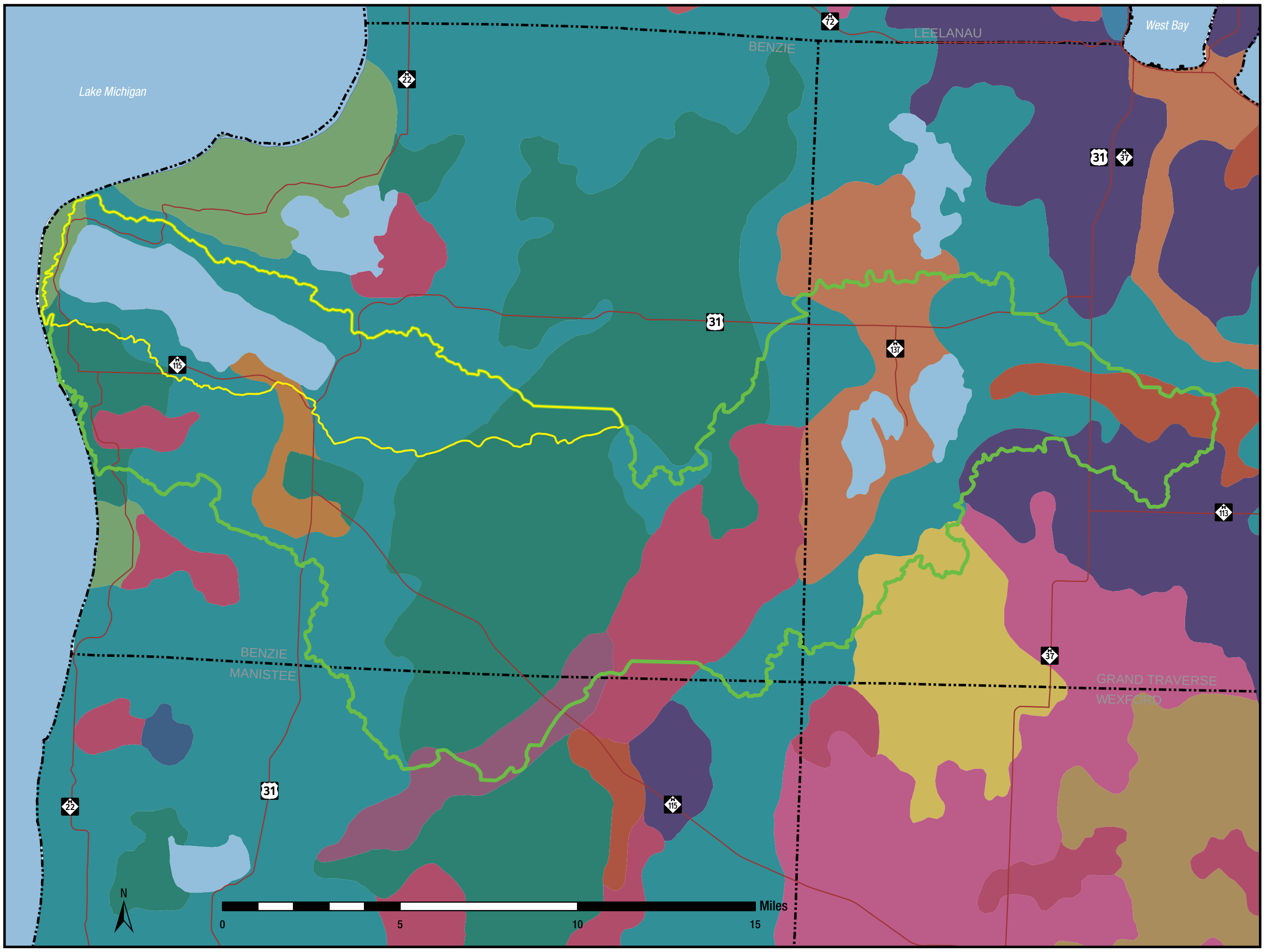
KEY | BEDROCK TYPE

- ANTRIM SHALE
- BEREA SANDSTONE & BEDFORD
- COLDWATER SHALE
- ELLSWORTH SHALE
- MARSHALL FORMATION
- MICHIGAN FORMATION
- SUNBURY SHALE
- TRAVERSE GROUP

Much of the watershed is classified in the Kalkaska or Rubicon soil series, which support forest ecology. Rubicon is described as "very deep, excessively drained soils formed in sandy deposits on disintegration moraines, ground moraines, end moraines, kame moraines, lake plains, outwash plains, stream terraces, beach ridges, and sand dunes."

Kalkaska soil is similar but only "somewhat excessively drained," which means water is more likely to be available in the tree root zone during dry periods.

Map 10 - Soils



KEY | SOIL TYPE

- BLUE LAKE-LEELANAU-MONTCALM (MI113)
- DEER PARK-UDIPSAMMENTS-EASTPORT (MI123)
- EASTPORT-EAST LAKE-DEER PARK (MI118)
- EMMET-MONTCALM-KALKASKA (MI107)
- IOSCO-BREVORT-GLADWIN (MI111)
- KALKASKA-LEELANAU-EMMET (MI116)
- KALKASKA-RUBICON-DUEL (MI117)
- KARLIN-HODENPYL-NEWAYGO (MI109)
- LUPTON-CARBONDALE-TAWAS (MI131)
- NESTER-KAWKAWLIN-SIMS (MI097)
- ROSCOMMON-TAWAS-AU GRES (MI121)
- RUBICON-EAST LAKE-EASTPORT (MI125)
- RUBICON-GRAYCALM-MONTCALM (MI124)
- RUBICON-GRAYLING-CROSWELL (MI126)
- TAWAS-ROSCOMMON-CATHRO (MI132)
- WATER

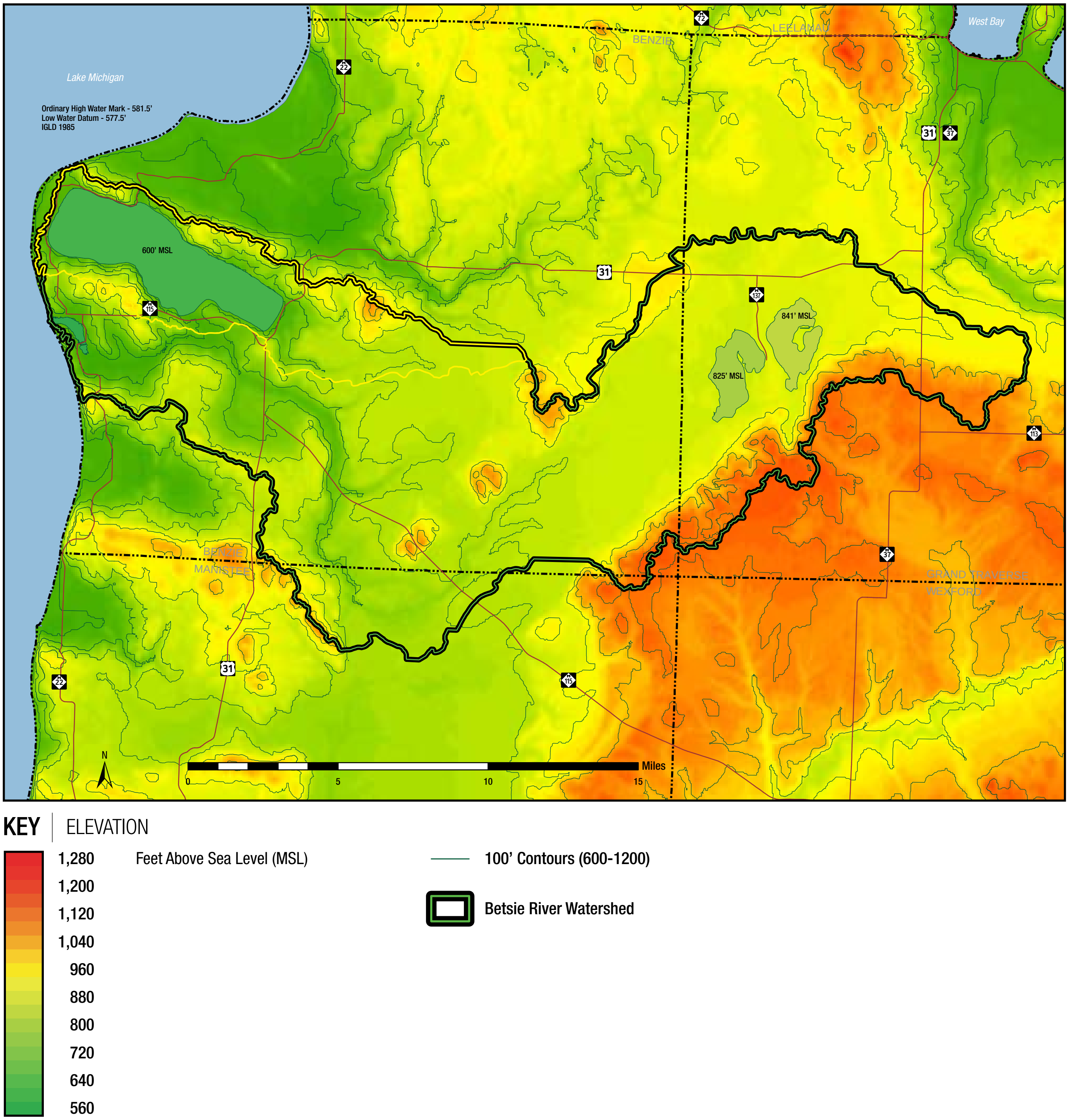
Among wetland soils found in the watershed, the Lupton series is described as “very deep, very poorly drained soils formed in organic deposits more than 51 inches thick within depressions on lake plains, moraines and outwash plains.”

Descriptions of all soil classifications are listed on the United States Department of Agriculture Website.[8]

Tall glacial moraines define the margins of the Betsie Lake and Crystal Lake subwatersheds near Lake Michigan. These steep slopes extend inland to the “Buck Hills” area near Thompsonville where the Crystal Mountain Resort is located.

The eastern portion of the watershed is characterized by more low rolling hills and less elevation change.

Map 11 - Elevation



In general terms, the topography slopes gradually from east to west. The headwaters lakes are at altitude of about 840 feet above sea level, while Lake Michigan, at the watershed's point of discharge, is at about 580 feet.

The Antrim Shale formation underlies a southeastern segment of the watershed near the communities of Thompsonville and Karlin. Porous rock in this layer has produced oil and gas for several decades. Though the majority of Michigan's hydrocarbon production has occurred in areas farther east and south, a number of oil and gas wells, along with several deep injection wells, operate in this segment of the watershed.

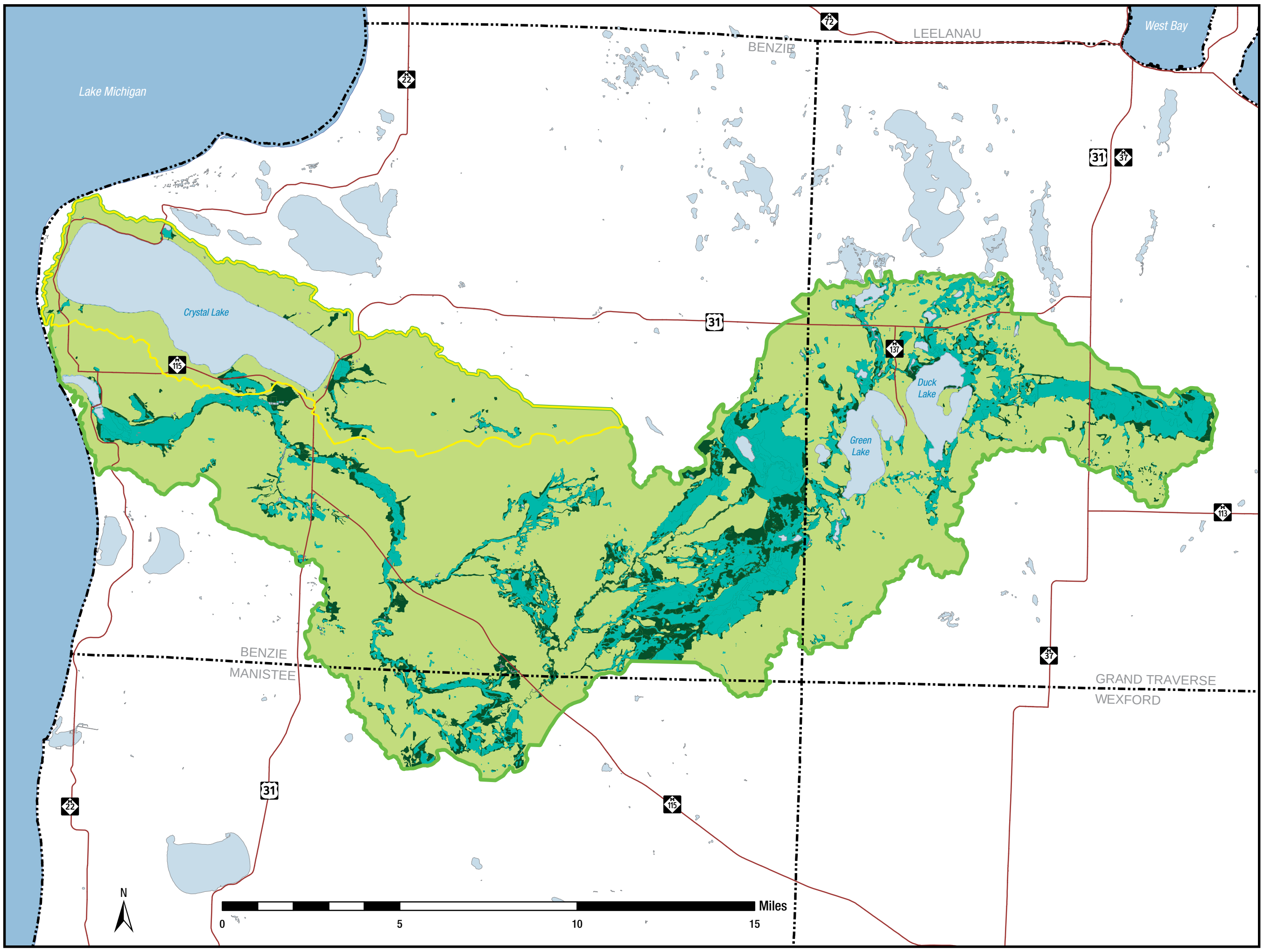
Wetlands

Wetlands in the Betsie River / Crystal Lake Watershed provide vital ecological services, including flood mitigation, filtration and groundwater recharge, sediment retention, and wildlife habitat. It is an objective of the WMP to protect and restore wetlands within the watershed (Chapter 5; Objective 2e).

Wetlands comprise approximately 15 percent of the land cover in the watershed, according to a 2014 Hydrology study conducted for this WMP (Appendix B).

Mapping shows extensive wetland complexes in the forested region between Green Lake and Thompsonville. Smaller, but still significant, wetland areas exist along the Mason Creek corridor upstream of Duck Lake and along the lower stretches of the Betsie River.

Map 12 - Wetland Inventory



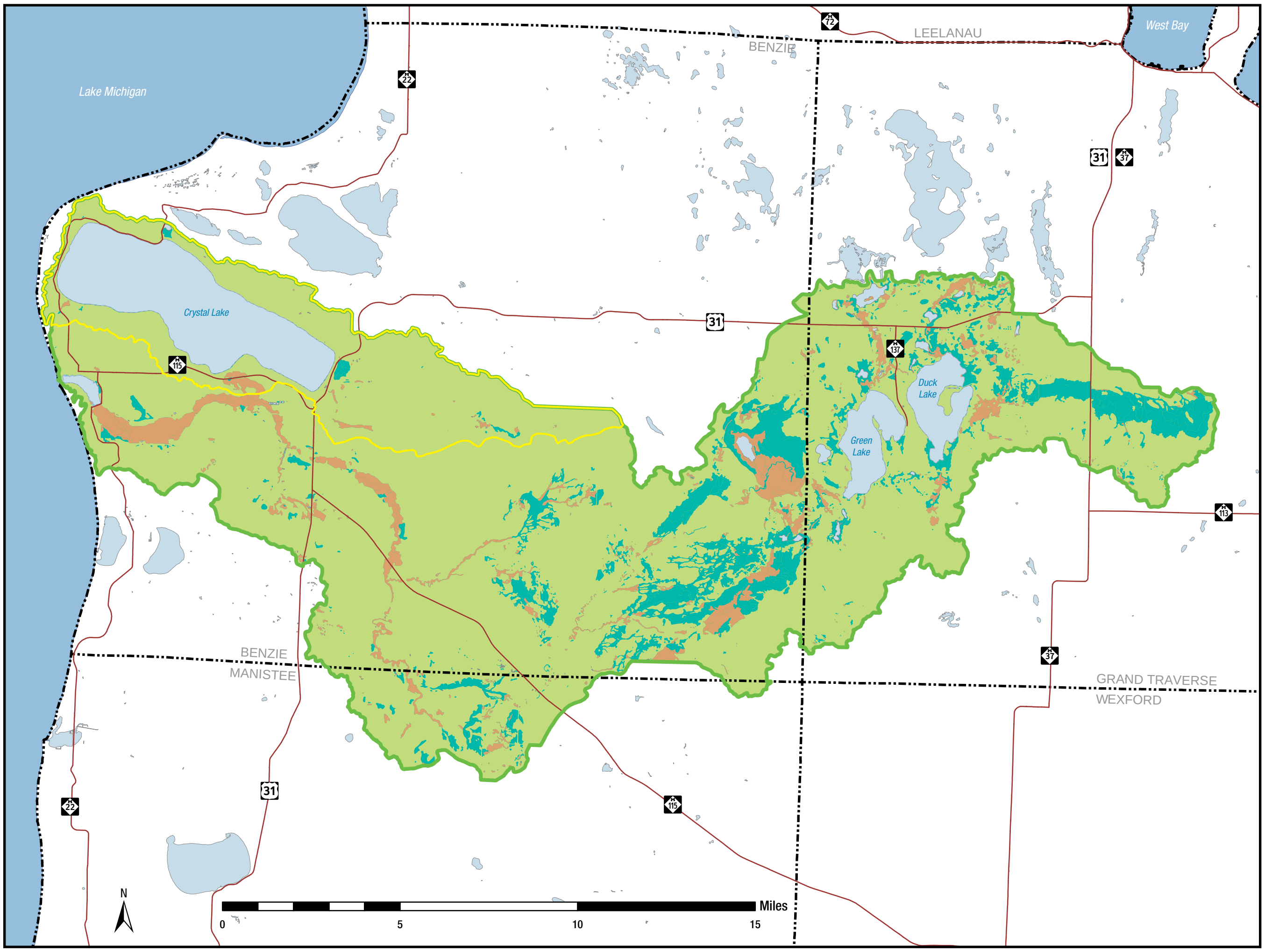
KEY | INVENTORY SET

- Wetland - 2005NWI
- Part 303 Wetland

Note: The Part 303 Wetland Inventory consists of overlaying the 2005 National Wetland Inventory (2005NWI); the Land Cover, as mapped by the Michigan Department of Natural Resources' Michigan Resource Inventory System (MIRIS); and the Soils, as mapped by the U.S. Department of Agriculture, Natural Resource Conservation Service.

Areas shown as wetlands, wetland soils, or open water on the map are potential wetlands. The maps may not identify all potential wetlands. It may show wetlands that are not actually present and it may not show wetlands which are actually present.

Map 13 - Wetland Functional Assessment - Sediment and Other Particulate Retention



KEY | FUNCTIONAL CLASSIFICATION

- Wetland - 2005NWI
- Sediment and Other Particulate Retention

Note: The Sediment and Other Particulate Retention Wetland (SOPR) area is a subset of the 2005 National Wetland Inventory (2005NWI)

The NWI Wetland is indicated to add context to the extent of the SOPR Wetlands.

Wetland and flood plain areas along Cold Creek and the Crystal Lake Outlet are considered in the critical and priority issues section of Chapter 4. Wetlands in the Upper Watershed are crucial to recharging aquifers that feed prime cold-water streams including Dair Creek and the Little Betsie River.

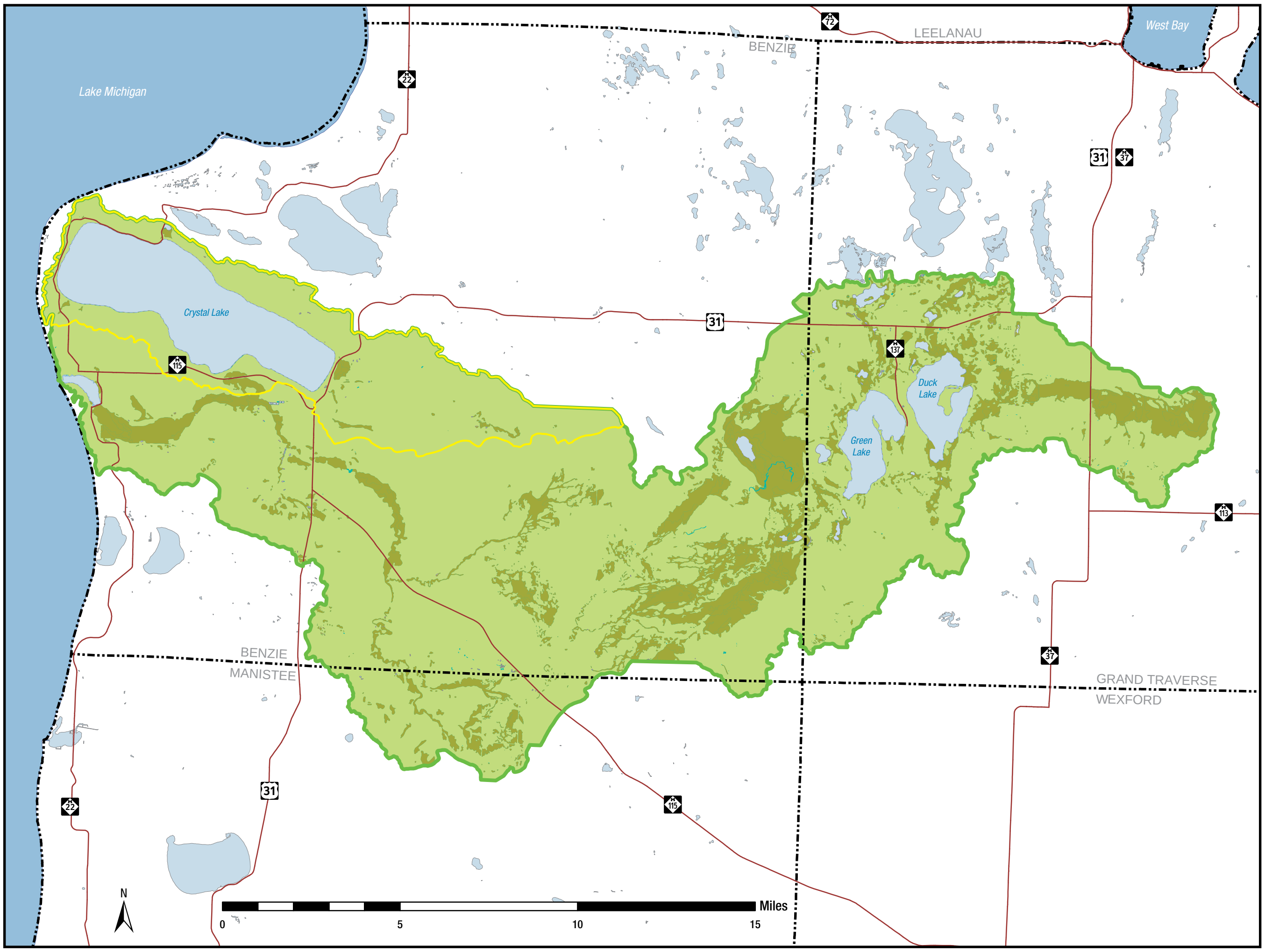
Under current regulations, federal and state agencies regulate development in wetlands which are 5 acres or greater, or which exhibit a hydrologic connection to the Great lakes.

In addition, Michigan Law protects wetlands which are located within 500 feet of a water body or which are determined by MDEQ to be essential to the preservation of natural resources.

The diversity of wetland areas is documented in a 2014 analysis by the Michigan Department of Environmental Quality. The Betsie River / Crystal Lake Watershed is one of several in Michigan for which MDEQ completed a Landscape Level Wetland Functional Assessment (LLWFA).

The assessment is intended as a tool to assist in targeting wetland protection and restoration efforts on a watershed basis. LLWFA analyzes all wetland areas in the watershed on the basis of how well each wetland fulfills specific ecological functions.

Map 14 - Wetland Functional Assessment - Nutrient Transformation



KEY | FUNCTIONAL CLASSIFICATION

- Wetland - 2005NWI
- Nutrient Transformation

Note: The Nutrient Transformation Wetland (NT) area is a subset of the 2005 National Wetland Inventory (2005NWI)

The NWI Wetland is indicated to add context to the extent of the NT Wetlands.

According to the MDEQ website, (www.michigan.gov/deq) the agency utilizes a computer model to integrate wetland maps with hydrologic data, site topography, soil types and other ecological information to evaluate the wetland functions provided by each mapped wetland area.

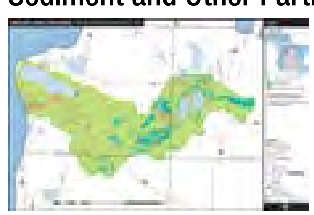
The resulting analysis can be used to provide a generalized map of current wetland functions within a watershed. It also can show the loss of wetland function associated with past land use changes, and it can identify potential wetland restoration areas.

Michigan's LLWFA process analyzes each wetland area for its ability to perform 13 specific wetland functions:[9]

Nutrient Transformation

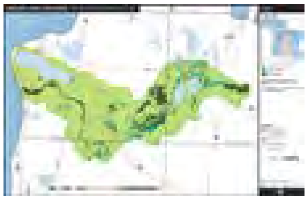
The ability of the wetland to remove nutrients from the water.

Sediment and Other Particulate Retention



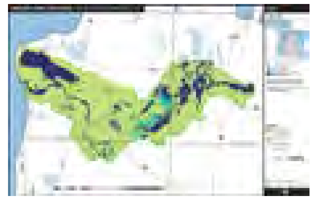
The ability of the wetland to retain the sediment that would otherwise move downstream and build up in rivers, streams and lakes.

Amphibian Habitat



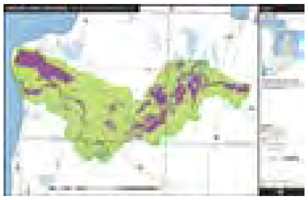
The ability of the wetland to provide habitat for amphibians and other invertebrates.

Conservation of Rare & Imperiled Wetlands & Species



Wetlands that are considered rare either globally or at the state level. They are likely to contain a wide variety of flora and fauna, or contain threatened or endangered species.

Fish Habitat

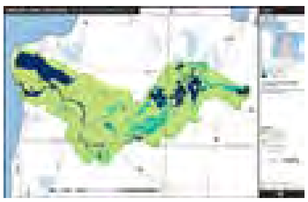


The ability of the wetland to provide habitat for fish and shellfish.

Flood Water Storage

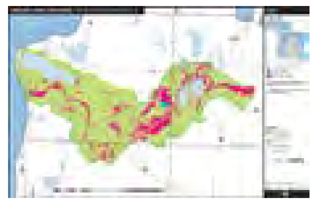
The ability of the wetland to store excess water during flood events.

Ground Water Influence



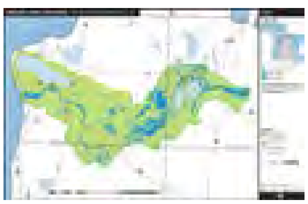
The ability of the wetland to receive some or all of their hydrologic input from groundwater reflected at the surface.

Interior Forest Bird Habitat



The ability of the wetland to provide streamside and floodplain forest habitat for interior forest birds.

Shorebird Habitat

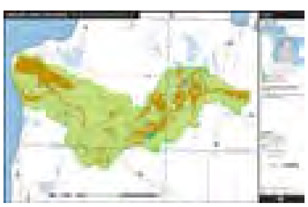


The ability of the wetland to provide habitat for shorebirds to accumulate fat reserves for migration.

Shoreline Stabilization

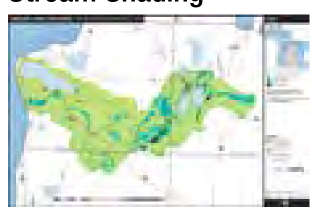
The ability of the wetland to protect shorelines by minimizing bank erosion caused by wave action and currents.

Streamflow Maintenance



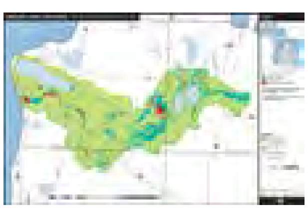
The ability of the wetland to provide a base flow of water for streams, especially critical during dry periods.

Stream Shading



The ability of the wetland to buffer water temperature fluctuations.

Waterfowl and Waterbird Habitat



The ability of the wetland to provide habitat for waterfowl and waterbirds.

Nutrient transformation and sediment retention are among the most significant ecological services in this watershed, given that sediment and nutrient pollution are of concern throughout the watershed. LLWFA maps are reproduced here as part of the WMP. Large format wetland functional maps are included in the mapping section of the electronic versions of the plan (www.NWM.org/brclwmp).

The Watershed Protection Committee (chapter 7) will communicate the entire LLWFA to planning commissions and appropriate public and private agencies throughout the watershed.

Master Plan & Zoning Review

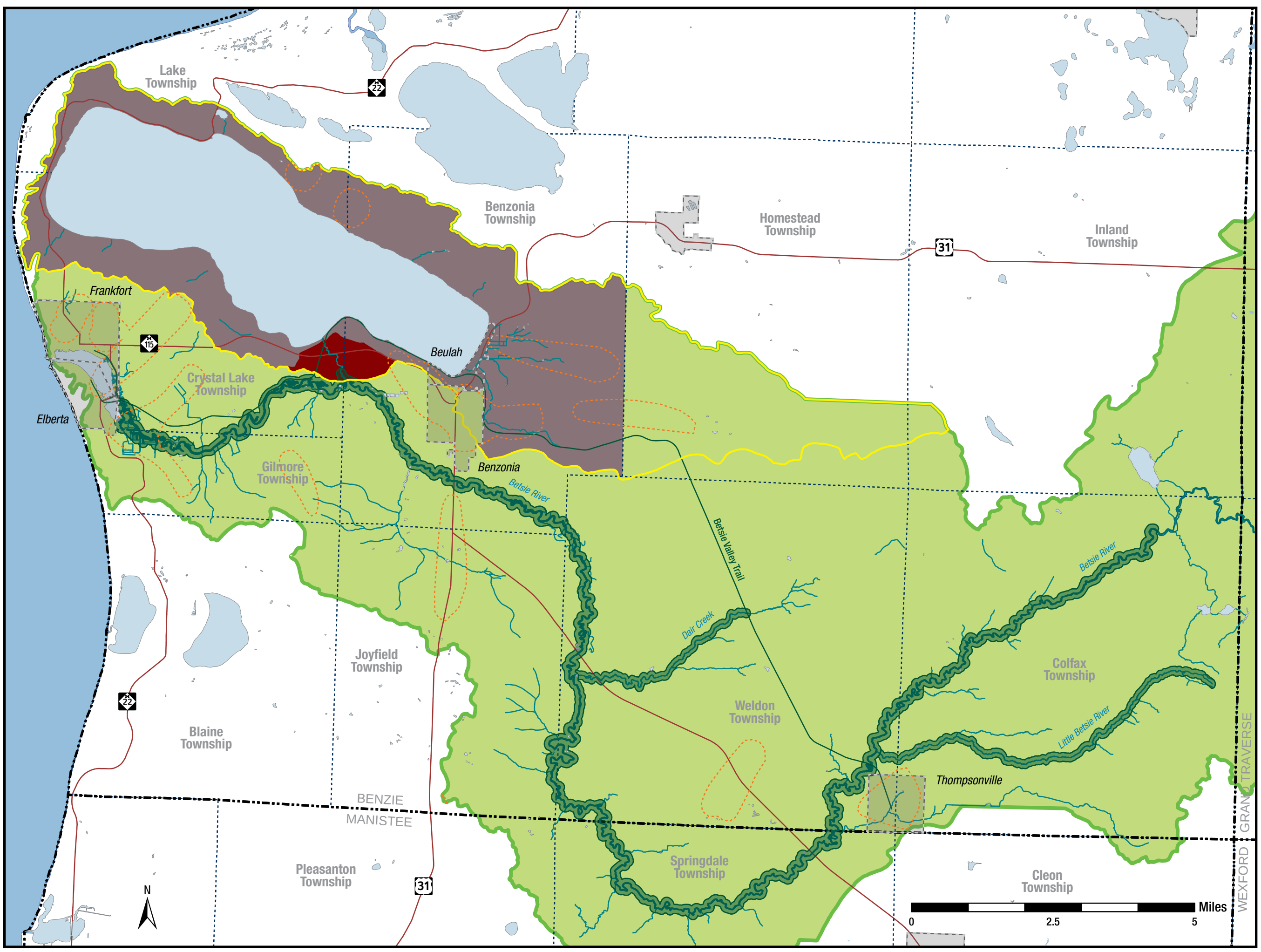
Land use is known to have a significant impact on water quality and non-point source pollution. For example agricultural operations, residential on-site waste water systems, impervious surfaces and open space areas all have differing effects on lakes and streams throughout the Watershed.

Regulations enforced by counties and municipalities, by the district health department, by county building departments, and by state agencies may all limit some types of land development and incentivize others.

In the Betsie River / Crystal Lake Watershed, water quality has been positively affected by two long-standing provisions:

The Michigan Natural River designation for the Betsie River covers a 400-foot corridor on either side of the mainstream from the Grass Lake Dam to the Mouth at Betsie Lake, as well as Dair Creek west of the Betsie Valley Trail and all of the Little Betsie River. In the Natural River corridor, vegetation cutting within 50 feet of the stream is restricted, and most new buildings must be set back a minimum of 200 feet from the stream.

Map 15 - Special Zoning Districts



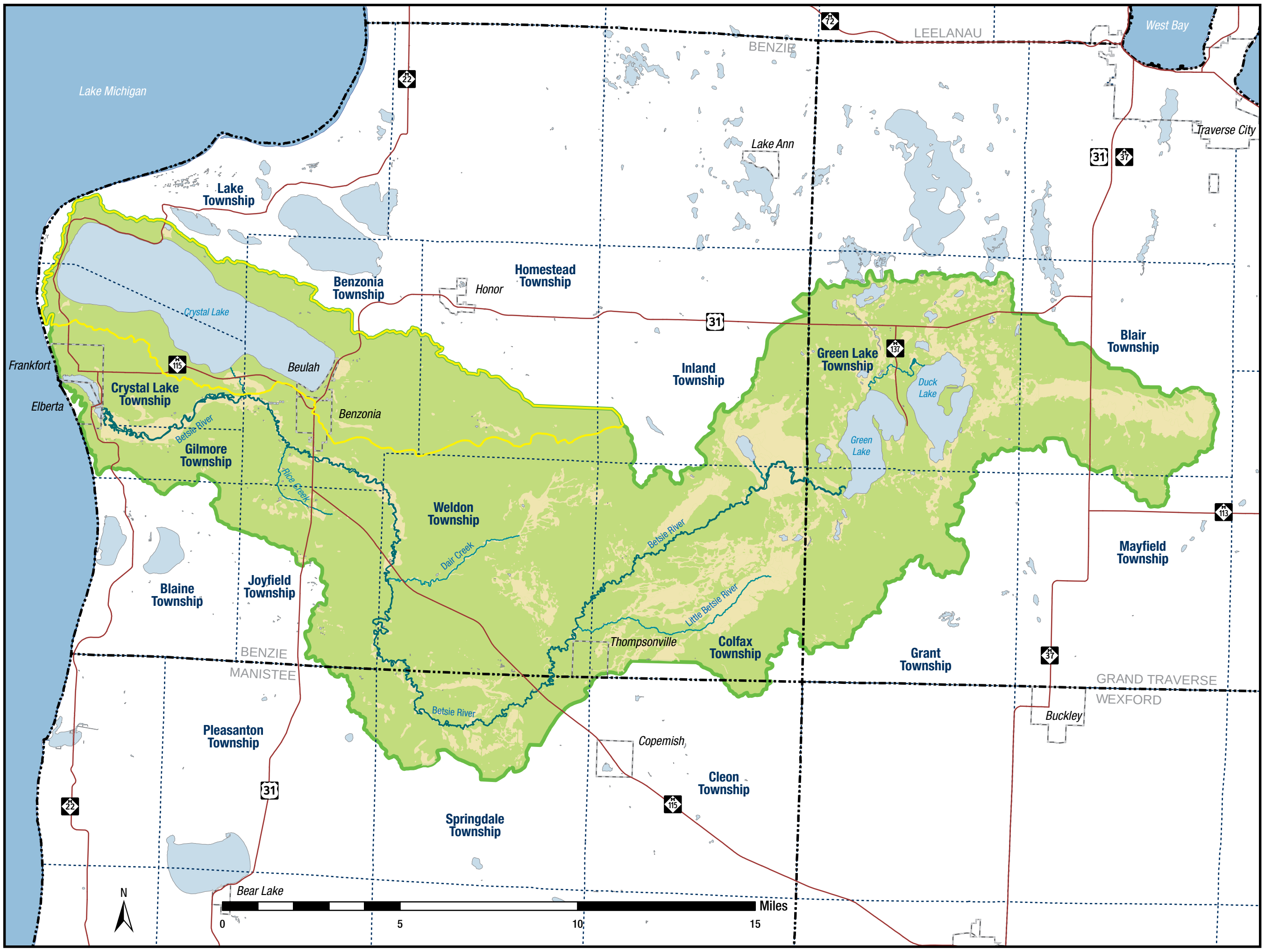
KEY | ZONING DISTRICTS

- Crystal Lake Watershed Overlay District
- Natural Rivers Zoning
- Outlet Creek Subwatershed (Not Currently Designated in the CLWOD)
- Wellhead Protection Areas

The Crystal Lake Watershed Overlay District includes the western portion of the Crystal Lake subwatershed, including the entire Crystal Lake shoreline and the steep slopes and wetlands surrounding the lake. The district extends into three townships (Benzonia, Crystal Lake and Lake) and the Village of Beulah. The district requires a minimum 35 foot building setback from the lake, and regulates development on steep slopes near Crystal Lake.

Within the Watershed, a total of 25 separate governmental units share some aspect of land use regulation. In support of this Watershed Management Plan, Networks Northwest undertook a review of those 25 units.

Map 16 - Governmental Jurisdictions



KEY | POLITICAL JURISDICTIONS

CITY OR VILLAGE

TOWNSHIP

COUNTY

Master plans, zoning regulations and other ordinances were examined for each of the three counties, 17 townships four villages and one city having jurisdictions within the watershed.

These governmental units include:

- In Benzie County: Benzonia Township; Blaine Township; Colfax Township; Crystal Lake Township; Gilmore Township; Homestead Township; Inland Township; Joyfield Township; Lake Township; Weldon Township; Village of Benzonia; Village of Beulah; Village of Elberta; Village of Thompsonville; City of Frankfort.
- In Grand Traverse County: Blair Township; Grant Township; Green Lake Township; Mayfield Township.
- In Manistee County: Cleon Township; Pleasanton Township; Springdale Township.

The full results of the review are presented in tabular form and organized by county.

The creation and enforcement of zoning ordinances is addressed at the township, city or village level. Twenty of the twenty two such jurisdictions in the watershed have adopted zoning, either independently or jointly with adjacent areas.

Master plans serve as instruments which guide the evolution of the community by bringing the social, physical, and economic and political considerations into more meaningful focus.[10] The master plan provides the guidance for the future use of the land resources as well as the employment of other capital resources such as infrastructure to support community goals. A thoughtful and comprehensive master plan can lay the framework to improve the quality of life, make more efficient use of resources, provide for a cleaner environment, and build an economically vibrant community.

While the master plan provides the underpinnings for the zoning ordinance, the zoning ordinance regulates the current use of land. As a guide, the master plan is not a binding, legal document, but is useful to support the legal strength of the zoning ordinance. A key difference between a comprehensive plan and the zoning ordinance is timing. The comprehensive plan is intended to show the future use of land at some point during the planning period, which could project as far ahead as 20 years or more. The zoning ordinance, on the other hand, is immediate, regulating land use today.[11]

Decisions surrounding land use are increasingly complex as we gain more knowledge of effects and interrelationships in our environment that may significantly impact the ecological functions of watersheds. Several tools are available to assist communities in making decisions to mitigate these potential impacts. These tools not only help to maintain water quality but can improve the economic efficiency of the community and provide for greater opportunity and choice.

One of the available tools is the EPA's Water Quality Scorecard. Many of the criteria used in this review of land use policy for local governments in the Betsie River / Crystal Lake Watershed were selected from the Scorecard.

Community master plans were checked to see if they adopted broad environmental goals among the major priorities for implementation as well as specific environmental protection language related to water quality and the economic advantages of environmental stewardship. Plans were also checked for the inclusion of smart/sustainable growth recommendations, which include major tenets of smart/sustainable growth policies such as mixed land uses, compact building design, walkable neighborhoods, open space and critical environmental area preservation, infill development, and planning for a variety of transportation choices. The review also checked for the incorporation of wetland and shoreline protection language, goals for the reduction in impervious surfaces, and recommendations to adopt best practices for stormwater management including low impact development and the utilization of green infrastructure.

Zoning ordinance reviews where conducted looking for the inclusion of two major policy classifications: Regulations that promote land use efficiency and those that provide environmental protections. Research has demonstrated that increasing the density of development in existing growth and investment areas can reduce impervious surfaces compared to low density development for a given amount of new housing unit creation. This concentration of development also lends itself to lowering the cost and impact of infrastructure.

Policies that promote the efficient use of land resources include:

- Allowing a mix of uses on the same site with the inclusion of mixed-use by-right districts
- Creating higher density neighborhoods that create economies of scale for walkable neighborhood commercial districts
- Multi-family allowed by-right
- Compact lots (minimum 6 units per acre)
- Clustered site plan ordinance with density bonus for large open space dedications or for the use of low impact development techniques

Examples of Low Impact Development

Zoning ordinances were also checked for the presence of watershed overlay districts; wetland protections; surface water protections; setbacks and buffers; groundwater protections; floodplain reviews; steep slope protections; and special environmental areas protection.

The plan review completed by Networks Northwest highlights the presence or absence of significant provisions in ordinances in effect as of 2015. The compilation will be communicated to the jurisdictions, and may be used as a benchmark in tailoring the local regulations to support water quality.

Table 8 - Master Plan Review: Part A

Jurisdiction	Master Plan Review								
	Adoption/Revision Info			Major Priorities					
				Environmental Goals			Smart/Sustainable Growth Recommendations		
	Master Plan Adoption Date	Revision In Process	Joint Planning	Environmental Protection Priority	Water Quality Recommendations	References Economics of Environmental Stewardship	"Smart Growth" / New Designs	Mixed Land Uses (Residential w/Commercial)	Compact building design
Benzie County									
County Master Plan	2000	Yes	(i)	Yes	Yes	Yes	No (m)	Yes	Yes
Townships									
Benzonia	N/A								
Blaine	2014	No	Yes (g)	Yes	Yes	No	Yes (a)	No (c)	Yes (b)
Colfax	2012	No	Yes (e)	Yes	Yes	Yes	Yes	Yes	Yes (a)
Crystal Lake	2014	No	Yes (g)	Yes	Yes	Yes	Yes	No	Yes
Gilmore	2014	No	Yes (g)	Yes	Yes	Yes	Yes	No (c)	Yes (a)
Homestead	2008		Yes (f)	Yes	Yes	No	No	No	Yes (a)
Inland	2008		Yes (f)	Yes	Yes	No	No	No	Yes (a)
Joyfield	2014	No	Yes (g)	Yes	Yes	Yes	No	No	Yes
Lake	2010	No	Yes (g)	Yes	Yes	Yes	No	Yes	Yes (a)
Weldon	2012	No	Yes (e)	Yes	Yes	Yes	Yes	Yes	Yes (a)
Villages									
Benzonia	2011 (l)								
Beulah	1997	No	No	Yes	Yes	Yes	no	Yes	Yes
Elberta	2012	No	Yes (g)	Yes	Yes	Yes	Yes	Yes	No
Thompsonville	2012	No	Yes (e)	Yes	Yes	Yes	Yes	Yes	Yes (a)
Cities									
Frankfort	2010	No	Yes (g)	Yes	Yes	Yes	no	Yes	Yes
Grand Traverse County									
County Master Plan	2013	No	reviewed local plans/goals	Yes	Yes	Yes	Yes (j)	Yes	Yes
Townships									
Blair	2009	No	No	Yes	Yes	No	Yes	Yes	Yes
Grant	N/A								
Green Lake	2011	No	No	Yes	Yes	No	Yes	Yes	Yes (a)
Mayfield	N/A								
Manistee County									
County Master Plan	2008	No	(k)						
Townships									
Cleon	N/A								
Pleasanton	5/1/15 (h)	yes	Yes (g)	Yes	Yes	Yes	No	No	No
Springdale	N/A								
Criteria Summary									
% Containing				72%	72%	52%	40%	44%	64%
% Not Containing				0%	0%	20%	32%	28%	8%

Table 9 - Master Plan Review: Part B

Jurisdiction	Master Plan Review (cont.)								
	Major Priorities (cont.)				Environmental Protection				Misc
	Smart/Sustainable Growth Recommendations (cont.)								
	Walkable Neighborhoods	Preserve open space and criticial environmental areas	Direct development towards existing communities	Provide variety of transportation choices	Wetland Protection	Shoreline Protection	Impervious Surface	Stormwater Management	Notes
Benzie County									
County Master Plan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Townships									
Benzonia									(n)
Blaine	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Colfax	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	
Crystal Lake	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Gilmore	No	Yes	Yes	No	Yes	Yes	Yes	Yes	
Homestead	No	Yes	No	No	Yes	No	No	No	
Inland	No	Yes	No	No	Yes	No	No	No	
Joyfield	No	Yes	Yes	Yes	Yes	No	No	No	
Lake	No	Yes	Yes	No	No	No	No	No	
Weldon	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	
Villages									
Benzonia									(o)
Beulah	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Elberta	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Thompsonville	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	
Cities									
Frankfort	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Grand Traverse County									
County Master Plan	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	
Townships									
Blair	Yes	Yes	Yes	Yes	Yes	No	No	Yes	
Grant									
Green Lake	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Mayfield									
Manistee County									
County Master Plan		Yes			Yes				
Townships									
Cleon									
Pleasanton	No	Yes	No	Yes	Yes	Yes	Yes	No	
Springdale									
Criteria Summary									
% Containing	44%	76%	60%	56%	72%	52%	48%	40%	
% Not Containing	28%	0%	12%	16%	4%	20%	24%	32%	

Table 10 - Zoning Review: Part A

Jurisdiction	Zoning Review								
	Adoption/Revision Info			Land Use Efficiency					
	Zoning Ordinance Adoption / Revision Date	Revision In Process	Joint Zoning	Mixed-Use Zoning	Mixed Use by Right	Multi-Family Zoning	Multi by Right	Higher Density/ Walkable Districts	Maximum Density (Units per acre)
Benzie County									
County Master Plan									
Townships									
Benzonia	7/3/12	No	Yes	Yes	Yes	Yes	Yes	Yes	17
Blaine	4/2/13		No	Yes	No	Yes	No	No	4
Colfax	3/12/15	No	Yes	Yes	Yes	Yes	Yes	Yes	34
Crystal Lake	5/15/14		No	Yes	Yes	Yes	Yes	No	10
Gilmore	Apr 2010	Yes	No	No (ac)	No (ad)	No (ad)	No (ad)	No (ad)	3 (ad)
Homestead	2009	No	Yes	No	No	Yes	Yes	No	9
Inland	2009	No	Yes	No	No	Yes	Yes	No	9
Joyfield	N/A(q)		No	N/A	N/A	N/A	N/A	N/A	N/A
Lake	7/22/10		No	Yes	No	Yes	No	No	8
Weldon	3/12/15	No	Yes	Yes	Yes	Yes	Yes	Yes	34
Villages									
Benzonia	10/2/97		No	Yes	Yes	Yes	Yes	Yes	48
Beulah	4/17/12		No	Yes	Yes	Yes	Yes	Yes	62
Elberta	4/19/13		No	Yes	No	Yes	Yes	Yes	68
Thompsonville	3/12/15	No	Yes	Yes	Yes	Yes	Yes	Yes	34
Cities									
Frankfort	7/15/14	No	No	Yes	Yes	Yes	Yes	Yes	35
Grand Traverse County									
County Master Plan									
Townships									
Blair	2/26/14		No	Yes	Yes	Yes	Yes	Yes	41
Grant	1/31/10		No	No	No	Yes	No	No	7
Green Lake	2/20/15		No	Yes	Yes	Yes	Yes	Yes	70
Mayfield	10/25/10		No	No	No	Yes	No	No	9
Manistee County									
County Master Plan									
Townships									
Cleon	4/1/13		No	No	No	Yes	Yes (x)	No	1
Pleasanton									
Springdale	N/A(q)		No	N/A	N/A	N/A	N/A	N/A	N/A
Criteria Summary									
% Containing				52%	40%	72%	56%	40%	0%
% Not Containing				32%	44%	12%	28%	44%	8%

Table 11 - Zoning Review: Part B

Jurisdiction	Zoning Review (cont.)								
	Land Use Efficiency (cont.)							Environmental Protection	
	Compact Lots (6+ units per acre)	PDRs	Form Based Code	PUD Ordinance	Clustered Site Plan Ordinance	Minimum Density	Density Bonus (LIDs, Open Space)	Watershed Overlay District	Wetland Protections
Benzie County									
County Master Plan									
Townships									
Benzonia	No	Yes (t)	No	Yes	Yes	No	Yes (u)	Yes	Yes
Blaine	No	Yes (aa)	No (z)	Yes	Yes	No	Yes	No	Yes
Colfax	Yes	No	No	Yes	Yes	No	No	No	Yes
Crystal Lake	No	Yes (aa)	No	Yes	Yes	No	Yes	Yes	Yes
Gilmore	No	Yes (aa)	No	Yes	Yes	No	Yes	No	Yes
Homestead	No	No	No	No	No	No	No	No	Yes
Inland	No	No	No	No	No	No	No	No	Yes
Joyfield	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lake	Yes	No	No	No	Yes	No	No	Yes	Yes
Weldon	Yes	No	No	Yes	Yes	No	No	No	Yes
Villages									
Benzonia	Yes	No	No	Yes	Yes (r)	No	No	No	Yes
Beulah	Yes	No	No	No	Yes	No	No	Yes	Yes
Elberta	Yes	No	No	Yes	Yes (r)	No	No	No	Yes
Thompsonville	Yes	No	No	Yes	Yes	No	No	No	Yes
Cities									
Frankfort	Yes	No	Yes	Yes	Yes (r)	No	No	No	Yes
Grand Traverse County									
County Master Plan									
Townships									
Blair	Yes	No	No	Yes	Yes	No	Yes	Yes (ae)	Yes
Grant	No	No	No	No	Yes	No	Yes	No	Yes (af)
Green Lake	Yes	No	Yes	Yes	Yes	No	No	No	Yes (af)
Mayfield	No	No	No	Yes	Yes	No	No	No	Yes (w)
Manistee County									
County Master Plan									
Townships									
Cleon	No	No	No	No	Yes	No	No	No	Yes
Pleasanton									
Springdale	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Criteria Summary									
% Containing	40%	16%	8%	52%	68%	0%	24%	20%	76%
% Not Containing	44%	68%	76%	32%	16%	84%	60%	64%	8%

Table 12 - Zoning Review: Part C

Jurisdiction	Zoning Review (cont.)								
	Environmental Protection (cont.)								Misc
	Water Setbacks	Surface Water Buffers	Surface Water Protections	Natural Rivers Zoning Authority (Betsie River)	Groundwater Protection/Hazardous Waste	Floodplains Review Requirement	Steep Slopes Protections	Environmental Areas Protection	Notes
Benzie County									
County Master Plan									
Townships									
Benzonia	Yes	Yes	Yes	No (y)	Yes	Yes	Yes	Yes	(ag)
Blaine	No	Yes	Yes	No (v)	Yes	Yes	Yes	Yes	
Colfax	100 ft (s)	Yes (ab)	Yes	No (y)	Yes	Yes	No	Yes	
Crystal Lake	35 ft	Yes	Yes	No (y)	Yes	Yes	Yes	Yes	
Gilmore	25ft/35ft	Yes	Yes	No (y)	Yes	Yes	Yes	Yes	
Homestead	50 ft	Yes	Yes	No	Yes	No	Yes	Yes	
Inland	50 ft	Yes	Yes	No	Yes	No	Yes	Yes	
Joyfield	N/A	N/A	N/A	No	N/A	N/A	N/A	N/A	
Lake	25ft/35ft	Yes	Yes	No (v)	Yes	Yes	Yes	Yes	
Weldon	100 ft (s)	Yes (ab)	Yes	No (y)	Yes	Yes	No	Yes	
Villages									
Benzonia	No	No	Yes	No	Yes	No	Yes	Yes	
Beulah	35ft/75ft	Yes	Yes	No	Yes	No	Yes	No	(ah)
Elberta	No	No	Yes	No	Yes	No	Yes (p)	Yes (p)	
Thompsonville	100 ft (s)	Yes (ab)	Yes	No (y)	Yes	Yes	No	Yes	
Cities									
Frankfort	25 ft	Yes	Yes	No	Yes	Yes	Yes	Yes	(ai)
Grand Traverse County									
County Master Plan									
Townships									
Blair	Yes (ae)	Yes (ae)	Yes	No (ae)	Yes	Yes	Yes	Yes	
Grant	60 ft	Yes (af)	Yes (af)	No	Yes	No	No	No	
Green Lake	60 ft	Yes (af)	Yes (af)	No	Yes (af)	Yes (af)	Yes (af)	Yes (af)	(aj)
Mayfield	60 ft	No	Yes (w)	No (v)	Yes (w)	No	No	No	
Manistee County									
County Master Plan									
Townships									
Cleon	100 ft	Yes	Yes	No (v)	Yes	Yes	No	No	
Pleasanton									(ak)
Springdale	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Criteria Summary									
% Containing	8%	64%	76%	0%	76%	48%	52%	60%	
% Not Containing	20%	20%	8%	84%	8%	36%	32%	24%	

Table 13 - Stormwater Sedimentation Review | Geographic Data

Jurisdiction	Stormwater/Sedimentation			Geographic Data					Misc
	Stormwater Ordinance	LIDs Requirement/ Recommendation	Soil Erosion & Sedimentation Ordinance	Total Area (acres)	Betsie River Watershed Area (acres)	Percent of Jurisdiction within watershed	Betsie River Watershed Wetland Area (acres)	Percent Betsie River Watershed Wetlands	Notes
Benzie County									
County Master Plan	Yes	No	Yes	222,461.2	104,562.5	47.00%	19,125.0	8.60%	
Townships									
Benzonia	No	Yes (al)	Benzie County	20,671.3	14,639.8	70.82%	1,303.3	6.30%	
Blaine	No	No	Benzie County	13,476.9	689.3	5.11%	-	0.00%	
Colfax	No	No	Benzie County	22,656.2	20,816.4	91.88%	9,983.5	44.07%	
Crystal Lake	No	No	Benzie County	10,928.2	10,638.8	97.35%	990.8	9.07%	
Gilmore	No	No	Benzie County	4,156.9	3,852.1	92.67%	714.9	17.20%	
Homestead	No	No	Benzie County	19,059.4	6,699.9	35.15%	128.2	0.67%	
Inland	No	No	Benzie County	23,148.4	6,073.3	26.24%	2,355.6	10.18%	
Joyfield	No	No	Benzie County	12,793.4	8,148.2	63.69%	349.2	2.73%	
Lake			Benzie County	22,464.3	6,835.5	30.43%	39.0	0.17%	
Weldon	No	No	Benzie County	23,122.8	23,122.8	100.00%	3,232.6	13.98%	
Villages									
Benzonia	No	No	Benzie County	722.4	722.4	100.00%	0.2	0.02%	
Beulah	No	No	Benzie County	266.0	266.0	100.00%	3.0	1.14%	
Elberta	No	No	Benzie County	627.4	460.5	73.40%	14.7	2.34%	
Thompsonville	No	No	Benzie County	637.7	619.2	97.09%	96.3	15.09%	
Cities									
Frankfort	Yes	Yes	Benzie County	1,013.5	978.0	96.49%	27.8	2.74%	
Grand Traverse County									
County Master Plan	Yes	No	Yes	313,737.4	41,062.0	13.09%	9,231.9	2.94%	
Townships		.							
Blair	No	No	Grand Traverse County	23,007.8	9,825.9	42.71%	3,253.3	14.14%	
Grant	No	No	Grand Traverse County	23,046.3	10,698.3	46.42%	1,111.9	4.82%	
Green Lake	No	No	Grand Traverse County	23,290.9	19,996.0	85.85%	4,803.2	20.62%	
Mayfield	No	No	Grand Traverse County	23,075.1	542.2	2.35%	63.4	0.27%	
Manistee County									
County Master Plan	Yes (am)	Yes	Yes	356,899.8	9,503.9	2.66%	2,256.9	0.63%	
Townships									
Cleon	No	No	Manistee County	22,475.5	282.8	1.26%	-	0.00%	
Pleasanton			Manistee County	22,683.2	806.1	3.55%	20.6	0.09%	
Springdale	No	No	Manistee County	22,812.8	8,414.9	36.89%	2,236.3	9.80%	
Criteria Summary									
% Containing	16%	12%							
% Not Containing	76%	80%							

Table 14 - Policy Review Notes

Master Plan Notes	
(a)	Cluster Development
(b)	Compact Residential Development
(c)	No - Ordinance Does Contain Commercially or Industrially Zoned Districts
(d)	Draft Available
(e)	Colfax Township, Weldon Township, Village of Thompsonville Joint Planning Commission
(f)	Homestead Township & Inland Township Joint Planning
(g)	Lakes to Land Regional Initiative
(h)	Draft master plan used for review
(i)	Overall County Master Plan
(j)	References New Designs For Growth
(k)	References Review of Local Master Plans
(l)	Not confirmed
(m)	"balanced growth"
(n)	Benzonia Township uses elements from the 2000 Benzie County Master Plan in their planning efforts.
(o)	Village Planner/Zoning Administrator will provide planning documents that may or may not be an approved master plan.
Zoning Notes	
(p)	Through Critical Dune Areas and High Risk Erosion Areas - Part 353, Sand Dunes Protection & Management as amended
(q)	Has not adopted a zoning ordinance
(r)	Clustering as provided in the Planned Unit Development ordinance language
(s)	Except where a greater setback is required by the Natural Rivers Act. Section 8.19 Open Space Preservation Communities reduces setback
(t)	The designation of Transfer of Development Rights Overlay Zone is provided for in the zoning ordinance. However, as of 11/20/2014 no Transfer of Development Rights Overlay Zone have been designated.
(u)	Ordinance allows for up to a 33% density bonus for exceptional design, large open space preservations, or affordable housing.
(v)	Municipality does not contain designated Nartural Rivers areas
(w)	Protections apply to Special Use Permit review.
(x)	Multi-family residential by right is limited to supporting owners, operators, and employees of farming operations.
(y)	The rules and regulations adopted under Part 305, Section 324.30501 of the Michigan Natural Resources & Environmental Protection Act, PA 451 of 1994 are referenced in the zoning ordinance.
(z)	The Neotraditional PUD ordinance has a pattern book requirement.
(aa)	Transfer of Development Rights framework incorporated into ordinance.
(ab)	Buffer requirement limited to certain uses.
(ac)	PUD section of the zoning ordinance allows for incorporation of mixed-use.
(ad)	Does not include districts contained in the zoning ordinance but not located on zoning map
(ae)	Natural Rivers/Watershed Overlay Districts incorporated in Zoning Ordinance for watersheds other than Betsie River Watershed.
(af)	Environmental protections are non-specific and require review standards to insure compatibility with the natural environment.
(ag)	West Benzie Joint Zoning Ordinance includes Benzonia and Platte Townships.
(ah)	Weed Ordinance
(ai)	No setback requirement, but demonstrated protection.
(aj)	Special Land Uses can require an Environmental Impact Statement from a qualified environmental engineer.
(ak)	Unable to obtain a copy of the zoning ordinance.
Stormwater-GIS Notes	
(al)	25 year Stormwater runoff limited to predevelopment levels, no specific stormwater BMPs required.
(am)	Stormwater management contained in the Manistee County Drain Commissioner's Guidelines for Storm Water Management

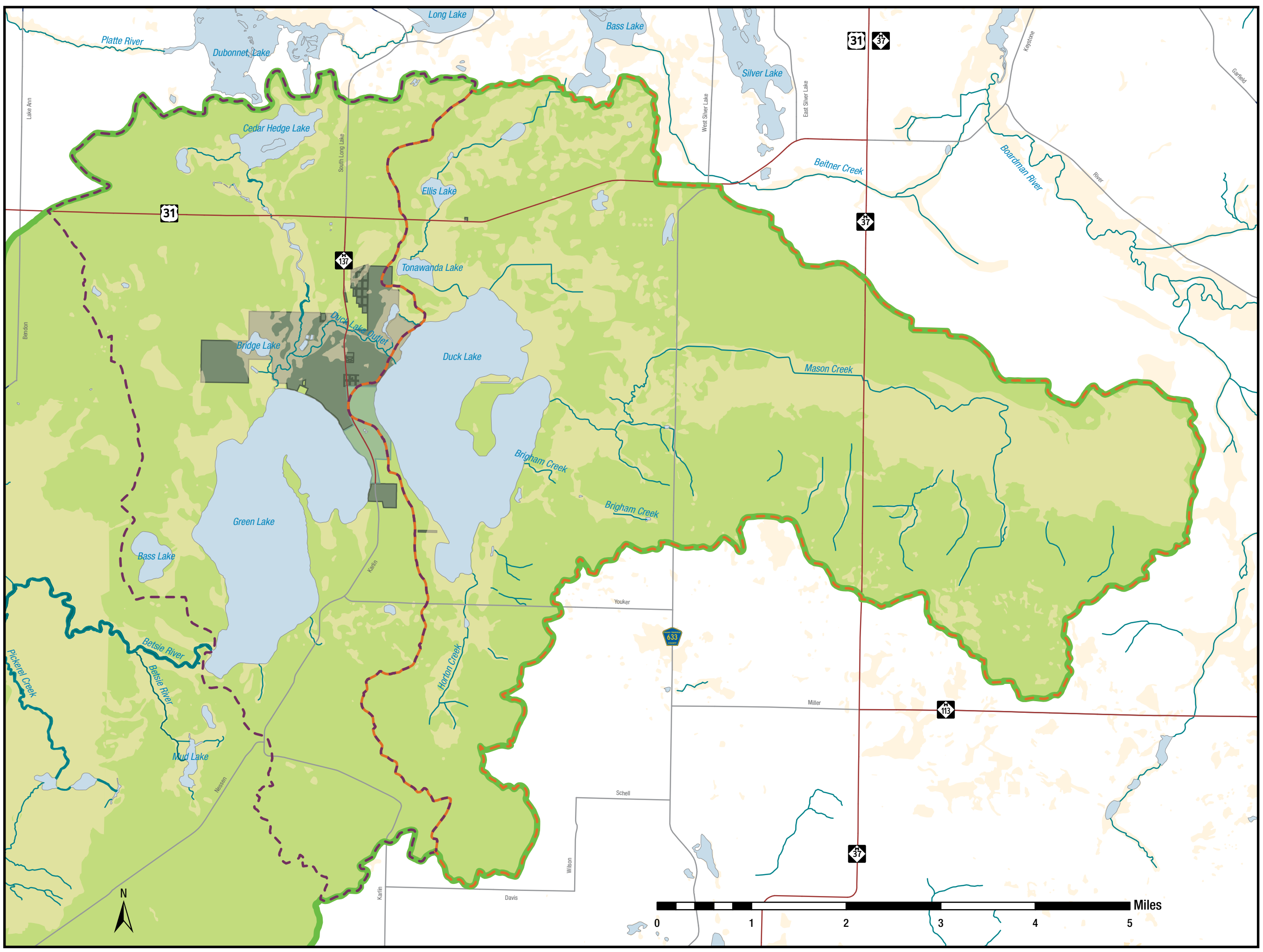
Duck Lake & Green Lake Subwatersheds

Duck Lake and Green Lake are located in the two “upstream” subwatersheds of the Betsie River / Crystal Lake Watershed. The two large lakes are connected by a short stretch of the Betsie River, and are closely related in a number of ways: Geographically they are separated by only a narrow corridor of land in the community of Interlochen; hydrologically, both are fed by groundwater and small streams; demographically they share a region of Grand Traverse County that houses more than half of the overall watershed’s population.

Property owners on the two lakes are represented by a single organization, the Green Lake and Duck Lake Association.

For clarity, the two lakes are mapped together here. The subwatershed boundary is delineated on the base map. The shoreline condition inventory map is the product of data collected in 2014 with assistance of the Green Lake and Duck lake Association.

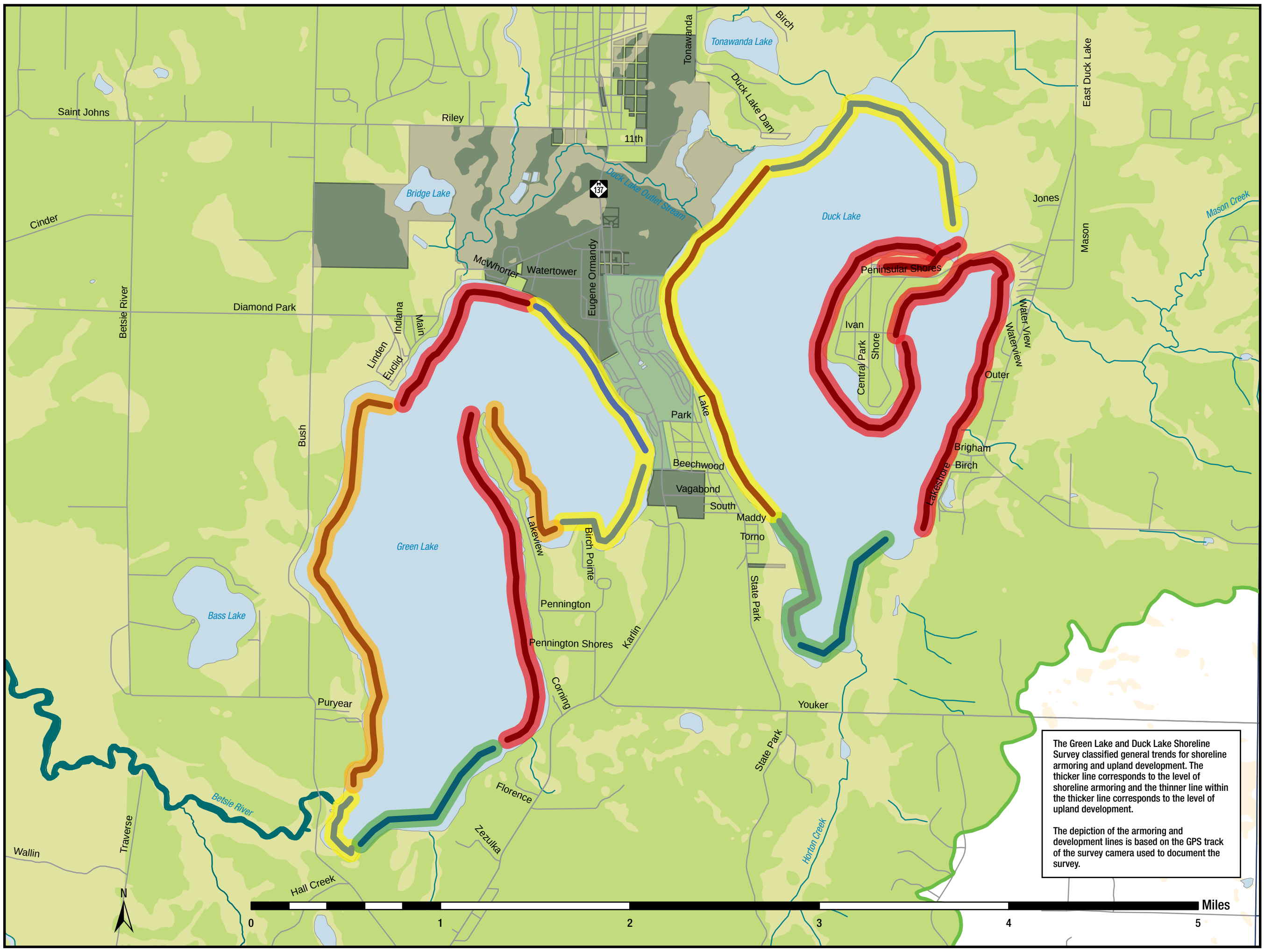
Map 17 - Duck Lake & Green Lake Subwatersheds



KEY | HUC 12 SUBWATERSHEDS

- Duck Lake Watershed
- Green Lake Watershed
- Shared Border
- Betsie River Watershed
- Wetlands
- Lakes and Water Bodies
- Interlochen State Park
- Interlochen Center for the Arts

Map 18 - Duck Lake & Green Lake Shoreline Survey



KEY | SHORELINE ARMORING

- More than 50%
- Less than 50%
- Less than 10%
- None

KEY | SHORELINE DEVELOPMENT

- Dense Development
- Moderate Development
- Mixed Development
- Lite Development
- Undeveloped

- Betsie River Watershed
- Wetlands
- Lakes and Water Bodies
- Interlochen State Park
- Interlochen Center for the Arts

The above maps are referenced in the following WMP sections describing the two lakes.

Duck Lake

Duck Lake, located in Green Lake Township of Grand Traverse County, is often considered the headwater lake for the Betsie River system, though several much smaller lakes actually exist “upstream.”

The water area of Duck Lake is 1,930 acres (three square miles), with a land-and-water drainage area of 18,297 acres (28.6 square miles).

According to water quality reports prepared from 2005 to 2010 for the Green Lake and Duck Lake Association, Duck Lake is a “natural, moderately hard-water kettle lake.” The lake’s several deep basins are the result of ice blocks that separated from the retreating glacier and melted at the end of the most recent ice age.

Table 15 - Duck Lake Water Quality Testing

YEAR	Total Phos (ppb)		Secchi depth (feet)		Chlorophyll a (ppb)	
	spring	summer	spring	summer	spring	summer
2005	7.0	7.0	17	11	0.6	0.9
2005	7.0	7.0	17	9	0.3	1.7
2005	8.0	6.0	21	9	0.3	1.2
2006	4.0	7.0	14	10	0.3	2.9
2006	5.0	8.0	12	10	0.3	2.6
2006	4.0	7.0	10	10	0.3	1.5
2007	8.0	9.0	17	17	0.3	0.6
2007	7.0	8.0	14	16	0.3	0.6
2007	9.0	8.0	16	16	0.3	0.6
2008	9.0	9.0	13	15	0.4	0.7
2008	9.0	8.0	16	15	0.4	1.4
2008	9.0	9.0	17	15	0.4	0.7
2009	9.0	7.0	15	11	0.4	2.1
2009	10.0	8.0	17	11	0.4	2.1
2009	9.0	9.0	17	11	0.4	1.8
2010	10.0	9.0	24	12	0.2	0.6
2010	10.0	11.0	23	12	0.1	0.3
2010	10.0	8.0	24	12	0.1	0.6

The lake has a maximum depth of 96 feet and average depth of 23.3 feet. The length of the shoreline is just under 60,000 feet (11.25 miles), including a large peninsula that extends from the eastern shore

Duck Lake is fed by direct groundwater and by water from several small lakes and streams in the upper watershed.

Tonawanda Creek flows from Ellis and Tonawanda lakes into an inlet near the northern tip of Duck Lake. A separate small stream flows in from Mud Lake.

On the eastern shore, Mason Creek drains a large area of Blair, Mayfield and Green Lake Townships. Horton Creek flows north into Duck Lake from Grant Township, and Brigham creek drains a smaller area of Green Lake Township near the southeast corner of Duck Lake.

The water level of Duck Lake is maintained at approximately 837 feet above sea level by a low-head dam at the point where the outlet stream, generally called Betsie River, flows from the northwest shore of the lake.

The outlet stream meanders through the community of Interlochen to nearby Green Lake.

Both the Interlochen State Park and the Interlochen Center for the Arts set on the narrow corridor of land between Duck and Green lakes, with frontage on both bodies of water.

Interlochen State Park is Michigan's first state park. With swimming areas, boat launch facilities and some 400 campsites it is a popular destination for outdoor recreation. The state park swimming beach on Duck Lake has a sign alerting bathers to the possibility of contracting Swimmer's Itch from the water.

Swimmer's Itch results from contact with a microscopic organism which cycles between native freshwater snails and waterfowl as its natural hosts. It is a persistent problem that presents both quality of life and economic issues on many Northern Michigan lakes.

The WMP recommends a program of research and action to address Swimmer's Itch throughout the watershed. A detailed discussion of this issue appears in Chapter 4.


Duck Lake

The Interlochen Center for the Arts includes a nationally known summer arts and music program, a concert venue and a residential high school for students with interest in music and the arts. The Center has its own wastewater treatment system, as does the state park.

A shoreline survey, conducted in the summer of 2014, found significant development on the east and west shores of Duck Lake, while segments of the north and south shores remain largely undeveloped. (See accompanying Map). Residential development on the lake dates back many decades, with established neighborhoods especially on the peninsula and cove on the eastern shore.

The shoreline of the peninsula, exposed to west winds across a mile of open lake, is heavily armored with seawall and rip-rap which appear to have been in place for a considerable amount of time.

A small culvert at the base of the peninsula allows water to flow under the road between the protected eastern cove and the open lake. A man-made canal creates additional water frontage and docking for several properties in the interior of the peninsula.

Development is less intensive on the western shore, and prevailing winds and wave action less intense. Many properties there have been able to maintain more natural shoreline vegetation.

Despite the significant amount of development, a 2008 DNR survey noted that Duck Lake has more sunken tree trunks and other “woody debris” than similar lakes. The presence of such woody debris is often used as one measure of fish habitat.

Duck Lake has long been a popular fishing destination, both for lake residents and boaters who launch at the State Park access site. A 2008 survey by the Michigan Department of Natural Resources found healthy game fish and panfish populations. In particular, the survey found that largemouth and smallmouth bass in Duck Lake were growing at rates in excess of the average for all Michigan waters.

The population of rock bass was found to be “robust.” More than half the fish captured in the 2008 survey were of that species.

DNR researchers expressed concern about the absence of lake herring (cisco) in the 2008 sampling. That species is listed as threatened in Michigan, and has not been captured in recent surveys of the major lakes in the watershed. The WMP recommends continued monitoring of the health of this species.

Michigan DNR records show a history of fish stocking in Duck Lake dating back to 1905. Species stocked in Duck Lake during the early 20th century included walleye, largemouth and smallmouth bass, perch and bluegill.

Lake trout were first stocked in the lake in 1951, and that species has been stocked regularly since then. Duck is considered a good habitat for lake trout because of its depth and the presence of dissolved oxygen near the bottom at most times of year.

A history of water quality data exists for Duck Lake through the efforts of local residents working with the Green Lake and Duck Lake Association and their former consultant: Water Quality Investigators of Dexter MI. In general these data show the lake maintaining high water quality, though with some reasons for concern.

Sampling by the lake association in past years has intermittently found elevated levels of *E. coli* at the inlet of one small creek. Weekly monitoring of the Interlochen State Park public beach in the summers of 2013 and 2015 showed barely detectable levels of *E. coli*, well within all state standards.

A survey in 2015 found an infestation of Eurasion watermilfoil near the south end of the lake. The lake association and Green Lake Township have proposed a special assessment to finance treatment. Preventing the introduction or spread of invasives is a priority of the WMP.

Green Lake

Green Lake covers 2,063 acres (3.2 square miles) in Green Lake Township and Grant Township of Grand Traverse County. In size, depth and water quality it is quite similar to Duck Lake, which is located a few hundred yards to the east.

Water quality reports compiled for the Green Lake and Duck Lake Association describe Green Lake as a “natural, moderately hard-water lake.” Maximum depth is 102 feet, and the average depth is 36.3 feet. About one-eighth of the lake is shallower than 15 feet, according to Michigan Department of Natural Resources fishery reports. The bottom is largely marl, sand and organic material.

The Lake Association collected water-quality data through 2010, using a paid consultants. Volunteers handled some limited monitoring in later years. Renewed monitoring is an important element of the Watershed Management Plan.

Table 16 - Green Lake Water Quality Testing

YEAR	Total Phos (ppb)		Secchi depth (feet)		Chlorophyll a (ppb)	
	spring	summer	spring	summer	spring	summer
2001	14.0	15.0	10	9	1.5	1.4
2001	13.0	16.0	9	9	2.2	1.4
2001	14.0	15.0	10	9	2.1	1.1
2002	6.0	8.0	17	13	3.3	2.4
2002	11.0	9.0	15	13	1.4	2.7
2002	9.0	9.0	16	13	3.0	1.6
2003	9.0	10.0	17	15	0.7	1.7
2003	9.0	11.0	14	15	1.0	1.0
2003	9.0	12.0	16	12	1.3	1.4
2004	13.0	5.0	19	17	1.2	1.3
2004	12.0	7.0	17	16	1.9	0.3
2004	14.0	7.0	20	16	1.9	0.9
2005	11.0	10.0	22	14	0.6	0.8
2005	12.0	9.0	23	14	0.6	0.8
2005	11.0	9.0	21	14	1.2	0.8
2006	11.0	9.0	23	15	0.3	2.6
2006	12.0	10.0	21	15	0.3	2.0
2006	12.0	9.0	24	15	0.6	2.3
2007	12.0	8.0	20	15	0.5	0.6
2007	13.0	9.0	21	15	0.5	0.3
2007	11.0	8.0	21	16	0.5	0.3
2008	8.0	10.0	22	17	0.1	1.4
2008	7.0	10.0	21	17	0.1	1.0
2008	8.0	9.0	21	17	0.4	1.0
2009	12.0	9.0	24	20	1.1	1.8
2009	11.0	11.0	25	20	0.4	2.1
2009	10.0	10.0	26	20	0.4	1.8
2010	7.0	10.0	27	16	0.2	0.6
2010	8.0	9.0	25	16	0.1	0.6
2010	7.0	8.0	26	16	0.2	0.6

Interlochen State Park and the Interlochen Center for the Arts occupy a significant share of the eastern shore, extending across the narrow corridor of land between Green and Duck Lakes.

Much of the remaining shoreline has been developed for residential uses. There remains a significant amount of natural shoreline, especially near the southern tip of the lake.

Green Lake is a popular fishing destination in both summer and winter. Public boating access is through the state park and via a second boat launch site on the western shore.

The water level is approximately 825 feet above sea level. While there is no formal water level control, the Grass Lake Dam, downstream on the Betsie River, does exert some control over the level.

Green Lake is fed by ground water and by a single stream, the Betsie River, which flows from the northwest shore of Duck Lake and enters Green Lake at its northern tip. Between Duck and Green Lakes, the stream also merges with outflow from Cedar Hedge, Tullers, Round and Bridge lakes.

Green Lake has a single outlet, also the Betsie River, which flows out from the southwest shore of the lake.

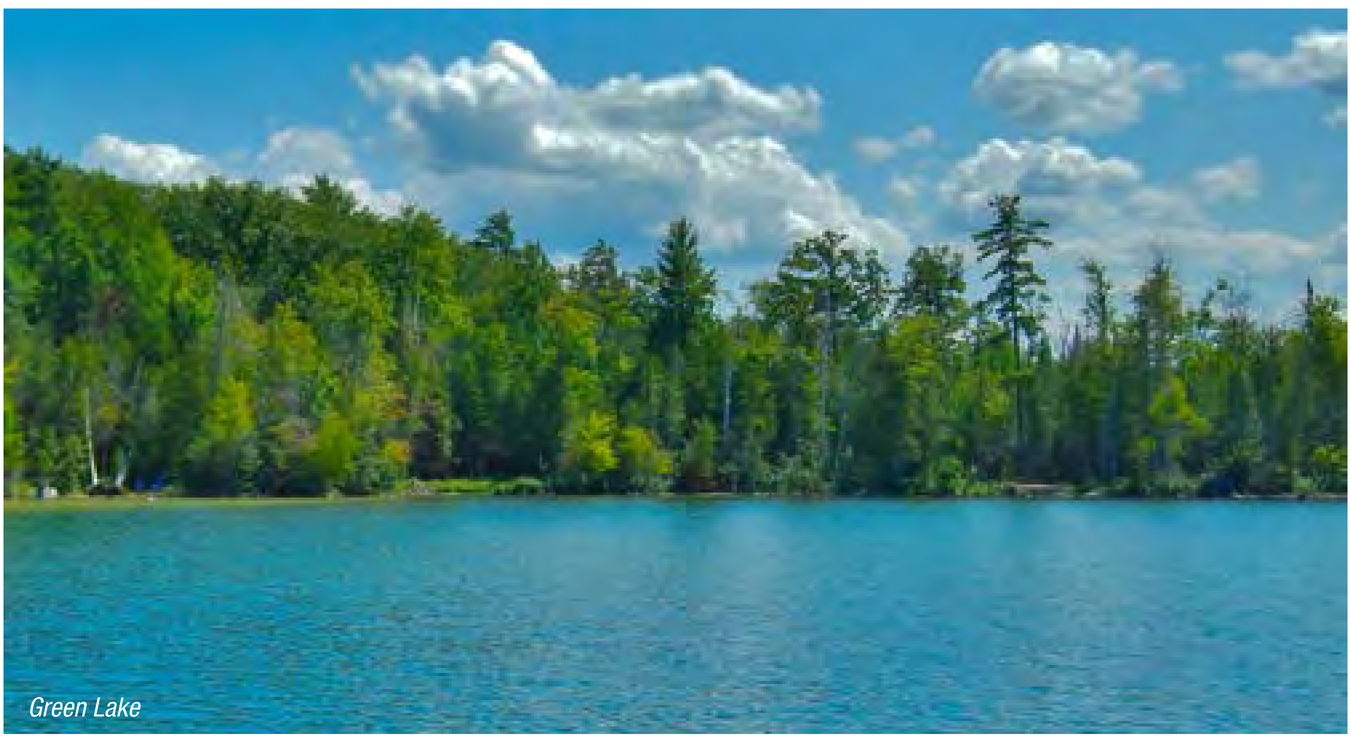
A shoreline conditions inventory was conducted by boat in the summer of 2014. Green Lake has approximately 56,000 feet (10.6 miles) of shoreline, which includes one long peninsula and several protected coves.

The densest development occurs on the northwest end of the lake, near the stream inlet, and on the eastern shore. Several Interlochen Center for the Arts buildings are directly on the shore, though other sections of the institution have natural shoreline.

Seawalls are common on the eastern shore, which is exposed to strong wave action and westerly winds. Shoreline hardening is likely to remain in this area, given the long-standing development of shoreline residences.

About a mile of shoreline on the southeastern tip of the lake has natural shoreline protected by a conservation easement.

Preservation of existing natural shoreline, as well as property owner education about shoreline stewardship are recommendations of the Watershed Management Plan.



Green Lake

Analysis over the past decade shows Green Lake to be generally of high water quality. Levels of phosphorus and Chlorophyll a are in the range that indicates the water is not providing excess nutrients. No large weed infestations were noted, and water clarity as measured by Secchi disk readings, has improved.

Surveys in 2014 indicated the lake remains clear of invasive Eurasian milfoil. Invasive zebra mussels are in the lake. Preventing the introduction of additional invasives – including milfoil and quagga mussels, is a priority of the Watershed Management Plan.

In a 2014 report, DNR fishery biologist Mark Tonello described Green Lake as "a rare natural resource in that it has deep, cold water that can harbor such species as lake trout, cisco and rainbow smelt."

Since 1982, the state has annually stocked lake trout into the lake. That is expected to continue at a rate of about 12,000 yearling lake trout a year, since the population of the species in Green Lake is entirely dependent on stocking.

While lake trout apparently do not naturally reproduce in Green Lake, the hatchery fish placed in the lake do grow at a faster annual rate than in most lakes. That is likely because of the abundant "forage base" provided by Green Lake's population of rainbow smelt.

In addition to feeding the trout, the smelt provide the basis for a very popular winter ice fishery. A creel census in 2003-04 estimated that ice-anglers made more than 9,000 trips to the lake and caught some 55,000 smelt.

Bass, pike and panfish populations in the lake are all heathy, according to the Tonello report (Appendix C).

Sampling conducted in the spring and summer of 2013 found healthy populations of bass, pike and panfish. The most frequently collected species in that sampling was rock bass. Of 1,072 fish netted during that sampling period, 499 were rock bass.

One point of concern about the fishery, also noted in Duck and Crystal lakes, was the absence of cisco (also known as lake herring), a state-designated threatened species which is native to those lakes and has been found in earlier samplings. Further monitoring of the situation with this species is recommended in the WMP.

Green Lake Township and the Interlochen community are among the watershed's fastest-growing segments, in terms of construction and population growth.

A township master plan envisions significant additional growth in the "gateway" at the intersection of US31 and M137, the state route that passes between Green and Duck Lakes. The plan recognizes the likelihood that new development will require additional waste-water services – either on-site or through a central sewer system – as well as BMPs to capture stormwater from impervious surfaces.

Installation of BMPs for low-impact development is a priority of this WMP as well.

Betsie River

The Betsie River rises from lakes and wetlands in Grand Traverse County, and traverses portions of Manistee and Benzie counties in Michigan's northwestern Lower Peninsula before flowing into Betsie Lake and Lake Michigan

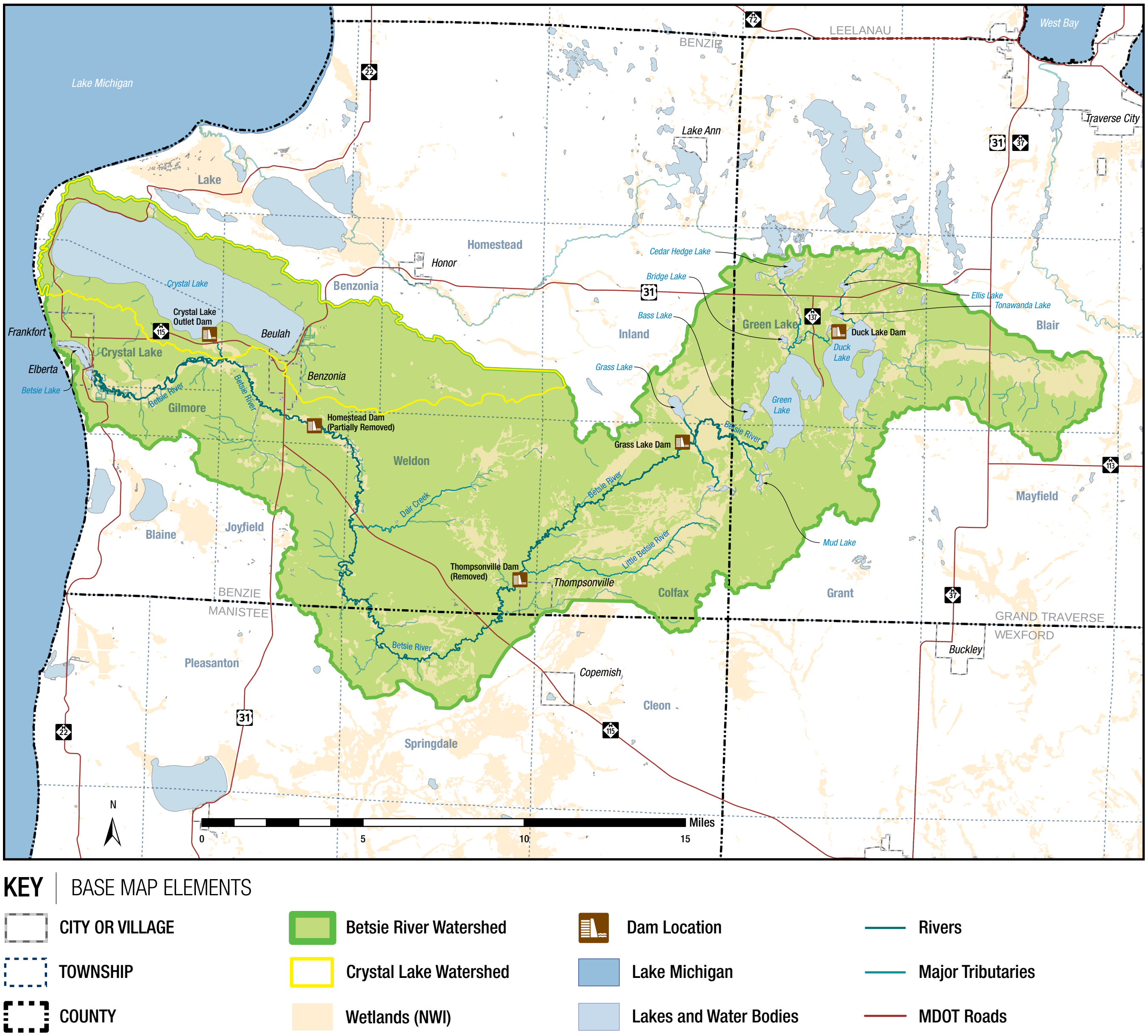
The mainstem of the river is generally defined as beginning at the outlet of Green Lake, in Grand Traverse County, though an upstream segment connecting Duck and Green Lakes is also referred to as "The Betsie River." Smaller streams originating in southern Grand Traverse County, upstream from Green and Duck Lakes, add several miles of flowing water.

From the Green Lake outlet to Betsie Lake, the mainstem extends 52 miles. There is no active stream flow gaging in the watershed. The 2014 Hydrologic Study estimated base flow of 58 cubic feet per second at the Grass Lake Dam, (6 km downstream from the origin) and 183 cfs at the river mouth at Betsie Lake. The Crystal Lake Outlet, which enters the Betsie five miles upstream from the mouth, is estimated to have a base flow of 34 cfs, but is known to be highly variable.

The lack of consistent stream flow data is considered an impediment to planning and management of the stream and is an issue addressed in the WMP.

Hydrologic modeling performed by the Great Lakes Environmental Center in 2014 indicates the river's rise and fall due to rain events is expected to be less than in other streams of similar size. That is because the three large lakes in the watershed (Crystal, Green and Duck) provide significant "reservoir capacity" which allows water to be captured and released slowly into the stream.

Map 19 - Betsie River System



The large surface area of lakes near the headwaters (totaling more than 5,000 acres) also tends to increase water temperature in the stream. Summer temperatures in the mainstream often exceed the threshold for trout species. The upper stretch of the stream receives almost no direct infusion of cold groundwater above Thompsonville, where the Little Betsie merges with the mainstream.

The Betsie River is a popular stream for paddlers and anglers. Salmon, steelhead and brown trout are taken on the mainstream, while cold tributaries such as the Little Betsie River, Dair Creek and many smaller streams support brook trout.

The mainstream has two dams:

– The Grass Lake Dam, a low-head facility installed in the mid-20th century to improve wetland wildlife habitat near the upper reaches of the river. This state-owned dam creates a slack-water impoundment of Pickerel Creek and Grass Lake Creek, stabilizes the level of Grass Lake, and likely maintains the water level of Green Lake. It is also believed to have some warming impact on the temperature of the upper river.

Grass Lake Dam

– The Homestead Dam, in Benzonia Township near the midpoint of the watershed. A hydroelectric facility at this site was removed in 1974. The present steel and concrete dam functions as a lamprey barrier and impounds only a small amount of water. The two-meter head of the dam is stepped at the northern bank to allow passage of migratory salmon and steelhead. The DNR maintains a public access at the site, which is heavily fished during spring and fall migrations.

Homestead Dam

Steelhead catch

Steelhead fishing below the Homestead Dam

Hatchery-reared steelhead and brown trout are planted in the river annually. Runs of Pacific salmon are self-sustaining, based on natural reproduction. Maintaining the high-quality river fishery is an important objective of the WMP.

A third dam – a former hydroelectric facility at Thompsonville – failed in 1989 releasing tons of sediment into the river.

Remnants of the dam have since been removed, and a small day-use area established near the site.

The failure of the Thompsonville Dam led to creation of the Betsie River Watershed Restoration Committee (BRWRC).

BRWRC, together with the Conservation Resource Alliance, has spearheaded efforts to restore streambanks and other impaired stretches of the river. BRWRC, which includes representation from government and private groups, is considered a model for cooperation in watershed restoration. BRWRC is identified in the WMP as an important component in long-term monitoring, implementation and education.

In 1973, the Betsie became the second stream to be designated as a natural river by the state of Michigan. That designation protects the stream corridor from overdevelopment, and it marks one point in the river's recovery from the environmental degradation caused by Michigan's logging era.

Like most of Northern Michigan, the Betsie River Watershed was clear-cut of native timber at the end of the 19th and beginning of the 20th century, and the river was used to transport logs to sawmills and markets downstream and beyond the watershed.

Research suggests that prior to logging, the river edges were heavily timbered, and numerous log jams existed in the stream. That "woody debris" provided habitat for native fish and other indigenous wildlife, but was removed because it impeded the movement of timber.

In addition, high banks of streams were commonly used as "rollways" to introduce cut timber into rivers.

By the end of the timbering era, virtually all of the native hardwood and softwood forest had been removed from the watershed. Much of the stream bank was denuded of vegetation. Organic matter in the region's sandy soils was consumed by fires that burned through the "slash" left after loggers removed the valuable timber.

Those changes resulted in a river that was wider and warmer than it had been, with streambanks eroding tons of sand into the watercourse.

Hundreds of feet of streambank have been protected by stone, woody debris or other strategies as part of restoration efforts that date back to the 1960s and accelerated with creation of the BRWRC.

A significant amount of work remains to be accomplished. The WMP envisions continued monitoring, regular updates of streambank conditions, and restoration/protection of high priority bank segments, using BMPs adapted to the specific site conditions.

Betsie River – King Road Stream Gauge Location

The entire length of the mainstream was inventoried for streambank erosion in 2015 by crews from the Conservation Resource Alliance. The inventory identified 87 erosion sites totaling nearly a mile of eroded streambank. Twenty-one of the sites were rated as “severe” according to the Streambank Erosion Severity Index. The WMP calls for mitigation of all the severe sites and 20 percent of the lesser sites, primarily through installation of whole tree revetments. The streambank erosion inventory and mitigation plan is discussed in more detail in the Priorities section of Chapter 4.

An additional concern is the aging of transportation infrastructure, including more than 100 bridges or culverts where roads cross the mainstream and tributaries in the watershed. An inventory of these sites shows many are subject to erosion, and some are impeding fish passage. Road-stream crossings are considered a critical issue in the WMP and are discussed in detail in Chapter 4.

The upper and middle reaches of the watershed include significant acreage of state-managed wetlands and upland forest. A number of large, undeveloped parcels of private land are also present.

Maintaining wetlands and other natural habitat is important to both the protection of stream quality and the survival of fish and other indigenous wildlife. The WMP supports preservation of significant properties, (as identified in the priority parcel map, Chapter 4) through purchase, conservation easements or voluntary action of property owners.

Public and private campgrounds offer hundreds of sites on or near the river. Canoe and kayak rentals are offered at several sites. The upper and middle stretches of the river are also used by commercial river-fishing guides, drift boats and individually owned paddle craft.

The annual task of moving deadfalls in spring to open the river for navigation has sometimes been controversial. The WMP recommends oversight of this annual process by the Benzie Conservation District or MDNR to ensure that in-stream habitat is protected.

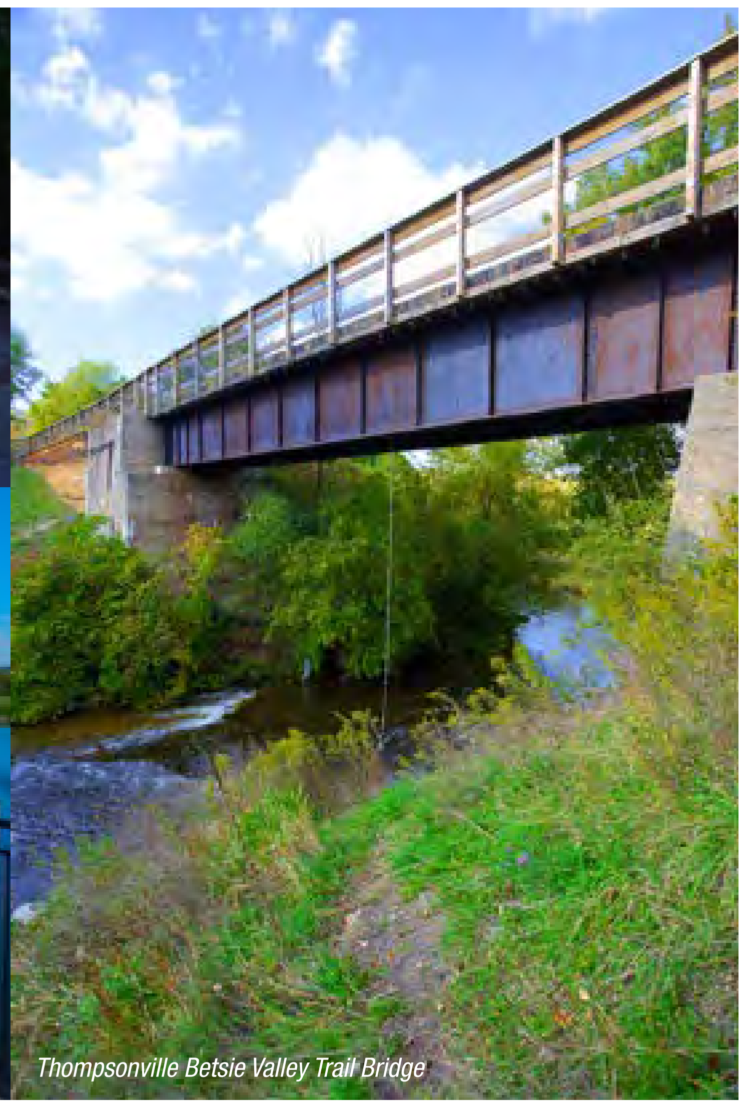
The Benzie Conservation District sponsors an annual river clean-up, collecting trash and lost or abandoned fishing gear.

Public access is adequate on the lower river, but is considered inadequate in the upper stretches. As a result, anglers and paddlers sometimes cause erosion by accessing the stream at locations with steep banks, wet conditions or other shortcomings.

Michigan DNR is working with stakeholders on development of a public access plan. That process is supported by the WMP.

Betsie River-River Road Access Site

Elberta Betsie Valley Trail Bridge



Thompsonville Betsie Valley Trail Bridge

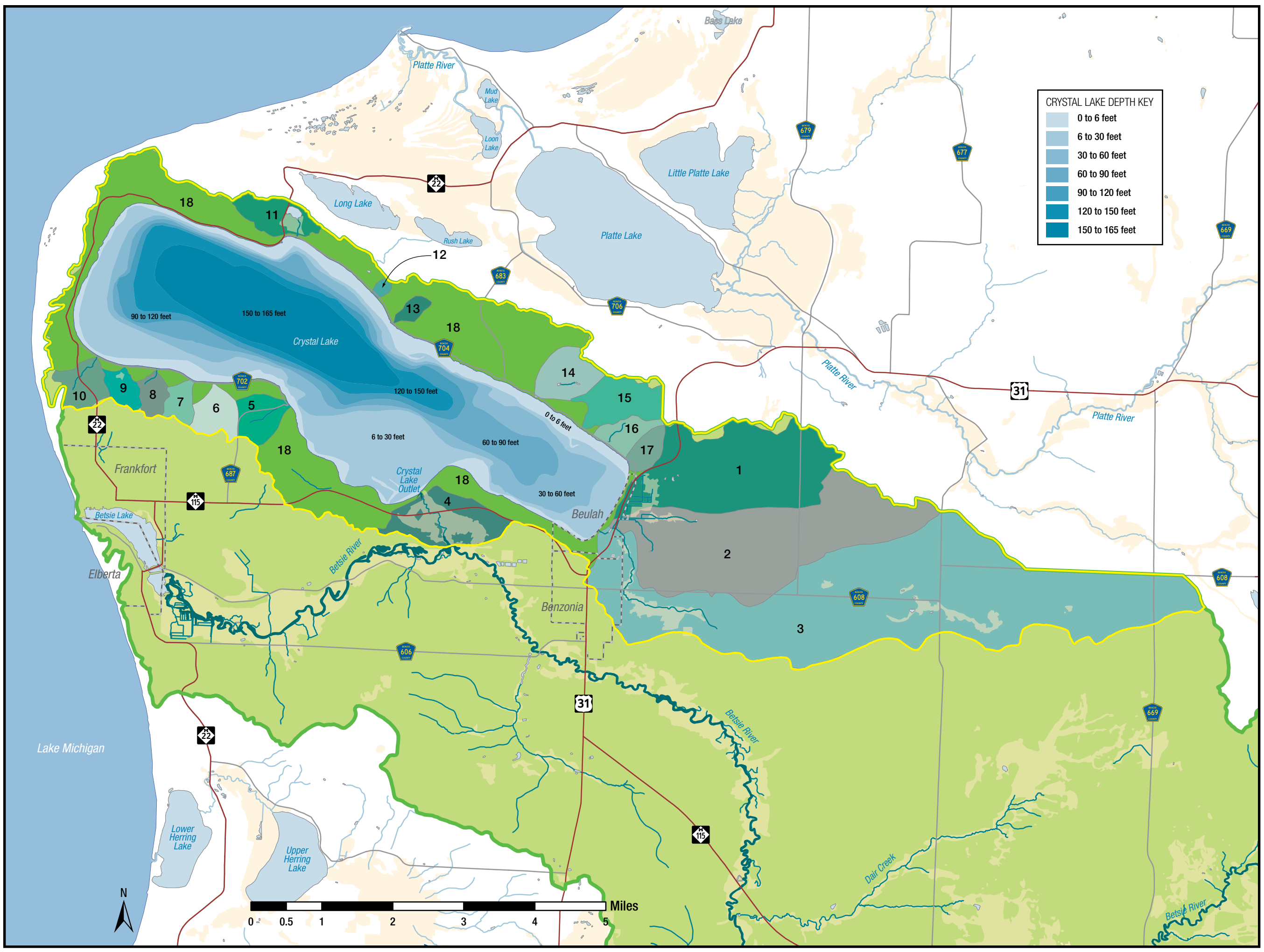
Crystal Lake

Crystal Lake, at approximately 9,850 acres (15.4 square miles), is the 9th largest inland lake in Michigan. It is located in Benzonia, Lake and Crystal Lake townships of Benzie County.

The Crystal Lake watershed includes the lake itself, plus 18,290 land acres. Most of the land that drains to Crystal is located east of the lake. The watershed extends into parts of six townships, all in Benzie County.

The shoreline is highly developed with seasonal and year-round dwellings. The Railroad Point Natural Area, a Benzie County park on the south shore, provides about 3,000 feet of undeveloped, public shoreline. The Betsie Valley Trail, a non-motorized pathway on the former Ann Arbor Railroad right-of-way, parallels the lake's southeastern shoreline for about three miles, traversing segments of both private and public waterfront.

Map 20 - Crystal Lake & Crystal Lake Outlet Watershed



KEY SUB WATERSHEDS

1 - Cold Creek North	7 - Figg Road	13 - Glen Rhoda
2 - Cold Creek Middle	8 - Thomas Road	14 - Nichols Road
3 - Cold Creek South	9 - Bellows Road Creek	15 - Harris Road
4 - Outlet Creek	10 - Burrow's Creek	16 - Shadko Road
5 - Lobb Road	11 - Round Lake Outlet	17 - Mitchell Creek
6 - Robinson Road	12 - Glen Ellen	18 - Crystal Lake

The Village of Beulah and the City of Frankfort maintain public swimming beaches and boat launch sites. The Beulah Beach has been subject to advisories for *E. coli* contamination at times in the summers of 2013, 2014 and 2015. Streams or storm drains at each of these public beaches also have exceeded full- and partial body contact standards for *E. coli* bacteria in recent testing. This impairment is a critical issue addressed in Chapter 4 of the WMP.

In addition to the parks, the lake has approximately 20 public road ends that allow access for relatively small boats. A Michigan DNR public boating access site, suitable for all inland-water vessels, was developed in 2012 on the south shore at Mollineaux Road.

The Crystal Lake & Watershed Association provides free boat-washing facilities at the DNR site. Crystal Lake harbors invasive zebra mussels and small to moderate sized patches of Eurasian milfoil. It is believed to be free of quagga mussels and several other invasives that are present in nearby Lake Michigan.

Protecting the water from aquatic invasives is a priority of the WMP.

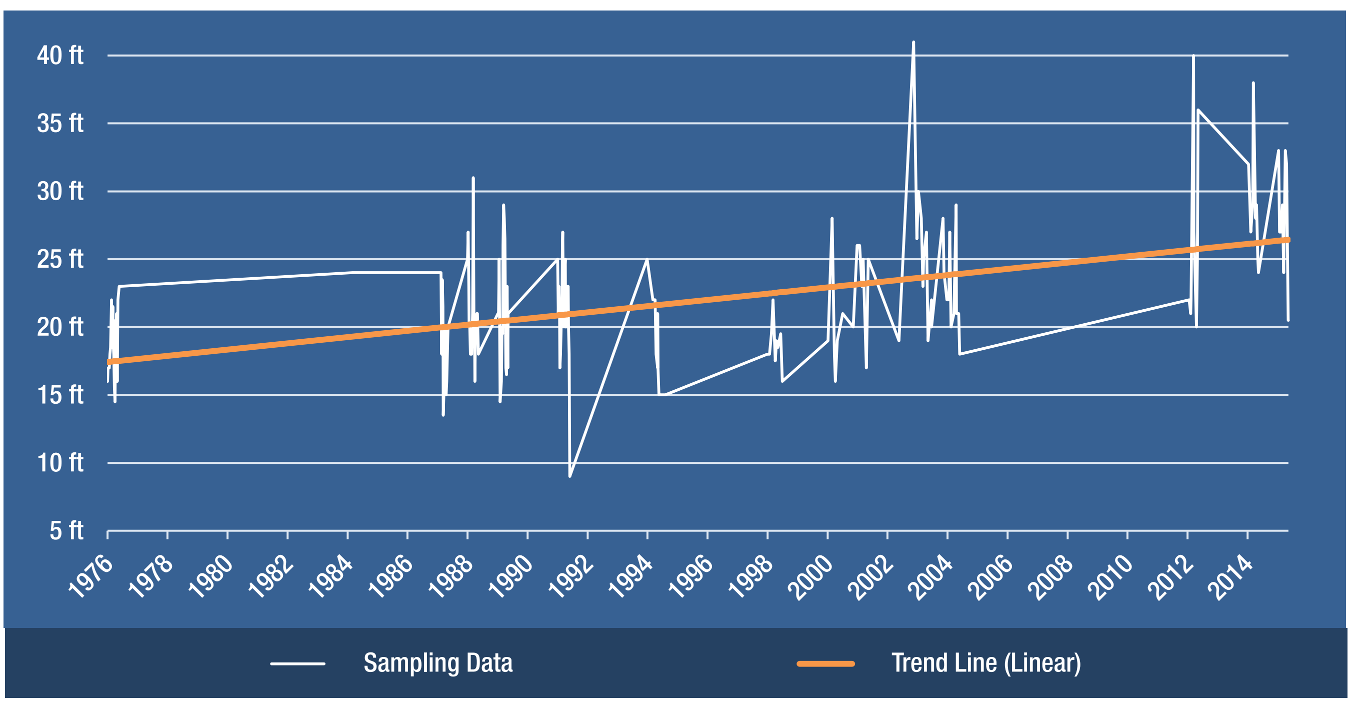
Like many Northern Michigan lakes, Crystal is subject to Swimmer's Itch, or "cercarial dermatitis" a condition caused by chance encounters with a larval form of native flatworm shed by freshwater snails.

The CLWA has sponsored research into the condition and is working with representatives of other lakes on plans for future research.

Swimmer's Itch has been identified as an economic and quality-of-life issue in the watershed, and is considered a priority concern in the WMP.

Sampling data indicates Crystal Lake is an extremely high-quality oligotrophic water body, with high clarity and low levels of phosphorus and chlorophyll a. Water clarity, measured by Secchi disk monitoring has increased in recent decades, perhaps due to the introduction of zebra mussels.

Table 17 - Crystal Lake Secchi Disk Testing



The lake is 8.1 miles in length, with the western end located less than a mile from Lake Michigan. The width, at its widest point, is 2.46 miles. The shoreline perimeter is 20.8 miles. Crystal Lake has a maximum depth of 165 feet and average depth of 70 feet. It is fed by direct precipitation and groundwater, and by the flow of more than a dozen small streams, the largest of which is Cold Creek, which enters in the Village of Beulah at the east end of the lake.

Table 18 - Crystal Lake Total Phosphorus Testing

YEAR	Total Phos (ppb)	
	spring	summer
2015	<= 3	6.0
2014	7.0	5.0
2013	5.0	5.0
2012	NA	NA
2011	< 5.0	6.0
2010	NA	NA
2009	< 5.0	<= 3.0
2008	6.0	< 5.0
2007	NA	NA
2006	NA	NA
2005	6.0	< 5.0
2004	5.0	< 5.0
2003	6.0	7.0
2002	NA	NA
2001	<= 3.0	5.0
2000	9.0	<= 3.0
1999	11.0	11.0
1998	5.0	8.0
1997	6.0	NA
1996	11.0	NA
1995	NA	NA
1994	7.0	NA

Fishing on Crystal Lake near Beulah

The Crystal Lake Watershed is a subwatershed of the Betsie River. The Crystal Lake Outlet exits the lake at the site of a water-level-control structure on the southern shore, and merges with the Betsie River about 5 miles upstream from the river's mouth. During dry autumn months, the Outlet flow may diminish to near zero. At other times, it may contribute 20-30 percent of the downstream flow of the Betsie River.

The Crystal Lake fishery is known for lake trout, brown trout, steelhead, smallmouth bass, rock bass, perch and smelt. Coho salmon have entered the lake through the connection with the Betsie River and established what is one of only two known self-sustaining populations of Pacific salmon on inland lakes in Michigan. In 2013 and 2014, Chinook salmon were also observed jumping the Outlet Dam into the lake. It is not known whether they will establish a population.

The Michigan DNR annually stocks the lake with hatchery-bred lake trout and rainbow trout.

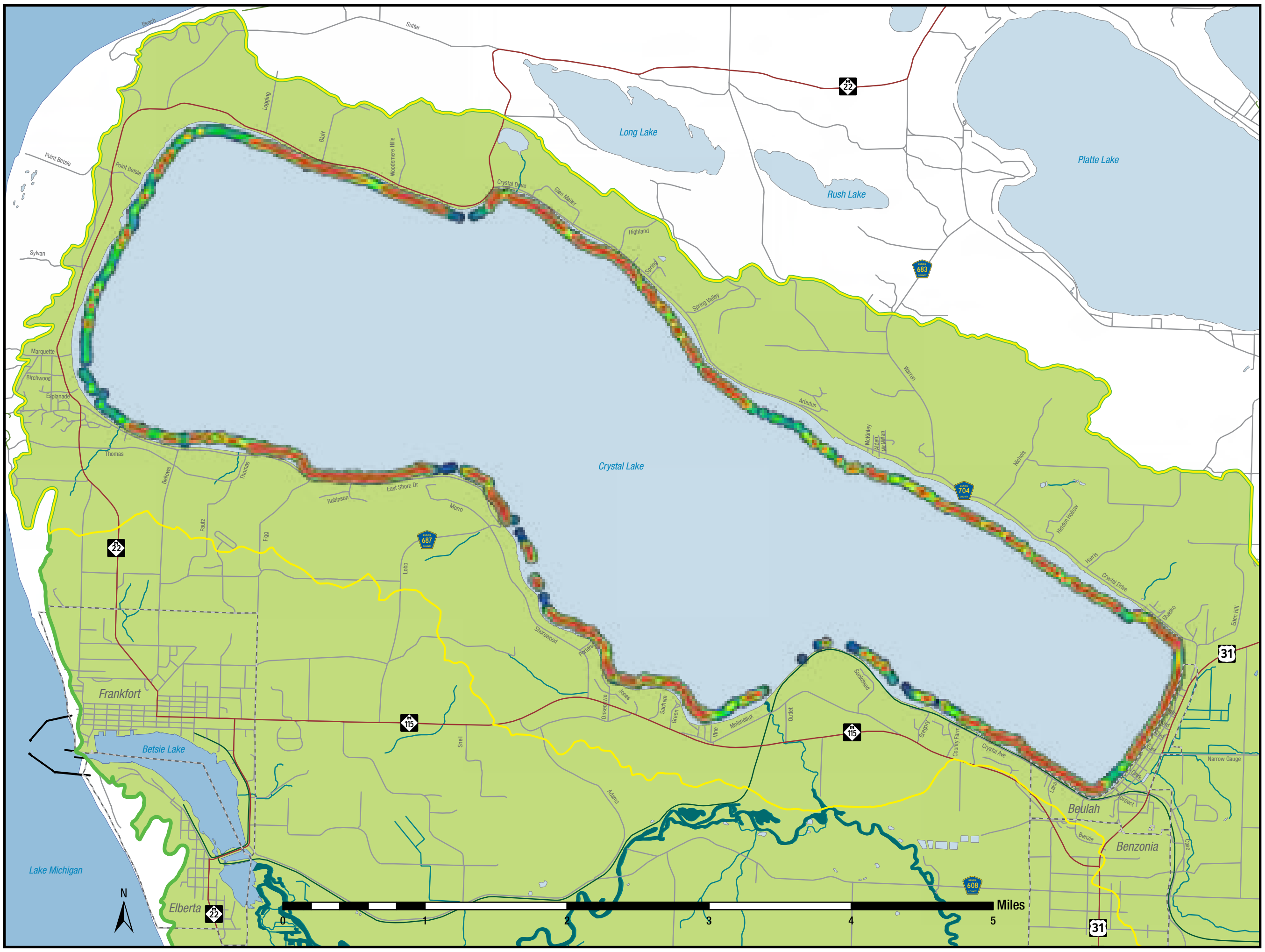
A fishery survey by the Michigan DNR in 2014 found generally healthy fish populations (Appendix C), but raised concerns about the fate of the cisco (lake herring), a Michigan threatened species which is native to the lake but was not found in the recent survey.

Continued monitoring of the fishery is a priority of the WMP.

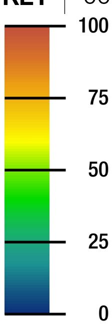
Crystal Lake sits on an east to west-northwest orientation, exposed to prevailing winds that often kick up heavy surf on the north, south and east shores. (Some early maps identified it as “Cap Lake,” a reference to the white-capped waves).

The water level of Crystal Lake is determined by court order to be 600.25 feet above sea level in summer, and 599.75 feet from November 1 to May 1. The six inch lower level in November-May is intended to reduce ice push and winter erosion; the higher summer level is intended to provide adequate depth for docking along shallow segments of the shoreline.

Map 21 - Crystal Lake Shoreline Survey



KEY COMBINED SURVEY RATING



Color scale indicates the average score of the Shoreline Survey Rating within a 250 foot radius. The Shoreline Survey Rating consists of the combined shoreline armoring rating and the adjusted upland vegetation and impervious surface rating to favor the shoreline armoring rating over the upland rating by a factor of 2.

Higher Shoreline Survey Ratings correlate to larger negative impacts to water quality compared to a natural shoreline state.

Shoreline Survey Rating depiction is based on the location of the GPS track of survey camera.

The water level is regulated via a concrete Outlet Dam, which is owned by Benzie County and managed by the Benzie County Drain Commissioner. Natural features of the lake – essentially a very large body of water with a single outlet – have made it difficult in the past to maintain water levels within the legally prescribed limits. Historic data show that the water has typically been above the prescribed level in May and June, and often below that level in autumn.

In 2013, heavy flows in The Outlet channel caused flooding downstream. In 2014, an unusually high water year, the water level remained above the legal level for much of the summer, leading to concerns about wind and wave erosion.

Dam improvements such as cable-operated lift gates have been funded by the Drain Commissioner and the CLWA in recent years. Beginning in 2014, CLWA installed an automated monitoring system that provides real time data about the water level. The association and the Drain Commissioner expect the real-time data will lead to more precise management of the water level.

The Crystal Lake shoreline is ringed with residential uses, and with roads that often lie within 25 feet of the water. This leaves little space for natural shoreline management, and emphasizes the importance of water level management as a vital tool in minimizing erosion.

Crystal Lake formed in the post-glacial period as an embayment of Lake Michigan. Sand dune formation closed off the mouth of the bay some 3,000 years ago, leaving Crystal as an inland lake.

The north and south sides of the lake are bounded by tall glacial end moraines. The land east of the lake is primarily a sandy outwash plain. The west end, between Crystal Lake and Lake Michigan, includes the Point Betsie sand dune complex and the Crystal Downs Country Club and residential area.

Land surveyors and the earliest settlers to the region found the lake some 35 feet above the level of Lake Michigan. In 1873, a company called the Benzie County River Improvement Co. formed with the goal of building a canal between Crystal Lake and the Betsie River for transport of timber products and other goods.

In his 2015 book "The Comedy of Crystal Lake," local historian Dr. Stacy Leroy Daniels described the outcome of the canal effort.

In late summer of 1873 the project was in its final stages, with sections of the river cleared of obstructions to allow boat passage, and a canal dug from the Betsie River to the shore of Crystal Lake. The company apparently intended to construct a lock that would allow travel from the higher level of the lake to the lower elevation of the river. But before that happened, a storm blew up. Waves washed away the embankment separating the lake from the canal, and a torrent of water went rushing out of Crystal Lake.[12]

By the time it stabilized, the lake had lost some 20 feet of elevation.

Eventually, in 1911, a dam was constructed at the site of the washout to stabilize the water level. The present lake level is about 20 feet above the elevation of Lake Michigan – or 15 feet below the pre-1873 level.

The 1873 drawdown had – and continues to have – significant impacts on the lake and community. The lowering exposed a shelf of former lake bottom along most of the shoreline, allowing construction of telegraph lines, railroad tracks, and eventually streets and cottages. What is now the Village of Beulah was developed on former wetlands at the eastern extremity of the lake.

Also exposed, along a branch of Cold Creek at Beulah, were deep muck soils that had accumulated over the centuries from decaying lake-bottom vegetation. The newly exposed muck formed the basis for a profitable vegetable farming operation in the 20th century. The farm is no longer in operation, and much of the land is protected as the

Trapp Farm Nature Preserve of the Grand Traverse Regional Land Conservancy. However, the friable organic soil continues to be a source of nutrients, sediment and possible bacterial contamination flowing into Crystal Lake. Addressing this critical situation is a priority of the WMP (Chapter 4).

Around much of the lake, the inadvertent drawdown exposed a narrow strip of buildable land – in some cases no more than 100 feet between the new shoreline and the base of the bluffs. Roads and buildings constructed years ago on that former bottomland are often much closer to the water than would be allowed under modern zoning. This creates a sensitive situation, where segments of residential shoreline and lakeside roads have been armored with rip-rap, rock groins or seawalls as protection against erosion.

Because of its size and exposure to prevailing winds, Crystal Lake experiences significant wave action which can result in severe erosion, especially during high water times.

It is a goal of the WMP to seek a balance that protects water quality and enhances the lake's ecology while respecting the legitimate concerns of riparian owners.

The Crystal Lake Watershed Overlay District, adopted by the three shoreline townships, requires setbacks and buffer strips for new construction, it also places restrictions on building on steep slopes.

Most of the nearly 1,000 homes along the Crystal Lake shoreline are served by on-site wastewater systems – either private septic systems or holding tanks. Holding tanks, which must be pumped regularly, are used in areas where soil conditions or lack of sufficient space make septic systems impossible.

The village of Beulah is served by municipal sewer service.

Betsie Lake (aka Betsie Bay)

Betsie Lake is a 290 acre "drowned river mouth" connected to Lake Michigan by a short channel. The lake has served as a harbor for boat traffic from Lake Michigan for more than a century. Though it is hydrologically considered an inland lake, local residents refer to it as "Betsie Bay" and Great Lakes boaters call it Frankfort Harbor. For purposes of this Watershed Management Plan, the terms Betsie Lake and Betsie Bay are used interchangeably.

The Betsie River flows into the east end of Betsie Lake after passing under three bridges: A former railroad crossing that now serves the non-motorized Betsie Valley Trail; a Michigan highway bridge carrying M-22; and a bicycle and pedestrian bridge for a trail segment that links the city of Frankfort, on the north side of the lake, with the village of Elberta on the south shore.

The outlet to Lake Michigan is through a man-made channel at the southwest corner of Betsie Lake. The lake's natural outlet was located somewhat north of the present location. It was realigned in the 19th Century to improve ease of navigation.

Through most of the 20th Century, Betsie Lake served as home port for the Ann Arbor Rail Road's car ferry fleet, which carried rail cars across Lake Michigan to Wisconsin. The car ferry service ended in 1982. The old rail yards and other industrial and transportation facilities on the Elberta side of the lake have been removed and the site remediated. A portion of the site is now a village park, with other sectors, including the south side of the channel, planned for residential development.

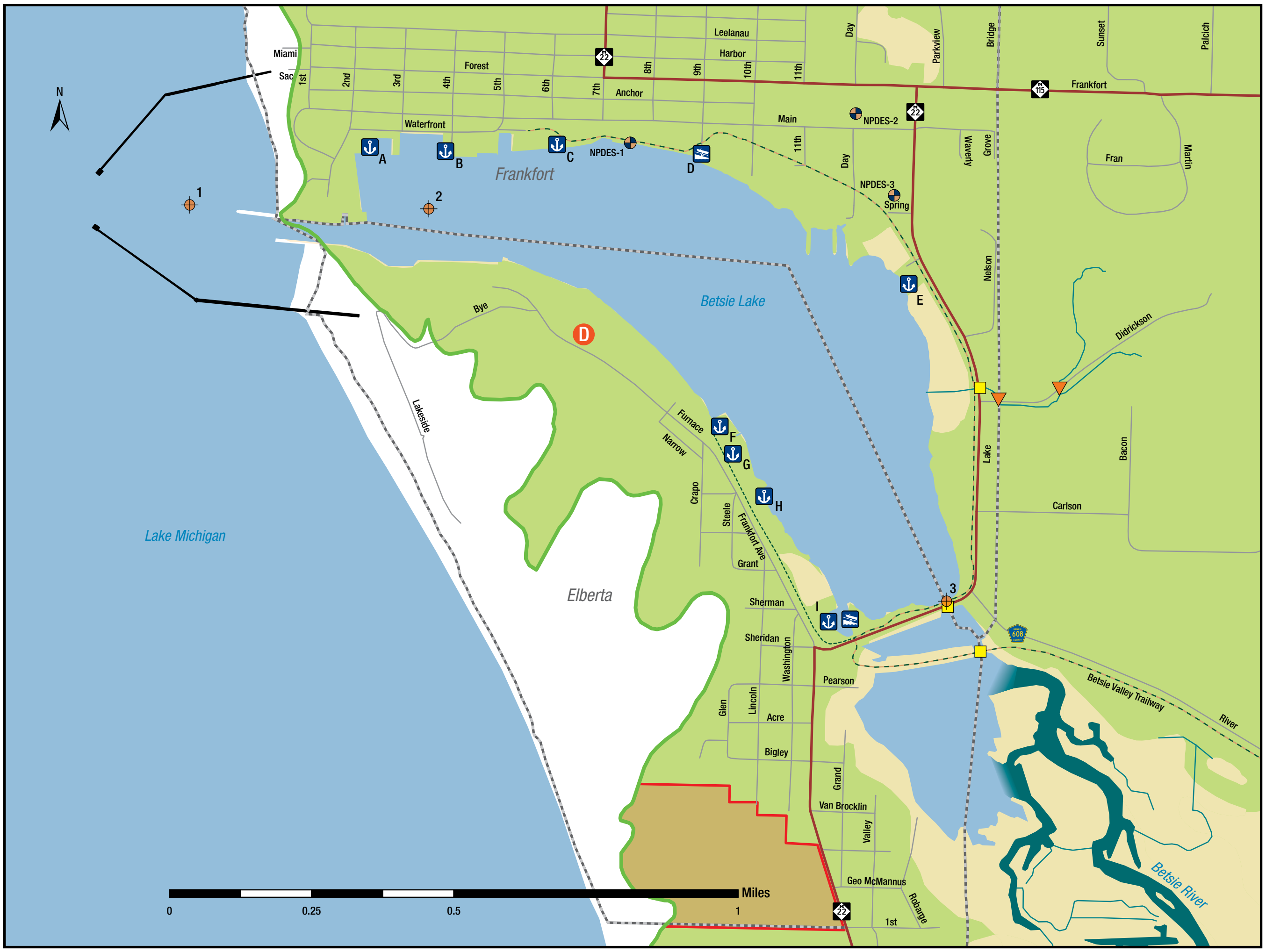
Entry to the channel from Lake Michigan is protected by angled breakwalls which create a large wave-attenuated Outer Harbor. The historic Frankfort North Breakwall Light sets at the tip of the northern pier. The light is now owned by the city of Frankfort, which is seeking funds for preservation.

While the Outer Harbor is physically located in Lake Michigan, it is considered part of the Betsie River Watershed for purposes of this WMP.

Betsie Lake has a maximum depth of 34 feet. The western sectors of the lake are periodically dredged – most recently in 2014 – to maintain navigable depths.

The harbor supports one public and five private marinas, with a total of approximately 250 boat slips, the largest of which can accommodate vessels up to 145 feet in length. Gasoline and diesel fuel are available at two marinas.

Map 22 - Betsie Lake



KEY | BOUNDARIES & SPECIAL LOCATIONS

- CITY OR VILLAGE
- GTRLC Protected Lands
- Critical Area
- Marinas
- Boat Launch Ramps
- NPDES Permit Location
- Monitoring Locations
- Minor Road Stream Crossing
- Moderate Road Stream Crossing

ID	MARINA & LAUNCH RAMP LOCATION	LAT	LONG
A	Harbor Lights Marina	+44.631676	-86.242579
B	Jacobsons Marina	+44.631564	-86.239888
C	Frankfort Municipal Marina	+44.631862	-86.235941
D	City of Frankfort Launch Ramp	+44.631724	-86.230747
E	East Shore Marina	+44.628499	-86.223230
F	Betsie Shores Dockominium	+44.624640	-86.229855
G	Betsie Bay Marina	+44.624020	-86.229573
H	North Star Marina	+44.622989	-86.228171
I	Village of Elberta Marina	+44.619945	-86.225081

The water level in Betsie Lake is determined by the level of lakes Michigan-Huron. In late 2012 and early 2013, the Michigan-Huron level approached record lows, making it difficult to maintain adequate depths for navigation. A major dredging project took place in 2014 with federal funding.

Great Lakes water levels have since risen to above the long-term average. As of early 2015, the Betsie Lake surface was 36 inches above the level from January 2013.

A municipal boat launch facility on the Frankfort side of the lake is heavily used by anglers and pleasure boaters, many of whom travel through the channel to Lake Michigan. Fishing docks on both sides of the lake provide access for shore anglers. There are no public swimming beaches on Betsie Lake, though Frankfort does maintain a beach on the Lake Michigan shore in the Outer Harbor.

Shorelines near the channel and the western end of the lake are hardened with metal seawalls, often connected directly to docking facilities. At the southeast corner, weathered pilings remain from old dock structures. The eastern end is bounded by a mix of natural shoreline, wetlands, scattered residences and storage areas for Luedtke Engineering Co., a marine services company.

Also at the east end of the lake is the wastewater treatment plant operated by the Betsie Lake Utilities Authority (BLUA). The plant opened in 1990 to provide primary and secondary treatment to sanitary sewage from both Frankfort and Elberta. Opening of the plant led to significant improvements in lake water quality.

The city of Frankfort has separated most of its storm water system from the sanitary sewer lines in recent decades. The city has installed filtration at one stormwater outfall. Elberta's village streets generally lack curb and gutter, so there is only limited stormwater collection there.

Planned future development of residences on the former railroad and industrial sites on the south shore will require a stormwater collection and filtration system.

Mouth of Betsie River, Betsie Lake, Frankfort Outer Harbor, and Lake Michigan

Studies in the 1960s and 1970s found Betsie Lake was subject to high levels of nutrients from municipal wastewater, shipping, and commercial point-source outfalls, in addition to nutrient flow from upstream segments of the Betsie River. At that time the lake was classified as eutrophic, indicating high levels of algae, excess nutrients, and low water clarity.

Water quality is clearly much better today. Unfortunately, there has been no regular monitoring to document trends or to provide early warning of negative changes.

The most recent testing was accomplished in 2007 by the non-profit Friends of Betsie Bay and the Benzie Conservation District. That series of samples found total phosphorus levels ranging from 13 to 20 parts per billion and clarity measured by the Secchi Disc at about 7 feet. Those numbers are indicative of a mesotrophic, or medium clarity lake. The FoBB and BCD have developed plans for increased monitoring of the lake, beginning in 2016. That outcome is strongly supported by the WMP.

As the connecting link between the Betsie River and Lake Michigan, Betsie Lake is vitally important to the passage of migratory fish, including steelhead and Pacific salmon. The lake is also popular as an ice-fishing destination. From spring through fall, anglers also fish from the harbor breakwalls.

A Michigan Department of Natural Resources survey in 2008 netted 22 fish species in the lake, including large numbers of rock bass and yellow perch.

Since that time, an invasive species of fish, the round goby, has colonized the lake. It is unknown at this time whether the goby population has impacted other species.

(The MDNR report, written by biologist Mark Tonello, contains much useful information on the history and biology of Betsie Lake. It is included in Appendix C to the WMP.)

Priorities for management of Betsie Lake will include maintaining of water quality sufficient to support navigation and fishing.

To accomplish those goals, the WMP recommends:

- A comprehensive monitoring program – including chemical and biological parameters – to assess and respond to water quality problems;
- Preservation of natural shorelines and wetlands that exist on the east end of the bay;
- Continuing improvement of upstream stretches of the Betsie River;
- Stormwater management in both Frankfort and Elberta;
- Maintenance and preservation of the Harbor breakwalls and lighthouse for their historical, navigational and recreational values
- Fishery status evaluations at least once every 10 years to assess impacts of invasive species and water quality changes.

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Chapter 3

Non-point Source Pollution Inventories

By its very nature, Non Point Source pollution is difficult to quantify. This is especially true in a largely rural area such as the Betsie River / Crystal Lake Watershed, where most surface waters meet quality standards, and sources of pollutants tend to be small and widely separated.

Despite that challenge, it is important to create an inventory of actual and potential sources, and to estimate current pollution loads. The source inventory and load estimates may help to identify problem sites and also provide a baseline to monitor progress in meeting the Watershed Management Plan goals.

In the case of the Betsie-Crystal Watershed, there are no watershed-wide impairments. Most loadings are moderate and well below levels that threaten the designated and desired uses of lakes and streams. The lone "non-attainment" sites in the watershed are related to excessive bacterial (*E. coli*) levels on two public beaches on Crystal Lake. Monitoring has confirmed that small streams and village storm drains discharge excessive concentrations of *E. coli* on or near the public beaches during rain events. These issues are discussed in detail in the Critical Issues section (Chapter 4), Implementation Tasks (Chapter 6) and Monitoring and Evaluations Strategies (Chapter 7).

With the exception of *E. coli* at the specific Crystal Lake sites, the Watershed's major environmental stressors – nutrients, biological pathogens, sediments and elevated water temperatures – are not present at levels that impair the designated uses of surface waters. The State of Michigan is in the process of developing a statewide Total Maximum Daily Load (TMDL) for *E. coli*, which is the only pollutant contributing to impaired designated uses in this Watershed. The plan adopts a non-degradation standard, requiring that pollutant loads must not be allowed to increase from the present levels. Achieving this standard will require long-term monitoring of water quality, along with application of Best Management Practices (BMPs) to identified stressors. Those plan elements are discussed in later chapters of this document.

The major stressors in this watershed may enter the water from a number of sources. This chapter provides estimates of pollutants and identifies several potential sources, such as land use practices, recreational infrastructure and road crossings.

These pollutants have not been systematically or comprehensively monitored for the overall watershed in the past. For that reason, much of the information presented here is based on estimates, derived through the best available data. As in other sections of the plan, it must be noted here that improved monitoring (See Chapter 7) is a necessary element for long-term preservation of the resource.

Table 19 - Sediment & Phosphorus Loading Estimates by Assessment Category

Assessment Category	Total Sediment Tons	Phosphorus Loading in Pounds
Run-off from Land [A]	5,945	18,607
Septic Systems [B]	NA	2,394
Road Stream Crossings [C]	185	157
Streambank Erosion [D]	2,177	1,980
Total	8,307	23,139

Notes:

Figures in this table are best estimates for pollution loadings associated with the assessed categories in the Betsie River / Crystal Lake Watershed. The estimates are derived by applying generally accepted conversion factors to data specific to this Watershed.

A Loadings from land run-off are estimated through the Spreadsheet Tool for Estimating Pollution Loads (STEPL), provided by US-EPA and MDEQ, using data from the Betsie River Hydrologic and Hydraulic Study (Appendix B). Also, see tables 19 and 20 in Chapter 3.

B An estimate of active septic systems (full-year and part-year) was calculated from U.S. Census data on housing. Assumptions of wastewater flow of 60 gallons per person/day, phosphorus content of 10 mg/L and 90 percent efficiency were entered in the spreadsheet to determine the overall estimate. Also, see Table 22, chapter 3

C Road Stream Crossing Inventory data are in Appendix D. The initial inventory, conducted prior to 2000, did not determine sediment loadings. Sediment estimates are included in 40 site assessments (out of a total of 130 crossings) that were updated in 2014 for this WMP. The updated site data was averaged by category, and those averages were used to extrapolate a watershed-wide estimate. Phosphorus content was estimated through the same conversion factor used in the streambank erosion category.

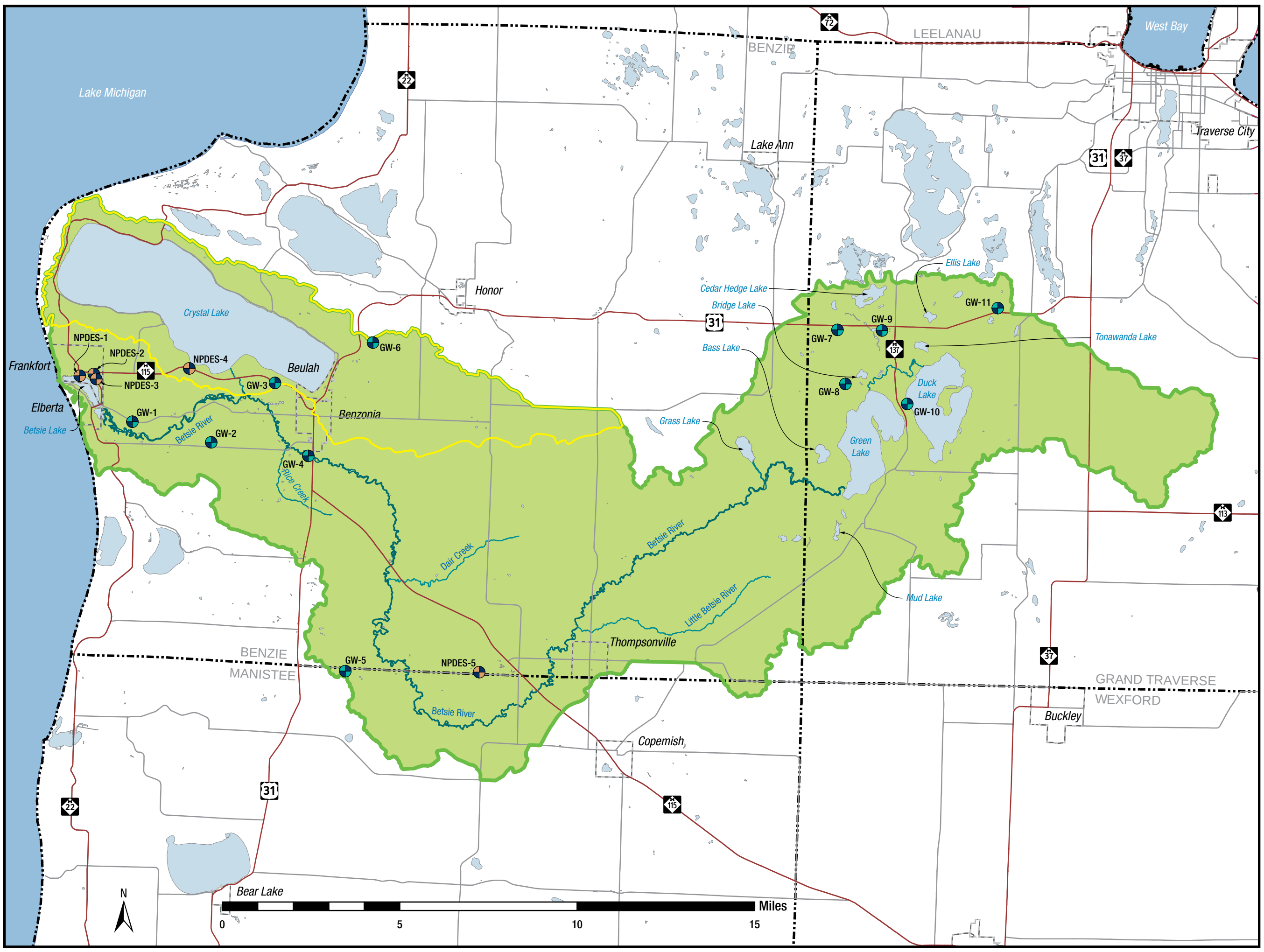
D The Streambank Erosion Inventory in Appendix E includes the length and height of each eroding segment, along with the predominant soil type and the severity of erosion at the site. The NRCS provides a spreadsheet method for estimating sediment. The above inventory data are entered, plus an estimate of annual bank recession (0.2 feet a year for minor sites; 0.5 feet for moderate sites and 0.8 feet for severe sites) and a soil-weight factor (1.05 for sand; 0.85 for clay). The result is converted to tons of sediment, for comparison with other categories. Phosphorus loading is estimated by multiplying the sediment loading (in pounds) by a factor of 0.0005.

Permitted "Point source" discharges:

Facilities with permits through the National Pollutant Discharge Elimination System (NPDES) are monitored and regulated through the authority of the Michigan DEQ, and generally fall outside the purview of this Watershed Management Plan. These facilities are typically mandated when human, animal or plant wastes are produced in such volumes or concentrations that they would overload the natural systems of breakdown and conversion.

The great majority of the land area in the Betsie River / Crystal Lake Watershed continues to rely on distributed systems such as septic systems, manure spreading or composting to break down wastes and recycle them into forms usable to new plants and animals.

Map 23 - Point Source Discharge Permits



KEY | POINT SOURCE DISCHARGE PERMITS

NPDES Permit Location

ID	LOCATION	LAT	LONG
NPDES-1	Graceland Fruit, Incorporated	+44.631900	-86.233300
NPDES-2	Gateway Products, Incorporated/ Graceland Fruit Incorporated	+44.632780	-86.225280
NPDES-3	Betsie Lake Utilities Authority	+44.630718	-86.223847
NPDES-4	Tom Killingsworth, Michigan Department of Transportation	+44.635888	-86.170849
NPDES-5	Crystal Enterprises Incorporated	+44.514444	-86.001666

Groundwater Discharge Permit Location

ID	LOCATION	LAT	LONG
GW-1	Betsie River Campsite	+44.613660	-86.202640
GW-2	Graceland Fruit Cooperative In	+44.605950	-86.157330
GW-3	Green Valley Comm Septic Sys	+44.630740	-86.121690
GW-4	Vacation Trailer Park	+44.601280	-86.101750
GW-5	Kampvilla RV Park	+44.513740	-86.078030
GW-6	Stoneridge Lakeviews	+44.648090	-86.066130
GW-7	Deerings Jerky Co LLC	+44.656890	-85.800760
GW-8	Interlochen Center For Arts	+44.634940	-85.795730
GW-9	Westside Condominiums	+44.656990	-85.775310
GW-10	DNR-Interlochen State Park	+44.627180	-85.760140
GW-11	Cherry Growers Inc-Green Lake	+44.666940	-85.709350

Some additional treatment is required at the permitted sites in order to reduce nutrient loads before effluent is discharged to land or to surface waters. The sites include: Two fruit processing firms; three large campgrounds; the Crystal Mountain Resort; The Interlochen Center for the Arts; and municipal wastewater treatment facilities which service Beulah and Frankfort-Elberta.

The largest of the permitted facilities is the Betsie Lake Utilities Authority, which treats municipal sewage from Frankfort and Elberta. BLUA also processes wastes collected by septic tank pumping companies, and leachate trucked to the site from a landfill outside the watershed.

Treated effluent from BLUA is discharged into the east end of Betsie Lake.

BLUA began operation in 1990, replacing separate primary treatment facilities that had served Elberta and Frankfort. The presence of the treatment plant resulted in dramatic improvement in the lake, which had previously been classed as eutrophic, due to the excessive nutrient loadings.

The BLUA plant has a listed capacity of 575,000 gallons per day. Monthly reports show plant efficiency in the range of 90 percent or greater for removal of phosphorus, suspended solids, and biological oxygen demand.

BLUA and Crystal Mountain Resort and Spa are the only sites in the watershed permitted for direct discharge into surface waters. The other permitted sites discharge treated water to land either through infiltration or by spraying it onto crops.

Nutrient and sediment loadings in runoff

Sediment and nutrients in runoff are often directly correlated to land cover, with, for example impervious surfaces generally yielding both higher volumes of runoff and higher pollutant loads.

To help in estimating sediment and nutrient loadings where specific monitoring is not available, the United States Environmental Protection Agency has developed the Spreadsheet Tool for Estimating Pollutant Loads (STEPL).

STEPL uses annual runoff volume and pollutant concentration to estimate pollutant loadings, including sediment loadings. It can also be used to compare effects of land use changes and installation of BMPs.

With assistance from the Michigan Department of Environmental Quality, STEPL was applied to existing land cover data to produce the best-possible approximation of loadings for the Betsie River / Crystal Lake Watershed. In the interest of consistency, the calculation made use of land cover data and runoff coefficient numbers that were developed as part of the 2014 Hydrology Study of the watershed (Appendix B). After input of those figures, the STEPL software was able to calculate estimates of nitrogen, phosphorus and biological oxygen demand for the watershed and its seven major subwatersheds (see Map 24).

The accompanying chart presents estimates for the overall watershed and each subwatershed. The figures are presented in two ways: total pounds per year, and pounds per acre per year.

Not surprisingly, the calculations indicate the highest pollution loadings, on a per-acre basis, are in the areas with the highest level of development: the two westernmost subbasins near Frankfort-Elberta, and the easternmost subbasin around Duck Lake.

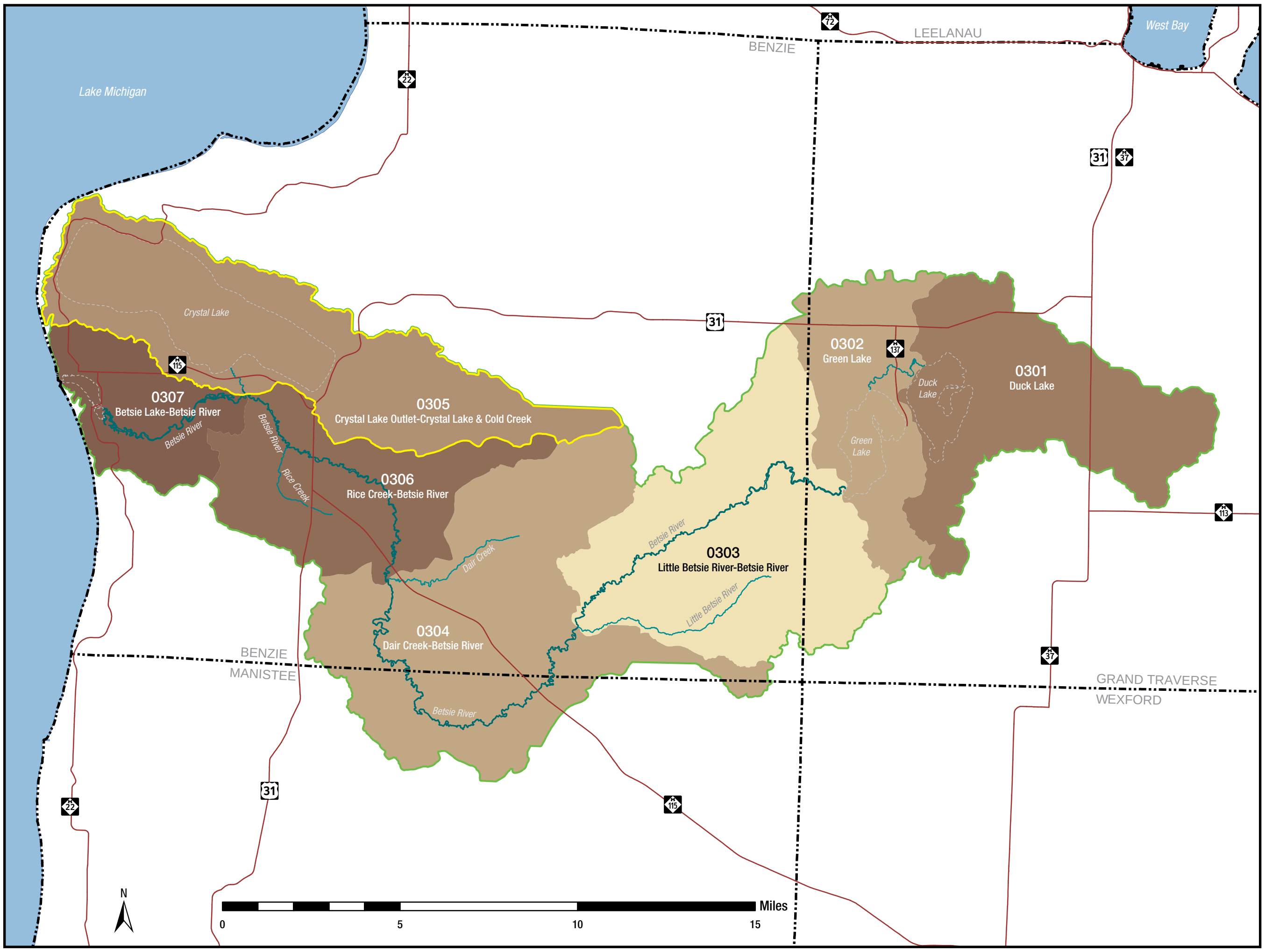
Table 20 - STEPL • Total

Watershed	N Load (no BMP) lb/year	P Load (no BMP) lb/year	BOD Load (no BMP) lb/year	Sediment Load (no BMP) t/year	Acres in Subwatershed
Little Betsie River 40601040303	6,274	1,808	16,217	509	29,338
Dair Creek 40601040304	12,338	3,072	36,387	731	34,625
Crystal Lake Outlet 40601040305	14,703	3,261	43,438	1,010	28,379
Rice Creek 40601040306	14,554	3,460	37,071	1,342	17,195
Betsie River 40601040307	10,636	2,393	29,661	948	9,643
Duck Lake 40601040301	16,460	3,446	43,681	1,141	22,171
Green Lake 40601040302	5,161	1,166	15,950	264	13,689
Total	80,127	18,607	222,405	5,945	155,041

Table 21 - STEPL • Per Acre

Watershed	N Load (no BMP) lbs per acre	P Load (no BMP) lbs per acre	BOD Load (no BMP) tons per acre	Sediment Load (no BMP) tons per acre
Little Betsie River 40601040303	0.21	0.06	0.55	0.02
Dair Creek 40601040304	0.36	0.09	1.05	0.02
Crystal Lake Outlet 40601040305	0.52	0.11	1.53	0.04
Rice Creek 40601040306	0.85	0.20	2.16	0.08
Betsie River 40601040307	1.10	0.25	3.08	0.10
Duck Lake 40601040301	0.74	0.16	1.97	0.05
Green Lake 40601040302	0.38	0.09	1.17	0.02

Map 24 - Phosphorus Loading by Subwatershed



KEY

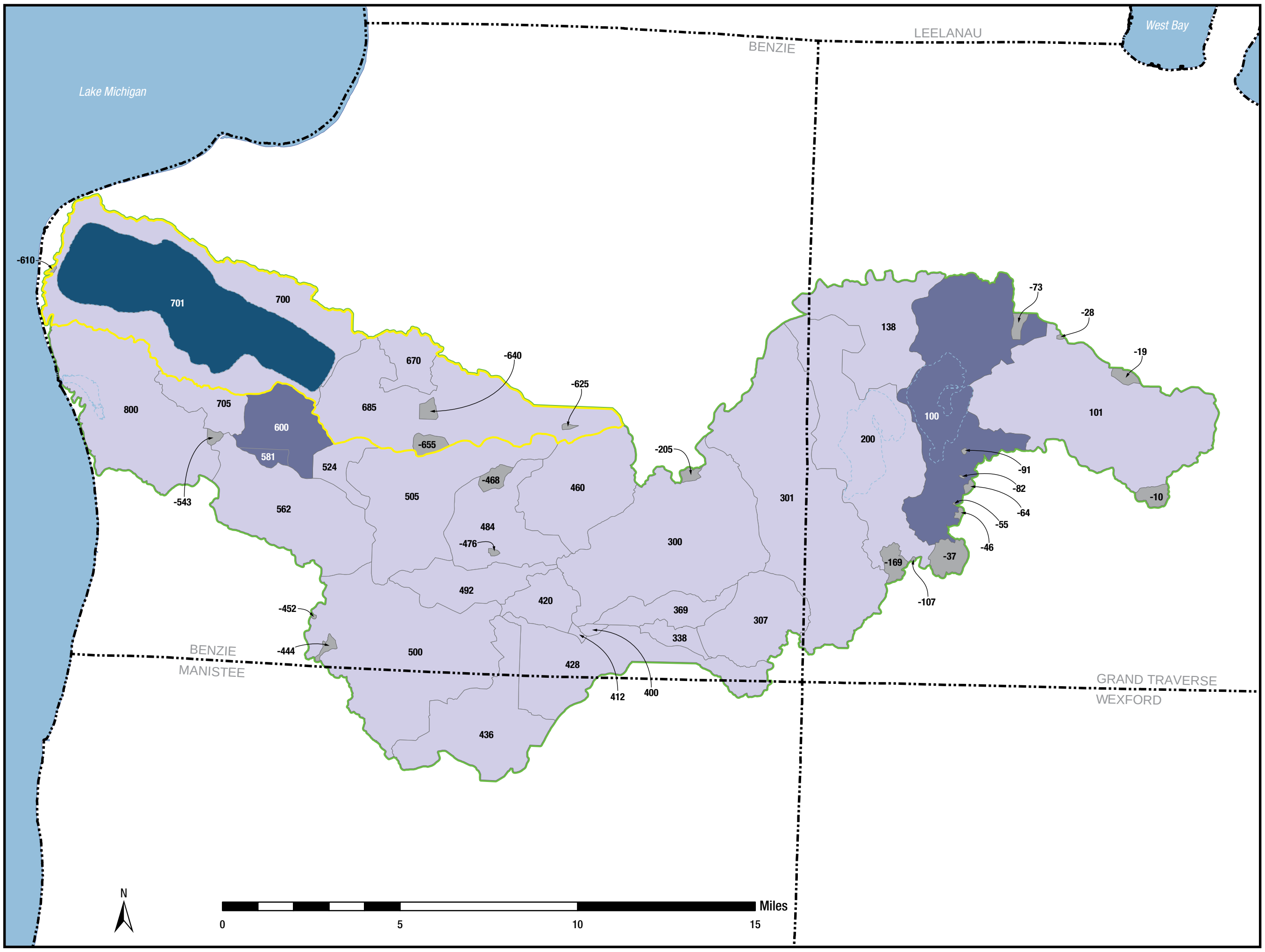
Pounds per Acre
0.06 - 0.07
0.07 - 0.08
0.08 - 0.11
0.11 - 0.13
0.13 - 0.17
0.17 - 0.21
0.21 - 0.25

The estimated phosphorus loadings were calculated with the EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL). STEPL was applied with the assistance of the MDEQ to existing land cover data to produce the best-possible approximation of loadings. The calculation used land cover data and runoff coefficient numbers from the 2014 Hydrology Study.

Supporting the STEPL data, the 2014 Hydrology Study includes runoff calculations for each of 29 small areas in the watershed. The study considered soil types, slopes, land cover and other hydrological factors to determine these runoff values for each of three time periods: 1800 (pre-settlement), 1978 and 2006.

As a general statement, pollutant levels are correlated with runoff, which simply means that greater volumes of water are capable of carrying more sediment and nutrients. Areas with higher runoff volumes can be assumed to also produce higher pollutant loadings.

Map 25 - Subbasins / Storm Runoff



KEY | PEAK FLOW YIELD

- Non-Contributing
- Less Than 0.01
- Between 0.01 and 0.1
- Greater than 0.1

Units - Cubic Feet per Second per Acre

- Major Watershed Lake

Note: The subbasin that has the highest peak flow yield is subbasin 701, which represents Crystal Lake. Precipitation that falls on this subbasin is directly added to the existing water in the lake, and this subbasin was included in the hydrologic and hydraulic analysis in order to represent the precipitation falling onto this lake directly. It does not make for a good point of comparison for analyzing the peak flow yield of other subbasins, since it is so unique in its characterization.

Storm on Crystal Lake - Beulah Beach

Table 22 - Peak Flow Yield In Cubic Feet Per Second Per Acre

Subbasin	1800 Peak Flow Yield	1978 Peak Flow Yield	2006 Peak Flow Yield	Subbasin	1800 Peak Flow Yield	1978 Peak Flow Yield	2006 Peak Flow Yield
100	0.021	0.025	0.028	484	0.000	0.000	0.000
101	0.001	0.002	0.003	492	0.000	0.000	0.000
138	0.001	0.002	0.001	500	0.000	0.000	0.000
200	0.005	0.005	0.004	505	0.000	0.000	0.000
300	0.001	0.000	0.001	524	0.000	0.000	0.000
301	0.003	0.002	0.002	562	0.000	0.000	0.001
307	0.001	0.000	0.001	581	0.000	0.000	0.015
338	0.002	0.008	0.003	600	0.002	0.005	0.012
369	0.005	0.006	0.010	670	0.000	0.000	0.000
400	0.001	0.000	0.000	685	0.000	0.000	0.000
412	0.012	0.000	0.000	700	0.000	0.002	0.001
420	0.002	0.001	0.003	701	0.108	0.108	0.108
428	0.000	0.000	0.000	705	0.000	0.001	0.004
436	0.001	0.000	0.000	800	0.001	0.003	0.005
460	0.000	0.000	0.000				
Units	Cubic feet per second/acre						

The Hydrology Study shows the highest runoff, on a per-acre basis is in catchment No. 100, located near Duck Lake.

(The higher number of Catchment No. 701 is misleading. That area consists entirely of the surface of Crystal Lake. Since all rainfall here adds directly to the level of the lake, it is classed as runoff. The study authors note that this site should not be used as a comparison.)

These calculations provide a baseline which can be adjusted in the future to gauge the impact of changing land uses or installation of best management practices associated with agricultural systems, transportation infrastructure or low-impact development.

The WMP envisions long-term monitoring of water quality parameters and stream flow to better define loadings in the future.

Septic systems:

Based upon population and housing statistics from the 2010 Census, together with statistics from the Benzie-Leelanau District Health Department, it is estimated that the Betsie River / Crystal Lake Watershed has approximately 6,000 on-site wastewater systems, including about 4,500 that are used on a year-round basis and 1,500 which are used seasonally.

In addition, some 1,400 residences in Beulah, Elberta and Frankfort are connected to municipal wastewater treatment systems. An undetermined number are connected to systems at Crystal Mountain Resort, The Interlochen Center for the Arts and several small mobile home communities.

The majority of the on-site facilities are traditional septic tank and drain field systems. About 300 residences, mostly around Crystal Lake and in Green Lake Township, use holding tanks, which retain 100 percent of wastewater until the waste is pumped out and trucked away for disposal and treatment. Holding tanks are used where sanitary sewer is unavailable and where soil conditions or lot size are unsuitable for drain fields.

In Benzie County, where most of the watershed's holding tanks are located, the pumped waste is typically taken to the Betsie Lake Utilities Authority for treatment.

A large number of studies of wastewater flow have been conducted over the years, producing a wide range of estimates of both the volume and concentration of septic tank effluents.[13]

Taking approximate median values of those estimates, the WMP will assume residential wastewater flows of about 60 gallons (230 liters) per person per day, and phosphorus concentration in the effluent of 10 mg/L.

Applying those assumptions to a full year and an average of 2.5 residents per dwelling (and converting all measures to pounds and gallons) would indicate that the effluent flowing from the septic tank to the drain field of an average dwelling will carry about 4.6 pounds of phosphorus annually.

Based upon those assumptions, total phosphorus effluent from the 4,500 year-round systems is estimated at 20,560 pounds annually. Assuming the seasonal systems are used for six months a year, those 1,500 systems would contribute an annual total of 3,380 pounds of phosphorus, bringing the total estimate for all septic systems in the watershed to 23,940 pounds of phosphorus.

That is not the end of the story, of course, since most treatment actually takes place in the drain field, not the septic tank itself. In a high functioning system, more than 90 percent of that phosphorus is taken up in the drain field soil through the processes of precipitation and adsorption (National Environmental Services Center; 2013). A 90 percent removal rate would reduce the phosphorus loading to 2,394 pounds.

Under ideal conditions – widely spaced residences and proper separation of the drain field from groundwater or surface water – these on-site systems are highly efficient. Problems may occur, allowing phosphorus and other nutrients to migrate away, when the system is improperly maintained, overloaded, or constructed too close to a waterway.

Table 23 - Estimates Of Annual Septic System Impacts

System Type (Seasonal or Year-round)	Number of Systems	Daily Effluent per User (gallons)	Average Number of Users per System	Daily Effluent per System (gallons)	Annual Effluent per System (gallons)	Total Annual Effluent (gallons)
365-day systems	4,500	60	2.5	150	54,750	246,375,000
180-day systems	1,500	60	2.5	150	27,000	40,500,000
Total for all systems	6,000	60	2.5	150		286,875,000

System Type (Seasonal or Year-round)	Total Annual Phosphorus Released to Drain Fields (pounds)	Phosphorus Removal at 90% Efficiency (pounds)	Phosphorus Remaining (pounds)
365-day systems	20,560	18,504	2,056
180-day systems	3,380	3,042	338
Total for all systems	23,940	21,546	2,394

Golf Courses:

Golf courses are potential sources of chemical and nutrient pollution as a result of fertilizers and pesticides used in turf management. However, best management practices can minimize these problems.

The Betsie River / Crystal Lake Watershed is home to seven golf courses.

The Crystal Downs Country Club, overlooking Lake Michigan and Crystal Lake in Benzie County's Lake Township, is a historic, private facility that is annually ranked among the top courses in the world.

The Crystal Mountain Resort and Spa has two championship level courses in Benzie's Weldon Township, near the middle stretch of the Betsie River.

The watershed's remaining four golf properties are free-standing 18-hole courses with relatively small amounts of associated residential development.


Crystal Downs Golf Course


Pinecroft Golf Course

The Interlochen Golf Club, in Grand Traverse County's Green Lake Township, is located near the watershed's fast-est growing residential area, along US31 north of Green and Duck Lakes and the village of Interlochen.

Crystal Lake Golf Club overlooks the east end of Crystal Lake and the Trapp Farm Nature Preserve in Benzie County's Benzonia Township. The course was built in the 1970s on former orchard property.

Pinecroft, in Benzonia Township, and Champion Hill, in Homestead Township, were created around the year 2000. The two courses are under common ownership. Both courses have views of Crystal Lake and occupy property that in the past supported orchards and Christmas Tree farms.

Given the short summer tourist season and the relatively small year-round population, it remains unclear whether the market can support this many holes of golf in the long term.

The surrounding region boasts a large number of golf facilities, including several high end "designer" courses which draw summer play from the Midwest and beyond. Many of these courses – like the two at Crystal Mountain – are affiliated with full-service resort properties and therefor receive a majority of the group play and business conference usage in the shoulder season.

In some cases, historic orchard land remains contaminated from past use of harsh pesticides such as lead arsenate. That makes golf development appropriate, but may complicate any future transition to residential or other uses.

Excessive use of fertilizers and/or pesticides on fairways and greens may have negative impacts of ground water and surface water. In addition, heavy use of wells for turf irrigation may impact ground water levels, in some aquifers.

The WMP recognizes the importance of golf as an element of the local tourism and recreational economy, as well as the scenic impact of maintaining open space for such properties.

The Michigan Turfgrass Environmental Stewardship Program (MTESP) is designed to protect groundwater and surface water resources by promoting best management practices and increasing regulatory compliance within the golf industry. MTESP is a partnership between the Michigan Department of Agriculture and Rural Development, Michigan State University, and the Michigan Turfgrass Foundation. The program works with golf course superintendents to identify environmental risks and develop Environmental Action Plans to address those risks. Golf courses that have identified and abated all environmental risks on the property become "Certified" in MTESP. Currently, 71 properties statewide participate in the Program and 25 are certified.[14]

Implementation of this Watershed Management Plan includes a recommendation that all golf courses within the watershed commit to following these industry BMPs.

Agriculture:

The western segment of the watershed is within the West Michigan fruit belt, with climate modified by proximity to Lake Michigan. The moderating impact of the Great Lake tends to reduce the probability of extremely cold winter nights or extremely hot summer days.

In addition, the cold lake water tends to reduce early spring temperatures, which delays the bloom time for fruit trees, reducing the probability of frost damage during the bloom.

In general, favored fruit sites will be on higher elevations, within about 12 miles of the lakeshore. Agricultural production figures are not available on a watershed basis. The National Agriculture Statistics Service figures for 2011 showed about 2,100 acres of cherry and apple orchards in all of Benzie County.

While climate conditions favor the growing of fruit in the area near Lake Michigan, soils in the watershed are generally not conducive to other forms of large-scale production agriculture. Well-drained to excessively drained sands make up much of region.

Corn is the most common field crop grown in Benzie, Grand Traverse and Manistee counties, with about 13,000 acres harvested in 2012. The most productive croplands in all three counties are in areas outside the Betsie/Crystal Watershed. The NASS statistics show both acreage and crop yields in the three counties far below the levels in counties with more productive soils.

In some Michigan watersheds, livestock farming has been correlated with diminished surface water quality. That appears not to be the case here, where there are no large farms or concentrated feeding operations. NASS figures show the three counties are among the lowest in the state in terms of cattle numbers, with a total of fewer than 8,000 cows and calves.

In past years, significant acreage in Benzie County was dedicated to growing Christmas Trees. That has diminished in the past two decades, as several operations transitioned the land to golf courses or rural residential uses. The most recent agricultural census showed just 77 acres of Christmas trees in the entire county.

With the exception of fruit orchards, most of the farms in the watershed and the surrounding counties are now small, diversified operations with specialty crops and/or small numbers of animals. Many of the farm operators work in non-farm jobs for the majority of their income. Many parcels of open land, which once supported crops or pasture, are now left fallow for hunting, recreation or scenic values.

Of 1,009 farms counted in Benzie, Grand Traverse and Manistee, the median size was about 50 acres. Approximately 64 percent reported farm earnings of less than $10,000 in 2012.

While agriculture, with the exception of the orchards, is not a major economic driver in the watershed it remains an important component of the community, significant for its ecological value and its connection to the community's food system and rural roots.

Several farms in the watershed are successfully using low-impact techniques such as managed grazing of cattle or pasture-raised poultry. Grow Benzie, a non-profit agency in Benzonia, has created a business-incubator kitchen to assist in development of value-added items from local farms.

The Natural River designation for the Betsie River, and the overlay zoning for Crystal Lake both include provisions to exclude livestock from riparian and shoreland areas.

The Michigan Department of Agriculture and Rural Development sponsors a voluntary environmental verification program called the Michigan Agriculture Environmental Assurance Program (MAEAP). The program includes education and on-farm assessments to encourage best management practices in such areas as fuel storage, fertilizer and pesticide application, manure handling, water use and soil conservation.

At the present time, fewer than five farms in the watershed have completed the MAEAP verification process. The WMP envisions doubling that number in coming years.

Recreational Infrastructure

Economy and lifestyles in the Watershed are closely associated with boating, fishing, camping and other forms of outdoor recreation. As such, the watershed has a significant recreational infrastructure in the form of campgrounds, trails, guide services, boating access sites, marinas and paddlecraft liveries.

These facilities provide economic value to the community and are vital to allowing the public to enjoy the designated and desired uses of the waters.

However, careful management must be practiced to minimize pollution. Of particular concern are erosion at poorly designed or casual river entry sites; nutrient loadings from concentrated uses such as campsites near the water, and the spread of invasive species at campgrounds and water access sites.

None of these issues have been quantified locally, though erosion is evident at several sites. The emerald ash borer was likely transported to the region in campfire wood and has since destroyed thousands of trees in the watershed and adjacent areas.

Additionally, there is a well-documented risk of introducing aquatic invasives such as milfoil and zebra mussels through boating access sites.[15]

Crystal Lake Sailing Regatta

Ellis Lake Access Site

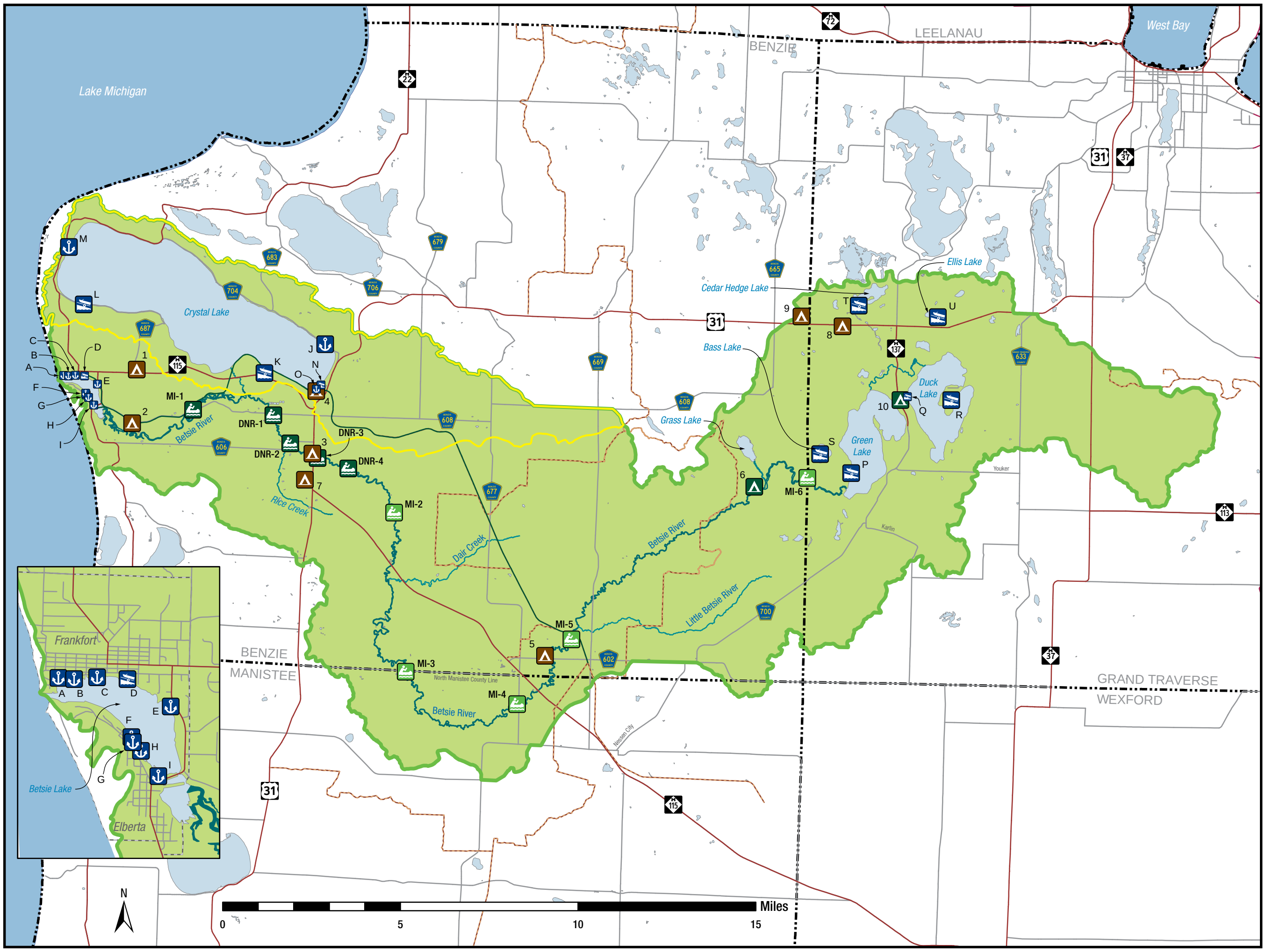
Elberta Betsie Valley Trail Bridge

The WMP recommends improved access sites on the upper stretches of the Betsie River to reduce erosion and enhance appropriate uses of the resource. The concern about spread of invasive species is addressed through the free boat-washing facility at the MDNR site on Crystal Lake, and through the educational component detailed in Chapter 8.

DNR Crystal Lake Boat Launch

Recreational access to the forests and waterways of this watershed need not be compromised. A goal of the WMP is to ensure that best management practices are applied in all situations to minimize the negative impacts.

Map 26 - Recreational Infrastructure



KEY | RECREATION SITES

- Marinas
- Boat Launch Ramps
- State Campgrounds
- Commercial Campgrounds
- MDNR Access Sites
- State Owned Unimproved Access Sites (not included in inventories)
- Betsie Valley Trailway
- MDNR Snowmobile Trail

ID	ACCESS LOCATION	LAT	LONG
DNR-1	River Road Access	+44.617417	-86.122550
DNR-2	Grace Road Access	+44.606065	-86.112595
DNR-3	US31 Access	+44.600390	-86.096808
DNR-4	Homestead Dam Access	+44.596375	-86.079167
MI-1	River Rd & Adams Rd	+44.618941	-86.168309
MI-2	Freds Landing	+44.578795	-86.052464
MI-3	County Line & Moore Rd	+44.514005	-86.044000
MI-4	Kurick Rd & Dzuibanek Rd	+44.501700	-85.980146
MI-5	Wolf Road	+44.528557	-85.950011
MI-6	Betsie River Rd	+44.596152	-85.817291

ID	CAMPGROUND LOCATION	LAT	LONG
1	Frankfort Crystal Lake RV Resort	+44.634849	-86.201048
2	Betsie River Camp Sites	+44.612874	-86.202960
3	Vacation Trailer Park Campground	+44.602146	-86.099820
4	Village of Beulah Camp Ground	+44.627635	-86.098334
5	Betsie River Canoes & Campground	+44.521705	-85.964881
6	Grass Lake State Forest Campground	+44.592196	-85.847486
7	Timberline Campground	+44.591428	-86.103714
8	Cycle Moore Campground	+44.658236	-85.798738
9	Interlochen Eagles #3503	+44.661965	-85.822347
10	Interlochen State Park	+44.628568	-85.764964

ID	MARINA & LAUNCH RAMP LOCATION	LAT	LONG
A	Harbor Lights Marina	+44.631676	-86.242579
B	Jacobsons Marina	+44.631564	-86.239888
C	Frankfort Municipal Marina	+44.631862	-86.235941
D	City of Frankfort Launch Ramp	+44.631724	-86.230747
E	East Shore Marina	+44.628499	-86.223230
F	Betsie Shores Dockominium	+44.624640	-86.229855
G	Betsie Bay Marina	+44.624020	-86.229573
H	North Star Marina	+44.622989	-86.228171
I	Village of Elberta Marina	+44.619945	-86.225081
J	Crystal Lake Marina LLC	+44.646808	-86.093773
K	MDNR Crystal Lake Boat Launch	+44.634491	-86.128059
L	Bellows Beach Launch Ramp	+44.660868	-86.232073
M	Crystal Lake Yacht Club	+44.684118	-86.241299
N	Beulah Boat Launch	+44.630151	-86.095652
O	Beulah Boat Dock	+44.628358	-86.098258
P	Green Lake Boat Launch	+44.598437	-85.792294
Q	Interlochen State Park Boat Launch	+44.629977	-85.761018
R	Duck Lake Boat Launch	+44.628856	-85.735945
S	Bass Lake Access	+44.605979	-85.810253
T	Cedar Hedge Lake Access	+44.666768	-85.789763
U	Ellis Lake Access	+44.662594	-85.744429

Transportation Infrastructure

While the network of roads, streets and highways is an essential component of daily life in the watershed, this infrastructure also poses a significant water quality concern. Petroleum products and sediment enter surface waters along with road runoff at locations throughout the watershed.

The Conservation Resource Alliance has inventoried 130 road stream crossings in the Betsie River / Crystal Lake Watershed (www.northernmichiganstreams.org). The sites range from busy highway bridges, to culverts that route tiny tributaries under remote gravel roads. Thirteen sites are rated as "severe," with some allowing tons of sediment to erode annually into the streams.

Road stream crossings are the largest, but not the only, potential source of transportation-related pollution in the watershed.

A number of local roads "dead-end" at the lakeshores, allowing runoff to carry petroleum residues, nutrients and sediment directly into the water. This is a particular issue on Crystal Lake, where the shore is ringed with hills and stormwater strikes road ends with considerable velocity.


Elmwood Street End - Beulah


South Shore Drive - Crystal Lake

Dust control agents used on public and private gravel roads have the positive effect of reducing the deposition of windblown particles, but also introduce the potential for brine or other road treatments to leach into the water.

Also of concern here is the potential impact of logging roads. Much of the watershed is in timber – either publicly or privately owned. Logging on steep slopes may result in erosion, and poorly constructed logging roads may contribute to sedimentation, particularly in headwater streams.

Additionally, a number of roadways, including Crystal Drive, M-22, South Shore Road and Narrow Gauge Road, run parallel and adjacent to lakes or streams, allowing roadside runoff to flow unfiltered into the water at some locations.

Road stream crossings are considered to be a critical issue in the Watershed, and are considered more fully in Chapter 4. The need for improvements in the aging infrastructure of bridges and culverts accounts for more than 50 percent of the total cost of implementing the WMP. Transportation infrastructure issues are also addressed in the "Implementation of the Plan" section of Chapter 6.

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Chapter 4

Sources and causes of pollution/ critical areas for mitigation and preservation

After considering relevant water quality data, public input and the results of the social indicators survey, the WMP Steering Committee identified six primary environmental stressors in the Betsie River / Crystal Lake Watershed. The stressors were then assigned priority levels from (1) to (3), with (1) denoting the level of greatest significance in this Watershed.

The identified stressors and priority levels are listed below and presented in greater detail in the following section. Later sections of this chapter will discuss the impacts of these stressors on Watershed segments designated as critical sites or priority areas.

Table 24 - Priority Level of Stressors

Level 1	⚠ Biological Pathogens: *E. coli* ⚠ Sediments
Level 2	⚠ Excessive nutrients ⚠ Invasive Species ⚠ Biological pathogens: Swimmer's Itch cercariae
Level 3	⚠ Elevated Temperatures ⚠ Other unspecified pollutants

It should be noted that natural processes produce some level of most surface water contaminants. It would, for example, be counter-productive (not to mention impossible) to remove all nutrients from a body of water. Further, it is clear that some water bodies are more naturally productive than others. That is, because of soils and other conditions, some lakes and streams contain more nutrients and therefor produce more plant growth.

As a general statement, the goal of watershed management is to observe the natural conditions of each water body and, to the extent possible, reduce any excessive or human-caused loadings of pollutants.

Sediment:

Sediment includes sand, silt, muck and other naturally occurring soils and minerals that may be washed from land into water and/or moved to new locations due to stream flow or wave action.

This type of pollution may arise from a number of sources, including construction sites, shoreline or streambank erosion, road-stream crossings, urban storm runoff, logging operations, unmanaged recreational access sites, and runoff from non-vegetated open or agricultural land.

Once introduced to the surface waters, sediment may cover fish-spawning areas, interfere with benthic invertebrate life cycles, create hindrances to navigation, alter water temperatures or contribute to turbidity.

Another significant concern is that other pollutants – including phosphorus and nitrates, animal manures, chemicals, and biological pathogens – may adhere to small sediment particles and be washed into surface waters. For this reason, sedimentation almost always contributes to levels of other pollution.

Nutrients:

Nutrient pollution refers to excessive loadings of substances that act as fertilizers to increase plant and algae growth. Aquatic vegetation generally requires the same three primary nutrients as do terrestrial plants: nitrogen, phosphorus and potassium.

In most Michigan waters, the “limiting” nutrient is phosphorus. That is to say, the other nutrients tend to be available in greater supply in surface water, so that an increase in phosphorus often results in increased production of weeds and algae. Conversely, reductions in phosphorus loadings often result in decreased weed growth, even when the other nutrients are available in ample amounts.

Excessive weed and algae growth may disrupt pre-existing habitats, and may also interfere with recreational uses such as swimming and boating. Some invasive species and undesirable cyanobacteria are believed to thrive and potentially outcompete more desirable plants in waters with high phosphorus levels.[16]

In addition, bacteria involved in the decomposition of dead vegetation make use of dissolved oxygen from the water column. Where heavy blooms of vegetation have occurred, this may deplete the oxygen supply to the point that fish cannot survive.

Michigan has taken steps to reduce phosphorus loading by restricting use of high-phosphorus detergents, and lawn fertilizers containing phosphorus.

Non-point sources of nutrient pollution include on-site septic systems, animal manures, bird droppings, runoff from agricultural and turf areas, and streams or storm sewer inlets into lakes.

As noted above, nutrients may adhere to particles of sediment that are washed into surface waters, so sources of the two pollutants are often related.

Invasive Species:

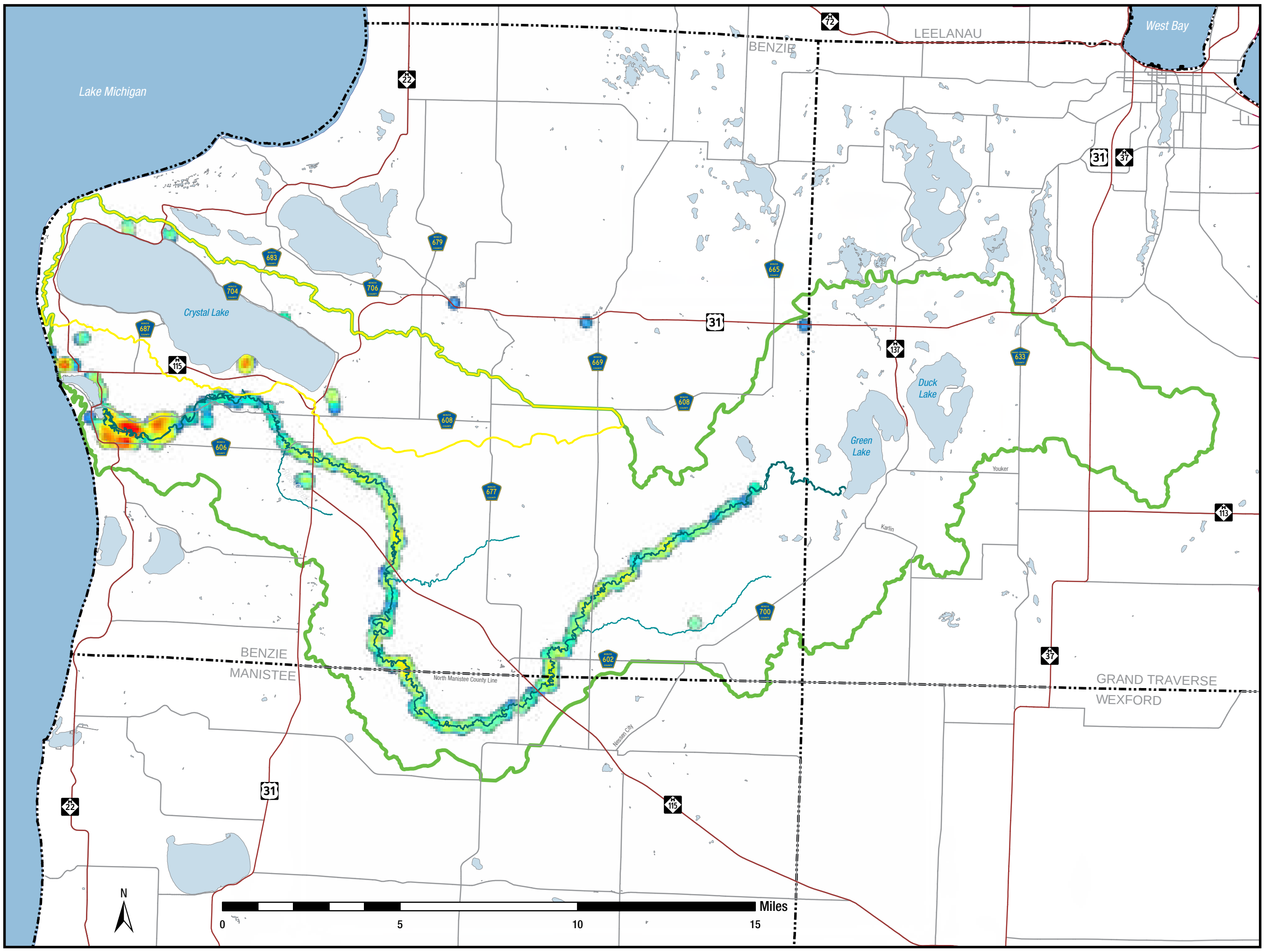
Invasive species, for the purposes of this Watershed Management Plan, are those non-native plants and animals which, if allowed to become established, are likely to interfere with human uses of the water or to cause negative impacts on native ecosystems.

Invasive species of significant concern include: Zebra and quagga mussels; Eurasian milfoil; garlic mustard, non-native or hybrid strains of phragmites, narrow-leaf cattails, purple loosestrife, baby’s breath, reed canary grass, Japanese knotweed, round gobies, spiny water fleas and potentially, various species of Asian carp.

Many of the above plant species are known to create dense monocultures which displace native vegetation and disrupt existing habitat. Invasive fish and invertebrates have the potential to alter aquatic food chains to the extent that some native species can no longer survive.

The interactions between native and invasive species are often complex. Zebra mussels, for example, are efficient filter feeders, which selectively remove algae from the water column and deposit their own wastes as nutrient in the bottom sediments. The effect may be to dramatically increase the clarity of the water column, while at the same time promoting excessive growth of rooted weeds.

Map 27 - Terrestrial Invasive Species



KEY INVASIVE SPECIES DETECTION RATE

3 - 10	
10 - 16	
16 - 26	
26 - 40	
40 - 65	
65 - 100	
100 - 160	
160 - 245	
245 - 380	

Color scale indicates average density of invasives detected within a 1000 foot radius.

(50 foot cell resolution)

Invasive species detected include:

Autumn Olive
Baby's Breath
Black Locust
Bull Thistle
Canada Thistle
Cow Vetch
Crown Vetch
Cypress Spurge
European Swamp Thistle
Forget Me Nots
Garlic Mustard
Giant Knotweed
Glossy Buckthorn
Honeysuckle
Japanese Barberry
Japanese Knotweed
Kudzu
Leafy Spurge
Motherwort
Mullein
Multiflora Rose
Narrowleaf Cattail
Oriental Bittersweet
Periwinkle
Phragmites
Purple Loosestrife
Reed Canary Grass
Spotted Knapweed
White Sweet Clover
Wild Parsnip

Note: Inventory based on public reports and targeted area surveys by the Northwest Michigan Invasive Species Network.

Invasive species are commonly introduced by inadvertent human action, and then may be spread by animals, wind, flowing water, recreational boating, or additional human behaviors.

Michigan law prohibits launching a boat with any non-native plant adhered to the vessel or trailer. Free boat-washing facilities are available at Crystal Lake. Boating and water recreation are important economic and social elements in the local community. The WMP supports expansion of boat washing , in addition to the installation of boot- and wader-cleaning facilities at trailheads and popular river-access sites and other voluntary measures to ensure that invasives are not spread by the public.

It is recognized that much of the region's existing flora and fauna – from apple trees to rainbow smelt to Pacific salmon – are in fact exotic species that were purposefully introduced to the region by humans. Those species have become naturalized in the existing ecosystem, and are not addressed in the WMP.

Biological Pathogens: Pathogenic Bacteria

The bacteria *Escherichia coli* are considered a marker for potential disease-causing pathogens. *E. coli* grow in the intestines of humans and warm-blooded animals, including birds, pets and agricultural livestock.

Water borne *E. coli* typically originates in the digestive systems of humans or warm-blooded animals. It may be deposited directly in the water, as with waterfowl droppings, or transferred from land via storm runoff, erosion, leaking septic systems or other modes of transport.

Rain events may cause elevated *E. coli* counts by washing pollution from the land into storm drains or directly to surface waters, or by increasing stream flow and thereby stirring up contaminated bottom sediments.

When high levels of the bacteria are detected in water sampling, it is generally considered as an indicator that human or animal fecal matter is somehow entering the water. Though most strains of *E. coli* are harmless, the finding of fecal matter in the water increases the probability that disease-causing microorganisms may also be present.

E. coli is chosen as the indicator species because it is a familiar organism that is relatively simple to test for in the laboratory. The USEPA determined that higher *E. coli* counts correlate with greater chances of illness for people using the water.[17]

The standard sampling method is to draw a minimum of three samples representative of a given area (for example, the waters just off shore in a public beach area). Laboratory technicians culture those samples and determine the number of "colony forming units" (CFU) per 100 ml of each sample. A geometric mean of the three counts is then calculated for comparison to the health standard.

According to the Michigan standard, a geometric mean of less than 300 CFU on a single testing day indicates the water is OK for full and partial contact recreation. The Benzie-Leelanau District Health Department refers to this as a Level 1 condition.

A mean of 300-1,000 CFU indicates a Level 2 advisory, meaning the water is acceptable for partial body contact such as wading or paddling, but health officials advise no contact with water above the waist.

A sampling mean above 1,000 CFU triggers a Level 3 health advisory, with a recommendation to avoid all body contact with the water.

In any advisory situation, the water is retested as soon as possible, and the advisory is removed when new sampling shows *E. coli* levels below the 300 CFU standard.

According to the Michigan DEQ's 2014 Integrated Report, a water body can be determined to be "not supporting" of the full body contact designated use, if regular sampling occurs and at least 10 percent of the daily mean values exceed the standard.

Biological Pathogens: Swimmer's Itch Cercariae

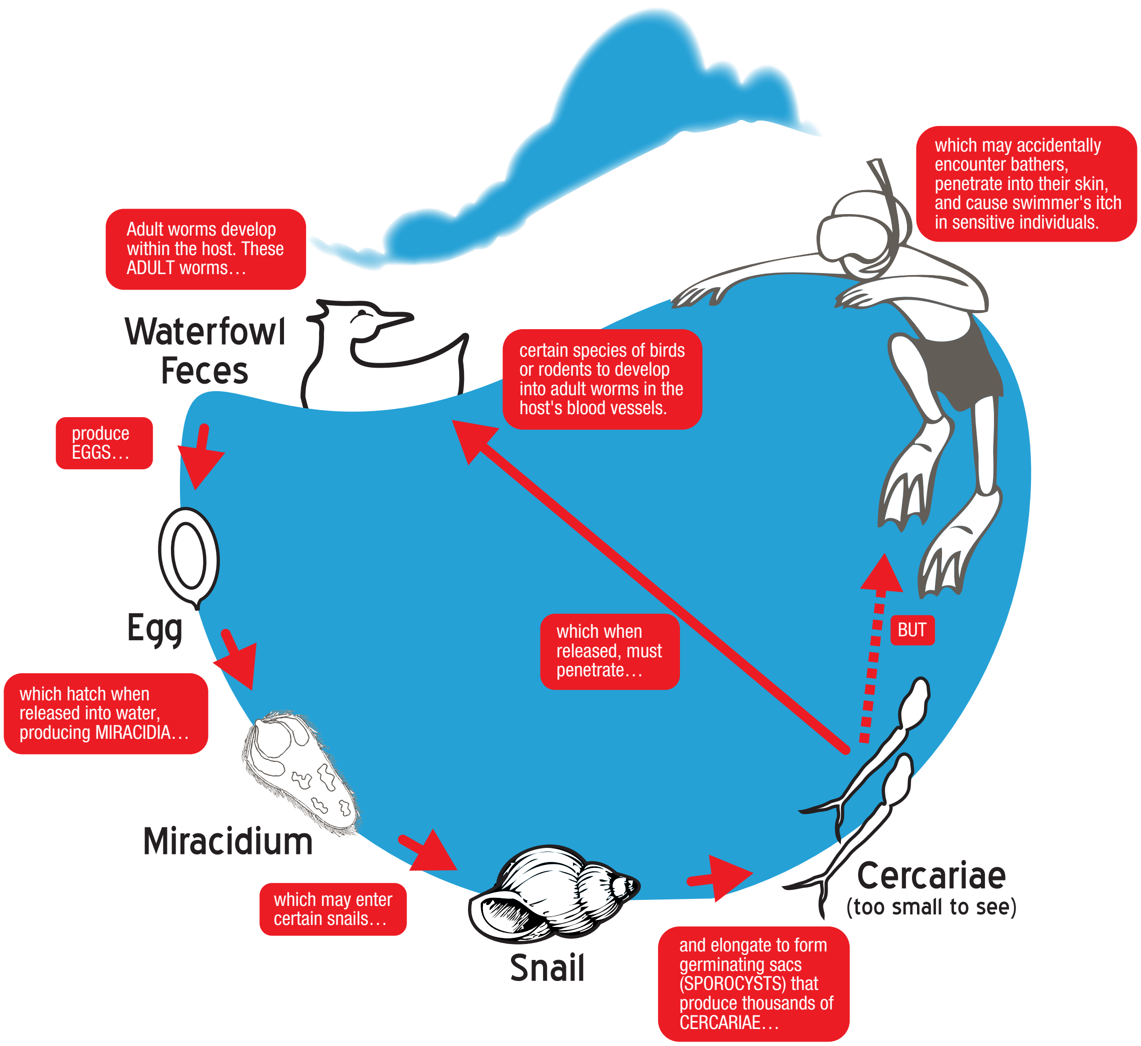
Swimmer's Itch or "cercarial dermatitis" is a skin condition caused when sensitive individuals come in contact with a microscopic larval form of a schistosome, or blood fluke, that normally parasitizes native waterfowl and freshwater snails.

The condition results in raised papules similar to insect bites. It causes severe itching at the site of the infestation. The most severe cases – with multiple infestation papules – may require a physician's care.

Cases of Swimmer's Itch have been reported in many Northern Michigan lakes, including Crystal, Green and Duck lakes in the Crystal/Betsie Watershed. Respondents to a social indicators survey conducted as part of the WMP process identified Swimmer's Itch as the watershed's most severe water quality concern.

The organism that causes the condition has a complex life cycle in which it infects warm blooded animals – typically common merganser ducks in this region – and specific species of snails.

Summary of the Life Cycle of the Causative Agents of Swimmer's Itch



As part of that life cycle, infected snails shed thousands of free-swimming, microscopic, schistosome larvae called cercariae, each resembling a tiny tadpole with a split tail. If a cercaria encounters a duck of the proper species it will burrow through the skin and potentially mature in blood vessels of the bird's digestive system to repeat the life cycle.

If the organism instead contacts a human, it may seek to burrow into the skin, where it will quickly die, often causing an allergic or immune reaction.

As a result of Swimmer's Itch, some individuals refuse to swim or wade in affected lakes. The condition is not correlated with water contamination or pollution. The snail species associated with Swimmer's Itch generally prefer clear water, as do the common mergansers which are the most common warm-blooded hosts.

In past decades, the accepted response to Swimmer's Itch was to treat the lake bottom in affected areas with copper sulfate crystals to reduce or eliminate the snail population. This strategy was not completely effective and raised concerns about the environmental impact of annual treatments with a persistent toxic substance. While copper sulfate applications continue to be permitted in Michigan, lake associations are seeking a more effective and less environmentally detrimental solution.

It is recognized that Swimmer's Itch cannot be addressed by the traditional water-quality measures. Despite that, the presence of parasitic schistosomes at times makes the water unsuitable for even partial body contact.

The WMP identifies a need to address Swimmer's Itch on several levels, each of which will require funding and expertise beyond the resources presently available within the watershed:

1) Basic Biological Research. Most knowledge about the life cycles of waterfowl and snails that serve as hosts to Swimmer's Itch is based on studies conducted 20 to 50 years ago. (Michigan's Swimmer's Itch control program was defunded in the 1970s.) Additional university research is necessary to confirm existing information, provide lake-specific data and explore possible impacts related climate change, waterfowl populations, the presence of aquatic invasives and other factors.

2) Mitigation pilot projects. Over the years, a number of strategies have been tried (e.g. using copper sulfate to kill snails; trapping and removing certain duck species; disturbing lake-bottom areas to deter snail colonization, etc.) Funding is needed to develop, test and analyze new strategies.

3) Development of topical preventatives. One promising area of research is the investigation of topical cremes to protect swimmers by preventing penetration by the cercariae. While several alternatives have been proposed here and in Europe, field testing is an expensive proposition beyond the resources of any single lake association. Some form of government matching funding will be necessary for development, testing and commercialization of such products.

Elevated Water Temperatures

Coldwater fish species including brook trout and steelhead are unable to reproduce or thrive if water temperatures rise above certain thresholds (Table 1, page 12). In this Watershed, a total of four lakes and 14 stream segments are identified as coldwater habitat (Table 2, page 13).

Coldwater habitat originates with groundwater inflows into lakes and streams. Because of that, the single most important element in maintaining the coldwater fishery is to protect groundwater through such strategies as wetland protection, low impact development, and limitation of impervious surfaces.

On lakeshores, the impervious surfaces associated with residential development – driveways, streets and roofs – may impact water temperatures by allowing increased inflows of storm runoff. Shoreline protection structures such as seawalls may also have a warming effect.

On flowing streams, maintaining forest covers and streamside vegetation are vital to the preservation of coldwater habitat.

As discussed in Chapter 2, temperatures in the Betsie River mainstream continue to be affected by changes wrought during the timbering era of the 19th and early 20th centuries. The removal of streamside forest cover and use of the river to float logs in that era left a wider and shallower waterway that is more susceptible to summer warming.

Temperature issues are often exacerbated by the presence of other water quality stressors. Dams and other obstructions allow water to pond up and absorb heat from the sun. Sediments may increase warming by slowing stream flows; excessive nutrients can cause weed growth and have a similar effect.

Other Unspecified Pollutants:

National studies have found low levels of such substances as pesticides, pharmaceutical metabolites, petroleum products, plastic microbeads, PCBs, mercury and others in many surface waters.

PCB and mercury are known to be taken up by fish. As a result, Michigan has issued health advisories, limiting the consumption of fish from the state's waters.

To date, there has not been an analysis of other additional pollutants in the waters of this watershed. If they occur here, it is likely at extremely low levels. There appears to be no scientific consensus as to the impact of such minuscule traces, though some studies have raised concern that they could function as endocrine disruptors or otherwise affect aquatic life.

The potential impact of these pollutants does raise significant concern, worthy of further study but outside the control of the local community and beyond the scope of this Watershed Management Plan.

Fortunately, strategies designed to reduce loading of sediment, nutrients and pathogens are also likely to minimize the introduction of additional pollutants into surface waters.

Table 25 - Status of State-Designated Water Uses in the Betsie River / Crystal Lake Watershed

Designated Use	Impaired Locations For WQ Standards see: Table 1 on page 13	Sites at Risk	Special Concerns	Pollutant (Known or Suspected)
Navigation	**None**	**Betsie Lake and Bay:** • dredging required in 2014 • Low water levels at head of bay in 2012	**Upper Betsie River:** • Improved access needed for non-motorized water-craft	Sediment
Agriculture	**None**		• Chemicals and nutrients may reach ground water through sandy, well-drained soils	Nutrients, Agricultural chemicals
Full-Body Contact Recreation	**Crystal Lake:** • Bellows Park Public beach (*E. coli*) • Bellows Road Creek (*E. coli*) • Beulah Public Beach (*E. coli*) • Cold Creek (*E. coli*)	**Frankfort Outer Harbor:** • Excessive algae blooms	**Crystal, Duck, Green Lakes:** • Swimmer's Itch	• *E. coli* • Swimmer's Itch Cercariae • Algae
Partial-Body Contact	**Crystal Lake:** • Bellows Park Public beach (*E. coli*) • Bellows Road Creek (*E. coli*)		**Crystal, Duck, Green lakes:** • Swimmer's Itch	• *E. coli* • Swimmer's Itch Cercariae
Warm-Water Fishery	**None**	**None identified**	**Entire Watershed:** • All fishery vulnerable to sedimentation and competition from invasive species	Sediment Invasive species
Cold-Water Fishery (applies to state-designated coldwater lakes, trout lakes and trout streams)	**None**	**Cold Creek:** **Betsie River and Tributaries:**	**Dair Creek and Little Betsie River:** • Groundwater protection vital to support trout in tribs and mainstream **Minor Tributaries:** • Small stream fishery not evaluated since 1960s **Status of native lake herring**	**Cold Creek:** • Silt **Betsie and tributaries:** • Climate change, silt, water temps, groundwater threats
Other Indigenous Aquatic Life & Wildlife	**None**	**Entire watershed:** • Nutrients, silt, shoreline hardening, competition from invasive mussels		Nutrients, sediment, invasive species,
Industrial Water Supply	**No significant industrial uses of surface water**			
Fish Consumption			**Entire watershed:** • Consumption limits and advisories	Mercury and PCB contamination from outside sources. (Not addressed in WMP)

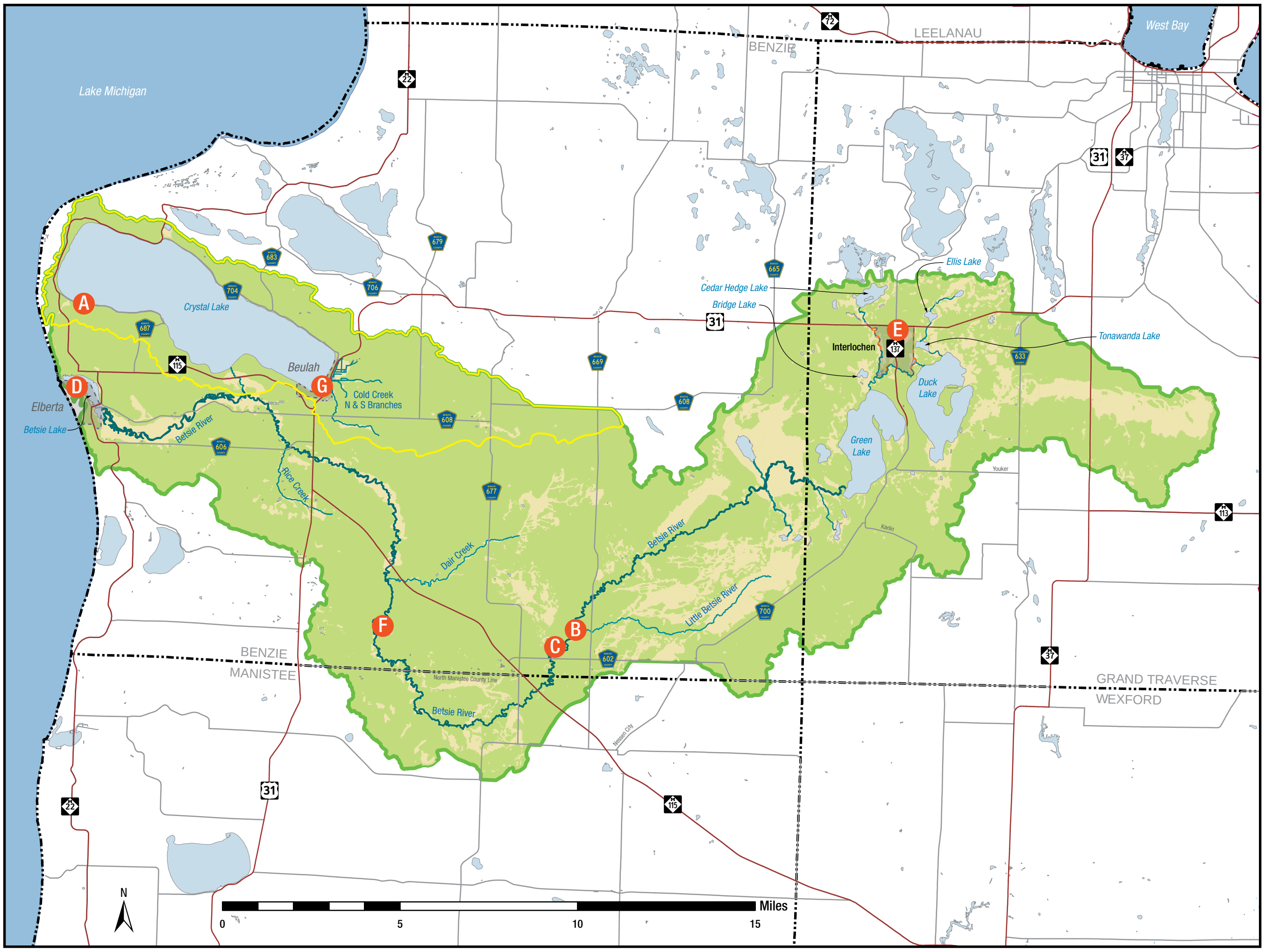
Table 26 - Desired Uses Not Mandated by Michigan

Desired Use or Condition	Critical Sites For Mitigation Or Monitoring	Priorities For Preservation	Potential Actions
High-Quality Groundwater	Oil/Gas sites; wastewater treatment lagoons; on-site wastewater systems (septics and holding tanks); former dump sites	Wetlands; wellhead protection areas; vegetated forest and rangeland	Inspection requirements for on-site wastewater systems Zoning and regulation to protect critical/priority areas
Clear-Water, Oligotrophic Lakes		Crystal Lake Green Lake Duck Lake	Natural shoreline education; monitoring; riparian zoning
Control of Swimmer's Itch	Crystal Lake Green Lake Duck Lake:		Research on snails, waterfowl and trematodes; development of protective strategies
Preservation of Scenic Beauty		Natural areas; glacial landscapes; riverbanks and lake shorelines ; working farms and orchards; Frankfort North Breakwall Light	Shoreline zoning; conservation easements Forest and landscape education; purchase of significant sites from willing sellers; invasive species control; promote native species; maintain traditional agricultural landscapes .
Outdoor Recreation Opportunities		Non-motorized trails; water access; access to natural areas; wild areas for hunting or observing wildlife	Work with government, riparian owners and the public to develop and maintain appropriate access; control invasive species at recreational and access sites
Economic Opportunities for Watershed Residents		Recreational industries; farm production and processing; construction and real estate; retail and tourism related businesses.	Master plans to encourage appropriate siting of businesses and to protect the environment; promotion of "cottage industries" and arts related business; regulations for low-impact development.

WMP Critical Areas

Critical Areas identified in the WMP are those sites in the Watershed which are most severely affected by existing or potential sources of the pollutants discussed above. The priority section which follows identifies issues that require special attention to preserve designated or desired uses within the watershed. Specific recommendations for addressing these concerns are included in the Implementation sections in Chapter 6.

Map 28 - Critical Areas



KEY | CRITICAL AREAS

- **A** Crystal Lake - Bellows Park and Bellows Creek
- **B** Thompsonville Dam Backwater Area
- **C** Former Haze Road Bridge Road Stream-Crossing
- **D** Elberta Brownfield Site
- **E** Green Lake Township/Interlochen Development Sites
- **F** Streambank Erosion - Multiple Sites
- **G** Crystal Lake - Beulah and Cold Creek Subwatershed

- Village
- Census Designated Place (Interlochen CDP)

A. Crystal Lake – Bellows Park and Bellows Creek

Pollutants: E. coli (known); sediment (known); nutrients (suspected)

Bellows Park (also known as Seventh Street Beach) is a public park located in Crystal Lake Township on the South Shore of Crystal Lake. The park is owned and managed by the city of Frankfort, though it is outside the city limits.

Past monitoring at Bellows Park in 2001 and 2004 showed *E. coli* contamination in the lake water at the beach. The site is listed on the 2014 Integrated Report as "not supporting" full or partial body contact recreation.

In addition, rainstorms result in significant erosion of sediment into Crystal Lake from Bellows Park and the adjacent road ditches and forest.

Weekly sampling of the beach in the summers of 2013, 2014 and 2015 found the lake water to be in full compliance with Michigan's full-body-contact standard for *E. coli* (less than 300 colony forming units per 100 ml of water).

However, monitoring of Bellows Creek, a small stream which discharges at the western edge of the public beach, revealed high *E. coli* levels following rain events. DNA source tracking performed in 2013 for the MDEQ revealed markers for human fecal bacteria, indicating a likelihood that human fecal matter was entering the creek. Stream sampling during two moderate rain events in 2014 found high *E. coli* counts – including an extremely high count of 18,424 cfu/100ml on Sept. 29, 2014. DNA source tracking did not find human bacterial markers in the 2014 samples.

Bellows Park & Creek Area

Table 27 - Bellows Beach *E. Coli* Sampling

E. Coli Daily Mean Values (CFU/100ml)					
Summer 2015		Summer 2014		Summer 2013	
Date	Value	Date	Value	Date	Value
2-Sep	2.0	3-Sep	13.8	28-Aug	25.3
26-Aug	16.0	27-Aug	1.8	21-Aug	10.8
19-Aug	6.0	20-Aug	8.6	14-Aug	1.0
12-Aug	13.0	13-Aug	10.7	7-Aug	28.8
5-Aug	0.0	6-Aug	1.4	31-Jul	4.3
29-Jul	6.0	30-Jul	6.0	24-Jul	1.0
22-Jul	1.0	23-Jul	45.6	17-Jul	7.0
15-Jul	12.0	16-Jul	13.6	10-Jul	33.3
8-Jul	7.0	9-Jul	13.4	1-Jul	1.0
30-Jun	6.0	3-Jul	7.7	26-Jun	3.7
24-Jun	11.0	25-Jun	11.6	19-Jun	3.8
				12-Jun	1.0
				5-Jun	1.0

Past "High" Bellows Beach Values (above 300 CFU/100ml)	
Date	Value
August 22, 2001	788.1
August 9, 2004	1,107.4
September 7, 2004	1,574.6

MDEQ "rain-event" monitoring values (CFU/100/ml)		
Date	Beach Sample	Stream Sample
October 31, 2013	2.0	3,300.0
August 29, 2014	7.0	18,424.0
September 4, 2014	83.0	3,214.0
October 12, 2014	1.0	4.0

Source: MDEQ

Crystal Lake water on the Bellows public beach was sampled at the same time as the stream samples were taken. The beach samples were all well within the state standard. It is likely that water from the stream – which normally flows at less than 0.3 cubic feet per second – was quickly diluted by the lake.

Since high *E. coli* counts in the stream did not correlate with readings on the beach, the WMP envisions two concurrent strategies, one to address the beach and the other for the stream.

The stream will be addressed cooperatively by the Crystal Lake & Watershed Association and private streambank property owners. Monitoring will be conducted at upstream locations to better identify potential pollution entry sites, and streamside inspections will locate and remove likely sources. Property owners will be encouraged to use native vegetation to reduce storm water flows into the stream.

A park improvement project, presently in the planning phase, should significantly reduce runoff and erosion from Bellows Park into Crystal Lake. The City of Frankfort has initiated an engineering study to improve the park's infrastructure and storm water management. BMP's under consideration include retention swales, infiltration areas, native plantings and permeable pavements. The city also will upgrade park amenities such as the boat launch, public restrooms and playground area. Work to implement the improvements is expected to take place in 2016. Private funding has been committed to the project.

B. Thompsonville Dam Backwater Area

Pollutants: Sediment, nutrients (known)

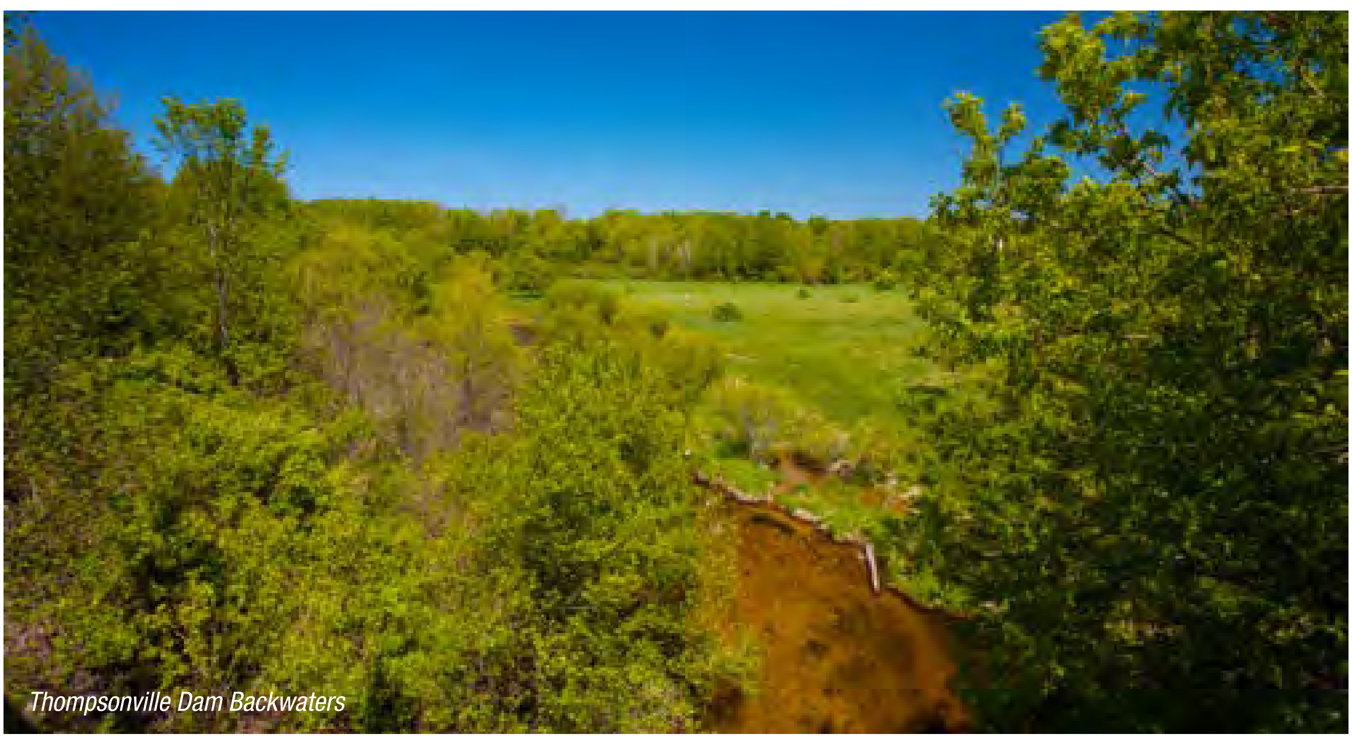
The Thompsonville Dam, a former hydroelectric facility, failed in 1989, releasing tons of sediment into the river below the damsite.

In subsequent years, the Betsie River Watershed Restoration Committee, the Conservation Resource Alliance and the Michigan Department of Natural Resources have made significant progress in mitigating downstream impacts of the dam failure. A small day-use access site for the public has been developed below the former dam.

However, the former impoundment area behind the dam remains a concern. Representatives of the Conservation Resource Alliance and the Benzie Conservation District floated the river through the impoundment area in 2013. They found the stream flowing between vertical banks of sand and silt, generally 3-8 feet in height. In many locations, the banks are continuing to erode into the stream.

The river in this segment appears to be continuing to search for its permanent channel, even 25 years after the impoundment was drained.

While it would be counterproductive to attempt to redirect the stream or to harden the bank along the entire stretch, it does appear that water quality and fish habitat would potentially benefit from woody debris work and reconfiguring the vertical bank in several high-erosion locations. This work must be designed to enhance the bank stability, promote formation of a flood plain, and enable natural revegetation as a sustainable solution to the concerns in this critical area.



Thompsonville Dam Backwaters

C. Road Stream Crossings, Including Former Haze Road Bridge

Pollutants: Sediment (known); nutrients (known); petroleum products and road salt (suspected)

As a result of past land uses (e.g. logging) and the sandy soils in the watershed, the Betsie River is vulnerable to sedimentation. Of particular concern are the coarse sands that erode into the stream and cover fish spawning beds and invertebrate habitat.

Roads cross the Betsie River or tributary streams at well over 100 sites in the watershed. At many of these sites, erosion is moving sediment into the streams, likely along with nutrients and transportation-related chemicals such as salt and petroleum products. In addition, some old or poorly maintained culverts have the effect of inhibiting fish passage.

Conservation Resource Alliance inventoried the majority of road stream crossings in the watershed in 1998, and a number of crossings have been improved. The inventory was updated in 2014 and additional crossings added in preparation for this WMP.

CRA biologists and field staff in 2015 prioritized the crossings most in need of mitigation (Appendix D). At many of the listed sites, aging transportation infrastructure will require investment to maintain traffic function, as well as to protect water quality. Because of the high costs involved with bridge or culvert replacements, addressing this critical issue will require continuing cooperation with county road commissions and the Michigan Department of Transportation. The entire road-stream inventory is on-line at www.northernmichiganstreams.org.

Of particular concern is the site of the former Haze Road crossing on the Betsie River west of Thompsonville. The Haze Road Bridge was closed due to unsafe conditions in 2008 and the bridge structure collapsed into the river in 2014.


Haze Road Bridge Site

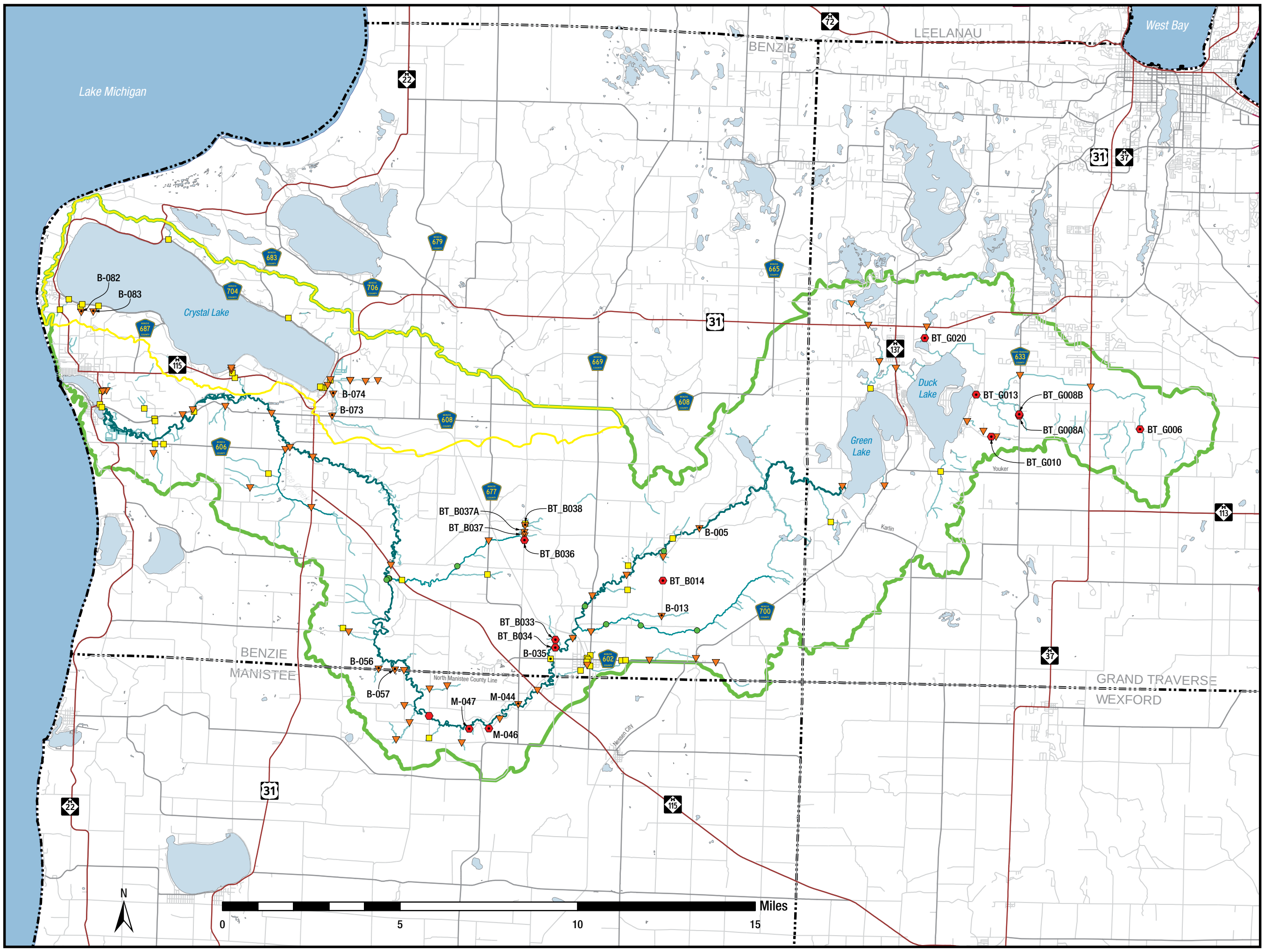
The bridge piers remain, and the site is subject to erosion from the gravel road and roadsides on both banks. Erosion potential is especially severe on the north bank, where the roadway is sloped significantly toward the water.

Proposals have been forwarded to either replace the bridge crossing or to convert the site to a recreational access site.

Because the bridge had been closed for several years before its ultimate failure, the site is ineligible for the normal state bridge-funding mechanisms. This would make it appear that establishment of a road end recreation access site is the more realistic option. The conversion would require approval from Weldon Township and the Benzie County Road Commission, in addition to agencies involved in funding and permitting.

In any case, significant investment will be required to minimize erosion, remove the aged bridge piers, and restore a stable riverbank.

Map 29 - Road Stream Crossing Inventory



KEY | SEVERITY OF STREAM IMPACT

- Restored
- Minor
- Moderate
- Severe
- Minor (WMP Recommended Restoration)
- Moderate (WMP Recommended Restoration)
- Severe (WMP Recommended Restoration)

Note: Sites recommended for restoration during the 10-year period of the Betsie River / Crystal Lake Watershed Management Plan are listed in the table and identified by the ID number on the map.

ID	STREAM NAME	ROAD NAME	SEVERITY	LAT	LONG
B-005	Betsie River	Reynolds Rd	Moderate	+44.574670	-85.877870
B-013	Little Betsie Tributary	Long Rd	Moderate	+44.538590	-85.898480
B-035	Betsie River	Lindy Rd	Minor	+44.520470	-85.961470
B-056	Betsie River Tributary	North County Line Rd	Moderate	+44.514770	-86.059220
B-057	Betsie River Tributary	N. County Line Rd	Moderate	+44.514570	-86.049930
B-073	Cold Creek	Homestead Rd	Moderate	+44.617580	-86.088750
B-074	Cold Creek	Case Rd	Moderate	+44.626550	-86.088420
B-082	Crystal Lake Tributary	Bellows Rd	Moderate	+44.657630	-86.233270
B-083	Crystal Lake Tributary	Thomas Rd	Moderate	+44.657870	-86.226440
BT_B014	Unknown (Betsie Tributary)	Long Rd	Severe	+44.553220	-85.898250
BT_B033	Red Creek	Haze Rd	Severe	+44.528310	-85.958830
BT_B034	Betsie River	Haze Rd	Severe	+44.525070	-85.958800
BT_B036	Dair Creek	S. Weldon Rd	Severe	+44.568650	-85.977620
BT_B037	Dair Creek	Weldon Rd	Moderate	+44.570370	-85.977550
BT_B037A	Dair Creek	Weldon Rd	Moderate	+44.571700	-85.977650
BT_B038	Dair Creek	Weldon Rd	Moderate	+44.574420	-85.977380
BT_G006	Mason Creek	Mill Rd	Severe	+44.618340	-85.627460
BT_G008A	Mason Creek	Co. 633	Severe	+44.623090	-85.696570
BT_G008B	Mason Creek	Co. 633	Severe	+44.623630	-85.696570
BT_G010	Brigham Creek	E Duck Lake Rd	Severe	+44.614300	-85.712350
BT_G013	Mason Creek	E Duck Lake Rd	Severe	+44.631650	-85.721450
BT_G020	Unknown (Near Tonowanda Lake)	Birch Rd.	Severe	+44.391440	-85.450407
M-044	Betsie River	Kurick Rd	Moderate	+44.501520	-85.979260
M-046	Betsie River Tributary	Old Grade	Severe	+44.491560	-85.995770
M-047	Betsie River Tributary	Old Grade	Severe	+44.491270	-86.006950

D. Elberta Brownfield Site

Pollutants: Heavy metals (known); sediment, nutrients, other contaminants (suspected)

The Betsie Lake (Betsie Bay) shoreline in the Village of Elberta was used for industrial and transportation purposes for more than a century, beginning with an iron smelter in the years after the Civil War.

The Ann Arbor Railroad carferries began operating on the site in the 1890s and remained in operation until 1982. A tank farm for heavy petroleum products such as liquid asphalt continued in use near the channel to Lake Michigan into the first decade of the 21st Century. Harbor facilities handled lake shipments of stone, aggregate, logs and other bulk materials during the same period.

Much of the former rail yard is built on historic fill, and the majority of the shoreline is hardened with either metal sheet piling or rock riprap. While much environmental clean-up has occurred, the soil is still contaminated to some extent.

At the writing of this WMP, the site is in transition to residential and recreational uses, with cooperation among the State of Michigan, the Village of Elberta and a private development firm.

A historic U.S. Lifesaving Service depot was relocated to a public portion of the site, which also includes a public park, bandshell, fishing platform and a section of the non-motorized Betsie Valley Trail.

The private portion of the redevelopment has been cleared of most of the old facilities. Construction of the proposed private residential area has been delayed, largely due to national economic conditions. It is anticipated that the development will take place, sooner or later. Having been cleared of the industrial facilities, the site is regarded as prime real estate. It is one of a very few remaining undeveloped sites with access to Lake Michigan and a protected harbor.

The shoreline residential area – with its potential tax base replacing the defunct industrial base – is considered to be vital to the financial well-being of Elberta Village.

From a water-quality point of view, the development need not have any detrimental effects. The site is already substantially altered from its natural condition. Properly designed, using low impact development principles, the project may result in improvements in stormwater management and public access, two priorities of this WMP.

This will require two major considerations (both of which are being addressed in the village's present requirements).

First, stormwater management on the site must be designed to prevent pollution from leaching into the bay. In all likelihood, this will require installation of filtration facilities at any storm outfall sites.

Secondly, the development must increase public access to the scenic assets of the bay. Extension of the public non-motorized trail along the shoreline, with the addition of shore fishing access site(s) will likely address this concern.

This former industrial area is the most heavily altered site in the Betsie/Crystal Watershed. Its redevelopment, taking into account long-term water quality protection and a mix of public and private uses, definitely constitutes a positive step for the local economy and population.

E. Green Lake Township/Interlochen Development Sites

Pollutants: Sediment, nutrients (suspected)

The Interlochen area – an unincorporated village within Green Lake Township – is the watershed's fastest developing area in terms of population growth and potential commercial construction.

Growth appears to be enhanced by a number of factors including: The attraction of Green and Duck lakes; cultural amenities offered by the Interlochen Center for the Arts; excellent transportation links on US31 and M137; and the proximity to Traverse City with its employment and cultural opportunities.

A hydrology study prepared for the WMP (Appendix B) identified this area as one in which continued development could result in long-term impacts on water quality, due to increased impervious surfaces and faster stormwater runoff.

The most likely areas for future commercial and residential development are in the Interlochen village area and on separate large parcels near the intersection of US31 and M137 highways.

The township master plan calls for expansion of small existing water and sanitary sewer systems concurrent with new development. The plan also recognizes the importance of stormwater management to keep runoff from leaving new development sites.

The forward-looking plans must be strongly administered to ensure low-impact development principles are followed, allowing development to proceed in this critical area without diminishing water quality.

Interlochen Downtown Development Authority - The Village of Interlochen, Gateway Master Plan

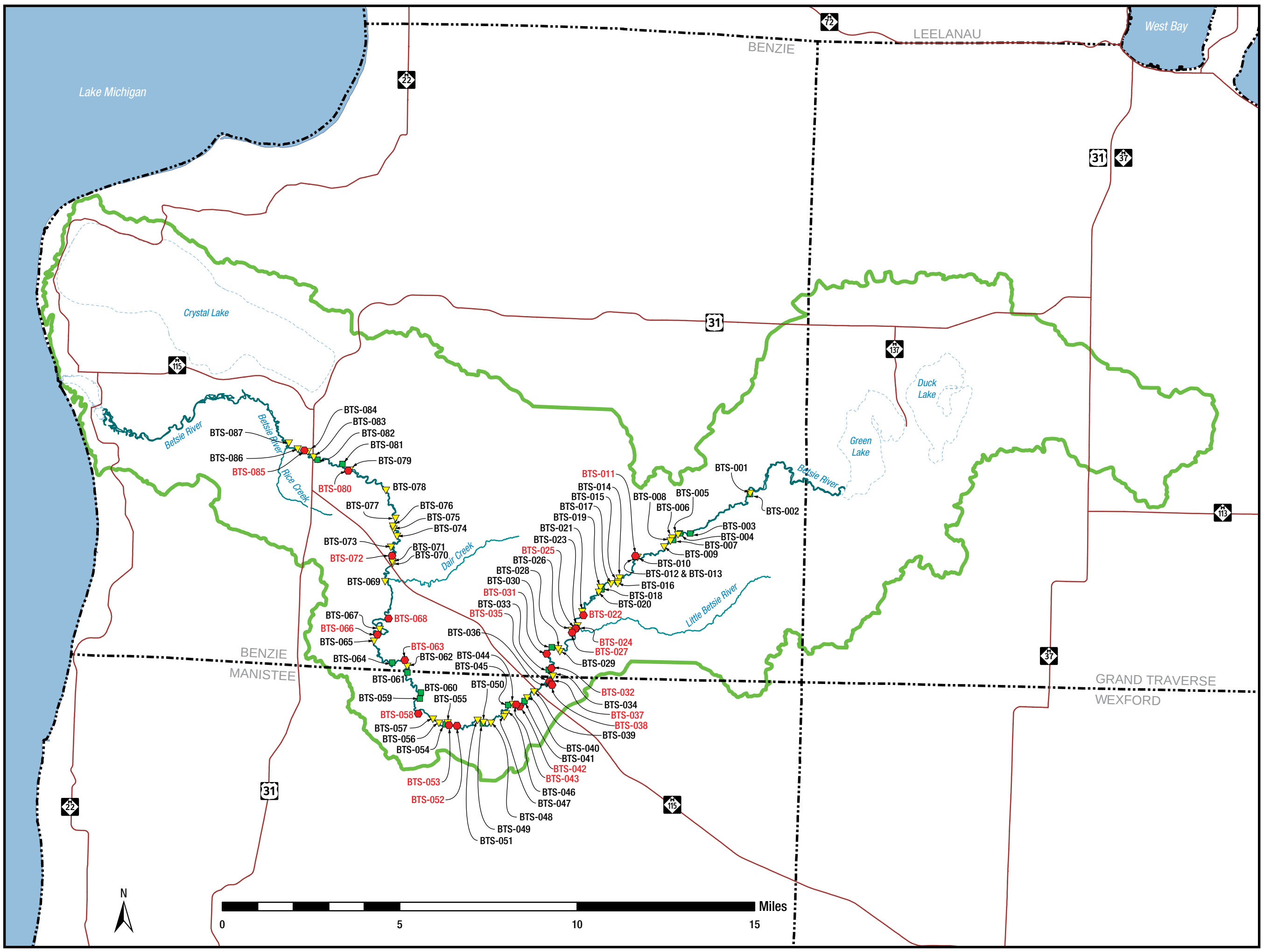
F. Streambank Erosion Sites

Potential Issues: Sedimentation; fish habitat; thermal issues

Streambank erosion has been identified since at least the 1960s as a source of sediment pollution to the Betsie River. Some bank erosion is a natural process of a free-flowing stream. But, as noted in Chapter 2, excessive erosion on the Betsie is often related to past land uses including logging and vegetation removal.

Considerable work to restore the natural resilience of Betsie River streambanks was accomplished in recent years through the Betsie River Watershed Restoration Committee and Conservation Resource Alliance. Despite those efforts, unstable banks continue to erode sediment into the stream at a number of locations. Of particular concern are the course sands that can accumulate on the river bottom, potentially covering fish spawning habitat and also creating a shallower and warmer stream.

Map 30 - Streambank Erosion Inventory



KEY | STREAMBANK EROSION CONDITION

- Minor
- Moderate
- Severe

Note: Sites recommended for restoration during the 10-year period of the Betsie River / Crystal Lake Watershed Management Plan include the Severe sites identified with red ID text and 20% of the Moderate sites to be determined during the course of the plan implementation.

As part of the field work for the WMP, crews from Conservation Resource Alliance floated the entire river to complete an updated streambank erosion inventory. The inventory identified erosion at 87 locations, totaling nearly a mile of riverbank (See Appendix E).

The sites were scored on the Streambank Erosion Severity Index (See Appendix E) which assigns numerical values for such variables as: The site's general condition; vegetation cover; trend toward increasing or decreasing erosion; length and height of eroded bank; current and depth of the river; and other factors. Sites scoring less than 28 points are considered as minor; those with 28-31 points are ranked as moderate; and those scoring 32 or above are classed as severe.

Of the locations inventoried, 20 were rated as "minor" sites totaling 770 feet of streambank; 46 were considered "moderate" sites, totaling 2,600 linear feet of bank; and 21 were scored as "severe" sites, impacting 1,740 feet of streambank.

The entire inventory – including point scores, GPS coordinates, photographic images and recommended mitigation methods – is online at www.northernmichiganstreams.org

Because the Betsie is a Natural River, bank stabilization projects should use native materials and the least obtrusive methods. Placements of whole tree revetments, and/or revegetation are the preferred treatments where applicable.

The WMP envisions stabilization of all the "severe" sites and 20 percent of the minor and moderate sites. In addition, the bank erosion inventory should be updated on a 10-year cycle.

G. Crystal Lake – Beulah and Cold Creek Subwatershed

Pollutants: E.coli (known); sediment (known), nutrients (known) invasive species (known)

The Village of Beulah – including the Crystal Lake waterfront – and the Cold Creek subwatershed together comprise a critical site in the Watershed (see Map 31 on page 110).

Sampling at Beulah Beach on Crystal Lake showed excessive levels of *E. coli* bacteria on six occasions in 2013, 2014 and 2015, indicating the site is in non-attainment of Michigan's "full body contact" and "partial body contact" designated uses. The state designated uses of "Coldwater Fishery" and "Other Indigenous Aquatic Life and Wildlife" on Cold Creek are believed to be at risk due to nutrients, sediment and invasive species.

In addition, the WMP identifies significant threats at this site to several locally desired uses and conditions: Clear Water Oligotrophic Lakes; Control of Swimmer's Itch; Preservation of Scenic Beauty; Outdoor Recreational Opportunities; and Economic Opportunities for Watershed Residents.

In preparation for this WMP, a community meeting was convened at the Benzonia Township Hall in April of 2014 to discuss issues related to the site. Problems identified by stakeholders included:

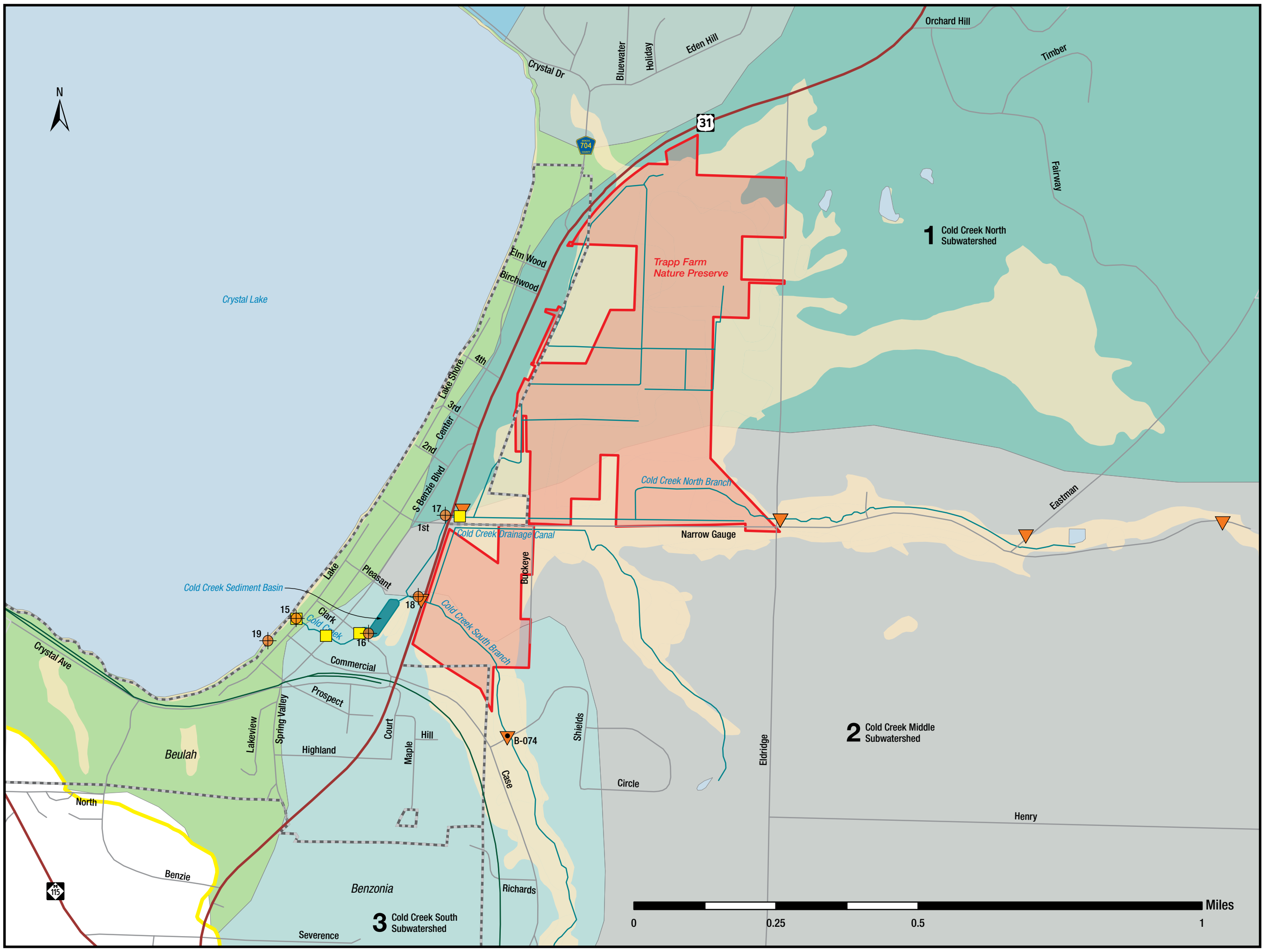
- *E. coli* contamination of the waters on Beulah Beach, which required beach advisories on several occasion.
- Flooding of private properties in the commercial district on US31
- Deterioration of the coldwater fishery in the North Branch of Cold Creek
- Siltation and nutrients flowing into Crystal Lake from muck soils on a former vegetable farm along Cold Creek
- Beach erosion during moderate to heavy rain events
- The cost of maintaining the Cold Creek sediment basin, which cost is borne entirely by the Village of Beulah and the Township of Benzonia.
- Loss of economic potential due to the above problems.

Site data on bacterial (*E. coli*) pollution are complete and up to date as of 2015. However, existing data on nutrient and sediment loading are inconsistent and may be outdated. Additional monitoring is included in the plan in order to confirm those findings.

The WMP recommends a robust program of monitoring at significant points on Cold Creek. Also recommended, at the conclusion of this section and in the Implementation Tasks listing (Chapter 6), are an engineering study to analyze together all aspects of site conditions, and a program to address and mitigate the contamination of Crystal Lake and the public beach areas in Beulah.

Because the site has been significantly altered over a long period of time, the plan envisions that active management will be required for the foreseeable future.

Map 31 - Beulah & Cold Creek Subwatershed



KEY

1 - Cold Creek North Subwatershed	CITY OR VILLAGE	Monitoring Locations
2 - Cold Creek Middle Subwatershed	GTRLC Protected Lands	Minor Road Stream Crossing
3 - Cold Creek South Subwatershed		Moderate Road Stream Crossing
17 - Mitchell Creek Subwatershed		Moderate Road Stream Crossing (WMP Recommended Restoration)
18 - Crystal Lake Subwatershed		

The village of Beulah is built along the eastern shore of Crystal Lake, on former lowlands exposed when the lake was lowered by a proposed canal project in 1873. Though the canal was never completed, the level of the lake remained 10 to 15 feet below pre-settlement conditions, allowing development of residential, agricultural and commercial infrastructure on what had been marsh and beach ridges at the east end of Crystal Lake.

The present footprint of the village includes the lowland area, as well as some upslope properties to the south. The village of Benzonia occupies the crest of a glacial moraine adjacent to Beulah's southern village limit. A moraine to the north is in Benzonia Township.

Beulah maintains public water and sanitary sewer systems. Sanitary waste is pumped to lagoons south of the village, in the Betsie River Watershed.

The village owns approximately 2,000 feet of Crystal Lake waterfront, including: An RV campground; a public swimming beach; public docks for day users and fishermen; a boat launch ramp; and several hundred feet of frontage leased to village residents for private dockage. The North Branch and South Branch of Cold Creek merge within the village and flow through a man-made sedimentation basin before discharging to Crystal Lake near the center of the publicly owned shoreline.

The village's downtown commercial street runs parallel to the beach and one block (approximately 300 feet) east of the waterfront. The village is significantly developed. More than 75 percent of the land is covered with impervious surfaces such as rooftops, streets and parking lots.

The Beulah storm water system has not been adequately mapped. (The Village Council applied unsuccessfully for a Michigan S.A.W. grant for this purpose in 2014.) The topography directs virtually all stormwater to the publicly owned shoreline, either as surface drainage on paved streets or through catch basins and subterranean pipes.

There are three storm sewer outfalls on the public beach, as well as several that discharge into Cold Creek. A beach improvement project in 2013 installed rock grottos at the outfalls in an attempt to reduce erosion during storm events. Significant rains tend to wash out the sand under the rocks. The same project also installed a strip of permeable pavement along the beachfront road in an effort to increase infiltration. At the time the project was installed, the village's consulting engineer indicated the rocks and permeable pavement should be seen as interim measures, not sufficient to fully address stormwater and erosion issues on the beach.

The water off Beulah Beach was sampled for *E. coli* weekly during the summers of 2013, 2014 and 2015. On six sampling dates, *E. coli* in the water was found to exceed the one-day health limit of 300 colonies per 100 ml of water.

Each of the high readings occurred after periods of rainfall. The Benzie-Leelanau District Health Department ordered beach advisories to be posted on each occasion.

In 2014, the Michigan DEQ supported this Watershed Management Plan by contracting for additional bacterial sampling of Beulah Beach, Cold Creek and the three storm sewer outfalls. This sampling took place on three dates, during rainfall events.[18]

Each of the MDEQ sample sites exceeded the full body contact recreation standard on at least one of the three dates (See on Table 28 on page 115).

E. coli in the Cold Creek samples fell in a range of approximately 600 to 800 on all three dates. The discharge pipe labeled as storm sewer No. 2 was above 1,000 on each date, with a high of 4,298 on Aug. 29.

In addition, genetic source tracking conducted for MDEQ showed DNA from human intestinal bacteria in storm sewers No. 2 and No. 3 on Aug. 29, and storm Sewer No. 2 and Cold Creek on Oct. 2.

The MDEQ report on the monitoring includes the following explanation of the significance of the DNA source tracking:

"These host specific bacteria types are not *E. coli*, and the relationship of host specific bacterial DNA to the counts of *E. coli* in a water sample is not direct or established as fact. Therefore, it cannot be concluded that the *E. coli* in a water sample is from a specific host animal simply because the DNA of the host specific bacterium is found alongside a high *E. coli* count. The state of Michigan has no water quality standard for the DNA of host specific bacteria, but **the information is considered useful in helping to determine potential sources of *E. coli* which may be present in the feces along with the host specific bacteria."**

According to the 2010 Census, Beulah had 375 housing units, of which 57 percent were vacant on the April 1 census day. The majority of the "vacant" dwellings are occupied in summer. The year-round population has been declining since at least 1970, according to census figures. Village population in 2010 stood at 342.

The Cold Creek subwatershed occupies a long, relatively narrow valley which extends eastward from the village approximately 10 miles and is bordered on the north and south by tall glacial moraines.

The western portion of the subwatershed, up to about 0.75 miles from Crystal Lake, contains several hundred acres of wetlands with organic muck soils that developed at a time when the site was inundated by the waters of Crystal Lake. The muck fields were ditched and drained for agricultural use in the early 20th century. Today, much of the North Branch of Cold Creek flows in the old farm ditches.

Two roads: US Highway 31, and the local Narrow Gauge Road, were constructed on causeways of historic fill through the former mucklands. A commercial area was developed in the mid-20th century on fill along US31. While some buildings on the site have been subject to flooding or mold related to saturated soils, other businesses remain viable and are important to the local economy.

Since at least the 1930s, village residents have complained of silt washing off the farmland to Cold Creek and ultimately into Crystal Lake. The creekbed was modified sometime prior to World War II to create a basin to capture sediment. The basin was rebuilt about 1975 and remains in use.

Farming on the site ceased in the 1970s. Most of the former farmland east of the commercial area was donated to the Grand Traverse Regional Land Conservancy in the 1980s and is now managed as the Trapp Farm Nature Preserve. A portion of the preserve is included in a wetland restoration project under development by the Natural Resource Conservation Service (NRCS) and is subject to a conservation easement held by the agency.

Organic muck from the old farm fields has the capacity to remain suspended even in slow-moving water for several hours. Following moderate to heavy rains, black silt carried by Cold Creek creates a dark plume in Crystal Lake. A dense bed of weeds, including Eurasian milfoil, grows offshore from the creek mouth and is thought to be nourished by the creek's input.

A 2012 report by NRCS showed that organic soils in the preserve are being lost as carbon volatilizes to the atmosphere. This loss of soil has apparently been an ongoing process since the soil was exposed by lowering the lake surface 140 years ago. Ash trees on the site have been killed recently by the emerald ash borer, and other trees have fallen due to soil loss. Footpaths through the Trapp Farm Preserve were closed in 2012 for safety reasons and to limit the spread of invasive species, especially garlic mustard.

NRCS is proposing to revegetate ditch and stream banks with shrubs, conifers and other plantings to slow the loss of soil. Planning for that project is projected to be complete in 2016, with the plantings to take place in the spring of 2017.

All of Cold Creek – including the former agricultural ditches on the Trapp Farm – is designated as a coldwater trout stream (MDNR Fisheries order 210.07). A 2006 survey documented the presence of brook trout, rainbow trout, brown trout and Coho salmon in the stream. Loss of the tree canopy and siltation of the waterway pose a threat to these coldwater species.

Cold Creek is the main spawning area for the Crystal Lake population of coho salmon, is one of two known self-sustaining populations of "landlocked" Pacific salmon in Michigan. (Tonello, 2006) The creek also provides important spawning habitat for rainbow smelt.

Cold Creek has two main branches: the North Branch which drains the former Trapp Farm and locations to the north and east; and the larger South Branch which extends into upland areas to the southeast. (A smaller tributary, sometimes called the Middle Branch, parallels Narrow Gauge Road and joins the North Branch east of US31.)

The North and South branches pass in separate culverts below US31, and then merge west of the highway.

Immediately after the confluence of the two branches, Cold Creek flows through a large sedimentation basin – 420 feet long by 90 feet wide – which collects some, but not all, of the sediment and muck. The basin accumulates sediment in the range of 1,000 cubic yards annually. It is generally excavated on a 3-5 year cycle. Excavated sediment is placed in an adjacent dewatering area for up to three years, and then trucked away.

From the lower end of the basin, Cold Creek flows about 600 feet through the heart of the village business district before discharging into Crystal Lake.

Sampling in 1997-98 found the South Branch flow to be larger, and more consistent, ranging from 8,017 to 10,859 cubic meters per day. The North Branch was at its lowest in late summer, 1,639 M3/day and its highest in October, 4,064 M3/day .

At its terminus, Cold Creek was found to discharge an average of 12,300 M3/day, a flow rate equivalent to 5 cubic feet per second.

On average the South Branch accounted for 76 percent of the flow, but only 31 percent of the phosphorus recorded at the creek mouth. The North Branch, conversely, had 24 percent of the flow, but 46 percent of the phosphorus, on average, during the 11 completed sampling dates in 1997-98.

The figures indicate more than 20 percent of the phosphorous flowing into Crystal Lake via Cold Creek actually entered the creek in the short stretch below the confluence of the two branches.

It is possible that phosphorus and sediment may at times be resuspended from the sedimentation basin, or that factors within the village are contributing additional quantities.

Sampling of the combined creek in 2003 by the Michigan Water Research Center at Central Michigan University found similar flow rates and phosphorus loadings.[19] The 2003 sampling estimated average sediment loading at the creek mouth to be 150 pounds per day. Data from that study indicate the concentration of solids in the creek increases significantly along with stream flow. Total suspended solids were measured at 15.6 mg/l on the highest flow day in the 2003 study, compared with 3.1 mg/l on the lowest flow day.

The WMP recommends the following actions to address the multiple problems at this site. These actions are included in the "Implementation Tasks" chart in Chapter 6 as Category N.

- Implement a monitoring program to document stream flow and nutrient and sediment loadings at four sites: The North Branch culvert under US31; the South Branch culvert under US31; the outflow structure at the Sedimentation Basin; and the pedestrian bridge at the mouth of the creek at Crystal Lake.

- Complete a detailed engineering study of the Cold Creek subwatershed, including Trapp Farm Nature Preserve, road corridors, all stream branches and Beulah sedimentation basin, to determine sources and quantities of sediment, nutrients and E.coli entering Crystal Lake. Recommend remediation, which must include protection of existing coldwater fishery and wetland function.
- Based on the above study, design and implement a long-term monitoring and management component to minimize loadings into Crystal Lake. Design and implement BMP's to minimize the identified problems on Cold Creek and protect the stream's resource benefits. The plan should include an interpretive trail or overlook in Trapp Farm as a long-term goal to provide public access and education at the site.
- Complete streamside revegetation of Trapp Farm Nature Preserve, per plans under development by Natural Resource Conservation Service, with NRCS monitoring on long-term basis.
- Map and inventory Beulah stormwater system. Design and install BMP's (e.g. rain gardens, filters, infiltration trenches) to minimize erosion, nutrient loadings and bacterial contamination to Crystal Lake. For efficiency, this project should be coordinated with the proposed village streetscape project and Cold Creek remediation.
- Protect existing viable businesses in historic wetland fill area on east side of US31. Allow no additional impervious surfaces in this critical area. Consider removal of impervious surfaces from parcels with no operating business or residence.
- Develop community consensus for long-term funding component (e.g. Special Assessment, County Drain, Lake Board, inter-local agreement or other) to finance the maintenance of the Beulah Sedimentation Basin and management of Cold Creek and to ensure that costs are fairly spread among all benefiting parties.

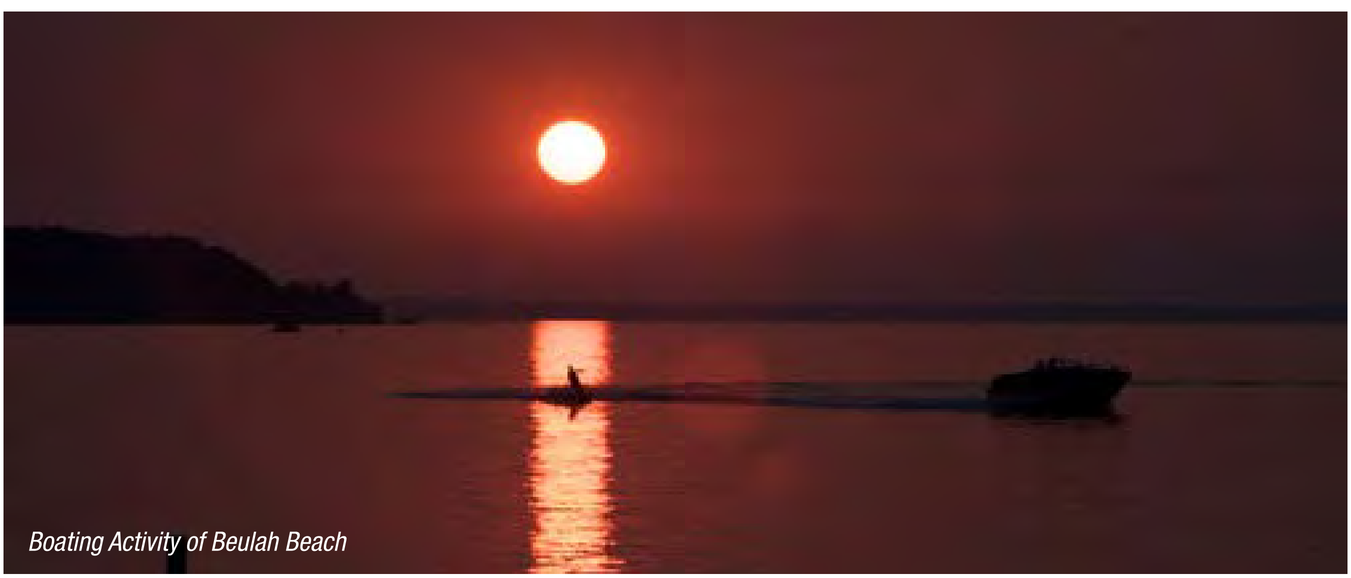
Beulah Beach

Table 28 - Beulah Beach *E. Coli* Sampling

E. Coli Daily Mean Values (CFU/100ml)					
Summer 2015		Summer 2014		Summer 2013	
Date	Value	Date	Value	Date	Value
2-Sep	12.0	5-Jan	5.6	3-Sep	2.2
26-Aug	5.0	18-Feb	49.1	29-Aug	906.1
21-Aug	8.0	13-Oct	652.6	28-Aug	507.1
20-Aug	1,090.0	30-Jan	30.3	21-Aug	159.9
19-Aug	1,300.0	9-Jan	9.3	14-Aug	6.3
12-Aug	11.0	30-Jan	30.8	7-Aug	103.3
5-Aug	10.0	11-Jan	11.1	31-Jul	11.2
29-Jul	1.0	4-Mar	64.4	24-Jul	1.7
22-Jul	0.0	4-Jan	4.1	17-Jul	3.3
15-Jul	4.0	8-Jan	8.4	11-Jul	63.1
8-Jul	1.0	27-Jan	27.9	10-Jul	1,310.8
30-Jun	5.0	7-Jan	7.5	1-Jul	1.8
24-Jun	2.0	8-Jan	8.4	26-Jun	4.4
		8-Jan	8.8	19-Jun	5.3
				12-Jun	1.6
				5-Jun	2.8
2014 "Rain-Event" Monitoring Values (CFU/100 ml)					
Date	Beulah Beach	Cold Creek	Storm Outfall 1	Storm Outfall 2	Storm Outfall 3
29-Aug-2014	10.0	795.0	NA	4,298.0	1,184.0
4-Sep-2014	892.0	599.0	407.0	1,076.0	645.0
2-Oct-2014	2.0	593.0	30.0	1,421.0	14.0

Figures in Red Exceed Michigan Standard (storm outfalls are not classified as surface waters)

Source: MDEQ



Boating Activity of Beulah Beach

Priority Areas for Protection

Priority areas within the watershed are those general areas which may not be currently impaired or threatened, but must be protected in order to prevent future degradation of water quality. Watershed Plan goals, presented in Chapter 5, are intended to address these issues in such a way as to protect the designated and desired uses of surface water. Specific recommendations for addressing these concerns are included in the Implementation sections in Chapter 6.

Priority Parcel Analysis

One effective tool for preserving water quality is the permanent protection of sensitive land parcels, which may be accomplished through conservation easements, public purchase, land conservancy acquisition or other methods.

The Betsie River / Crystal Lake Watershed includes significant acreage protected through Michigan's state forest system. In addition, protected lands owned by local governments, land conservancies and private owners (through conservation easements) exist throughout the watershed. Protection of the watershed will be enhanced by enrollment of additional lands through the auspices of government, land conservancies and willing property owners.

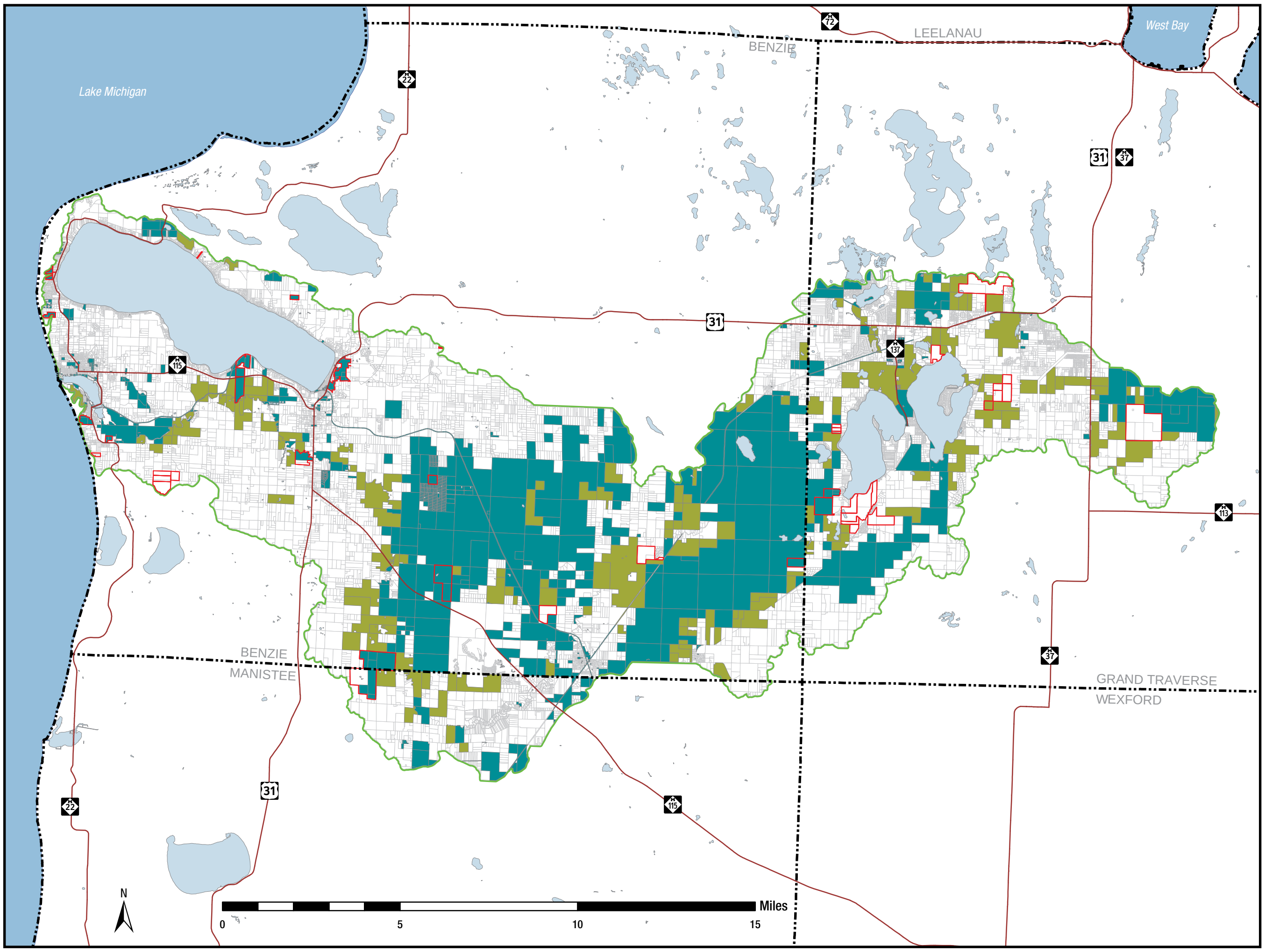
The Grand Traverse Regional Land Conservancy, in cooperation with other organizations, has developed a set of criteria to identify parcels that are likely to have the greatest impact on water quality and the ecosystem. These "Priority Parcels" should be among the first considered for investment of funds for acquisition of conservation easements, development rights and outright purchase from willing sellers.

The selection criteria for priority parcels in the accompanying map include the following: Parcel size (larger parcels are considered to have greater ecological impact); groundwater recharge potential, based on soils and topography; the presence of wetlands; lake or stream frontage; steep slopes; adjacency to previously protected lands; and the presence of endangered or threatened species.

These criteria stress water quality benefits and mesh closely with the overall priorities of the WMP.

Railroad Point Natural Area

Map 32 - Priority Lands for Protection



KEY | LAND CLASSIFICATION

- All Classifications of Public Property
- GTRLC Priority Lands for Protection
- Private
- GTRLC Protected Lands

Permanent protection or low-impact development in high priority areas will help ensure the ecological integrity of sensitive areas while preserving water resources throughout the watershed. The analysis also provides valuable assistance in efforts to protect threatened and endangered species, and to create wildlife corridors.

Lake Shorelines: On-Site Wastewater Systems, Perimeter Roads, Shoreline Hardening

Potential issues: Shoreline habitat; nutrient and sediment pollution; petroleum products and road salt.

Shorelines of four inland lakes in the watershed – Crystal Lake, Green Lake, Duck Lake and Cedar Hedge Lake – are occupied by significant residential development. With the exception of the *E. coli* findings at the critical sites on Crystal Lake (described above), all four water bodies appear to meet the designated and desired uses at the present time.

Concern remains about the long-term impacts of shoreland management. It is critical in these densely developed areas that shorelines be managed in ways to minimize the introduction of pollutants and to protect existing aquatic habitats.

Implementation of best management practices by private property owners is of paramount importance here. Much of the shoreline development dates from decades past. Given the location of structures and the potential impacts of wind, waves and ice push, it is likely that seawalls and riprap installed in the past to protect these properties will remain in place.

New shoreline hardening should be discouraged by enforcement of appropriate buffer zones and MDEQ permit requirements. Continuing education is needed to support the use of native plantings, greenbelts and other low-impact methods of shoreland management. Shoreline inventories were conducted in 2014. The WMP calls for re-inventorying the shorelines on a 10-year cycle to assess changes.

The majority of the frontage on the four lakes is without municipal sewer service, meaning that most dwellings are served by on-site systems – either septic systems or holding tanks. (The Village of Beulah on Crystal Lake is served by sanitary sewer, as are the Interlochen Center for the Arts, the Interlochen State Park, and homes in the Strawberry Point subdivision on Green Lake.)

For areas served by on-site systems, tanks should be pumped on an appropriate schedule, and inspection on sale requirements should be instituted and enforced. The WMP recommends education and information regarding septic system BMP's (Chapter 8).

On Crystal Lake in particular, miles of shoreline are ringed with perimeter roads, often so close to the water that there is little or no space for buildings on the lake side of the road. These perimeter roads have the potential to introduce nutrients, sediment, road salt and petroleum products into the water with each heavy rain event.

Road agencies should maintain appropriate ditches and employ BMPs to protect the shoreline and minimize impacts.

Duck Lake Shoreline

Headwaters and Small Tributary Streams and Lakes

Potential issues; Aquatic habitats; hydrologic connectivity; public access; nutrients, sediment

The headwaters segment of the Betsie/Crystal Watershed includes a number of small lakes and streams, many of which have not been scientifically evaluated for fishery or habitat since the 1960s.

While these water bodies are individually minor, together they have a significant impact on overall water quality, as well as presenting a potential recreational resource.

The WMP outlines a long-term strategy for monitoring water quality and detecting potential threats, along with an informational component to educate the public as to the importance of these elements of the watershed.

Dair Creek

South Banch Cold Creek

Groundwater

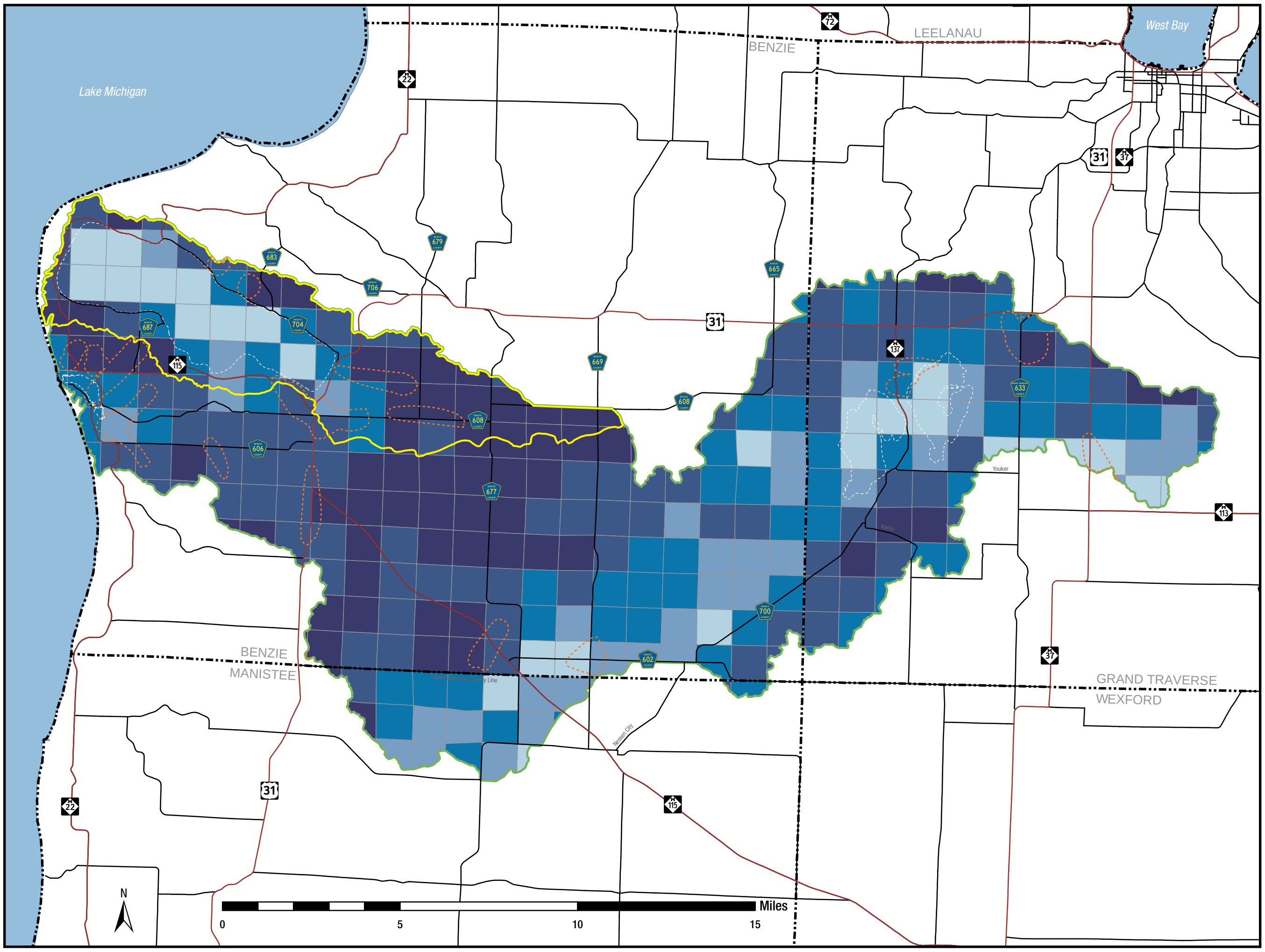
Potential issues: Contamination by oil and gas production or industrial food processing; depletion by overuse in minor aquifers; chemical and/or nutrient contamination by on-site wastewater systems or agricultural operations

Groundwater is a key resource in the Betsie/Crystal Watershed, providing water for human consumption and for agricultural and golf course irrigation. The three largest lakes, Crystal, Green and Duck, are all fed primarily by groundwater. Ground water also maintains the stable flow of the watershed's streams, and moderates stream water temperatures in ways that enable the survival of trout and other coldwater fish.

At the present time, groundwater supplies in the watershed are both abundant and of high quality. However, given the vital nature of the resource, steps must be taken to provide total assurance against future degradation.

Wellhead protection areas in effect for municipal water systems must remain in place. Groundwater recharge areas must be protected. Farms, orchards, golf courses and ski areas must employ best management practices to avert any chance of contaminants reaching the water table.

Map 33 - Groundwater Recharge



KEY | GROUNDWATER RECHARGE RATE

- 8 - 10
- 11 - 12
- 13 - 14
- 15 - 16
- 17 - 19

Color scale indicates Groundwater Recharge rate in inches per year.

(Cell Size: 1 Square Mile)

WELLHEAD PROTECTION AREA

MAJOR WATERSHED LAKE

Mining, mineral extraction and oil and gas production operations – along with their associated infrastructure – must be strictly regulated by state and local governments to provide 100 percent assurance against groundwater contamination.

Grass Lake Flooding

Potential issues: Siltation, access, water temperature, invasive species

The Grass Lake flooding, in Benzie County downstream from Green Lake, includes Grass Lake, Twin Lake and Upper Twin Lake, Grass Lake Creek, Pickerel Creek and a segment of the Betsie River mainstream. The area is mostly state-owned wetland, with water levels maintained by a low-head dam that was installed in 1951 to improve waterfowl habitat.

The dam also influences the water level of Green Lake.

Access to the flooding is by canoe, kayak or small motorboat from a launch at the Grass Lake Campground, a state forest facility located at the dam site.

While the flooding appears to serve its intended purpose of providing waterfowl habitat, the large impounded area also raises water temperature in the Upper Betsie River, to the detriment of cold water fish species (Newcomb, 1994).

The margins of Grass Lake contain invasive narrow-leaf cattails, interspersed with native cattails, as well as several stands of Phragmites. At least some of the Phragmites has been identified as being of the native variety.

Grass Lake Creek

Grass Lake itself was once considered a popular fishery for northern pike. In recent decades the lake has significantly silted in, and fishing quality is believed to have deteriorated.

Removal of the dam, as has been suggested in the past, would likely improve thermal conditions in the river, but would also reduce waterfowl habitat and would be expected to require installation of some other method of stabilizing the Green Lake water level.

On balance, it appears the flooding should be maintained and carefully monitored. The habitat could be improved by better management of invasives, and the possible reintroduction of native plants such as wild rice.

Steep and Forested Slopes; Scenic Ridgelines

Potential issues: Erosion, loss of diversity; loss of scenic viewsheds

Glacial moraines, especially in the western segments of the watershed, define many of the boundaries between subwatersheds as well as the borders of the overall watershed. These high, steep hills are particularly noticeable around Crystal Lake and Betsie Lake, and eastward to the Buck Hills region that includes the Crystal Mountain ski area. A scenic corridor, undeveloped but included in the General Management Plan of the Sleeping Bear Dunes National Lakeshore, extends along the ridgeline north of Crystal Lake. The long-term vision of the National Lakeshore includes a scenic road or trail in this corridor. Most of the corridor remains in private ownership. Development of the corridor is not expected to occur for 20 years, at least.

These hillsides give the watershed much of its scenic character, and old-growth forests have generally protected the slopes from significant erosion. The Crystal Lake Watershed Overlay District includes zoning provisions to limit the density of buildings on these sensitive hillsides near Crystal Lake. Provisions regulating vegetation cutting should be strengthened, as indiscriminate logging on sensitive slopes carries an unacceptable risk of soil erosion and sedimentation.


Betsie Lake

Of significant concern now is the loss of forest diversity as result of the emerald ash borer, oak wilt, beech bark disease and other threats to the health of native trees. Thousands of ash trees within the watershed have been destroyed by the emerald ash borer and removed from the forest canopy. While the other diseases have so far been less devastating, they also pose significant threats.

Conservation easements should be encouraged as one way to preserve the scenic and environmental resources inherent in slopes and ridges. Protecting and restoring forested slopes for the benefit of property owners and the public is likely to require enforcement of additional regulations, as well as education and funding assistance for property owners faced with the loss of forest cover.

Crystal Lake Outlet

Potential issues: Flooding, invasive species, fish passage, wildlife habitat

The Crystal Lake Outlet, on the south shore of Crystal Lake, is a popular recreational and scenic area, as well as an important ecological site.

A dam at the site is managed by the Benzie County Drain Commissioner in an effort to maintain the lake surface at a court-mandated level of approximately 600 feet above sea level – plus three inches in summer and minus three inches in winter. Stop logs in the dam can be raised or lowered to control the flow of water out of the lake.

The eastern shore of the stream at the damsite is owned by the State of Michigan and is adjacent to the Railroad Point Natural Area, a Benzie County park. The Betsie Valley Trail also passes through the property. A local historical marker at the site commemorates an 1873 event that resulted in lowering the Crystal Lake surface to its present level.

Stands of invasive phragmites have been observed and treated just downstream from the dam. The area also displays infestations of garlic mustard and invasive honeysuckles.

Below the dam, the Outlet stream (which has no name, other than “The Outlet”) meanders south for about a mile before joining the Betsie River, five miles upstream from Betsie Lake. Outlet stream volume is highly variable, primarily due to seasonal changes in the Crystal Lake water level.

At times in late fall, lake levels are so low that no water flows over the spillway into the Outlet channel, though springs and seeps do infuse a small amount of groundwater into the stream. Spring flows are sometimes so high that culverts downstream at Mollineaux Road and M-115 are barely able to handle the volume.

In 2013, strong flows in The Outlet resulted in flooding of a residential property on the north side of M-115. The parcel is currently vacant and available for sale. Adding the site to the Railroad Point Natural Area would enhance The Outlet’s floodplain and also provide habitat for wildlife. The WMP recommends acquisition of the property for those reasons. Grand Traverse Regional Land Conservancy is seeking a grant for the acquisition; Benzie County and the CLWA have committed local matching funds.

A recent expansion of the Railroad Point Natural Area, accomplished through the Grand Traverse Regional Land Conservancy, created the potential for a wildlife corridor along The Outlet between Crystal Lake and the Betsie River. Long-term plans also envision an improved trailhead for access to the Betsie Valley Trail.

The dam itself blocks passage of sea lamprey, which could otherwise enter Crystal Lake and potentially spawn in tributary streams. In high-water years, Coho and Chinook salmon, apparently straying from the Betsie River spawning runs, have been observed jumping the dam into Crystal Lake. Coho have established a self-sustaining population in Crystal Lake.

Crystal Lake Outlet Dam

The Outlet Dam site should be maintained both for water level control and for access to the trail and park area. Ideally, the site would become part of the county park, and a long-term plan developed to manage it for both water quality and public enjoyment.

Betsie Rivermouth at M-22

Potential issues: Invasive species; fish passage; navigation, siltation; wildlife habitat; scenic values

The Betsie Rivermouth at the upper end of Betsie Lake has been subject to invasions of phragmites and narrow-leaf cattails in recent years.

The site remains a popular scenic area and a key access point to the river and the Betsie Valley Trail, which transits the river on a former railroad bridge just upstream from the M-22 crossing. .

Much of the site is wetland included in the Michigan DNR's Betsie River Wildlife Area.

The Friends of Betsie Bay have worked with the Northwest Michigan Invasive Species Network and the Benzie Conservation District to treat small patches of phragmites, but a very large infestation remains.

The site appears as a nearly flat lake plain, bounded by high rolling hills to the south and east. Silt and nutrients from upstream tend to settle out as the river slows and spreads out over these flats. Water levels in the wetlands are largely determined by the changing levels of Lake Michigan.

In fall of 2012, with Lake Michigan near all-time lows, the river created a mudflat or delta that sprawled into the upper end of Betsie Lake, with water flowing through shallow, intermittent channels in the mud.

Thousands of migrating salmon were grounded in the mud during the fall run that year. The DNR responded by temporarily prohibiting fishing in the mud-flat area.

Also in the low-water years, invasive phragmites colonized much of the historic wetland area south and east of the former railroad bridge.

Water levels reversed rather suddenly in the winter of 2013. After setting an all-time January low in the first month of 2013, Lake Michigan had risen just over 36 inches by January of 2015, according to measurements by the U.S. Army Corps of Engineers.

The water level change will certainly affect wildlife and fish passage. And, for the time being, it has eased concern about small-boat navigation at the river mouth. If water remains high for several years, it could flood out much of the invasive phragmites, and potentially allow for revegetation with native species.

There is no likelihood that water levels can (or should) be artificially managed on this site. Conditions must be monitored to allow rapid response in order to minimize any degradation and take advantage of opportunities for ecological enhancement that may occur with changes over time.

Frankfort Outer Harbor

Potential issues: Navigation, invasive species; nutrients; scenic vistas; historic preservation

The Frankfort Outer Harbor is an area physically in Lake Michigan, but bounded by concrete breakwalls that isolate Betsie River water from the waters of Lake Michigan.

The historic Frankfort Light is located at the end of the north breakwall. The arrangement of the angled breakwalls provided a broad area which allowed carferries and other lake vessels to turn around before entering the Inner Harbor at Betsie Lake. Today, it offers scenic viewing opportunities and pier fishing, in addition to protecting recreational boaters from wave and wind.

Frankfort Lighthouse in large Lake Michigan waves

The city of Frankfort maintains public swimming areas on both sides of the northern pier, in addition to foot access to the pier and lighthouse. The south breakwall is accessed from a small parking area in the village of Elberta.

Significant accumulations of algae have been observed on the sandy shoreline inside the Outer Harbor, possibly due to interactions between nutrient rich water from Betsie Lake and invasive mussels in Lake Michigan and the harbor.

Frankfort Outer Harbor

Maintaining the historic harbor structures will support navigation and enhance the tourist economy in the watershed. Water quality in the Outer Harbor is largely dependent on the quality of water in the Betsie River and Betsie Lake. The harbor will benefit from continued improvement of inland surface waters.

Frankfort Beach Algae

Chapter 5

Goals and Objectives

After reviewing initial data and considering preliminary results of the property owner survey, the Watershed Steering Committee approved the following set of goals and objectives. These provided basic direction as the plan was developed

In general, the plan goals recognize that natural resources are inextricably linked to the economy and the quality of life within the watershed. The goals and objectives are structured to reflect the view that protection of water quality is a necessary element in promoting both the environment and human welfare within the region.

Goal 1: Preserve, protect and improve water quality to meet or exceed all applicable state and federal standards and locally desired conditions;

Objectives

a. Monitor public access areas for *E. coli* contamination; institute mitigation as appropriate.

b. Monitor waterways for current conditions and changes in physical or chemical parameters (e.g. clarity, phosphorus, dissolved oxygen, conductivity, temperature.)

c. Inventory urban stormwater systems, streambank erosion sites, road stream crossings and lake shoreline conditions. Update inventories on a regular schedule. Support BMP's to minimize water quality impacts.

d. Monitor external conditions beyond local control -- including climate change and atmospheric deposition of mercury -- to develop appropriate long-term responses.

e. Support research into Swimmer's Itch causes, prevention and mitigation.

Goal 2: Preserve, protect and improve the aquatic environment, focusing on: Warmwater and coldwater fisheries; aquatic plant and animal diversity; native species; and overall health of the ecosystem.

Objectives

a. Reduce sediment, nutrient and chemical inputs from residential sources.

b. Reduce sediment, nutrient and chemical inputs from transportation infrastructure and maintenance, including logging access roads.

c. Reduce sediment, nutrient and chemical inputs from recreational activity sources.

d. Reduce sediment, nutrient and chemical inputs from urbanized and developed sites.

e. Protect and restore critical resources, including groundwater recharge and discharge areas, headwater streams, wetlands and wildlife corridors.

f. Monitor aquatic and terrestrial invasive species for early detection and treatment.

g. Protect and restore natural hydrologic connectivity.

Goal 3: Protect the natural character of the watershed, while maintaining the recreational, scenic, economic and lifestyle benefits that flow from a high-quality natural environment.

Objectives

a. Support scientific management of fishery, wildlife and public lands and waters for recreational and environmental benefits.

b. Maintain and improve public access to recreational land and waters, with site designs to protect water quality, provide for public safety and minimize introduction of invasive species.

c. Support development of non-motorized trails and protected natural areas

d. Maintain navigation for boating recreation

e. Promote industry efforts to minimize environmental impacts of recreational infrastructure such as golf courses, campgrounds, ski areas, and marinas (e.g. the Clean Marinas program).

f. Protect significant viewsheds throughout the Watershed

Goal 4: Support efforts of governmental and citizen organizations to implement programs for both the protection and enjoyment of the watershed's natural features.

Objectives

a. Promote watershed protection practices, such as permanent land protection on critical sites, low-impact development techniques and periodic inspection of on-site wastewater systems.

b. Work with governmental agencies, land conservancies and other stakeholders to develop strategies and implement programs that protect water quality and natural resources

c. Work cooperatively with Watershed stakeholders to leverage funds, pool resources and skills, broaden outreach, and implement projects of the Watershed Management Plan.

d. Protect valuable lands that are critical to water quality, fisheries, and wildlife.

e. Monitor water levels to assess seasonally changing flows and improve environmentally sensitive management where levels are set by law or regulation.

Goal 5: Develop an educational component to inform and engage the public in long-term water-quality efforts.

Objectives

a. Support and promote boater safety and stewardship practices.

b. Promote development of a local clearinghouse to facilitate reporting of invasive species.

c. Support sustainable funding for conservation districts and invasive species network.

d. Work through conservation districts to coordinate and promote educational efforts of non-profits and government agencies.

e. Utilize print, broadcast, person-to-person and electronic communication to disseminate a clear, concise message about the public's role in protecting water quality in the Betsie River / Crystal Lake Watershed.

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Chapter 6

Implementation of the Plan

The accompanying charts (categories A through N) detail the tasks necessary to implement the WMP. Each row in the chart identifies one task, followed by columns showing costs, milestones for meeting a reasonable schedule, and other information.

The Watershed Protection Committee (Chapter 7) has the major role of monitoring tasks and coordinating activities among the many partners and stakeholders in the Watershed.

The charts assume a 10-year time frame for implementation of the plan. Costs listed for individual tasks are based on the best possible information and are necessarily subject to refinement. Interim milestones are included for each task so that the Watershed Protection Committee can evaluate progress toward accomplishing the plan goals within the 10-year schedule.

Information and Education tasks are detailed in a similar chart which accompanies the I/E narrative in Chapter 8.

Table 47 on page 151, following the main implementation chart, summarizes the anticipated costs of accomplishing the tasks.

While the tables contain an inclusive listing of tasks to be addressed by Watershed partners, it is helpful to define a smaller set of actions that can be initiated quickly. Defining – and accomplishing – those initial tasks will have a positive impact on water quality, and will help to create a strategic momentum for completing the remaining items on the lists.

Under this strategic plan, items to be addressed immediately upon approval of the plan (or, in some cases, underway during the WMP planning phase) are:

- The baseline monitoring program;
- The non-attainment area on Crystal Lake at Bellows Park and Bellows Road Creek;
- The non-attainment area on Crystal Lake at Beulah Beach and Cold Creek;
- The continuing mitigation of erosion and fish passage issues at road stream crossings;
- Land protection activities, for water quality benefits in wetlands and other significant sites.

The Baseline monitoring program, described and mapped in Chapter 7, is essential to defining the scope of long-term water quality activities. This program relies in part on existing monitoring activities sponsored by lake associations and other agencies. The Benzie Conservation District is in the process of developing costs and staffing estimates for additional monitoring recommended in the plan.

The City of Frankfort has received private funding to redesign and update the infrastructure at Bellows Park. Work may begin in the summer of 2016 to improve stormwater infiltration and reduce runoff at the site. It is anticipated that the project will reduce the possibility of *E. coli* contamination at the site, as well as limiting sediment erosion into Crystal Lake.

Actions to address the complex situation at Beulah Beach and Cold Creek are detailed in Category N of the table. This site requires a sequence of tasks to define the stream hydrology, stabilize soils, reduce storm runoff and identify the sources of *E. coli* contamination. The Benzie Conservation District and Crystal Lake & Watershed Association have jointly applied for a grant to monitor Cold Creek flows, while the Natural Resource Conservation Service is in process of developing a revegetation plan for former agricultural land at the site.

Some 130 road stream crossings exist throughout the Watershed. Many of these sites have aging and/or failing infrastructure that inhibits fish passage or introduces sediment into the waterway. Conservation Resource Alliance and the Betsie River Watershed Restoration Committee have protected a number of crossings through grant funding and cooperation with the local road commissions. Updating of the stream crossing inventory as part of the WMP process will allow this work to continue.

Grand Traverse Regional Land Conservancy has the institutional infrastructure in place to accomplish land protection through donations, purchases or conservation easements on parcels of property with significant water quality benefits. At the time the WMP is under review, the Conservancy is working cooperatively with Benzie County and the Crystal; lake & Watershed Association to purchase and restore a parcel in the floodplain of the Crystal Lake Outlet.

For each task, the charts list one or more "Project Partners." Where multiple partners are given, the organization listed first and in bold, underlined text, is the lead organization working to accomplish that task. The phrase "lake assocs" is used to indicate that each lake association is the lead organization on its specific lake. Where the letter "X" appears in any milestone column, it indicates that no activity is anticipated in that milestone period. The letter "C" is used to indicate that activity continues from the prior column.

The implementation task listing, like the overall WMP, is intended as a "living document" to be revised periodically by the Watershed Protection Committee as tasks are accomplished and new information becomes available.

Table 29 - Category A: Shoreline/Streambank Issues

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
A1	Restore/protect high priority streambank erosion sites on the Betsie River and tributaries, using whole tree revetments or stone, as appropriate to each site: 21 sites totalling 1740 linear feet rated as severe, plus 20 percent (670 l.f.) of 66 sites rated "minor" or "moderate".	2,410 linear feet at $100 per linear foot	$241,000	7 sites completed or funded	18 total sites completed or funded	33 total sites completed or funded	**CRA**, BRWRC, private property owners, MDNR	G.L. Fisheries Trust, grants, private property owners	Goal 2c
	Priority - High	Notes	Per 2015 streambank inventory (Item A4) See Streambank inventory map page 108; By reference, full inventory at northernmichiganstreams.org						
A2	Work with Road Commissions and riparian owners to demonstrate BMP's to reduce runoff of sediment, salt and nutrients from public or private roads parallel and adjacent to surface waters	TBD		Identify problem sites	Identify funding for one site	Complete one "model" site	**Lake Assocs**, R.C.'s, CRA, Property owners	Private funds, grants	Goal 2b
	Priority - Medium	Notes	BMPs may include proper ditching, rain gardens, French drains, etc.						
A3	Survey shorelines of Betsie, Crystal, Duck and Green lakes on a 10-year rotation, using photographic images, GIS technology and checklists to assess erosion, shoreline alterations, greenbelts, etc.	$500 per mile	$25,000	Crystal Lake survey completed	Three lakes completed	All four lakes completed	**Lake Assocs**, Conservation dists	Grants, in-kind labor, lake association funds	Goal 2a
	Priority - High	Notes	Satellite imaging and drone photography advances may reduce costs of future surveys						
A4	Update Streambank inventory on Betsie River and major tributaries on 10-year rotation		$8,000	Update Completed	X	2025 Udate	**CRA**, BRWRC	T.U., G.L. Fishery Trust	Goals 2c, 3d
	Priority - High	Notes	Inventory updated in 2015 as part of WMP						
A5	Demonstrate natural shoreline protection techniques on each of the four major lakes.	$5,000	$20,000	X	Sites ID'd; one completed	Four sites completed	**Lake Assocs**, Conservation dists, Private owners, Natural shoreline partnership	Private shoreland owners, lake association funds	Goals 2a, 2c, 2d
	Priority - Medium	Notes							
A6	Develop real-time monitoring of Crystal Lake and Duck Lake water level to improve dam operation and minimize erosion and flooding.	$15,000 to install; $500 annual operaton	$20,000	Installed & operational	Database in use to predict water levels	C	**CLWA**, Benzie Drain Comm., DNR	CLWA funds	Goals 3d, 2g
	Priority - High	Notes	Sensor at Crystal Lake outlet records lake level and temp. Additional sensor locations under consideration						

Table 30 - Category B: Stormwater and Runoff

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
B1	Update stormwater infrastructure and impervious surface maps of all urbanized areas.		$300,000	Frankfort system mapped	Beulah system mapped	C	**Municipal govts.**, NNW, MDEQ, EPA	State and Fed. Grant funds	Goal 1c
	Priority - High	Notes	Beulah and Frankfort have largest stormwater collection systems in watershed. Approved S.A.W. grant will advance this task in Frankfort. Future developments in Interlochen and Elberta will require expanded systems.						
B2	Install filtration at all direct stormwater discharges to Betsie Lake	$10,000 for filtration systems	$150,000	X	Filtration systems installed	C	**Municipal govts.**, NNW, MDEQ, EPA	State and Fed. Grant funds	Goal 1c
	Priority - High	Notes							
B3	Inventory & monitor all tributaries to Crystal, Green, Duck lakes for nutrients, *E. coli*, and other pollutants.	$5,000 per lake	$15,000	Sites inventoried	Sampling taken for *E. coli*, nutrients	Database; regular monitoring in place	Lake Associations	Foundation grants; local donors; volunteer labor	Goals 2b, 2c, 2f
	Priority - Medium	Notes							
B4	Evaluate & mitigate the major hydrology, stormwater, *E. coli* issues at village of Beulah and Cold Creek subwatershed. (See Category N)		See Cat. N				See Category N for detail	Grants, in-kind labor	all goals
	Priority - High (See Cat. N)	Notes	Beulah and Cold Creek issues are detailed in Chapter 4. Implementation tasks are grouped in Category N for convenience						
B5	Inventory erosion & sediment loadings at road ends & parallel roads on Crystal Lake.		$10,000	X	Inventory complete	C	**BCRC**, Frankfort, CLWA, Beulah, Frankfort; Crystal Lake Twp., Benzonia Twp.	Road Commission; Local governments	Goals 2b, 2c, 2e
	Priority - High	Notes							
B6	Use BMP's to mitigate erosion from road runoff at Bellows Park and other sites identified in inventory.		$150,000	BMPs in place	C	C	**Frankfort**, BCRC, CLWA	Private donation	Goals 2b, 2c, 2e
	Priority - High	Notes							

Table 31 - Category C: Planning, Zoning and Land Use – Part 1

Task		Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
C1	Maintain and enforce Overlay Zoning for Crystal Lake and Natural River Zoning for the Betsie River. Support similarily protective zoning around other water bodies, including setbacks, vegetation-cutting regulations, guidelines for turf management and impermeable surfaces, and restrictions on development of steep slopes.	Unknown	$200,000	Zoning in place	C	C	**Twp. Planning comms.**; MDNR, NNW	State and local government funds	Goals 2a-g, 3f, 4a
	Priority - High	Notes							
C2	Identify locally important viewsheds, including North Shore moraine on Crystal Lake; incorporate protection into master plans and local zoning ordinances		no new costs	X	Viewsheds identified by local governments	Zoning protection in place	**TWP planning comms.**; MSUE: NNW		Goals 3f, 4a
	Priority - Medium	Notes	Crystal Lake north shore moraine contains designated "Scenic Corridor" in long-term plan for Sleeping Bear Dunes National Lakeshore						
C3	Develop and adopt ordinance to prevent introduction of terrestrial and aquatic invasive species, and permit treatment of existing infestations		$10,000	X	Ordinances in place	C	**Twp planning comms**; NWISN	Grants, in-kind labor	Goals 2f, 3a
	Priority - High	Notes	Invasive species monitoring and treatment costs included in Category K						
C4	Promote agricultural BMP's for protection of water quality		$2,000	Educational materials available	C	C	**MDARD**, Local gov., Planning comm. MSUE		Goals 4a, 4b
	Priority - Medium	Notes							
C5	Promote cluster development for rural residential development to protect open space and riparian corridors.		$2,000	Educational materials in circulation	C	C	**Twp. planning comms**; MDARD: NNW		Goals 4a, 4b
	Priority - High	Notes							
C6	Promote the adoption of Low Impact Development (LIDs) stormwater design requirements into local zoning ordinances		$5,000	Develop programs	Education programs in place through Networks Northwest	C	**NNW**; Twp planning comms.; MSUE		Goals 2a-e, 2g, 4a, 4b,
	Priority - Medium	Notes	NNW has conducted LID training and promotion activities						

Table 32 - Category C: Planning, Zoning and Land Use – Part 2

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
C7	Encourage local governments to incorporate Low Impact Development (LID) Infrastructure into their planning process		$5,000	X	Education programs in place through Networks Northwest	C	**NNW**, MSUE, Twp Planning Comms.		Goals 1c, 2a-e, 2g, 3a-f, 4a, 4b,
	Priority - Medium	Notes	NNW has LID materials available						
C8	Promote land use patterns for new development that minimize additional impervious surface in the watershed		$5,000	Education programs in place through Networks Northwest	Local government adoption	C	**NNW**, MSUE, Twp Planning Comms.		Goals 1c, 2a-e, 2g, 3, 4b
	Priority - High	Notes							

Table 33 - Category D: Road-Stream Issues

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
D1	Update existing stream crossing inventory every 10 years to reflect changes & document improvements		$20,000	X	X	Inventory updated	**CRA**; BRWRC	SOGL Grants	Goals 2b, 2g
	Priority - High	Notes	Partially updated in 2014 as part of WMP						
D2	Restore & protect all identified high-priority road-stream crossings with appropriate BMP's. Restore & protect additional sites on road-stream crossing inventory as conditions require and funding becoems available.	Varies	$7,750,000 for 24 high-priority sites	Six sites funded or completed by year 3	Sixteen sites funded or completed by year 7	24 sites funded or completed by year 10	**CRA**; Road Commission.; MDNR; BRWRC	Grants; local road funds; MDOT	Goals 2b, 2g
	Priority - High	Notes	See high-priority site list page 105; complete inventory by reference on Northernmichiganstreams.org						
D3	Identify sites where roads run parallel & adjacent to surface water. Work with property owners & road comm. to minimize movement of sediments, nutrients, salts, etc. into adjacent water		$20,000	X	Sities identified	Demonstration site completed	**CLWA**, Road commissions., BWC; BRWRC, CRA	Grants, in-kind labor	Goals 2b, 2c, 2d
	Priority - Medium	Notes	BMPs may include proper ditching; rain gardens, French drains...						
D4	Develop & institute policies regarding use of dust control agents on unpaved roads near surface waters. Institute BMPs to prevent dust-control agents from entering surface waters.	Unknown		X	Policy in place in all counties	C	**Road commissions.**; Lake Assocs.; BRWRC; CRA	Road Commission funds	Goal 2b
	Priority - High	Notes							
D5	Develop permanent solution for public access, erosion control and traffiic at failed Haze Rd. crossing of Betsie River. Preferred option is conversion of site to recreational access facility.	$500,000	$500,000	Design and planning in place	Task Completed	C	**BCRC**; BRWRC; CRA; MDNR; Weldon Twp.	Grants	Goals 2b,3b; 3c
	Priority - High	Notes							
D6	Based on water quality and traffic issues, study and implement long-term solutions to conditions at aging rural-road stream crossings, including those at Nostwick and Reynolds roads.	Unknown	$500,000 to $2,000,000	X	Study initiated	Study and planning complete	**BCRC**; Manistee and G.T. Rd. Commissions.; CRA; BRWRC; MDNR	Road Commission Funds; MDOT funds; special grants	Goal 2b
	Priority - Medium	Notes	High estimate is for cost of bridge replacements						

Table 34 - Category E: Land Protection and Management

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
E1	Review & update priority parcel analysis every 10-years. Inform owners of high/medium priority parcels to encourage land protection		$5,000	Analysis and Map in Place	C	Map updated in 2025	**GTRLC**	GTRLC	Goals 4a, 4d
	Priority - High	Notes	See map page 117						
E2	Assist and support state and/or local government acquisition of property for protection of water quality.		$1,200,000	One site acquired	Three total sites acquired	Four total sites acquired	**GTRLC**; Local governments; MDNR	Nat. Res. Trust Fund; EPA and MDEQ funding; Local Govt funds; private donors	Goals 4c, 4d
	Priority - High	Notes	All acquisitons on willing-seller basis, when funds are available						
E3	Continue and support land-protection and land purchase activities on high-priority sites throughout watershed, including conservation easments and transfer/purchase of development rights where appropriate.		$500,000	X	Two sites protected	Five sites protected	**GTRLC**, MDNR	Nat. Res. Trust Fund; EPA and MDEQ funding; private donors	Goals 4c, 4d
	Priority - High	Notes	Transactions with willing sellers only						
E4	Promote participation in NRCS programs and Michigan Agriculture Environmental Assurance Program (MAEAP) to encourage BMP's in agricultural operations	$1,000 per assessment	$8,000	Five farms MAEAP certified	Eight farms MAEAP certified	C	**MDARD**; Cons. Districts; MSUE; NRCS; private landowners	MDARD Staff funding; Cons. Districts; MSUE; NRCS, private landowners	Goal 3g
	Priority - Medium	Notes	MDARD Staff conducts MAEAP assessments						
E5	Document and support managed grazing practices and sustainable agriculture at appropriate sites, especially historic farm fields.		none known	X	Inventory of grazing operations completed	C	**Grow Benzie**, MDARD, MSUE, NRCS	NRCS and SARE Funding	Goal 3g
	Priority - Low	Notes							
E6	Purchase vacant, flood-prone residential parcel on Crystal Lake Outlet at M-115. Restore flood plain and incorporate property into adjacent county parkland.		$150,000	Purchase completed	Restoration completed	C	**GTRLC**, Benzie County, CLWA	FEMA grant, county funds, CLWA cost share, private donors	Goals 41, 4c, 4d
	Priority - High	Notes							

Table 35 - Category F: Habitat for Fish and Wildlife – Part 1

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
F1	Maintain multiple-use management policies on public lands. Preserve upland habitat and wildlife corridors. Discourage new roads in state forest and wetland areas. Require BMPs for all logging.		no new ciosts	Current policies in place	C	C	**MDNR**; private landowners; sportsmans orgs.		Goals 3a, 3b
	Priority - High	Notes							
F2	Conduct fishery surveys on 10-year cycle to moni-tor changes & evaluate stocking & managment programs on the following: Betsie River and tributaries, Betsie Lake, Crystal Lake, Duck Lake, and Green Lake	$8,000 per lake	$40,000 per 10-years	All Fishery studies current within past 10-years	Restudy Betsie Lake and Betsie River	Restudy Green, Duck and Crystal lakes	MDNR	MDNR Funds	Goals 1b, 2a, 3c
	Priority - High	Notes	Fisheries Report included as "Appendix C: Status of the Fishery Resource Reports" on page 243						
F3	Maintain current fish stocking & management programs unless changes are warranted by scientific studies		No new costs	Current policies in place	C	C	MDNR	MDNR funds, Grants, in-kind labor	Goal 3a
	Priority - Medium	Notes							
F4	Evaluate, monitor & docu-ment nearshore habitats in Crystal, Duck, Green, and Betsie lakes for juvenile fish and invertebrate populations. Update on 10 year cycle.	See Task I1 on page 143	See Task I1 on page 143	See Task I1 on page 143	See Task I1 on page 143	See Task I1 on page 143	**Lake assocs**; conserva-tion dists. Volunteer assistance	Volunteer monitor-ing grants; MDEQ funds	Goals 1b, 2f
	Priority - Low	Notes							
F5	Evaluate & document stream and streamside habitat, including shade and forest cover for the Betsie River and major tributaries including the Little Betsie and Dair Creek		$12,000	X	X	Task Com-pleted	**MDNR**; GTB; BRWRC; Cons. Dists.; CRA	Trout Unlim-ited; Tribal grants	Goals 1b, 2e
	Priority - Low	Notes	LLWFA provides data to initiate this task						
F6	Restudy & document habitat and fishery potential in each of small lakes and streams in watershed, many of which have not been evaluated in more than 50 yrs.	varies	$50,000	X	Study complete	Evalua-tion report published	**MDNR**, Trout unlim-ited, local sportsmen groups	Grants; MDNR Funds	Goals 2f, 3a
	Priority - High	Notes							

Table 36 - Category F: Habitat for Fish and Wildlife – Part 2

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
F7	Evaluate Grass Lake flooding to determine if it continues to fulfill intended wildlife enhancement purposes; recommend changes if appropriate, consider wild rice planting, maintain dam until evaluation is complete.		$10,000	Evaluation complete	C	Management implemented	**MDNR**; GTB; BRWRC; Ducks Unlimited	State Firest funding; Tribal grants	Goals 2e, 3b, 3d, 4d
	Priority - High	Notes	See Grass Lake discussion starting on page 121						

Table 37 - Category G: Recreation, Safety and Human Health

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
G1	Monitor all public beaches for *E. coli* & other potential health hazards weekly during summer season. Report advisories & beach closings to public	$1,000 per year per beach	$40,000 (four beaches; 10 years)	All beaches in testing program	All beaches	All beaches	**Health Depts.**; BWC; Lake assocs.	MDEQ grant; local gov. lake assoc funding as necc.	Goals 1a, 1e
	Priority - High	Notes	Currently supported by MDEQ grant to Watershed Center of Grand Traverse Bay						
G2	Develop & implement a comprehensive public access plan for the Betsie River. In accord with Natural River regulations, develop access sites in such a way as to support public use while minimizing streambank erosion, invasive species and other environmental impacts.		$200,000	Plan developed	Property acquired if necessary	Task completed	**MDNR**, BRWRC, GTRLC, Riparian owners, river guides, canoe liveries; the public, township govts	Mich Water Trail program; Nat. Res. Trust Fund Grants	Goals 3b, 3c, 3d
	Priority - High	Notes	Michigan water trail grant proposal submitted						
G3	Initiate "adopt a stream" or similar volunteer program for ongoing river clean-up and tree management.	$2,000 per year	$20,000	Program implemented	C	C	**BCD**; paddle clubs; river guides	Conservation District staff support; volunteer in-kind labor	Goals3b; 5a
	Priority - Medium	Notes							
G4	Develop a program to monitor occurrences of Swimmer's Itch in affected water bodies; including Crystal, Green, Duck lakes.	$2,000 per year	$20,000	Monitoring implemented	C	C	**MSIP**, BCD, Lake assocs, Oakland Univ.	Grants, Legislative appropriation, private donors	Goal 1e
	Priority - High	Notes							
G5	Fund research and mitigation activities to manage or prevent Swimmer's Itch	$60,000 in 2016	$400,000	Pilot program implemented	C	C	**MSIP**, BCD, Lake assocs, Oakland Univ.	Grants, Legislative appropriation, private donors	Goal 1e
	Priority - High	Notes	CLWA and MSIP are developing a long-term strategy with other watersheds						
G6	Encourage owners of marinas and golf courses to follow BMP's (e.g. Clean Marina Program) developed by their professional organizations. Use media to recognize water-quality enhancements achieved through this voluntary effort	$500 per operation	$6,000	X	50 percent of affected businesses participating	100 percent of affected businesses participating	**WPC**, Business owners, chambers of commerce, local media	Private businesses	Goals 3e, 5e
	Priority - Medium	Notes							

Table 38 - Category H: Hydrology and Groundwater

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
H1	Install and monitor permanent gauges throughout watershed to evaluate & report stream flow and high-low water conditions. Investigate emerging technologies for automatic sensors, if USGS gauging is not available.	variable	$5,000 - $35,000	X	Permanent gauges in place	C	**BRWRC**, Lake Assoc., BCD, USGS	USGS; Local donors	Goals 2g, 3d, 4e
	Priority - High	Notes	Crowdsourced hydrology program in place with staff gauges; automated sensors preferred; $35,000 is estimate for USGS gauging station						
H2	Compile and report information on existing dams and water control structures. Create inventory of unregulated small dams		unknown	X	X	Dam Information complete	**BRWRC**; private landowners		Goal 2g
	Priority - Low	Notes	Major dams are documented. Data needed on private dams on small tribs.						
H3	Work with local government to enact ordinances that regulate installation of new impervious surfaces and mandate BMP's to control stormwater and mitigate impact of new and existing impervious surfaces.		$2,000	X	Stronger ordinances in place	C	**NNW**; Twp planning comms.	Grants, in-kind labor	Goals 2a, 2c, 2d, 2e
	Priority - Medium	Notes							
H4	Initiate programs to educate the public about the role of wetlands in water quality		$5,000	X	Wetland program offered to schools and service groups	C	**BCD**; MDNR, Twp. Planning comms.; GTRLC	Conservation Districts; Lake Associations	Goals 3a, 3b, 3c, 4d
	Priority - Medium	Notes	Wetland education costs also included in I/E progam estimates						
H5	Adopt state and local rules, protective of groundwater, to monitor and regulate the practices of horizontal drilling & hydraulic fracturing for oil & gas extraction, including associated infrastructure and disposal facilities		unknown	Michigan regulations revised	C	C	**Legislature, MDEQ**, Twp planning comms.		Goal 2e
	Priority - High	Notes	State rules revised in 2015						

Table 39 - Category I: Water Quality Monitoring

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
I1	Continue & expand volunteer stream monitoring program for biological markers. Expand monitoring for benthic invertebrates to sites in Crystal, Green, Duck, Betsie, and other lakes	$5,000 annually	$50,000	X	Two lake monitoring sites completed	C	**BCD**, Lake associations	Stream monitoring grants; MDEQ funds	Goals 1b, 5d
	Priority - High	Notes	See also Task F4 on page 139						
I2	Continue regular phosphorus and chlorophyll-a monitoring by lake associations & Cooperative Lakes Monitoring Program. Expand this program to include all public bodies of water.	$500 annually	$5,000	X	All lakes included in CLMP	C	**Lake assocs.**; BWC; CLMP; BCD	Lake Assocs	Goal 1b
	Priority - High	Notes							
I3	Develop a database of water quality information to be maintained on publicly accessible website such as the Benzie Conservation District, Networks Northwest or other organizations	See Item O1	See Item O1	X	Database completed and accessible to Public	C	**BCD**; NNW; CRA	Grants, in-kind labor	Goal 5b
	Priority - Medium	Notes	Included in Information/Education Task No. O1 (Chapter 8)						
I4	Continue weekly *E.coli* monitoring on public beaches	See Item G1	See Item G1	See Item G1	C	C	**Health depts.**; BWC; lake assocs.	Grants, local govt., Lake Assocs	Goal 1a
	Priority - High	Notes							
I5	Continue regular Hydrolab monitoring of temperature & oxygen levels in lakes	$600 per lake per year	$24,000	Monitoring program in place through BCD and lake associations.	C	C	**Lake assocs.**; BCD;	Lake Assocs	Goal 1b
	Priority - High	Notes	Benzie Conservation Dist. performs sampling under contract with lake associatons.						
I6	Continue MDEQ monitoring program to track stream biology		No new costs	X	Monitoring on five year cycle	C	MDEQ	MDEQ Funding	Goals 1b; 3a
	Priority - High	Notes							
I7	Expand and coordinate existing monitoring programs to monitor for nutrients, turbidity, flow and other markers throughout watershed.		$50,000	Monitoring in place on large water bodies	C	All waters included in program	**Lake Assocs**; BWC; MDEQ; CLMP	Lake associations, Grants	Goals 1a thru 1e
	Priority - Medium	Notes	See monitoring plan and locations, Chapter 7						

Table 40 - Category J: Wetlands

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
J1	Identify, evaluate, and publicize wetlands for habitat value, water quality benefits, and flood control benefits. Provide Landscape Level Functional Wetland Analysis maps to all planning agencies.		$2,000	Mapping and educational materials available	C	C	**NNW**; Twp. Planning Comms; local media; schools	Conservation Districts; grants	Goals 3a, 2e, 5c, 5d, 5e
	Priority - High	Notes	Landscape Level Functional Wetland Analysis completed for this watershed by MDEQ; Maps included in "Appendix G: Large Maps" on page 397.						
J2	Restore health of wetlands at the Trapp Farm Nature Preserve and surrounding road corridors and private parcels		See Cat N				**NRCS**; GTRLC; MDOT; Drain Comm.; Private owners		All goals
	See Cat. N	Notes	NRCS holds conservation easement on much of this site.						
J3	Identify for preservation existing wetlands adjacent to lakes and streams, including those near Green and Duck lakes		Cost included in Task E1	GTRLC Priority parcel map included in WMP	C	C	**GTRLC**; Green Lake Twp. MDEQ	Grants, in-kind labor	Goal 2e
	Priority - Medium	Notes	Priority parcel mapping completed by GTRLC. See page 117						
J4	Restore wetlands throughout the watershed, where appropriate to enhance biological and hydrological values.		$200,000	X	Two sites funded	C	**Private Landowners**; NRCS, MDEQ	NRCS program funding	Goal 2e
	Priority - Medium	Notes	Trapp Farm Nature Preserve not included - See Catagory N						

Table 41 - Category K: Invasive Species

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
K1	Develop terrestrial and aquatic invasive species monitoring program for entire watershed, use ISN staff and trained volunteers	$20,000 annually	$200,000	ISN Map of terres-trial invasive species included in WMP	Aquatic IS listed for all bodies of water	C	**ISN**; BWC; BCD, lake assocs	Multi-county grant fund-ing through ISN; lake associations for aquatics	Goals 2f, 3f, 5b, 5c, 5e
	Priority - High	Notes	Estimate includes existing funding through ISN						
K2	Use information from the monitoring program (K1) and existing strategies to develop and implement a comprehensive invasive species strategy, which will include elements of priori-tization, control, education, and habitat restoration.		$100,000	Strategy approved	Program in operation	C	**ISN**; Cons. Dists; Lake Assocs; Local govt.	ISN; Local Govern-ments; special as-sessments	Goals 2f, 3f, 5b, 5c, 5e
	Priority - High	Notes							
K3	Develop and implement plans to control or eradi-cate invasive phragmites, including the major phragmites infestation near the mouth of Betsie and re-vegetate the area with native plants		$100,000	X	Assessment completed	Treatment applied if appropriate	**FOBB**; MDNR, MDEQ, CRA, ISN	Grants, in-kind labor; local govt funds; special as-sessments	Goals 2f, 3f, 5b
	Priority - Medium	Notes	Costs not calculated for major infestation near Betsie Lake. Impact of rising water levels must be evalu-ated.						
K4	Research boat-washing methods and promote boat washing facilities throughout the watershed. Continue operation of Crystal Lake boat wash	$5,000 to $40,000 per site depend-ing on type of facility	$150,000	Boat wash facilities in use at Crystal Lake Yacht Club and DNR Access site	Faciities available at one addi-tional water body	C	**CLWA**; Lake assocs, Man-istee County, MDNR	Lake Assoc. funds, state grants	Goals 2f, 4b, 4c
	Priority - High	Notes							
K5	Develop educational and demonstration facilities for cleaning fishing gear at popular river entry sites	$1,000 per demo site	$1,000	Demon-stration equipment in place at Homestead Dam site	C	C	**BWC**; Conserva-tion dists; sportsmans orgs.	Private donations, volunteer labor	Goal 2f
	Priority - High	Notes	Invasive New Zealand Mud Snails have been found in nearby watersheds						
K6	Treat new infestation of Eurasian watermilfoil at south end of Duck Lake	$28,000 first year	$56,000	Survey completed, treatment begins	C	C	**GLDL**; Green Lake Township	Special assessment district	Goals 2f, 4b, 4c
	Priority - High	Notes							

Table 42 - Category L: Wastewater and Septic Systems

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
L1	Work with local governments to establish and enforce uniform mandatory "inspection-on-sale" regulations for septic systems throughout watershed	$500 per inspection	unknown	Program in place in Benzie County	Program expanded to additional counties	C	**Health depts**; county govs; NNE	Private property owners	Goal 4a
	Priority - High	Notes							
L2	Consider rules to ease the creation of community systems or other alternatives where individual septic systems are problematic		unknown	X	One new community system in palce	C	**Twp planning comms**; Health depts., NNW	Private property owners and developers	Goals 4a, 4b, 4c
	Priority - Medium	Notes							
L3	Develop clear educational and enforcement procedures for use of holding tanks		$4,000	Educational materials distributed to holding tank owners	C	C	**Health Depts**; Township govs	Grants, in-kind labor	
	Priority - Medium	Notes							

Table 43 - Category M: Navigation – Part 1

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
M1	Maintain appropriate depths in Betsie Lake to function as a recreational harbor & harbor of refuge		Unknown	Dredging complete in 2014	X	X	**USACOE**; Frankfort-Elberta; MDEQ; MDNR	State waterways funds; federal grants	Goals 2g, 3d
	Priority - High	Notes	Dredged with federal funds in 2013; Future needs highly dependant on Lake Michigan water level.						
M2	Monitor water level at mouth of Betsie River near M22. If necessary, develop BMP's to ensure passage of small boats and migrating fish during periods of low water		Unknown	X	X	X	**WPC**, MDNR, USACOE, Frankfort-Elberta		Goals 2e, 2g, 3a
	Priority - Medium	Notes	Water levels critically low in 2012; adequate in 2015						
M3	Manage water-control structures to maintain Crystal Lake and Duck Lake within court-mandated high and low water levels to minimize storm-event erosion and to ensure Spring and Fall boat access	$6,000 per year	$60,000	Continued operation	C	C	**Benzie and G.T. drain commissions**; lake assocs; county govs	County funding; Grants, in-kind labor	Goal 4e
	Priority - High	Notes	Cost estimates for management of level-control dams only. See also A6						
M4	Develop access system for upper Betsie River to ensure access for non-motorized craft while minimizing erosion		See G2	Access plan approved	C	Access sites developed per plan	**MDNR**; BRWRC, Property owners; Benzie Park & Rec. Comm	Michigan Water Trail Grant	Goals 3b, 3d, 5a
	Priority - High	Notes	See Item G2						
M5	Monitor aquatic and shoreline weeds - especially phragmites and Eurasian watermilfoil throughout watershed. Take remedial action when/if weed growth threatens recreational navigation	Monitoring only, $2,000 annually per lake	$60,000	Monitoring in place on Crystal, Duck, Green lakes	C	C	**Lake assocs**, ISN, BWC, conservation dists	Grants, donations, special assessments	Goals 2e, 2f, 2g, 5b, 5c
	Priority - Medium	Notes	Mitigation costs for Duck Lake included in task K6						
M6	Preserve and maintain historic light station and breakwall structure in Frankfort		$400,000	Engineering complete	C	Restoration tasks complete	Frankfort	Lighthouse grants; private donors	Goals 3d, 3f
	Priority - Medium	Notes							

Table 44 - Category M: Navigation – Part 2

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
M7	Assign MDNR or Conservation District personnel to participate actively in annual task of opening Betsie River for watercraft navigation in order to protect aquatic habitats		$5,000	Cooperative process in place	C	C	**MDNR**; BCD; private canoe liveries, river guides	Private donors	
	Priority - Low	Notes							

Table 45 - Category N: Beulah | Cold Creek Area of Special Concern – Part 1

Task		Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
N1	Inventory Beulah stormwater system. Design and install BMP's (e.g. rain gardens, infiltration trenches) to minimize erosion to Crystal Lake and *E. coli* on Beulah Beach. For efficiency, this project should be coordinated with village streetscape project and Cold Creek remediation.		$1,000,000	X	Inventory and design complete	Project complete	**Beulah Village**; Private businesses; MDEQ; MDOT	MDEQ SRF loan, SAW grant , Local match	Goals 1a; 1c; 2c; 2d;
	Priority - High	Notes	See Critical Area discussion on page 109						
N2	Complete revegetation of streambanks in Trapp Farm Nature Preserve, per plans under development by NRCS, with long term monitoring and vegetation management by NRCS.		$200,000	Initial vegetation plantings	Continued monitoring	Continued monitoring	**NRCS**; GTRLC	NRCS Funding in place	Goals 2d; 2e; 3b
	Priority - High	Notes	NRCS holds conservation easement on critical Trapp Farm acreage; revegetation design to be finalized in 2016.						
N3	Complete engineering study of Cold Creek subwatershed, to determine sources and quantities of sediment, nutrients and E.coli entering Crystal Lake. Recommend remediation, which must include protection of existing fishery and wetland function.		$50,000	Study and planning compete	See N4 & N5	See N4 & N5	**Beulah**; Benzonia Twp. CLWA; Benzie Drain Comm.	Grants, in-kind labor; private donors	Goal 1; Goalls 2d; 2e; 2f
	Priority - High	Notes							
N4	Based on information from N3, design and implement a long-term monitoring and management component to ensure efficient and timely cleaning of Cold Creek Sedimentation Basin.	$9,000 per year	$90,000	Project implementation complete	Monitoring continues	Monitoring continues	**Beulah Village**; Benzonia Township	Village & Township funds; See N8	Goal 1; Goal 2d
	Priority - High	Notes	This item implements part of study envisaged in N3						
N5	Based on information from N3, design and implement BMP's to minimize the identified problems on Cold Creek and protect the stream's resource benefits.		$250,000	X	Design & implementation complete	Monitoring continues	**Beulah Village**, Benzonia Twp. GTRLC	DEQ NPS Grants; local match	Goal 1; Goals 2d, 2e, 2f
	Priority - High	Notes	This item implements part of study envisaged in N3						

Table 46 - Category N: Beulah | Cold Creek Area of Special Concern – Part 2

	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
N6	Protect existing viable businesses in historic wetland-fill area on east side of US31. Allow no additional impervious surfaces in this critical area. Consider removal of impervious surfaces from parcels with no operating business or residence.		$50,000	X	Impervious surface removed from two sites	C	Beulah Village and Benzonia Twp planning commissions	FEMA	Goal 3
	Priority - Medium	Notes							
N7	Install interpretive trail or overlook in Trapp Farm to provide public access and education at the site, following completion of N2 and N5.		$30,000	X	X	Trail or overlook complete and open to public	GTRLC	Private donations	Goal 3c
	Priority - Medium	Notes	Environmental conditions make restoration of full trail system difficult at this site.						
N8	Develop long-term funding component (e.g. Special Assessment or other) for maintenance of the Sedimentation Basin and management of Cold Creek and to ensure that costs are fairly spread among benefiting parties.	Included in N4	Included in N4	Public Discussion	Implementation with public support	C	**Benzie Drain Commission**; Beulah Village and Benzonia Twp govs; property owners; CLWA.	TBD: Local government, private property owners	Goal 4d; goal 5
	Priority - High	Notes	This item is to ensure long-term management of infrastructure created per above items.						

Table 47 - Implementation Task Budget

Category	Anticipated costs
A: Shoreline and Streambank issues	$314,000
B: Stormwater and run-off (Excluding Cat. N)	$625,000
C: Planning, Zoning and Land Use	$229,000
D: Road-Stream Issues	$10,290,000
E: Land Protection and Management	$1,863,000
F: Habitat for Fish and Wildlife	$112,000
G: Recreation, Safety and Human Health	$686,000
H: Hydrology and Groundwater	$42,000
I: Water Quality Monitoring	$129,000
J: Wetlands	$202,000
K: Invasive Species	$607,000
L: Wastewater and Septic Systems	$4,000
M: Navigation	$525,000
N: Beulah Cold Creek Critical Area	$1,670,000
O: Information and Education	$83,000
Total Anticipated Cost	$17,381,000

Below are abbreviations for organizations listed as potential partners for implementation tasks.

BCD	Benzie Conservation District
BLHD	Benzie-Leelanau Health Department
BCRC	Benzie County Road Commission
BRWRC	Betsie River Watershed Restoration Committee
BWC	Benzie Watersheds Coalition
CLMP	Cooperative Lakes Monitoring Program
CLSIP	Crystal Lake Swimmer's Itch Partnership
CLWA	Crystal Lake &Watershed Association
CRA	Conservation Resource Alliance
EPA	U.S. Environmental Protection Agency
FOBB	Friends of Betsie Bay
GTB	Grand Traverse Band of Ottawa and Chippewa Indians
GTRLC	Grand Traverse Regional Land Conservancy
GLDLA	Green Lake and Duck Lake Association
ISN	Northwest Michigan Invasive Species Network
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MDARD	Michigan Department of Agriculture and Rural Development
MDOT	Michigan Department of Transportation
MSIP	Michigan Swimmer's Itch Partnership
MSUE	Michigan State University Extension
NRCS	Natural Resource Conservation Service
NNW	Networks Northwest
USACOE	U.S. Army Corps of Engineers
USDA	United States Department of Agriculture
WPC	Watershed Protection Committee

Chapter 7

Monitoring and Evaluation Strategies

Betsie River / Crystal Lake Watershed Protection Committee

Watershed planning can be effective only if the goals, tasks and other plan elements are monitored and reviewed on a regular basis to assess progress and compliance. Concrete steps must be taken up front to ensure that monitoring takes place during the plan's anticipated "lifespan" of 10 to 15 years.

To meet this important consideration for the Betsie/Crystal WMP, a Watershed Protection Committee has been organized through the auspices of the Benzie Conservation District and the Benzie Watersheds Coalition

Committee membership includes, at a minimum, representatives from: Manistee, Benzie and Grand Traverse county governments; the Betsie River Watershed Restoration Committee; Conservation Resource Alliance; Crystal Lake & Watershed Association; Friends of Betsie Bay; Grand Traverse Regional Land Conservancy; Green Lake and Duck Lake Association; Networks Northwest; Benzie Conservation District; townships; villages; City of Frankfort; Michigan Department of Environmental Quality; and Michigan Department of Natural Resources.

The committee structure is intended to recognize that a number of government agencies and non-profit organizations have long been active in efforts to preserve and improve separate elements of the watershed. These groups have come together for development of the WMP, but retain their primary interests in subsets of the larger watershed plan.

The Watershed Protection Committee will empower joint action where appropriate, while encouraging component groups to continue and expand their own effective work.

It is anticipated that most actions in fulfillment of the Betsie/Crystal WMP will be taken by component groups, rather than by the overall Watershed Protection Committee. For example, mitigation of streambank erosion sites will likely remain the purview of the BRWRC and CRA, while Crystal Lake water quality monitoring will continue to be handled by CLWA.

The Watershed Protection Committee will be tasked with monitoring overall progress, maintaining communication among the diverse entities that represent the watershed, and fostering support for watershed management and education.

Benzie Conservation District will provide staff to notify members of meeting times and to develop and distribute information including agendas, minutes and material shared by members.

Component members of the Watershed Protection Committee will provide regular updates of their own activities (meeting minutes, activity reports, grant summaries, etc.) to the Benzie Conservation District for distribution among committee members.

Discussion items may be placed on the agenda at quarterly meetings of the Benzie Watersheds Coalition.

The Watershed Protection Committee will meet a minimum of one time each year, initially at the time and place of the fall quarterly meeting of the Benzie Watersheds Coalition. Subsequent to that meeting, the Committee will prepare and distribute an annual report which will detail progress toward meeting the WMP milestones.

Evaluation Criteria and Milestones

In order to evaluate progress toward meeting the WMP goals and objectives, the Watershed Steering Committee has approved a set of measurable milestones and evaluation criteria.

The specific milestones for each task are included in the chart of implementation tasks in Chapter 6.

For example, in the category of Shoreline/Streambank Issues, task No. A5 envisions completing at least one demonstration of natural shoreline practices on each of the four major lakes (Betsie, Crystal, Duck and Green). As milestones, the plan indicates the sites should be identified, and at least one completed within the first three years after plan approval, with four sites completed within 10 years.

The Watershed Protection Committee will be the permanent body tasked with monitoring progress toward attainment of each of the 14 categories of tasks and milestones. The committee will report annually on progress.

Long-Term Monitoring Plan

Present conditions are of sufficient quality to support the majority of the designated and desired uses of surface water in the Betsie River / Crystal Lake Watershed. For that reason, much of the WMP is focused on preservation of the existing high water quality.

In furtherance of that preservation objective, the plan recognizes the need for long-term monitoring of physical, chemical, biological and social indicators in such a way as to create a baseline of information and to identify future challenges (See Table 48 on page 157, and Map 34 on page 158).

The purpose of this monitoring program is to provide early notice of changes – either positive or negative – and to track multi-year trends so that the community can respond rapidly and appropriately.

The program is structured to create baseline data and produce trend lines to alert the Watershed Protection Committee of emerging threats. Monitoring results will be evaluated relative to the following water quality objectives:

- *E. coli* levels in all watershed lakes and streams must meet state water quality standards.
- Dissolved oxygen levels in all watershed lakes and streams must meet state water quality standards.
- Water temperatures of all watershed lakes and streams must meet state water quality standards.
- No statistically significant increase may occur in average total phosphorus concentrations in any of the watershed's lakes and streams
- Macroinvertebrate communities in monitored stream sites should score "good" or "excellent" using the MDEQ procedure 51 scoring metrics for wadable streams.

- Aquatic invasive species communities are reduced to the smallest population levels possible. In no geographic area should there be a statistically significant increase in the area of aquatic invasive species communities.

Action is recommendation at any time monitoring indicates these goals are not being met.

In past decades, at least nine separate entities have performed important monitoring functions in varied segments of the watershed. Results of that monitoring typically not been shared outside the sponsoring organization.

For example, separate lake associations have sponsored work on Crystal, Betsie, and Green and Duck Lakes; the Betsie River Watershed Restoration Committee and Conservation Resource Alliance have characterized the flowing segments of the Betsie; MDNR, MDEQ and the Benzie Conservation District each have studied some fishery and biological parameters.

The effectiveness of that monitoring has been somewhat diminished by the absence of coordination and/or information sharing among the various groups. Creation of the Benzie Watersheds Coalition in 2011 served to improve communication. The WMP seeks to build upon that progress.

Another general issue with past monitoring has been the lack of consistent schedules and/or methods used in gathering some data. For example, phosphorus and Secchi Disk data have been collected on a rigorous schedule on some lakes, but sporadically on others.

Much of the interpretive value of monitoring stems from the creation of data which is consistent and can be compared over time. For that reason, the plan defines a level of basic monitoring that can be sustained over the long-term, even given the limited resources of some of the participating entities. The monitoring described in this section should be seen as a minimum level. Some lake associations may choose to go beyond these minimums.

The WMP seeks to improve coordination by tasking the permanent Watershed Protection Committee with the responsibility to collect, organize and distribute data generated by the member entities.

The monitoring in this program will generally be of moderate cost. The Benzie Conservation District has contracted with some lake associations to conduct the sampling on a reimbursement basis. Some grant support or local donations will be needed in order to accomplish regular monitoring on the smaller bodies of water (Cedar Hedge, Ellis, Bass, Bridge, and Grass lakes), which have no organized lake associations. Additional financial support is also required in order to institute the necessary flow and temperature monitoring on the Betsie River.

Monitoring of Cold Creek and Beulah Beach addresses a portion of the need for an engineering study and mitigation of complex issues in that subwatershed, which is discussed in greater detail starting on page 109 of Chapter 4 of the Watershed Management Plan.

The monitoring strategy includes these elements

(See Table 48 on page 157, and Map 34 on page 158):

- **Sampling for phosphorus, chlorophyll a, dissolved oxygen, temperature and water clarity on a consistent, annual schedule at designated monitoring sites throughout the Watershed (see Map).**

  Phosphorus and Chlorophyll a monitoring will be conducted at least annually on the schedule established by the Cooperative Lake Monitoring Program at sites 1-14. Additional phosphorus monitoring will take place in September (low water level) at sites 12-14. Monthly (May-Oct) phosphorus sampling is required at sites 15-18.

  Depth profiles of temperature and dissolved oxygen (using a Hydrolab sonde) along with Secchi Disk readings will be taken three times annually (April, July, September) at sites 1-10. The April profile will be on the same date as CLMP sampling.

- **Bacterial monitoring at non-attainment sites on Crystal Lake and tributaries.**

  Weekly *E. coli* sampling on Crystal Lake public beaches at Beulah and Bellows Park (Sites 19 and 20). Weather related sampling for *E. coli* on Cold Creek and Bellows Road Creek during two rain-event and two non-rain-event dates each summer. Rain event sampling for *E. coli* at Beulah Beach storm sewer outfalls on two dates each summer.

- **Flow measurements at designated monitoring sites on the Betsie River.**

  Continuous flow and temperature data will be taken at sites 12-14. This requires installation of monitoring devices and monthly uploading of data. The present volunteer flow monitoring program with staff gauges installed in the river will continue under sponsorship of the Betsie River Watershed Restoration Committee until automatic monitoring devices can be purchased and installed.

- **Volunteer stream monitoring for biological stream quality indicators at designated sites annually through the Benzie Conservation District.**

- **Stream monitoring for biological indicators on a five-year cycle through MDEQ.**

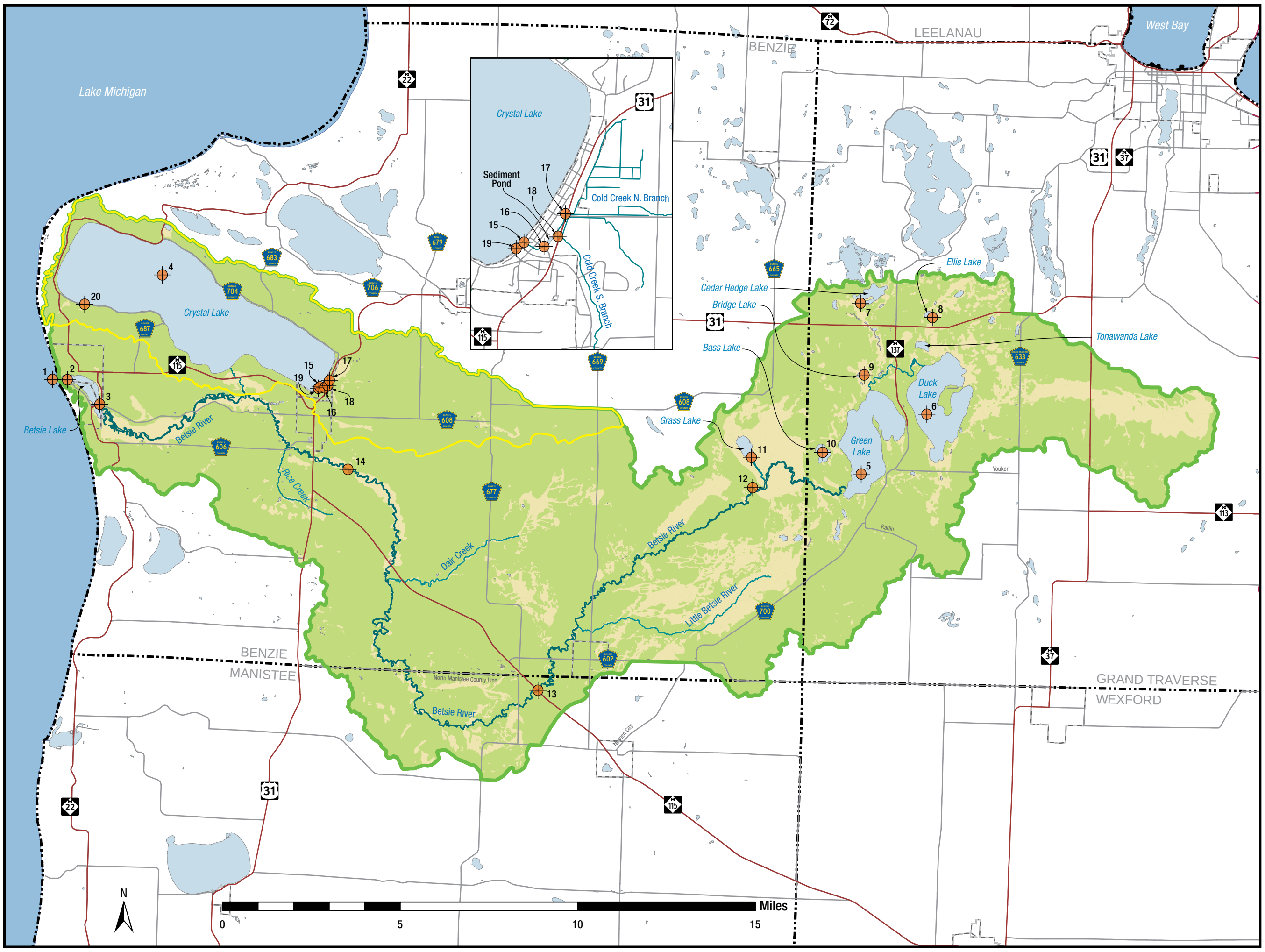
Flow Monitoring in Betsie River

- **Updates of road-stream crossings and streambank conditions on a 10 year cycle.**
- **Updates of fishery studies on Green, Crystal, Betsie and Duck lakes and the Betsie River on a 10-year cycle.**
- **Updates of lake shoreline conditions inventories on a 10-year cycle.**
- **Repeat of Social Indicators Survey after 10 years.**

Table 48 - Monitoring Sites (Key to Map 34 on page 158):

ID	LOCATION	LAT	LONG
1	Frankfort Outer Harbor	+44.629974	-86.247417
2	Betsie Lake West End	+44.630166	-86.246319
3	Betsie Lake East End at M-22 Bridge	+44.619292	-86.220848
4	Crystal Lake Deep Basin	+44.674236	-86.187079
5	Green Lake Deep Basin	+44.600576	-85.788774
6	Duck Lake Deep Basin	+44.624257	-85.757183
7	Cedar Hedge Lake	+44.667142	-85.787977
8	Ellis Lake	+44.663453	-85.748668
9	Bridge Lake	+44.637687	-85.788487
10	Bass Lake	+44.605652	-85.811117
11	Grass Lake	+44.604473	-85.850169
12	Betsie River at Grass Lake Dam	+44.592125	-85.847942
13	Betsie River at Upper M-115 Crossing	+44.507896	-85.969537
14	Betsie River at Homestead Dam	+44.595830	-86.078549
15	Cold Creek at Inlet to Crystal Lake	+44.629636	-86.095976
16	Cold Creek at Lower Sediment Basin Control Structure	+44.629264	-86.093698
17	Cold Creek North Branch at US31 Culvert	+44.632366	-86.090912
18	Cold Creek South Branch at US31 Culvert	+44.630446	-86.091992
19	Beulah Beach	+44.629705	-86.095471
20	Bellows Beach / Bellows Road Creek	+44.661009	-86.231295

Map 34 - Baseline Monitoring Sites



KEY | MONITORING SITES

CITY OR VILLAGE

COUNTY

Monitoring Locations

Chapter 8

Information and Education

Over the long term, watershed protection will occur only with the support of local stakeholders – including residents, businesses, government agencies, boaters and anglers.

For that reason, every Watershed Management Plan includes a detailed proposal for continuing information and education (IE), focusing on the general needs of the watershed and the specific goals and objectives of the plan.

The Goals and Objectives for the Betsie River / Crystal Lake Watershed Management Plan are detailed in Chapter 5 of this plan. The final goal, shown below, relates to the IE component:

Goal 5: Develop an educational component to inform and engage the public in long-term water-quality efforts.

Objectives

a. Support and promote boater safety and stewardship practices.

b. Promote development of a local clearinghouse to facilitate reporting of invasive species.

c. Support sustainable funding for conservation districts and invasive species network.

d. Work through conservation districts to coordinate and promote educational efforts of non-profits and government agencies.

e. Utilize print, broadcast, person-to-person and electronic communication to disseminate a clear, concise message about the public's role in protecting water quality in the Betsie River / Crystal Lake Watershed.

A social indicators survey conducted as part of the planning for this WMP helped to define the scope of the proposed IE component.

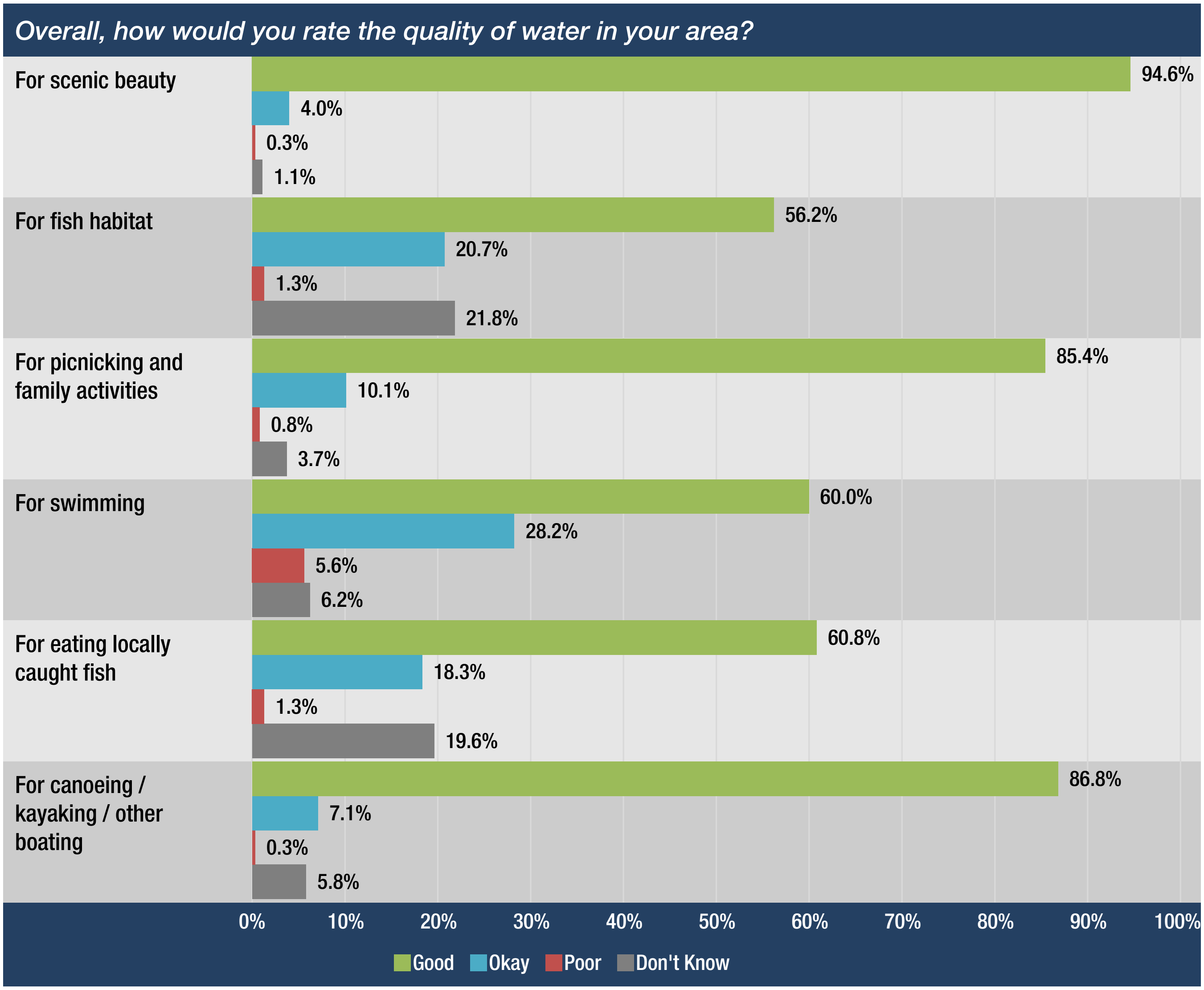
The survey was mailed to 1,000 randomly selected owners of property in the watershed. More than 400 responses were received, and tabulated in a software package called Social Indicators Data Management and Analysis.

Based upon the strong response rate, the survey results are considered to be statistically significant, with a 95 percent confidence level and a 5 percent margin of error.

Detailed survey results are included as Appendix A to this document.

Survey respondents gave high rankings to most measures of water quality in the Betsie/Crystal Watershed, and also showed a high appreciation for the importance of clean water.

Chart 1 - Water Quality Survey



More than 90 percent of respondents indicated agreement or strong agreement with the statement: "The quality of life in my community depends on good water quality in local streams, rivers and lakes."

Nearly 50 percent agreed or strongly agreed that "I would be willing to pay more to improve water quality (for example: through local taxes or fees)."

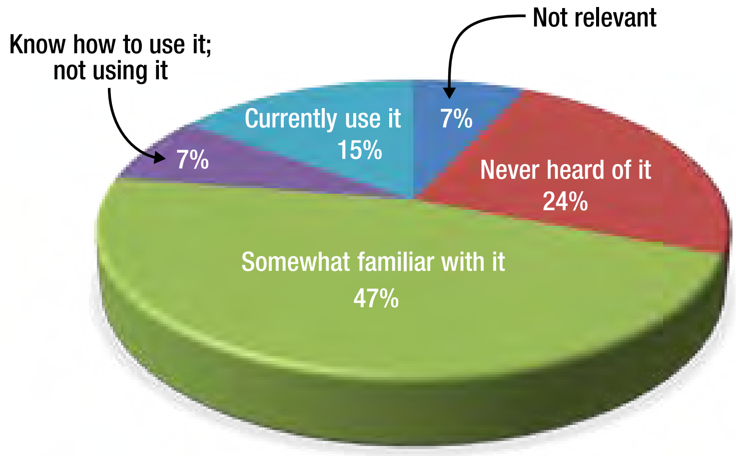
While the survey showed appreciation for high water quality, there was somewhat less awareness of the management practices and conditions necessary to maintain the desired levels of water quality.

Survey results made clear that property owners are well aware of visible impacts – for example litter and goose droppings – but less aware of the importance of some conditions that can't be readily viewed, such as wetland functions and groundwater protection.

The survey asked participants about their familiarity with two management strategies commonly used to preserve water quality: Employing regular maintenance of septic systems, and planting of deep-rooted native plants along shorelines.

Many respondents replied that they were unfamiliar – or totally unaware – of these practices.

Chart 2 - Social Survey - Native Plants



Native Plant Communities Restoration: How familiar are you with this practice?

Taken together, these results provide significant guidance to the development of the Watershed Plan's Information and Education component. Since the public is already aware of the importance of clean water, this component of the plan will identify activities that reinforce that appreciation while providing additional information on best management practices.

The key is to "connect the dots" to show how land use activities such as wetland preservation, low impact development, on-site wastewater system maintenance, and natural shoreland management can contribute to achieving and maintaining the desired water quality.

The IE component for the Betsie River / Crystal Lake Watershed Management Plan includes four major elements to address the needs determined through public comments, Steering Committee discussions and the Social Indicators Survey. The four elements, detailed below, are:

1. General watershed education, including coordination of ongoing activities sponsored by stakeholder groups.
2. Dissemination of information on Best Management Practices for properties with on-site wastewater systems.
3. Shoreland and streambank stewardship information, including natural shoreline demonstrations and BMPs for management of streambanks and shorelines.
4. Strategies for limiting the spread of aquatic and terrestrial invasive species.

The plan is designed to reach a diverse set of "target audiences" while recognizing that those audiences often overlap. For example, it is important that local government and business owners understand the economic importance of clean water, but the plan recognizes that government officials and business people are also likely to be fishermen, property owners, and parents of schoolchildren.

In order to retain credibility, the materials and messages must remain consistent, while emphasizing information that may be of particular relevance to a given audience.

For all audiences, several key messages apply: First and foremost, in this watershed we need not choose between environmental protection and economic health. The two values are inextricably linked, and protecting the environment also benefits the economy.

As the survey results show, the linkage is widely understood, at least in the abstract. But it remains important to restate the case in very specific terms that, for example, spending extra money on regular septic system maintenance can lead to cleaner water, which in turn supports local businesses and protects property values.[20]

In addition, the Information and Education plan emphasizes information that is of particular relevance to specific stakeholder groups:

- Local residents and property owners: Emphasis on personal responsibility for practices that are known to be protective of soil, ground water and surface water: e.g. proper septic system maintenance; proper fertilization procedures for lawns and gardens; the value of native perennial vegetation; proper disposal of used motor oil and hazardous chemicals, etc.
- Hunters/anglers: Best practices to minimize the spread of invasive species (cleaning boats and gear; properly disposing of bait); avoiding damage to streambanks; removing refuse and gear after ice-fishing.
- Tourists/boaters: Offer specific information on how to help preserve the scenic beauty and clear water of the region. Promote activities such as boat washing; picking up litter; removing campfire residue from beaches, etc. Stress the investment the local population has made in protecting and maintaining the local environment.
- Riparians: Stress the impact of clear water on property values; the value of natural streambanks and shorelines, where conditions permit; importance of septic system and holding tank maintenance; BMP's for turf maintenance.
- Builders/developers: Provide information on low impact development; training and certification for natural shoreline work; resources for managing storm water; BMPs for wetlands and sensitive areas.
- Local governments: Advocate for adequate funding and strong enforcement for health and safety regulations; Support zoning and other regulation to protect groundwater, surface water quality and property values for the long term
- Teachers/students: Explore the diverse ecosystems that make up our watershed; provide insight into the biology, chemistry and physics of the watershed; engender an appreciation of the natural world and the connections that exist throughout the watershed.

Element 1 – General Watershed Education:

Target Audience: *All residents and visitors*

A large number of environmental education efforts already exist in the watershed and the surrounding region, reflecting the work of lake associations and other community groups. The WMP envisions a strategy that will coordinate those disparate programs, and support additional offerings where there are perceived gaps.

A major focus will be to create a clearing house of watershed materials and a calendar of events to publicize activities that offer opportunities to engage with the watershed. This will include:

- Publication of a new tri-fold brochure with contact information for resources and project partners. The publication will include a map showing major access sites and monitoring locations, along with watershed concerns, and contact information. Distribution will be through WMP partners and local governments.
- Newsletters, websites, special events and annual meetings of the watershed's active lake and stream associations: The Friends of Betsie Bay, The Crystal Lake & Watershed Association, The Betsie River Watershed Restoration Committee and the Green Lake and Duck Lake Association.
- The Northernmichiganstreams.org Website, which provides detailed reports on streambank conditions and road-stream crossings.
- A dedicated section on the Networks Northwest website, to include electronic copies of this WMP and supporting documents, with links to partners' sites.
- Educational activities sponsored by the Benzie Conservation District, including water tours, natural shoreline workshops, river clean-up days.
- Park, trail and natural area activities sponsored by the Benzie Parks and Recreation Commission, The Friends of the Betsie Valley Trail, The Grand Traverse Regional Land Conservancy, Sleeping Bear Dunes National Lakeshore, Michigan DNR and others
- The annual Benzie County Water Festival, a winter-spring event that features hands-on youth education programs, as well as forums on such topics as invasive species, hydraulic fracturing, toxic algae and water levels.
- Regional events such as the annual Watershed Summit sponsored by the Watershed Center of Grand Traverse Bay and activities sponsored by surrounding watersheds.

Another key is the sharing of resources among the Betsie-Crystal Watershed and adjacent watersheds, including Platte River to the north, Herring Lakes to the South, and the Boardman River to the east. The Betsie, Herring and Platte watersheds together cover the majority of Benzie County, while both Betsie and Platte extend into western townships of Grand Traverse County and abut the Boardman Watershed.

Each of these watersheds is relatively small, and their boundaries meander across school district, county and township lines. Because of that, activities sponsored in one watershed are likely to draw participation from the others.

For example, the Crystal Lake Walkabout is an annual field day that provides hands-on learning to middle-school students in the Benzie Central and Frankfort-Elberta school districts. The event has been sponsored by the Crystal Lake & Watershed Association, but in fact the participants come from throughout the county, and interpretative sites have included locations on Lake Michigan, the Betsie River and Betsie Lake, as well as Crystal Lake.

Likewise, an annual “Leave No Trace” educational canoe trip on the Platte River includes students who live in the Betsie River and Herring Lakes watersheds.

Crystal Lake Walkabout

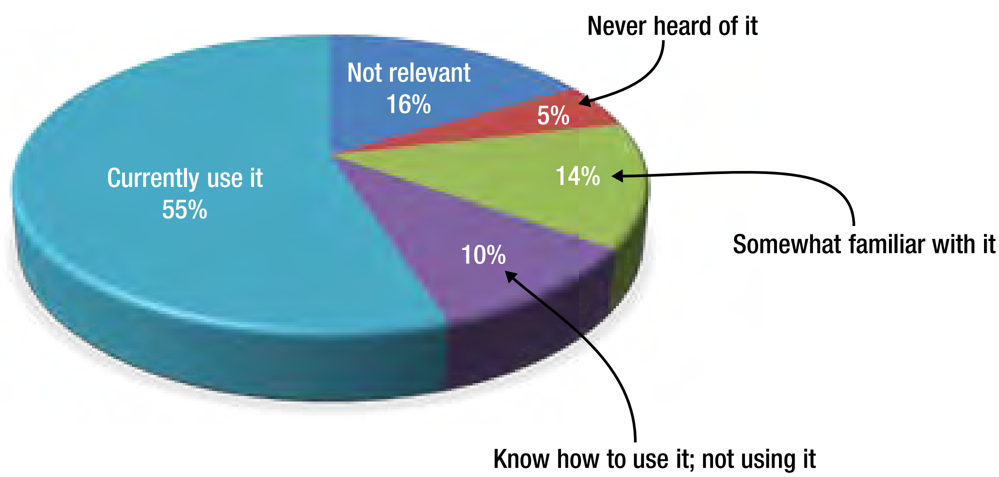
Creation of the Benzie Watersheds Coalition in 2011 provided an ideal venue for resource sharing. The coalition is staffed and coordinated through the Benzie Conservation District. Members meet quarterly and have initiated such projects as joint use of monitoring equipment and planning for a “landowners handbook” that can be customized to individual lakes.

Element 2 – On-site Wastewater Systems:

Target Audience: *Property owners*

As detailed in Chapter 3 (page 82) of this WMP, the majority of residential properties in the watershed are served by individual on-site wastewater systems – primarily by septic tanks and drain fields, but in about 300 instances by holding tanks which must be pumped out regularly.

Chart 3 - Social Survey - Septic Systems Servicing



Regular Septic System Servicing: How familiar are you with this practice?

These systems, when properly sited and maintained, can efficiently break down bacteria and nutrients in household waste, while protecting the environment. However, some property owners unfortunately take an "out of sight, out of mind" attitude toward these systems, and may ignore preventative maintenance.

Without proper attention, the systems may become clogged or overloaded. When that happens, nutrients and/or pathogens may contaminate the soil and ultimately reach groundwater, lakes or streams.

The most important BMP for septic systems (assuming the system is designed and installed properly) is regular pumping, with the waste transported to a facility for proper treatment. In Benzie County, the Betsie Lake Utilities Authority accepts septic waste. In Grand Traverse, the waste may be taken to a dedicated septic waste treatment plant.

Information is readily available on wastewater BMP's, but this information has not been communicated effectively to all property owners. To improve this communication, the Watershed Protection Committee will work with health departments to develop clear and simple information sheets, which can then be included on lake association websites, offered as public service announcements in local media, and mailed to property owners with regular township communications.

Element 3 – Shoreland Stewardship

Target Audience: *Lake and stream waterfront property owners*

The Benzie Conservation District has participated in natural shoreline demonstration workshops. The plan calls for at least one such demonstration on each of the major lakes during the coming 10 years.

In addition, the Crystal Lake & Watershed Association is one of five Northern Michigan lake associations participating in 2015 with the Michigan Natural Shoreline Partnership (MNSP) to develop an innovative "Shoreland Stewards" project as an educational tool for riparian property owners.

MNSP is a public-private group which promotes natural shoreline landscaping to protect Michigan's lakes. MNSP-sponsored activities include: Training contractors and landscape professionals; educating riparian property owners; researching and developing natural shoreline technologies; and encouraging local and state policies to promote natural shoreline management.

The Shoreland Stewards Program is envisioned as a web-based, self-evaluation system to recognize landowners who implement and maintain natural shoreline landscaping. If the development phase is successful, the program may be offered state-wide in coming years. Development funds are coming from the Michigan DEQ and the participating lake associations.

Many threats to designated and desired uses of surface waters in this watershed originate on very small tributary streams. For example, *E. coli* contamination has been documented in small streams entering Crystal and Green lakes. In addition, a number of small dams remain in place on minor tributaries, and small streams are often sites where invasive species thrive and nutrients or sediment may enter the surface water system.

In the spring of 2015, a tour of one-half-mile of a small stream found a dog tethered more-or-less permanently on the streambank, and two gardens placed where overnight rainfall had washed soil into the waterway.

To increase the understanding of small streams and promote the use of BMP's, the WMP will initiate an innovative Small Tributary Education and Management (STEM) project. The STEM project will make use of existing resources, including conservation districts, MSU Extension and native plant advocates, to create new educational materials targeted specifically to owners of property with small stream frontage. The project will employ AmeriCorps volunteers to distribute materials and meet with affected property owners.

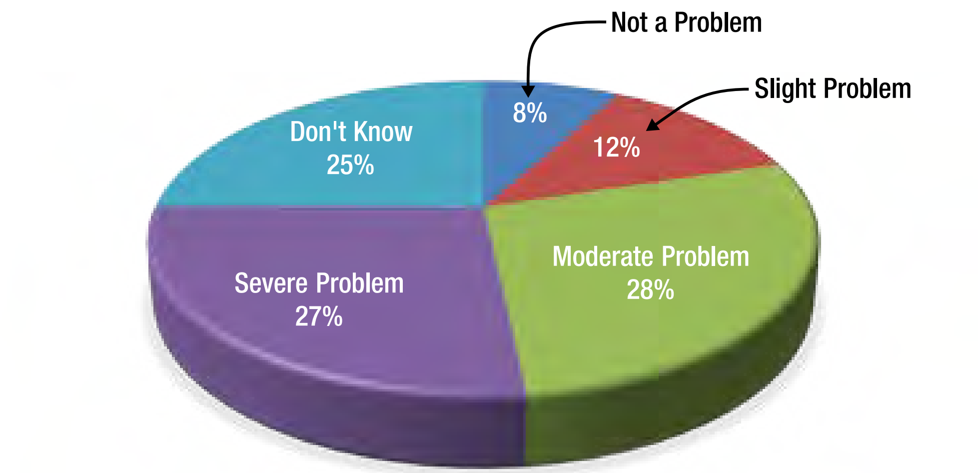
Element 4 – Address Invasive Species

Target Audience: *All residents and visitors*

Aquatic invasive species of concern in the watershed include zebra and quagga mussels, Eurasian milfoil, round gobies, spiny water fleas, sea lampreys, and potentially many others. Terrestrial plants of concern include garlic mustard, Phragmites, narrow leaf cattails Japanese knotweed, baby's breath and more.

The social indicators survey identified invasives as a major water-quality concern. But many residents and visitors may be unable to identify the problem species and may be unaware of the best ways to limit their spread.

Chart 4 - Social Survey - Invasives



In Your Opinion, how much of a problem are Invasive Aquatic plants and animals in your area?

The emerald ash borer likely reached the area in campfire wood transported from previously infested regions; zebra mussels and Eurasian milfoil have been inadvertently introduced to some lakes by recreational watercraft; hikers may accidentally spread garlic mustard seeds along forest trails.

The WMP recognizes that outdoor recreational activities – by both residents and visitors – are vital to the region's economic and cultural well-being. Therefore, it is important that this element of the plan focus on encouraging responsible recreation in ways that minimize the spread of invasives.

The Northwest Michigan Invasive Species Network operates an informative website with photographs and information about invasive plants that occur in the region. Additional ISN resources available to the public include print materials and the opportunity for group presentations and plant identification by network staff.

The Clean Boats, Clean Waters program, sponsored by Michigan Sea Grant, provides informational materials and instructional forums to educate boaters on ways to detect and remove weeds and other invaders before launching into new waters.

On Crystal Lake, a boat-washing station is available free of charge at the MDNR boat launch. The CLWA, developed the boat-washing facility and operates it under a lease with the MDNR. Staff at the facility distribute invasive species information, in addition to washing boats. CLWA and the Crystal Lake Yacht Club are working cooperatively to add a second washing facility at the Yacht Club, where sailing competitions often attract boats from other regions.

Table 49 - Category O: Information and Education Tasks

#	Task	Unit Cost	Estimated Total Cost	Milestone 2016-2019	Milestone 2020-2023	Milestone 2024-2026	Project Partners	Potential Funding Sources	Objectives Addressed
01	Create and maintain Webpage with access to all new and archived Water Quality data	$2,500	$25,000	Website online; data being imported	All new and archived data accessible	Updates continue	NNW; Lake Assocs.; CRA	Networks Northwest, Lake Assocs, CRA	Goal 5
	Priority - High	Notes	May operate as a page in "Benchmarks Northwest" site proposed by NNW. CRA sponsors northern-michiganstreams.org						
02	Develop Aquatic Invasive Species reporting system and website to complement terrestrial I.S. system offered by ISN	$1,000	$10,000	Website online with data from lake and river surveys	Updates continue	Updates continue	BWC; lake assocs; Cons. Dists. ISN, CRA, MDNR	Lake Associations	Goal 5b
	Priority - High	Notes							
03	Develop shoreline handbook with adjacent water groups	$10,000	$10,000	Handbook complete	Distributed by lake and river associations	C	BWC; BCD	Benzie Conservation District; private donors	Goals 5a, 5d
	Priority - High	Notes	This project was initiated by the Benzie Watersheds Coalition. Costs would be shared among several watersheds						
04	Develop brochure with water quality information, monitoring sites and contact information	$2,000 development	$2,000	Brochure design complete	Distribution to partners and the public	Update and continuing distribution	Watershed Protection Committee	CLWA, local foundation grant	Goals 5a, 5d, 5e
	Priority - Medium	Notes							
05	Develop Small Tributary Education and Management project	$1,000 development	$1,000	X	Project material developed and distributed	C	Watershed Protection Committee; BRWRC, MDEQ	Local foundation grant	Goals 5a, 5e
	Priority - Medium	Notes							
06	Reprise Social Indicators Survey	$10,000	$10,000	X	X	Survey readministered to property owners	Watershed Protection Committee	State and or local grant	Goal 5
	Priority - Medium	Notes							
07	Continue Crystal Lake Walkabout for Benzie County middle school pupils, expand to larger watershed as appropriate	$2,500	$25,000	Program in place	Program continues	Program continues	CLWA; BCD; school districts	CLWA, local foundation grant	Goal 5a, 5d, 5e
	Priority - High	Notes							

In delivering these messages it is important to recognize that the Betsie River / Crystal Lake Watershed extends into multiple counties and includes communities that often have only limited interaction. People living at the eastern portion of the watershed, near Interlochen and Grawn in Grand Traverse County are likely to be unaware of programs offered in the Benzie County communities at the western end of the watershed.

To address this problem, the plan employs a "layered" strategy, to coordinate educational and informational activities at neighborhood, county and regional levels.

Of the tasks outlined in the Information/Education table on the preceding page, the creation of an on-line water inventory of water quality data (Task O1), and the development of a landowner handbook (Task O3) should be accomplished quickly. Completion of these two items, along with continuation of existing educational events, will help to encourage completion of the remaining tasks during the life of the plan.

The Landowner Handbook project will fulfill a need that is recognized in this WMP and in a recent plan completed for the Platte River Watershed. It may also become an element of the IE component of the Herring Lakes plan, currently under development.

The IE component is structured as a continuing project, to be directed and monitored by a Watershed Protection Committee with representatives from all major stakeholders. The committee, as described in Chapter 7 of this WMP, will be created administratively as a subgroup of the Benzie Watersheds Coalition, with staff assistance from the Benzie Conservation District.

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Endnotes

Chapter 1

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(All appendices, if not included in this copy of the document, may be accessed online at nwm.org/brclwp)

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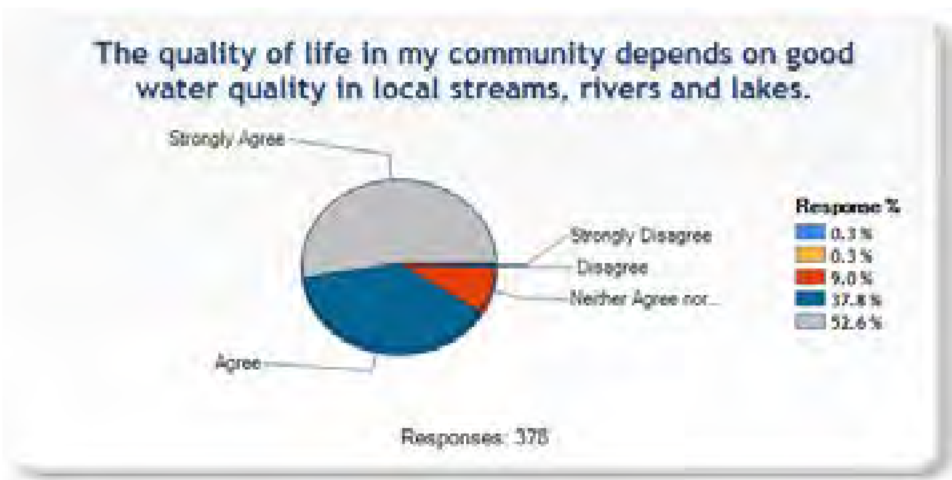
Appendix A: Analysis of Social Indicators Survey

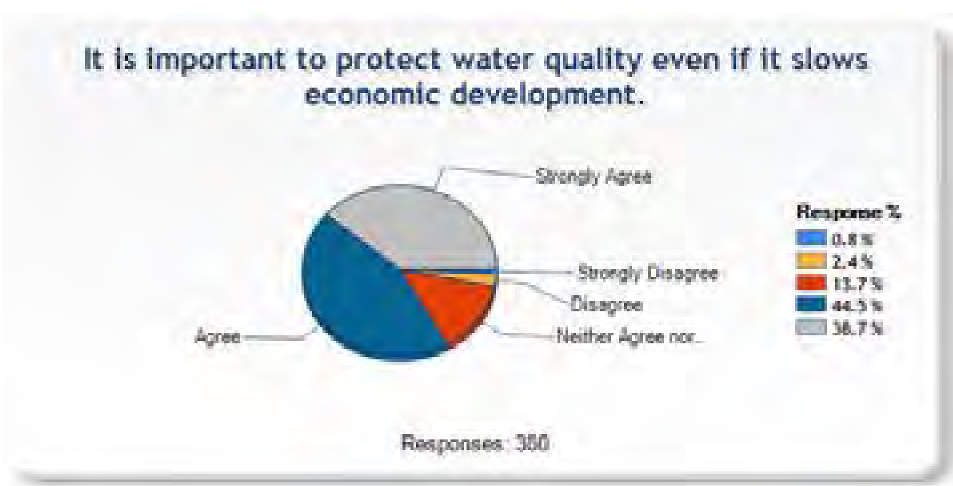
Social Indicators Survey for the Betsie River / Crystal Lake Watershed

The social indicators survey entitled “Preserving Water Quality in the Betsie-Crystal Watershed” was administered in 2014 to assess attitudes, knowledge and opinions of property owners in the watershed. Survey methods, outlined in a Quality Assurance Project Plan, were approved by the Michigan Department of Environmental Quality, which provided grant funds for the project.

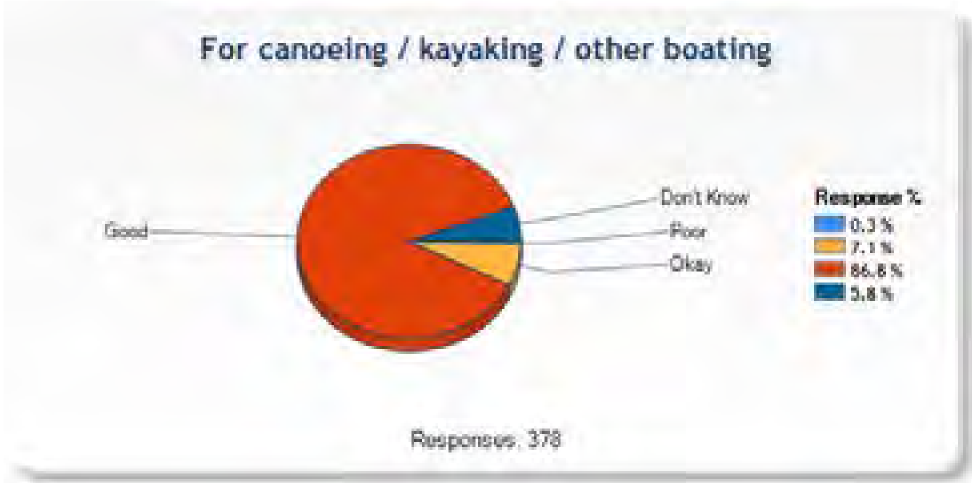
Approximately 12,000 property owners within the watershed were identified through tax records provided by Benzie, Grand Traverse and Manistee counties. From those lists, 1,000 property owners were selected at random to receive survey mailings. A total of 407 valid surveys were returned. Based on standard statistical measures, the results have a margin of error of 5 percent, at a 95 percent confidence level.

As a general statement, respondents indicated a very high appreciation for the importance of water quality, but were somewhat less aware of actions to preserve that quality. For example, 90 percent either agreed or strongly agreed with the statement “The quality of life in my community depends on good water quality in local streams, rivers and lakes,” and more than 80 percent said water quality should be protected even if that slowed economic growth.

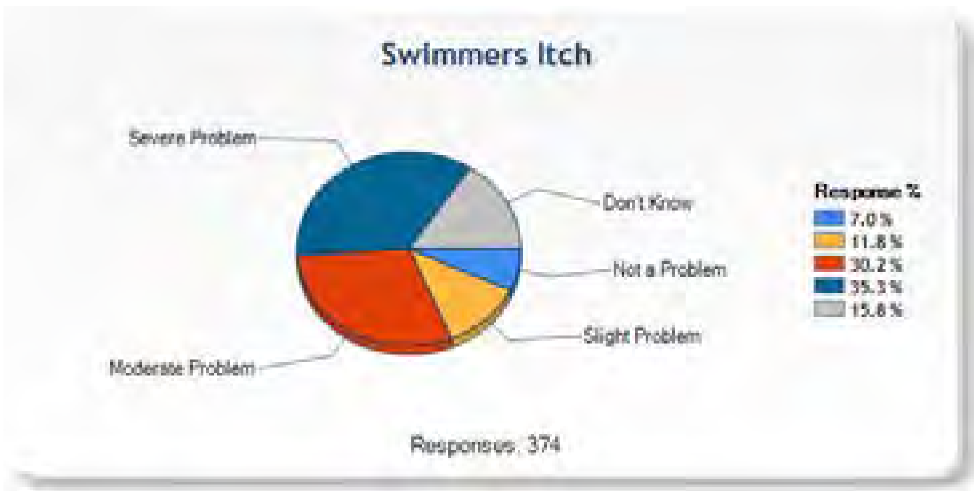




Asked to rate the quality of the local water for various activities, respondents gave the highest marks to “For Scenic Beauty” (94.7 percent “good”) and “For Canoeing, Kayaking, other Boating” (86.8 percent “good”). A majority of respondents rated water quality as “good” for all listed conditions.



The most serious "water Impairment" was judged to be Swimmer's Itch, rated by 35.3 percent as a "severe" problem and by 30.2 percent as a moderate problem. Invasive species and pesticides were the second and third most serious impairments, according to the survey.



Asked to rate 15 potential sources of water pollution, respondents ranked "Droppings from geese, ducks and other waterfowl" as the most problematic, followed by "Improperly maintained septic systems" and "Excessive use of lawn fertilizers and/or pesticides." The phrasing of the question asked whether each potential source was: "Not a problem"; "A slight problem"; "A moderate problem"; or "A severe problem."

On average, each of the potential sources was rated as less than a moderate problem, with most falling somewhere between slight and moderate.

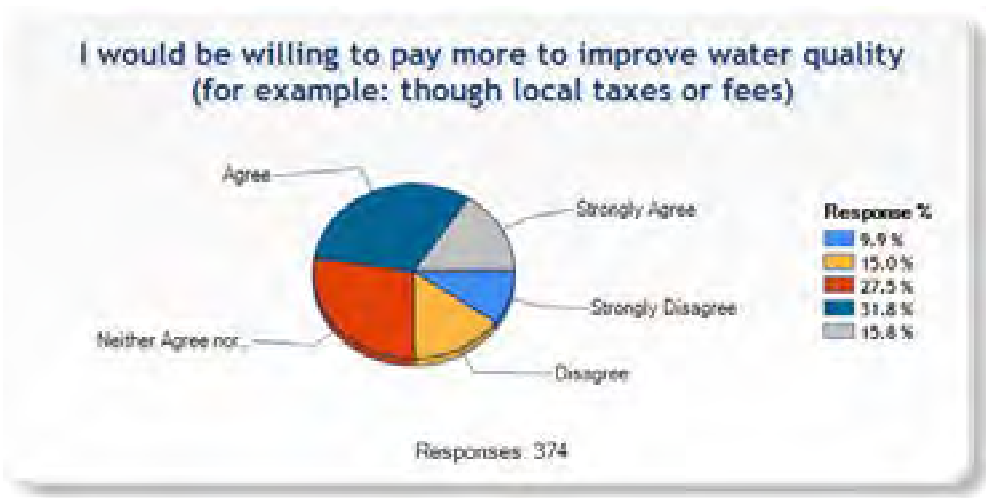
A related query asked about the consequences of poor water quality (e.g. polluted swimming areas; contaminated fish, etc.). "Excessive aquatic plants and algae" was rated as the most problematic consequence. About a third of respondents considered this to be a moderate or severe problem, while 42 percent considered it a slight problem or not a problem.

It is noted that significant percentages of respondents answered "Don't know," to the questions about sources and consequences of pollution. This lack of knowledge is a challenge to be addressed in the Information/Education component of the Watershed Management Plan.

A series of survey questions asked property owners about their familiarity with two common practices to preserve water quality: Regular septic system maintenance, and restoration of native plant species.

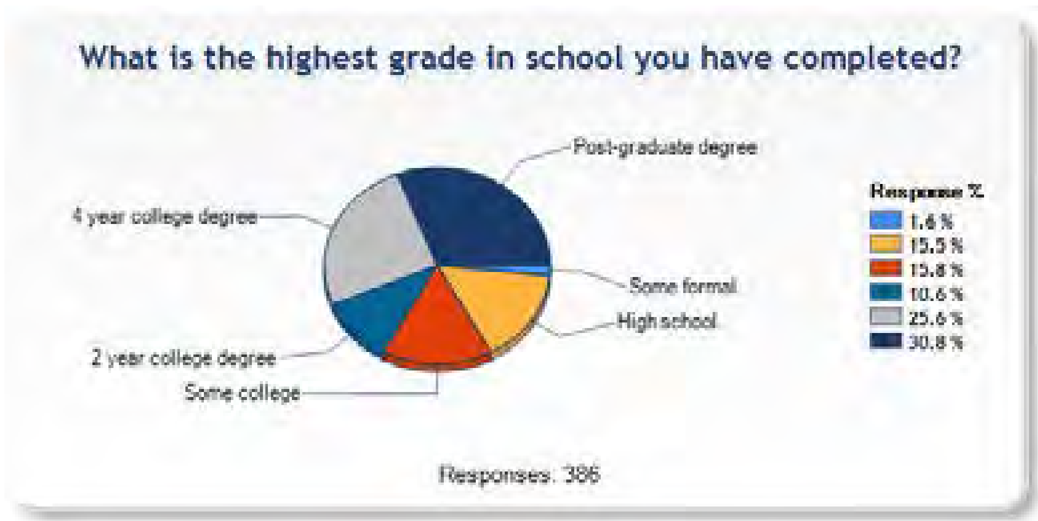
More than half indicated they have their septic system serviced regularly, and 16.5 percent indicated the practice was not relevant for their property, presumably because those properties are served by municipal systems. The remaining 28 percent indicated they were unaware of the need for regular servicing or were not following the practice. Cost was the most commonly cited reason for failing to follow the best practice.

On the question of native plant restoration, only 15 percent indicated they currently use the practice, while more than 70 percent indicated they were unfamiliar or only somewhat familiar with it.
The information/Education section of the WMP should respond to these findings by providing practical guidance on how to achieve these best management practices, as well as the information to show the links between property management and high water quality.
Interestingly, the survey indicates that property owners are likely to adopt best management practices, if they understand the positive impact of those practices. More than 90 percent of respondents agreed or strongly agreed with the statement "It is my personal responsibility to help protect water quality."
Additionally, nearly 50 percent indicated they would accept higher taxes or fees to protect water quality.



In conveying Informational and Educational messages to the public, the survey indicates that the most trusted sources are the local Conservation Districts, the local watershed project, and University Extension. An effective Information/Education plan in the Betsie River /Crystal Lake Watershed should make use of the services of those three entities.

The Watershed Plan Steering Committee chose to administer the survey to owners of property throughout the watershed – including those who own recreational or vacation property locally but reside elsewhere for part or all of the year.
This decision was based on the understanding that property owners have the greatest impact on land use practices that affect water quality. It is noted that the region is a popular retirement and vacation destination. This tends to skew property ownership demographics toward higher age and income cohorts than if the survey had been administered only to full-time watershed residents.
The median age of respondents was 62.7 years (minimum: 28 years; maximum 96 years). In terms of education, 56 percent had at least a four-year college degree.



Respondents' properties were in a diversity of locations: 23.7 percent were in a town, village or city; 40.1 percent were isolated, non-farm properties; 33.8 percent were in rural subdivisions; and 2.4 percent were described as farms. About 70 percent of the properties were less than 5 acres in size, and respondents indicated they had owned the property an average of about 17 years.

Full survey results are presented below.

Preserving water quality in the Betsie-Crystal Watershed

Rating of Water Quality

Overall, how would you rate the quality of the water in your area?

Question #	Poor (1)	Okay (2)	Good (3)	Don't Know (9)	Mean (SD)	Valid Responses / Total Responses
1. For canoeing / kayaking / other boating	0.3	7.1	86.8	5.8	2.92 (0.28)	356 / 378
2. For eating locally caught fish	1.3	18.3	60.8	19.6	2.74 (0.48)	304 / 378
3. For swimming	5.6	28.2	59.9	6.2	2.58 (0.6)	349 / 372
4. For picnicking and family activities	0.8	10.1	85.4	3.7	2.88 (0.35)	363 / 377
5. For fish habitat	1.3	20.7	56.2	21.8	2.7 (0.49)	295 / 377
6. For scenic beauty	0.3	4	94.7	1.1	2.95 (0.22)	374 / 378

Your Water Resources

1. *Of these activities, which is the most important to you? (Responses: 251)*

15.1% For canoeing / kayaking / other boating
10.8% For eating locally caught fish
23.9% For swimming
5.6% For picnicking and family activities
13.1% For fish habitat
31.5% For scenic beauty

Your Opinions

Please indicate your level of agreement or disagreement with the statements below.

Question #	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)	Mean (SD)	Valid Responses / Total Responses
1. The way that I care for my lawn and yard can influence water quality in local streams and lakes.	2.6	5	11.3	42	39.1	4.1 (0.97)	379 / 379
2. Using recommended management practices on farms improves water quality.	0.3	2.1	11.2	44.4	42	4.26 (0.76)	376 / 376
3. It is my personal responsibility to help protect water quality.	0.5	0.8	7.4	47	44.3	4.34 (0.7)	379 / 379
4. It is important to protect water quality even if it slows economic development.	0.8	2.4	13.7	44.5	38.7	4.18 (0.81)	380 / 380
5. My actions have an impact on water quality.	0.5	2.4	7.4	51.5	38.2	4.24 (0.74)	377 / 377
6. I would be willing to pay more to improve water quality (for example: though local taxes or fees)	9.9	15	27.5	31.8	15.8	3.29 (1.19)	374 / 374
7. I would be willing to change the way I care for my lawn and yard to improve water quality.	1.9	6.2	23.2	42.3	26.4	3.85 (0.95)	371 / 371
8. I would be willing to change management practices to improve water quality.	0.8	2.7	28	43.1	25.3	3.89 (0.84)	371 / 371
9. The quality of life in my community depends on good water quality in local streams, rivers and lakes.	0.3	0.3	9	37.8	52.6	4.42 (0.69)	378 / 378

Water Impairments

Below is a list of water pollutants and conditions that are generally present in water bodies to some extent. The pollutants and conditions become a problem when present in excessive amounts. In your opinion, how much of a problem are the following water impairments in your area?

Question #	Not a Problem (1)	Slight Problem (2)	Moderate Problem (3)	Severe Problem (4)	Don't Know (9)	Mean (SD)	Valid Responses / Total Responses
1. Sedimentation (dirt and soil) in the water	20.3	26.2	25.4	5.3	22.7	2.2 (0.91)	289 / 374
2. Phosphorus	7.6	11.9	14.9	7.6	58	2.54 (0.99)	155 / 369
3. Bacteria and viruses in the water (such as E.coli / coliform)	18.9	16.5	17.3	9.7	37.6	2.29 (1.06)	231 / 370
4. Trash or debris in the water	23.9	34.3	22.8	8.6	10.5	2.18 (0.94)	334 / 373
5. Oil and grease.	30.6	22.6	11	7.5	28.2	1.94 (1)	267 / 372
6. Cloudiness of the water	38.5	28	12.7	2.4	18.3	1.74 (0.83)	303 / 371
7. Mercury	11.9	7.6	7.6	6.8	66.2	2.27 (1.15)	125 / 370
8. Algae in the water	17.7	30.3	22.3	4.8	24.9	2.19 (0.87)	280 / 373
9. Invasive aquatic plants and animals	8	12.1	28.2	26.8	24.9	2.98 (0.97)	280 / 373
10. Habitat alteration harming local fish	11.8	15.5	18.2	10.7	43.7	2.5 (1.03)	210 / 373
11. High water temperature	37.2	10.9	10.1	3.3	38.5	1.67 (0.94)	225 / 366
12. Pesticides	9.5	12.2	18.6	11.9	47.8	2.63 (1.03)	193 / 370
13. High water levels causing erosion	34	18.9	14.3	8.1	24.8	1.95 (1.04)	279 / 371
14. Low water levels harming fish habitat and-or access	25.9	17	17.3	8.4	31.5	2.12 (1.05)	254 / 371
15. Swimmers Itch	7	11.8	30.2	35.3	15.8	3.11 (0.94)	315 / 374

Sources of Water Pollution

The items listed below are sources of water quality pollution across the country. In your opinion, how much of a problem are the following sources in your area?

Question #	Not a Problem (1)	Slight Problem (2)	Moderate Problem (3)	Severe Problem (4)	Don't Know (9)	Mean (SD)	Valid Responses / Total Responses
1. Discharges from industry into streams and lakes	27.6	17.2	14.9	7.2	33.2	2.02 (1.03)	252 / 377
2. Discharges from sewage treatment plants	24.8	15.2	12.5	9.1	38.4	2.1 (1.09)	231 / 375
3. Soil erosion from construction sites	24.2	26.1	10.5	4.6	34.7	1.93 (0.9)	243 / 372
4. Soil erosion from farm fields	20.5	20.8	15.5	3.7	39.5	2.04 (0.92)	227 / 375
5. Soil erosion from shorelines and/or streambanks	17.3	27.1	20.6	6.8	28.2	2.23 (0.92)	265 / 369
6. Excessive use of lawn fertilizers and/or pesticides	8	20.8	22.9	14.1	34.1	2.66 (0.95)	247 / 375
7. Improperly maintained septic systems	8	17.4	20.6	13.9	40.1	2.67 (0.98)	224 / 374
8. Stormwater runoff from streets and/or highways	15.2	23.1	22.6	7.7	31.4	2.33 (0.94)	258 / 376
9. Street salt and sand	12.8	24.5	23.7	8.2	30.9	2.4 (0.92)	260 / 376
10. Droppings from geese, ducks and other waterfowl	9.9	20.6	33.2	19.8	16.4	2.75 (0.95)	312 / 373
11. Specialty crop production (horticulture, citrus, nuts, fruits)	22.9	12.8	7.5	1.9	54.9	1.74 (0.88)	169 / 375
12. Highway/road/bridge runoff	15.2	25.3	16.8	5.1	37.6	2.19 (0.9)	234 / 375
13. Removal of riparian vegetation	13.5	15.9	14.1	4.3	52.2	2.19 (0.95)	177 / 370
14. Fueling of boats	17.9	28	19.5	6.7	28	2.21 (0.92)	270 / 375
15. Turf management (golf courses, sports fields)	20.1	21.2	15.5	7	36.2	2.15 (0.99)	238 / 373

Consequences of Poor Water Quality

Poor water quality can lead to a variety of consequences for communities. In your opinion, how much of a problem are the following issues in your area?

Question #	Not a Problem (1)	Slight Problem (2)	Moderate Problem (3)	Severe Problem (4)	Don't Know (9)	Mean (SD)	Valid Responses / Total Responses
1. Polluted swimming areas	33	26.3	14.4	8.2	18.1	1.97 (0.99)	308 / 376
2. Contaminated fish	25.9	23	11.5	6.1	33.4	1.97 (0.97)	249 / 374
3. Loss of desirable fish species	18.1	18.1	18.1	9.3	36.4	2.29 (1.04)	239 / 376
4. Reduced beauty of lakes or streams	41.6	25.7	13.1	8	11.5	1.86 (0.98)	330 / 373
5. Reduced quality of water recreation activities	33.3	27.7	14	9.4	15.6	1.99 (1)	314 / 372
6. Excessive aquatic plants or algae	15.5	26.7	24.6	10.4	22.7	2.39 (0.95)	289 / 374

Practices to Improve Water Quality

Please indicate which statement most accurately describes your level of experience with each practice listed below.

Question #	Not relevant for my property (9)	Never heard of it (1)	Somewhat familiar with it (2)	Know how to use it; not using it (3)	Currently use it (4)	Mean (SD)	Valid Responses / Total Responses
1. Following the manufacturer's instructions when fertilizing lawn or garden	33.3	0	7.6	23.4	35.7	3.42 (0.69)	256 / 384
2. Create a rain garden	30.5	38.3	15.1	13.8	2.3	1.72 (0.9)	267 / 384
3. Keep grass clippings and leaves out of the roads, ditches, and gutters	36	3.9	11	7.8	41.3	3.35 (0.97)	245 / 383
4. Follow pesticide application instructions for lawn and garden	33.5	0.8	7	22.9	35.8	3.41 (0.72)	256 / 385
5. Use phosphate free fertilizer	38.7	5.3	9.1	24.5	22.4	3.04 (0.93)	230 / 375
6. Properly dispose of household waste (chemicals, batteries, florescent light bulbs, etc.)	10.4	0.5	8.6	7.6	72.8	3.71 (0.66)	343 / 383
7. Stabilize and protect streambanks and/or shorelines	53.7	3.2	15.7	8.2	19.1	2.94 (1.02)	174 / 376
8. Establish riparian vegetation	41.6	24.3	17.3	8.3	8.5	2.02 (1.07)	219 / 375
9. Restore/enhance wetland	62.2	2.4	20.6	9	5.8	2.48 (0.83)	143 / 378
10. Plant vegetated riparian buffer	45	23.8	16.7	8.2	6.3	1.95 (1.02)	208 / 378
11. Protect streambanks and/or shorelines with vegetation	56.2	2.9	19.5	9	12.4	2.7 (0.96)	166 / 379

Specific Constraints of Practices

Regular Septic System Servicing: Having septic system thoroughly cleaned every 3-5 years to remove all the sludge, effluent and scum from the tank.

1. *How familiar are you with this practice? (Responses: 389)*

16.5% Not relevant
4.9% Never heard of it
13.6% Somewhat familiar with it
10% Know how to use it; not using it
55% Currently use it

2. *If the practice is not relevant, please explain why.*

3. *Are you willing to try this practice? (Responses: 322)*

73% Yes or already do
18.3% Maybe
8.7% No

How much do the following factors limit your ability to implement this practice?

Question #	Not at all (4)	A little (3)	Some (2)	A lot (1)	Don't Know (9)	Mean (SD)	Valid Responses / Total Responses
4. Don't know how to do it	61.3	7.3	12.5	6.3	12.5	3.41 (0.98)	251 / 287
5. Time required	60.3	10.7	11.7	4.5	12.8	3.45 (0.91)	253 / 290
6. Cost	33.4	12.7	19.7	23.1	11	2.64 (1.23)	266 / 299
7. The features of my property make it difficult	62.9	11	7.2	4.8	14.1	3.54 (0.87)	250 / 291
8. Insufficient proof of water quality benefit	54.8	7.6	9.3	5.9	22.4	3.44 (0.97)	225 / 290
9. Desire to keep things the way they are	61.9	6.2	10	10.7	11.3	3.34 (1.08)	258 / 291
10. Physical or health limitations	72.3	5.1	8.2	6.8	7.5	3.54 (0.93)	270 / 292
11. Hard to use with my farming system	74.2	1.8	2.2	1.1	20.8	3.88 (0.49)	221 / 279
12. Lack of equipment	62.3	3.9	6.3	9.5	18	3.45 (1.05)	233 / 284

Native Plant Communities Restoration: Restore plant species in a manner designed to produce plant communities comprised of native species.

13. *How familiar are you with this practice? (Responses: 373)*

7% Not relevant
23.9% Never heard of it
46.6% Somewhat familiar with it
7.5% Know how to use it; not using it
15% Currently use it

14. *If the practice is not relevant, please explain why.*

15. *Are you willing to try this practice? (Responses: 355)*

44.2% Yes or already do
44.8% Maybe
11% No

How much do the following factors limit your ability to implement this practice?

Question #	Not at all (4)	A little (3)	Some (2)	A lot (1)	Don't Know (9)	Mean (SD)	Valid Responses / Total Responses
16. Don't know how to do it	27.8	13.5	20.5	18.3	19.9	2.63 (1.18)	262 / 327
17. Time required	30	17.5	19.4	14.4	18.8	2.78 (1.13)	260 / 320
18. Cost	26.6	14.1	21.2	19.1	19.1	2.59 (1.17)	259 / 320
19. The features of my property make it difficult	42.2	10.1	13.5	9.8	24.5	3.12 (1.12)	247 / 327
20. Insufficient proof of water quality benefit	45	8.8	8.4	6.9	30.9	3.33 (1.03)	221 / 320
21. Desire to keep things the way they are	52.6	9.7	14.3	9.3	14	3.23 (1.08)	276 / 321
22. Physical or health limitations	57.9	8.4	13.4	8.7	11.5	3.31 (1.05)	284 / 321
23. Hard to use with my farming system	63.5	2.3	2.6	1.3	30.3	3.83 (0.57)	212 / 304
24. Lack of equipment	45.1	8.6	8.3	9.5	28.6	3.25 (1.11)	225 / 315

Making Decisions for my Property

In general, how much does each issue limit your ability to change your management practices?

Question #	Not at all (4)	A little (3)	Some (2)	A lot (1)	Don't Know (9)	Mean (SD)	Valid Responses / Total Responses
1. Personal out-of-pocket expense	17.6	16.5	29.3	28.2	8.4	2.26 (1.09)	338 / 369
2. Lack of government funds for cost share	31.8	10.9	15.3	17	25.1	2.77 (1.22)	269 / 359
3. My own physical abilities	45.9	12.8	19.7	15.6	6	2.95 (1.17)	344 / 366
4. Not having access to the equipment that I need	29.1	15.8	17.5	17.5	20.2	2.71 (1.17)	288 / 361
5. Lack of available information about a practice	22.1	14.8	24.6	23.7	14.8	2.41 (1.15)	305 / 358
6. No one else I know is implementing the practice	37.3	9.2	12.9	12.9	27.7	2.98 (1.19)	258 / 357
7. Concerns about reduced yields	55.7	3.1	5.7	3.4	32	3.63 (0.84)	238 / 350
8. Approval of my neighbors	64.6	7.6	5.1	3.9	18.8	3.64 (0.81)	289 / 356
9. Don't want to participate in government programs	50.3	8.9	11.7	10.1	19	3.23 (1.1)	290 / 358
10. Requirements or restrictions of government programs	36.3	9.9	13	14.4	26.5	2.93 (1.21)	261 / 355
11. Possible interference with my flexibility to change land use practices as conditions warrant	36	13.5	13.5	13.8	23.3	2.93 (1.17)	273 / 356
12. Don't know where to get information and/or assistance about those practices	30	13.4	20.2	14.8	21.6	2.75 (1.16)	280 / 357
13. Environmental damage caused by practice	39.6	8	10.5	6.8	35	3.24 (1.07)	228 / 351
14. Concerns about resale value	52.5	9	11.2	11	16.3	3.23 (1.11)	298 / 356
15. Not being able to see a demonstration of the practice before I decide	33.9	11.5	19	15.4	20.2	2.8 (1.18)	285 / 357

About You

1. *Do you make the home and lawn care decisions in your household? (Responses: 389)*

94.1%	Yes
5.9%	No

2. *What is your gender? (Responses: 387)*

61.5%	Male
38.5%	Female

3. *What is your age?*
   (Mean=62.7; SD = 13.15; Min = 28; Max = 96; Range = 68; n = 377)

4. *What is the highest grade in school you have completed? (Responses: 386)*

1.6%	Some formal schooling
15.5%	High school diploma/GED
15.8%	Some college
10.6%	2 year college degree
25.6%	4 year college degree
30.8%	Post-graduate degree

5. *What is the approximate size of your property? (Responses: 389)*

23.9%	1/4 acre or less
24.2%	More than 1/4 acre but less than 1 acre
22.6%	1 acre to less than 5 acres
29.3%	5 acres or more

7. *How long have you owned your property in the Betsie River Watershed (years)?*
   (Mean=16.97; SD = 8.44; Min = 2; Max = 25; Range = 23; n = 391)

8. *Which of the following best describes your property? (Responses: 379)*

23.7%	In a town, village, or city
40.1%	In an isolated, rural, non-farm residence
33.8%	Rural subdivision or development
2.4%	On a farm

9. *Do you use a professional lawn care service? (Responses: 390)*

8.5%	Yes, just for mowing
2.8%	Yes, for mowing and fertilizing
2.6%	Yes, just for fertilizing and pest control
3.3%	Yes, for mowing, fertilizing, and pest control
82.8%	No

10. Where are you likely to seek information about water quality issues? (Responses: 387)

48.8% Newsletters/brochure/fact sheet
38.2% Internet
8.8% Radio
32.6% Newspapers/magazines
14.7% Workshops/demonstrations/meetings
38.5% Conversations with others
12.4% None of the above

Information Sources

People get information about water quality from a number of different sources. To what extent do you trust those listed below as a source of information about soil and water?

Question #	Not at all (1)	Slightly (2)	Moderately (3)	Very much (4)	Am not familiar (9)	Mean (SD)	Valid Responses / Total Responses
1. Local watershed project	4.2	10.1	26.5	44.6	14.6	3.3 (0.86)	322 / 377
2. Soil and Water Conservation District	4.2	7.4	28.6	49.1	10.6	3.37 (0.83)	337 / 377
3. Local government	13.1	23	36.4	19.3	8.3	2.67 (0.96)	343 / 374
4. University Extension	6.6	9	26.7	44.7	13	3.26 (0.93)	329 / 378
5. Environmental groups	17.3	18.1	32.2	23.4	9	2.68 (1.06)	342 / 376
6. Farm Bureau	14.2	15.3	30.3	15	25.2	2.62 (1.01)	279 / 373
7. Local garden center	12.4	27.7	37.1	12.1	10.8	2.55 (0.89)	332 / 372
8. Neighbors / friends	9.6	28.1	41.7	14.2	6.4	2.65 (0.86)	350 / 374

Appendix B: Betsie River Hydrologic and Hydraulic Study

MI/DEQ/WRD-14/027

Betsie River Hydrologic and Hydraulic Study

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Background

The Michigan Department of Environmental Quality (MDEQ) Hydrologic Studies and Dam Safety Unit (HSDSU) supports the Nonpoint Source (NPS) Program by providing hydrologic analysis critical to understanding the impacts of stormwater runoff on stream dynamics. Watershed studies have been conducted by the HSDSU for a number of Michigan river basins for the purpose of long-range planning efforts, community stormwater ordinances, and Best management Practices (BMP) selection, design, and evaluation. The Betsie River Watershed hydrologic and hydraulic (H&H) study similarly characterizes the flow response of the Betsie River system, in order to support the development of the Betsie River Watershed Plan.

Sources of information for spatial watershed data are presented first in this report. These include landcover (and its variation with time), soils and topography; these properties were determined for individual watershed subbasins. The specification of the design storm used for hydrologic and hydraulic analysis is presented next, followed by sections presenting the key aspects of the hydrologic analysis: runoff Curve Numbers, times of concentration, and ponding adjustment. The final sections of the report present results in terms of runoff volume, peak flow yield, and stream flow; and, discussion of the results.

Watershed Description and Data Processing

Overview

The Betsie River Watershed is located in northwestern Lower Michigan in the counties of Benzie, Manistee, and Grand Traverse. The watershed is approximately 242 square miles, and it consists predominantly of forest and rangeland. The Betsie River originates at Green Lake and meanders for approximately 52 miles before discharging into Lake Michigan. The Betsie River also includes approximately 41 miles of tributary streams[1]. Figure 1 shows a map of the Betsie River Watershed.

[1] Michigan Department of Natural Resources. July 1973. Betsie River Natural River Plan.

Figure 1: Betsie River Watershed

Landcover

For the purpose of this project, three different years representing landcover at different stages of watershed development were analyzed. These include the 1800, 1978, and 2006 landcover conditions. The 1800 and 1978 landcover map data were obtained from the Michigan Center for Geographic Information (CGI) Geographic Data Library. The 1978 land cover map was published in 1978 and was created from aerial photo interpretation and county data using the Michigan Resource Inventory System (MIRIS) mapping framework at 1:24,000 scale. The 1978 land cover map utilizes the Anderson/Hardy Land Cover Classification System[2]. Land cover code descriptions are provided for each map polygon and are assigned descriptions and codes for Levels 1-3 of the classification system. The land cover classes used for the 1978 MIRIS land cover maps are the same as those utilized in the runoff curve number lookup tables found in the MDEQ method *Calculating Runoff Curve Numbers with GIS*[3] used for this study.

The 1800 land cover map was also published in 1978. Land cover polygons were created based on original surveyor's tree data and descriptions of the vegetation and land between 1816 and 1856. The land cover classification system for the 1800 land cover map is similar to the 1978 map system with some differences in level of detail and descriptions (e.g. 423 Mixed Conifer Swamp vs. 423 Lowland Conifer). For the purposes of this study, the 1800 land use classification scheme was easily interpreted as needed to match the 1978 MIRIS land cover and the MDEQ curve number lookup table scheme. Current-day (e.g., 2014) landcover is not available for the entire Betsie River Watershed in a form that follows the same map structure, level of detail (resolution), and classification schemes as the 1800 and 1978 land cover maps. As an alternative, the most recent National Land Cover Dataset (NLCD), which represents 2006 conditions, was used as the best available data to represent current landcover

[2] Anderson, Hardy, Roach, and Witmer, 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Department of the Interior Geological Survey.
[3] https://www.michigan.gov/deq/0,4561,7-135-3313_3684_3724-112833--,00.html

conditions. The NLCD data was downloaded from the NLCD website[4]. The 2006 NLCD was created by updating a prior (2001) NLCD map using LANDSAT spectral imagery. The NLCD is provided in a raster format (pixels) vs. the vector format (polygons) used to create the 1978 MIRIS and 1800 land cover maps. The NLCD landcover data uses a different 16-class classification scheme at a spatial resolution of 30 meters. In order to provide a meaningful comparison of the 2006 NLCD map to the 1978 and 1800 maps and utilize the runoff curve number lookup table, the NLCD land cover data was reclassified. This process is explained further in the section "Runoff Curve Numbers".

The major landcover classes for the three time periods (1800, 1978 and 2006) are shown in Table 1 (more detailed landcover classes were used for the hydrologic and hydraulic analysis). This table shows that over time, agricultural and urban land areas increase while forested land areas decrease. Rangeland increases from 1800 to 1978, but then decreases from 1978 to 2006. Wetland areas decrease from 1800 to 1978 and then increase from 1978 to 2006 based on the comparison between the 1978 MIRIS and 2006 NLCD maps. The area covered by water remains the same over time.

Table 1: Percent Area of Major Landcover Classes

Major Landcover Classes	1800 Conditions Percent of Total Area	1978 Conditions Percent of Total Area	2006 Conditions Percent of Total Area
Agricultural Land	0%	6%	8%
Forest Land	76%	51%	46%
Rangeland	0%	19%	13%
Urban and Built Up	0%	5%	8%
Water	10%	10%	10%
Wetlands	14%	9%	15%

Watershed imperviousness is a common indicator of the general water quality of a stream. The higher the imperviousness, the more likely that the stream water quality will be poor[5]. The impervious cover model, developed by Schueler[6], shows that when the imperviousness starts exceeding 5-10%, the water quality of the stream begins to significantly degrade. The imperviousness in the Betsie River Watershed increased from 0% (pre-development) to about 3% (current conditions), with individual subbasins displaying percent imperviousness ranging from 0% to 6%. While the percent imperviousness is still relatively low, the trend over time shows steady increases in imperviousness that, if left unmitigated, may significantly impact the water quality of the Betsie River and its tributaries in the future.

Subbasins

The Betsie River Watershed is divided into seven major subbasins according the USGS Hydrologic Unit classification system. These seven subbasins have been further divided into 48 subbasins by the MDEQ and provided as GIS polygons for this study[7]. Nineteen of the 48 subbasins are identified by MDEQ as "non-contributing" because they do not have a surface water outlet for stormwater runoff, and do not contribute surface runoff during precipitation. These areas are typically deep depressions in the landscape, and their subbasin numbers are preceded by a minus sign in the subbasin map (Figure 2).

[4] (http://www.mrlc.gov/nlcd2006.php

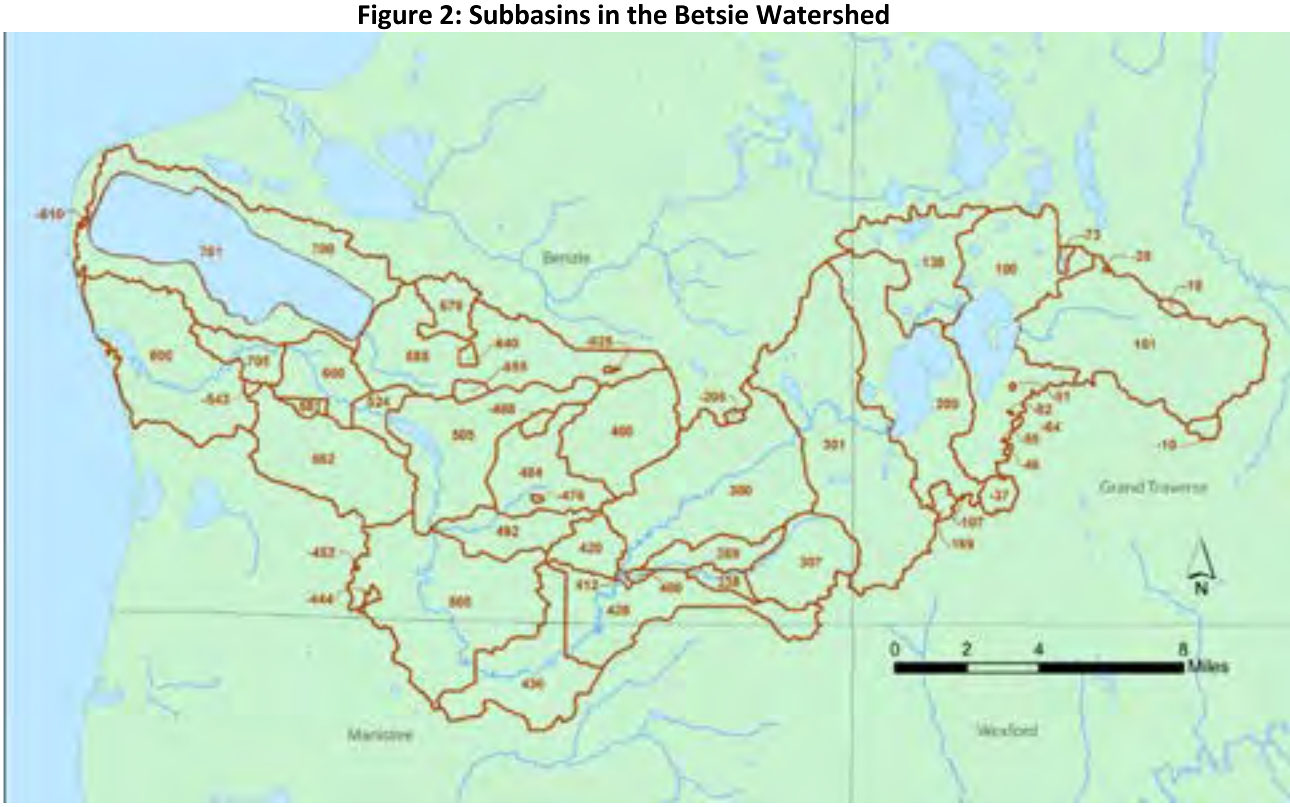
[5] Schueler and Holland, 2000. The Importance of Imperviousness, The Practice of Watershed Protection, published by the Center for Watershed Protection, Ellicott City, MD

[6] http://chesapeakestormwater.net/2009/11/the-reformulated-impervious-cover-model/

[7] BetsieWorking.shp transmitted by MDEQ to GLEC 6/10/2013

The subbasin areas that contribute to surface runoff range in size from about 78 acres to more than 23,300 acres. To properly calculate the runoff from the subbasins using the MDEQ methodology, the maximum subbasin area should not exceed 12,800 acres. Three subbasins (subbasin 100, 300, and 700) were larger than this limit and were therefore subdivided into two smaller areas each in order to comply with the runoff methodology (100/101, 300/301, and 700/701). Subbasin 100 was subdivided into two areas by delineating the drainage area of Mason Creek (subshed 101). This subdelineation was achieved based solely on the topographic divide between the Mason Creek drainage area and the rest of the watershed, using the digital elevation model (DEM). To subdivide subbasin 300, a location slightly downstream of the Grass Lake dam was chosen as a break point since it is an important hydrologic feature in this watershed and in the analysis. This subdelineation was achieved based solely on topography using the DEM. To subdivide subbasin 700, the entire footprint of Crystal Lake was considered its own subbasin and was therefore cut out of the overall watershed. After this subdivision, the maximum area of the subbasins is 12,842 acres, as shown in Table 2. A map of the subbasins is provided below in Figure 2.

Figure 2: Subbasins in the Betsie Watershed



Some landcover areas in the Betsie Watershed are “open pits” or excavation areas that do not contribute to the surface runoff volume. These excavation areas change between the three time periods. In 1800, there are no areas labeled as open pits. In 1978, approximately 208 acres of land cover are labeled as open pits. The 2006 NLCD dataset does not provide this level of detail, so no areas are labeled as open pits. Because of the differences in the classification method, the total area of analysis for 1978 and some of the individual subbasin areas are slightly smaller (by less than 0.5%) than the areas used for the 1800 and 2006 conditions, as shown in Table 2. This has a minor effect on the amount of total runoff generated in each subbasin, as explained in more detail in the Hydrologic Analysis Parameters section.

Table 2: Area in Acres per Subbasin

Subbasin Number	1800 Area (acres)	1978 Area (acres)	2006 Area (acres)
100	9,840	9,819	9,840
101	11,103	11,053	11,103
138	4,585	4,578	4,585
200	8,761	8,753	8,761
300	10,539	10,529	10,539
301	12,842	12,834	12,842
307	3,480	3,467	3,480
338	606	606	606
369	1,638	1,638	1,638
400	125	125	125
412	79	79	79
420	1,550	1,550	1,550
428	5,441	5,436	5,441
436	5,235	5,232	5,235
460	4,938	4,935	4,938
484	3,778	3,773	3,778
492	2,450	2,450	2,450
500	10,729	10,723	10,729
505	6,811	6,811	6,811
524	1,052	1,052	1,052
562	6,322	6,316	6,322
581	290	290	290
600	2,630	2,630	2,630
670	1,380	1,380	1,380
685	8,544	8,519	8,544
700	8,022	7,996	8,022
701	9,865	9,865	9,865
705	1,459	1,457	1,459
800	8,174	8,167	8,174
Total:	**152,270**	**152,062**	**152,270**

Soils

Soil map data for the hydrologic analysis were obtained from the Michigan CGI Geographic Data Library. The source of the soils data was the U.S. Department of Agriculture Natural Resources Conservation Service Soil Survey Geographic (SSURGO) data, published in 2000 for each county in Michigan. Data were prepared by interpreting 1:12,000 scale aerial photography and generally represents the most detailed maps of soil type polygons for any given area in Michigan. SSURGO soil maps for Grand Traverse and Benzie-Manistee counties were downloaded from the CGI library and geoprocessed in ArcGIS by merging the base soil maps, clipping the maps to the Benzie watershed boundary, and then joining the soil data to the overlying subbasin data to derive detailed soil maps for each subbasin in the analysis.

Topography

The topography of the Betsie River Watershed consists of gentle hills in the western part of the watershed, and steeper hills and ridges in the northeastern part of the watershed. The elevation at the headwaters of the Betsie River, Green Lake, is 825 feet above sea level while the elevation at the river's mouth at Lake Michigan is 580 feet. The highest elevation in the watershed is approximately 1,175 feet above sea level, while the lowest elevation, 576 feet, occurs in a few depressed areas. A DEM was prepared for the Betsie River Watershed by merging 10 meter USGS National Elevation Dataset DEMs obtained from the National Map Viewer and Download Platform[8] and clipping the surface to the general watershed boundary. The DEM was then processed in ArcGIS to generate contours at 1 foot intervals, and all slope calculations and point elevations were obtained using these contours.

Modeling Approach

The hydrologic and hydraulic study of the Betsie River Watershed follows the methodology outlined by MDEQ in the report *Computing Flood Discharges for Small Ungaged Watersheds (Sorrell, 2010)*[9]. The report describes the methodology for calculating the runoff curve number, determining the design storm depth, and calculating the runoff volume and peak discharge for each subbasin. The curve number and runoff volume calculations are based on procedures similar to those developed by the Natural Resource Conservation Service (NRCS) and commonly referred to as the "SCS method"[10]. The peak discharge calculations are computed using the unit hydrograph (UH) technique, a procedure that is also described in the SCS method. The main difference between the SCS method and the method described in Sorrell (2010) is that the latter uses a Michigan-specific unit hydrograph rather than a generic SCS unit hydrograph. The two methods produce identical runoff volumes, but differ in their characterizations of peak flow rates. The Michigan-specific unit hydrograph produces slightly smaller peak discharges, and more volume is placed under the falling limb of the hydrograph.

The MDEQ methodology allows the user to calculate runoff volumes and peak flow rates from each watershed of concern, but it is not a model that can route flow through streams and lakes. In order to accomplish that task, the United States Army Corps of Engineers HEC-HMS reservoir routing model[11] was applied to estimate peak flows at key locations in the Betsie River. The HEC-HMS (version 3.4) model

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[8] http://nationalmap.gov/viewer.html

[9] Sorrell, R.C. 2010. Computing Flood Discharges for Small Ungaged Watersheds. Michigan Department of Natural Resources and Environment, Land and Water Management Division. June 22, 2010. (http://www.michigan.gov/documents/deq/lwm-scs_198408_7.pdf).

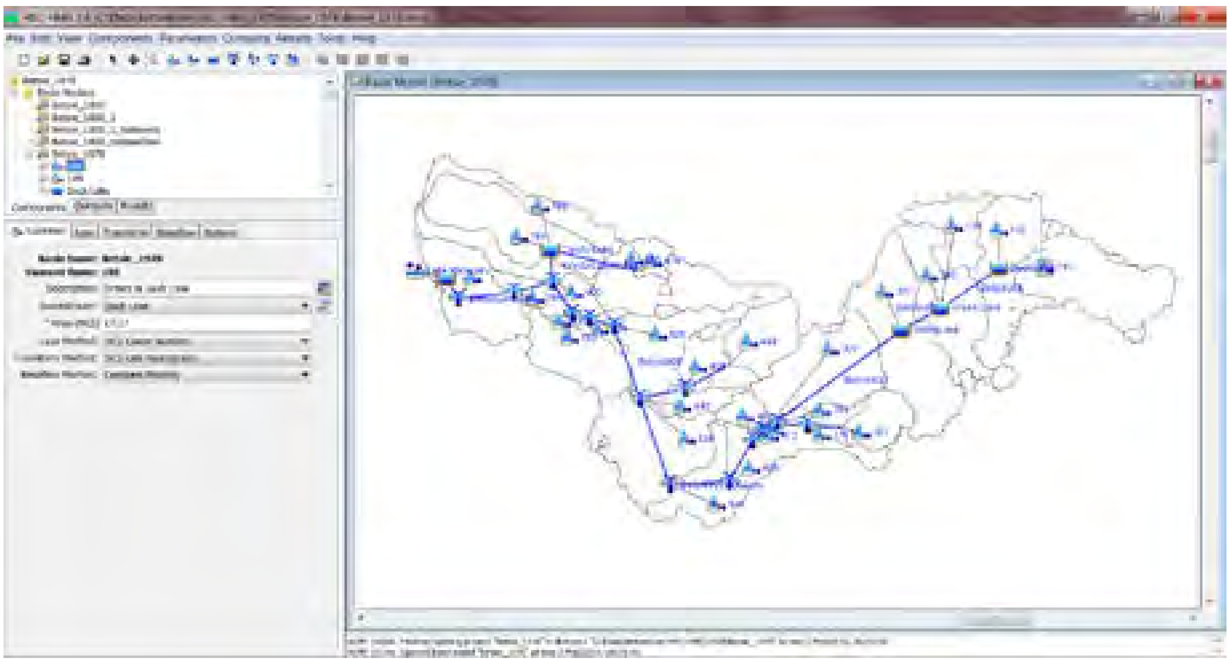
[10] USDA NRCS National Engineering Handbook (NEH), Part 630: Hydrology (2004). Downloaded from http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1043063 in Fall of 2013

[11] http://www.hec.usace.army.mil/software/hec-hms/

created for the Betsie Watershed also uses the SCS method to determine runoff volumes and peak discharges, and it uses the Muskingum attention method to route flows through the Betsie River. Flows through lakes and impoundments are calculated by specifying an elevation-storage curve and by characterizing the outflow weir/dam structure. Figure 3 illustrates how the Betsie River Watershed is represented in HEC-HMS as a network of hydrologic elements, including subbasins, reaches, junctions and reservoirs.

The hydrologic parameters that are used in the MDEQ method and in the HEC-HMS model are further described in the next section.

Figure 3: HEC-HMS representation of the Betsie Watershed



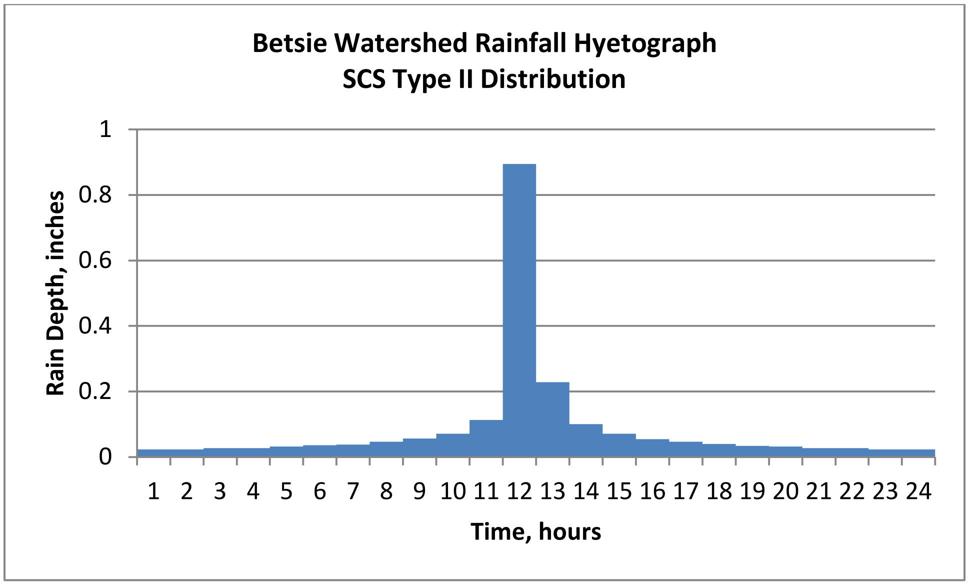
Hydrologic Analysis Parameters

Parameters that are used to calculate the watershed response to rainfall include precipitation, the curve number, the time of concentration, and ponding adjustments.

Rainfall

This hydrologic study uses the 2-year 24-hour design storm. According to Sorrell (2010), the Betsie River Watershed is located in Michigan Climatic Zone 3 (northwestern Lower Michigan), and the 50% annual probability (i.e., 1 in 2 year) rainfall depth for this zone is 2.09 inches. The rainfall distribution follows the SCS Type II distribution, as shown in Figure 4.

Figure 4: 2-year, 24-hour Rainfall Distribution for the Betsie Watershed



Runoff Curve Numbers

The curve number (CN) is a numeric value assigned to a subbasin based on its landcover and underlying soils. The higher the curve number, the more runoff is produced. For example, pavement has a curve number of 99, and virtually all rainfall that falls on pavement becomes runoff. The lower the curve number, the less runoff is produced. For example, grassland growing in Hydrologic Soil Group (HSG) Type A soils can have a curve number as low as 30. Rainfall falling on such an area is predominantly infiltrated into the soil, and only a small fraction of the rainfall is typically transformed into runoff.

The curve numbers for each subbasin in the Betsie watershed were calculated using the MDEQ method "Calculating Runoff Curve Numbers with GIS"[12]. This method uses lookup tables to assign a curve number based on the landcover and soils. As previously mentioned, areas that were listed as open pits were not included in the hydrologic analysis per the MDEQ methodology, and therefore those areas did not receive a curve number. As explained previously, the MDEQ curve number lookup tables use landcover classifications which are similar to or the same as the 1800 and 1978 landcover maps. The 2006 NLCD landcover data, however, uses a classification system different than from the 1978 MIRIS classification system. In order to use the MDEQ curve number look-up tables, the NLCD classes were reclassified to better match with the classes used in the curve number look-up tables. This reclassification is shown in Table 3. The NLCD categories for "developed" landcover were reclassified such that the curve number for high intensity development was higher than the curve number for medium intensity, which in turn was higher than the curve number for low intensity.

[12] http://michigan.gov/documents/deq/lwm-cn-calc-using-gis_202628_7.pdf

Table 3: 2006 Landcover Reclassification

Original 2006 NLCD Landcover Categories	Reclassified 2006 NLCD Landcover Categories
Barren Land	Barren
Cultivated Crops	Cropland
Deciduous Forest	Deciduous
Developed, High Intensity	Commercial
Developed, Low Intensity	Single Family
Developed, Medium Intensity	Industrial Park
Developed, Open Space	Open Land
Emergent Herbaceous Wetlands	Emergent Wetland
Evergreen Forest	Pine
Hay/Pasture	Permanent Pasture
Herbaceous	Herbaceous
Mixed Forest	Woodland
Open Water	Water
Shrub/Scrub	Shrub
Woody Wetlands	Wooded Wetland

Individual subbasins in the Betsie River Watershed are composed of a variety of soil types and landcovers; therefore an area-weighted or composite runoff curve number was calculated for each subbasin as follows:

$$CN_{avg} = \frac{CN_1 * Area_1 + CN_2 * Area_2 + \cdots + CN_n * Area_n}{Area_{tot}}$$

The composite curve numbers for the subbasins range from 42 to 100 (water), as shown in Table 4 below. Changes in landcover within the Betsie River Watershed have occurred over time and these changes are reflected in adjustments to the curve numbers. In most subbasins, the curve number increases slightly over time due to development. This trend is not observed in a few subbasins and is the result of converting areas with higher curve numbers, like wetland areas (CN ~ 75), to areas with lower curve numbers, like dense herbaceous areas (CN = 30).

Table 4: Curve Number per Subbasin

Subbasin Number	1800 CN	1978 CN	2006 CN
100	64	66	67
101	58	58	61
138	56	58	56
200	61	61	60
300	54	52	54
301	59	58	57
307	55	52	54
338	54	60	56

Subbasin Number	1800 CN	1978 CN	2006 CN
369	61	63	67
400	51	46	50
412	54	43	45
420	54	52	55
428	50	49	48
436	52	51	51
460	50	47	50
484	47	45	45
492	49	46	47
500	48	46	47
505	47	47	48
524	50	47	49
562	47	48	52
581	48	48	59
600	54	56	61
670	45	42	47
685	48	48	47
700	49	52	51
701	100	100	100
705	50	51	54
800	53	55	57

Time of Concentration

The time of concentration is the time it takes for a drop of water to travel from the hydraulically most distant point in the watershed (or subbasin) to the outlet point of the watershed/subbasin. The hydraulically most distant point in the watershed is typically governed by not only the longest distance a drop of water has to travel, but also involves consideration of the steepness (slope) of its flow path as well as the local landcover. The time of concentration affects the intensity of the peak flow rates: the longer the time of concentration, the lower the peak flow rate, and the shorter the time of concentration, the higher the peak flow rate (assuming all other variables remain the same). The time of concentration for each subbasin in the Betsie watershed was calculated using the approach outlined in the MDEQ guidance document. The slopes used to determine the time of concentration were calculated using the Michigan DEM, available online from the Michigan Department of Technology, Management & Budget[13], and converting the DEM into 1-ft contour lines. The time of concentration for the Betsie subbasins are the same across the three time periods and are shown in Table 5 below.

[13] http://www.mcgi.state.mi.us/mgdl/?rel=ext&action=sext

Table 5: Time of Concentration per Subbasin

Subbasin Number	Time of Concentration (hours)
100	2.75
101	19.32
138	17.34
200	9.02
300	7.51
301	11.48
307	10.68
338	3.89
369	9.86
400	1.20
412	0.39
420	2.86
428	8.05
436	3.71
460	9.42
484	3.42
492	5.44
500	9.14
505	5.33
524	2.00
562	4.38
581	1.45
600	3.11
670	2.81
685	16.68
700	1.51
701	8.89
705	1.33
800	3.06

Ponding Adjustments

Ponding represents temporary storage in the landscape provided by swampy areas, small depressions, and small ponds. Based on site-specific data including aerial photography and land cover maps of the Betsie River Watershed, it is clear that there are many small ponds and swampy areas scattered throughout the watershed. These landscape features retain and retard the runoff and cause peak flow rates to be reduced. Table 10.1 in Sorrell (2010) provides adjustment factors to determine this reduction based on the ratio of ponding area to the total drainage area. The ponding adjustment factor was selected based on a percentage of ponded area of 0.5% and an annual storm probability of 50%, resulting in a ponding factor of 0.88 for the entire Betsie River Watershed. This ponding factor is used to adjust peak flow rates, reflecting the attenuation that is provided by the small ponds and swampy areas. Ponding adjustments are replaced by reservoir routing for the larger lakes in the Betsie Watershed. All large lakes, including Duck Lake, Grass Lake, Green Lake, Crystal Lake, and Betsie Lake are explicitly modeled using HEC-HMS to estimate peak outflows from these waterbodies. Ponding factors were not used in HEC-HMS to calculate flow rates routed through the lakes and reservoirs.

Results

Runoff Volume Analysis

Runoff volumes were calculated for the 1800, 1978, and 2006 conditions for the 2-year, 24 hour (50% annual probability) design storm. Table 6 shows the runoff volume results for each of the subbasins. Note that subbasins with a curve number of less than or equal to 49 do not produce any runoff under the 2-year, 24 hour storm event, since the initial abstraction[14] in these subbasins is calculated to be equal to the precipitation depth. The total runoff volume increases approximately by 5% from predevelopment (1800) conditions to current conditions.

Table 6: Runoff Volume in Acre-Feet

Subbasin Number	1800 Runoff Volume (acre-ft)	1978 Runoff Volume (acre-ft)	2006 Runoff Volume (acre-ft)
100	120.61	141.44	160.52
101	47.23	52.28	86.29
138	11.31	20.93	12.19
200	61.73	66.69	58.22
300	16.39	6.66	13.65
301	68.25	50.94	43.79
307	7.35	2.26	5.38
338	0.93	3.84	1.50
369	12.40	16.12	27.84
400	0.04	0.00	0.01
412	0.11	0.00	0.00
420	2.32	0.93	2.61
428	0.13	0.09	0.00
436	2.69	0.98	1.31
460	0.16	0.00	0.11
484	0.00	0.00	0.00
492	0.03	0.00	0.00
500	0.00	0.00	0.00
505	0.00	0.00	0.00
524	0.02	0.00	0.00
562	0.00	0.00	2.79

[14] Initial abstraction refers to all water losses before runoff begins, including water retained in surface depressions, taken up by vegetation, evaporation and infiltration.

Subbasin Number	1800 Runoff Volume (acre-ft)	1978 Runoff Volume (acre-ft)	2006 Runoff Volume (acre-ft)
581	0.00	0.00	1.48
600	3.64	7.95	21.13
670	0.00	0.00	0.00
685	0.00	0.00	0.00
700	0.10	4.44	2.67
701	1622.34	1622.34	1622.34
705	0.12	0.33	1.70
800	7.71	17.43	26.87
TOTAL	**1,986**	**2,016**	**2,092**

In most subbasins, the runoff volume increases with time due to the effects of increased development. This is evident, for example, in subbasins 100, 369, and 600. In a few subbasins, this trend of runoff consistently increasing over time is not observed. A closer look at these subbasins shows that runoff decreases because areas with higher curve numbers (forest, wetland) were converted to areas with a lower curve number (rangeland, agriculture). This is evident, for example, in subbasin 420. The area and curve number breakdown for subbasin 420 is shown in Table 7 (the curve numbers were taken directly from the MDEQ lookup tables). The curve number decreases from the 1800 to the 1978 conditions because a large portion of wetlands were converted to forested and range land. This results in a decrease in the runoff volumes between these two time periods. The curve number then increased from the 1978 to the 2006 conditions because: (1) significant areas classified as forest and rangelands in the 1978 MIRIS map were classified as wetlands in the 2006 NLCD map, and (2) urban areas increased from 1978 to 2006.

Table 7: Detailed Runoff Analysis of Subbasin 420

Subbasin 420 Characteristics	Typical CN* (HSG A)	1800	1978	2006
Landcover breakdown				
Agricultural Land	45-65	0	112	11
Forest Land	45	1,144	1,008	876
Rangeland	30	0	311	174
Urban and Built Up	61-89	0	10	76
Wetlands	78-85	406	109	412
TOTAL		1,550	1,550	1,550
Composite Curve Number	-	54	52	55
Runoff Volume (acre-ft/acre)		2.32	0.93	2.61

*Note: The curve numbers (CNs) shown here are taken directly from the MDEQ lookup tables.

To provide a comparison of runoff volume generated from each subbasin, the runoff volumes were normalized by area. This creates a runoff depth per watershed, in inches, and provides an indication of which areas produce the most runoff due to their hydrologic characterization. Table 8 shows the area-normalized runoff volumes for all watersheds. The largest area-normalized contributors are subbasin 100, which is located in the eastern part of the Betsie watershed; subbasin 369, which drains to the Little Betsie River; and subbasin 701, which represents Crystal Lake proper. Subbasin 100 has a relatively high curve number, steep slopes, and short time of concentration, all of which contribute to a higher area-normalized runoff volume. Subbasin 369 also has a relatively high curve number because of the large amounts water relative to its total area (water has a curve number of 98), which drives the higher area-normalized runoff volume. Any precipitation that falls onto Crystal Lake (subbasin 701) is converted to “runoff” and should not be used as a point of comparison with the other subbasins because it represents water storage in a lake system rather than surface runoff from the landscape.

Table 8: Area-Normalized Runoff Volume in inches

Subbasin Number	1800 Runoff Volume (inches)	1978 Runoff Volume (inches)	2006 Runoff Volume (inches)
100	0.15	0.17	0.20
101	0.05	0.06	0.09
138	0.03	0.05	0.03
200	0.08	0.09	0.08
300	0.02	0.01	0.02
301	0.06	0.05	0.04
307	0.03	0.01	0.02
338	0.02	0.08	0.03
369	0.09	0.12	0.20
400	0.00	0.00	0.00
412	0.02	0.00	0.00
420	0.02	0.01	0.02
428	0.00	0.00	0.00
436	0.01	0.00	0.00
460	0.00	0.00	0.00
484	0.00	0.00	0.00
492	0.00	0.00	0.00
500	0.00	0.00	0.00
505	0.00	0.00	0.00
524	0.00	0.00	0.00
562	0.00	0.00	0.01
581	0.00	0.00	0.06
600	0.02	0.04	0.10
670	0.00	0.00	0.00
685	0.00	0.00	0.00
700	0.00	0.01	0.00
701	1.97	1.97	1.97

Subbasin Number	1800 Runoff Volume (inches)	1978 Runoff Volume (inches)	2006 Runoff Volume (inches)
705	0.00	0.00	0.01
800	0.01	0.03	0.04

Peak Flow Yield Analysis

The peak flows from each subbasins were also calculated following the MDEQ methodology outlined in Sorrell (2010). The peak flow analysis takes into account the ponding and the time it takes for runoff to flow through each subbasin. The peak flow rate, along with the runoff volume, provides a complete measure of the hydrologic responsiveness of each subbasin. The peak flow yield is the peak flow divided by the drainage area, and this metric allows for a direct comparison of the hydrologic responsiveness of differently sized subbasins.

Table 9 shows the peak flow rates from each subbasin for the three different time periods. In most cases, the peak flow rate from a subbasin increases over time due to increased development. In a few subbasins, this trend of increased peak flow rate over time is not observed. The reasons for this were described in the previous section.

Table 9: Peak flow rate in cubic feet per second

Subbasin Number	1800 Peak Flow Rate (cfs)	1978 Peak Flow Rate (cfs)	2006 Peak Flow Rate (cfs)
100	207	243	276
101	16	18	30
138	4	8	5
200	40	43	38
300	12	5	10
301	36	27	23
307	4	1	3
338	1	5	2
369	7	10	17
400	0	0	0
412	1	0	0
420	4	2	4
428	0	0	0
436	4	1	2
460	0	0	0
484	0	0	0
492	0	0	0
500	0	0	0
505	0	0	0
524	0	0	0
562	0	0	3

Subbasin Number	1800 Peak Flow Rate (cfs)	1978 Peak Flow Rate (cfs)	2006 Peak Flow Rate (cfs)
581	0	0	4
600	6	12	33
670	0	0	0
685	0	0	0
700	0	12	8
701	1,065	1,065	1,065
705	0	1	5
800	12	27	42

Table 10 shows the peak flow yield per subbasin. The subbasin that has the highest peak flow yield is subbasin 701, which represents Crystal Lake. Precipitation that falls on this subbasin is directly added to the existing water in the lake, and this subbasin was included in the hydrologic and hydraulic analysis in order to represent the precipitation falling onto this lake directly. It does not make for a good point of comparison for analyzing the peak flow yield of other subbasins, since it is so unique in its characterization. Subbasin 100 and 412 have the highest peak flow yields after Crystal Lake. All other subbasins have a peak flow yield that is a magnitude of order smaller than these two. Subbasin 100 has a relatively high curve number, a relatively steep slope, and a short time of concentration, all of which contribute to a higher peak flow yield. Subbasin 412 is one of the smallest subbasins in the Betsie watershed (79 acres), and while the peak flow for the 1800 conditions is fairly high, its contributing area is so small that the peak flow rates from this area are very small compared to the rest of the neighboring area, and should not be considered a hydrological area of concern.

Table 10: Peak flow yield in cubic feet per second per acre

Subbasin	1800 Peak Flow Yield (cfs/acre)	1978 Peak Flow Yield (cfs/acre)	2006 Peak Flow Yield (cfs/acre)
100	0.021	0.025	0.028
101	0.001	0.002	0.003
138	0.001	0.002	0.001
200	0.005	0.005	0.004
300	0.001	0.000	0.001
301	0.003	0.002	0.002
307	0.001	0.000	0.001
338	0.002	0.008	0.003
369	0.005	0.006	0.010
400	0.001	0.000	0.000
412	0.012	0.000	0.000
420	0.002	0.001	0.003
428	0.000	0.000	0.000
436	0.001	0.000	0.000
460	0.000	0.000	0.000
484	0.000	0.000	0.000

Subbasin	1800 Peak Flow Yield (cfs/acre)	1978 Peak Flow Yield (cfs/acre)	2006 Peak Flow Yield (cfs/acre)
492	0.000	0.000	0.000
500	0.000	0.000	0.000
505	0.000	0.000	0.000
524	0.000	0.000	0.000
562	0.000	0.000	0.001
581	0.000	0.000	0.015
600	0.002	0.005	0.012
670	0.000	0.000	0.000
685	0.000	0.000	0.000
700	0.000	0.002	0.001
701	0.108	0.108	0.108
705	0.000	0.001	0.004
800	0.001	0.003	0.005

Stream Flow Analysis

Flow from each subbasin was routed through the Betsie River and its lakes using the HEC-HMS model. The Muskingum-Cunge routing method was used to simulate the attenuation of flow through the Betsie River. This routing method requires information on the stream length and slope; Manning's roughness coefficient; and channel shape, bottom width, and side slope. The stream length and gradient were estimated in GIS using the NHDPlus dataset, which was developed under USEPA funding[15]. The shape of each river section was assumed to be trapezoidal. The bottom width, side slope, and Manning's roughness coefficient were estimated based on field surveys of similar streams in the Platte River Watersheds. The Platte River Watershed is located north of the Betsie River Watershed and both share features such as consisting largely of undeveloped areas, having many small lakes and tributaries, and being roughly of similar size. Figure 5 shows an aerial of the two watersheds. Reports on the Platte River Watershed study can be accessed at www.platte-lake.org[16].

[15] http://www.horizon-systems.com/nhdplus/

[16] http://www.platte-lake.org/October_2010_ASCE_Paper.pdf , http://www.platte-lake.org/BASINSReportPlatteRiverWatershed.pdf, http://www.platte-lake.org/BASINSAppendixG.pdf

Figure 5: Location of the Betsie River and Platte River Watershed

Flow through the lakes was simulated using an area-elevation rating curve for the lakes (Table 11) coupled to characterization of the outflow weirs (Table 12). The area-elevation rating curve was obtained by calculating the surface areas of topographic contours around the lake. These topographic contours were extrapolated from the Michigan DEM.

Table 11: Elevation-Area Rating Curves

Duck Lake Elevation (ft)	Duck Lake Area (acres)	Green Lake Elevation (ft)	Green Lake Area (acres)	Grass Lake Elevation (ft)	Grass Lake Area (acres)	Crystal Lake Elevation (ft)	Crystal Lake Area (acres)
840.00	1896.87	823.00	1951.75	824.0	721.76	600.0	9758.55
841.00	2528.07	826.00	1997.92	825.0	1153.86	601.0	9794.35
842.00	2602.52	827.00	4566.13	826.0	1634.44	602.0	9821.63
				827.0	4566.12	603.0	9850.56
						604.0	9909.03

Table 12: Spillway Characteristics

	Duck Lake	Grass Lake	Crystal Lake
Spillway Type	Broad-Crested	Broad-Crested	Broad-Crested
Spillway Elevation, ft	837.3	824.05	600.25
Spillway Length, ft	23	61	50
Spillway Coefficient	3.2	3.2	3.2

Green Lake has no outflow structure, so an elevation-discharge rating curve (Table 13) was used to describe the flow leaving Green Lake. This elevation discharge rating curve was obtained by applying the Manning Equation for open channel flow to the Betsie stream segment below Green Lake and calculating the flow at various elevations (water depths). A few basic assumptions had to be made to characterize this section of the river, including its shape (trapezoidal), manning's n (0.05), bottom width (14m, measured using GIS), side slope (45 degrees), and stream slope (0.0001).

Table 13: Green Lake Elevation-Discharge Rating Curve

Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
823.00	0.0	831.20	477.0
823.82	10.0	832.02	560.0
824.64	31.0	832.84	648.0
825.00	43.0	833.66	742.0
826.28	101.0	834.48	840.0
827.10	148.0	835.30	943.0
827.92	201.0	836.12	1051.0
828.74	261.0	836.94	1163.0
829.56	328.0	837.76	1280.0
830.38	400.0		

To characterize total streamflow through the Betsie River, baseflow was added to all stream segments. In lieu of site-specific baseflow information for the Betsie Watershed, the baseflow was estimated based on a study[17] that characterized the baseflow of streams in the Platte River Watershed. Since the Platte River Watershed is hydrologically similar in size and characteristics to the Betsie Watershed, it was considered reasonable to extrapolate the results from the Platte River Watershed and applied them to the Betsie River Watershed. The Platte River average baseflow was normalized by the contributing drainage area, and then applied to all the subbasin reaches in the Betsie River Watershed.
Once the stream and subbasin characteristics were defined in HEC-HMS, the model was run for the three time periods (1800, 1978, 2006) for the 2-year, 24-hour design storm. Table 14 below shows the base flow rate as well as the peak flow rate at several key hydraulic points within the Betsie River system, starting from the most upstream location and moving downstream. Reported results include the peak flow rates of major tributaries like the Little Betsie River, Dair Creek, Rice Creek, and the Crystal Lake Outlet. These key hydraulic points are also shown in Figure 6. Note that the flow rates in Table 14 are estimates based on the best available data and best professional judgment. No gaged flow data currently exist for the Betsie Watershed; therefore, it was not possible to calibrate the HEC-HMS model under this effort.

The results of the HEC-HMS modeling show that peak flow rates are significantly attenuated by the reservoirs and lakes in the Betsie River Watershed. Figure 7 shows that the peak inflow into Duck Lake is in excess of 300 cfs, but the corresponding outflow is only about 35 cfs. Similar predictions are made at the outflow of each of the lakes. These results are as expected, and they illustrate the importance of explicitly modeling lake storage and routing characteristics in the Betsie River Watershed and other

[17] Limno-Tech, Inc. Platte River Watershed Baseline Calibration Report. May 2004 (http://www.platte-lake.org/BASINSAppendixG.pdf).

similar watersheds that include significant lake systems. The predicted hydrographs at other key hydraulic points within the mainstem Betsie River are included as Figures 8 through 14 in an appendix to this report.

Table 14 shows that computed peak flow rates typically increase slightly over time, but exceptions are seen at several key locations. For example, peak flow rates below Grass Lake actually decrease over time. This is because the landscape of the drainage areas changes from being one that contributes more runoff (because of more open water, wetlands and forests) and has more contributing area to one that contributes less runoff (because some open water became wetlands, some wetlands became forests, and some forests became dense grasslands). Also note that the contributing area is slightly less in 1978 than in 1800, which also contributes, in a minor way, to the smaller runoff volumes observed in 1978. This follows the same explanation given in previous sections to describe the increasing curve numbers and runoff volumes for some of these watersheds.

Table 14: Peak flow rates at key hydraulic points in the Betsie River System

Location	Baseflow (CFS)	1800 Peak Flow (CFS)	1978 Peak Flow (CFS)	2006 Peak Flow (cfs)
1. Mainstem below Duck Lake	26	32	33	35
2. Mainstem below Green Lake	44	45	46	46
3. Mainstem below Grass Lake	58	71	68	67
4. Little Betsie River before confluence with Betsie River	7	19	22	29
5. Mainstem below Little Betsie River	79	109	103	116
6. Dair Creek before confluence with Betsie River	10	10	10	10
7. Mainstem below Dair Creek	119	151	143	159
8. Rice Creek before confluence with Betsie River	7	7	7	12
9. Crystal Lake outlet before confluence with Betsie River	34	60	60	60
10. Betsie River mainstem below connection to Crystal Lake	171	229	222	237
11. Mouth of Betsie River at Betsie Lake	183	232	227	239

Figure 6: Location of Key Hydraulic Points in the Betsie Watershed

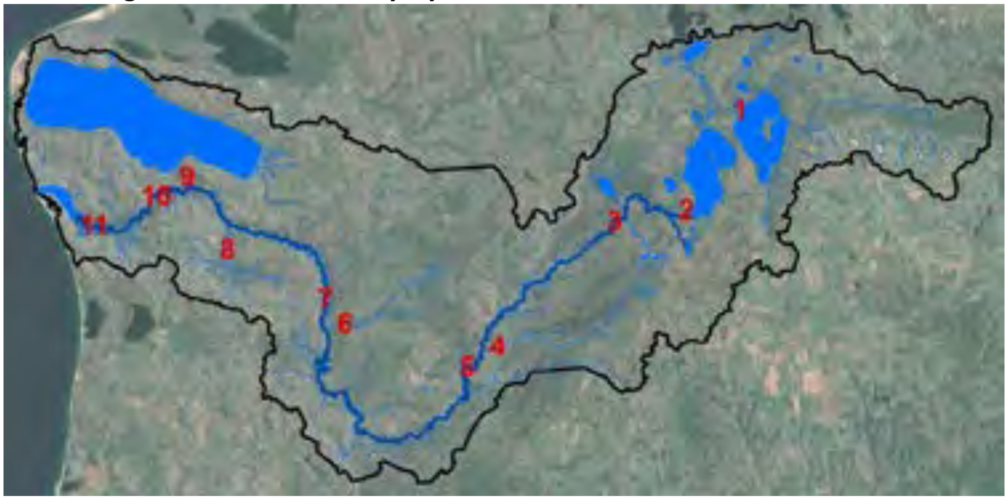
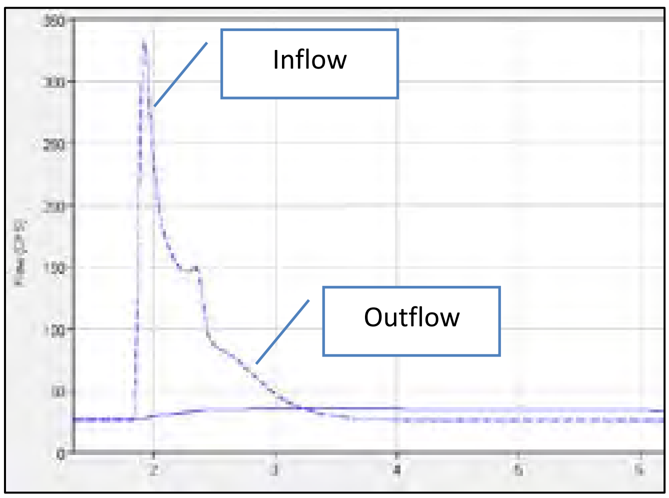


Figure 7: Inflow and Outflow hydrograph at Duck Lake



Discussion on the Limitations of the Study

The following limitations of runoff and peak flow analysis were identified during the course of the study:

- The 2006 NLCD landcover data has a different resolution and classification system than the 1978 and 1800 landcover data. The NLCD classifications were renamed to closely match the classifications used in the runoff curve number lookup tables (Table 3, pg. 10). However, differences in the NLCD land cover data resolution and production methods result in some inconsistent comparisons to the 1978 map data (e.g. large increase in wetlands). These inconsistencies affect the hydrologic parameters and the runoff calculations to a certain extent, but not enough to invalidate the study conclusions

- The 1978 data includes excavation pits which, according to the MDEQ methodology, should not be included in the computational analysis of direct contributing flows. However, by removing these areas, the effect of development on increases in runoff and peak flow rates is masked.
- The MDEQ methodology for determining peak flow rates is based on the Michigan-specific unit hydrograph. The HEC-HMS methodology for determining peak flow rates is based on the SCS unit hydrograph. The SCS unit hydrograph generally produces higher peak flow rates than the Michigan unit hydrograph, so the in-stream peak flow results are more conservative (higher) than if the Michigan unit hydrograph were used. At the time of the study, HEC-HMS did not provide the capability to change the unit hydrograph specifications. Runoff volumes calculated by the two methodologies are the same since they are not affected by the unit hydrograph.
- The Betsie River Watershed is ungaged, so it was not possible to calibrate the HEC-HMS model to any flow data. The runoff volumes and peak flow rates are based on the best available data that characterizes the watershed and best professional judgment. The confirmation of these predictions using observed flows is an important step in assuring the reliability of the results. Accordingly, it is recommended that MDEQ or its partner organizations involved in the Watershed Management Plan collect wet weather flow data at one or more of the key hydraulic points in the Betsie River system.
- The history of the dams that have been constructed along the Betsie River, and the differences that took place between 1800, 1978 and 2006 are factors that were not considered in this analysis. For example, the dam on Crystal Lake was built in 1911, the dam on Grass Lake was built in 1951, and dam on Duck Lake was built in 1959. There was also a dam built at Thompsonville in 1901 that failed in 1989 and was removed in 1998, and another, the Homestead Dam (construction date unknown) that was converted to a lamprey weir in 1974. These changing hydraulic controls on this river, due to the addition and removal of dams, likely affected peak flow rates. Although these factors were not analyzed, it should be recognized that these changes, in addition to changes in landcover, may have also affected the flood hydrographs.

Appendix: Predicted hydrographs at other key hydraulic points within the Betsie River Mainstem (Figures 8 through 14)

Note: In the following figures for each of the key hydraulic points, 3 inflow/outflow hydrographs are presented. These correspond to landcover conditions in 1800, 1978 and 2006, as discussed in the text.

Figure 8a: Betsie River Mainstem Below Duck Lake

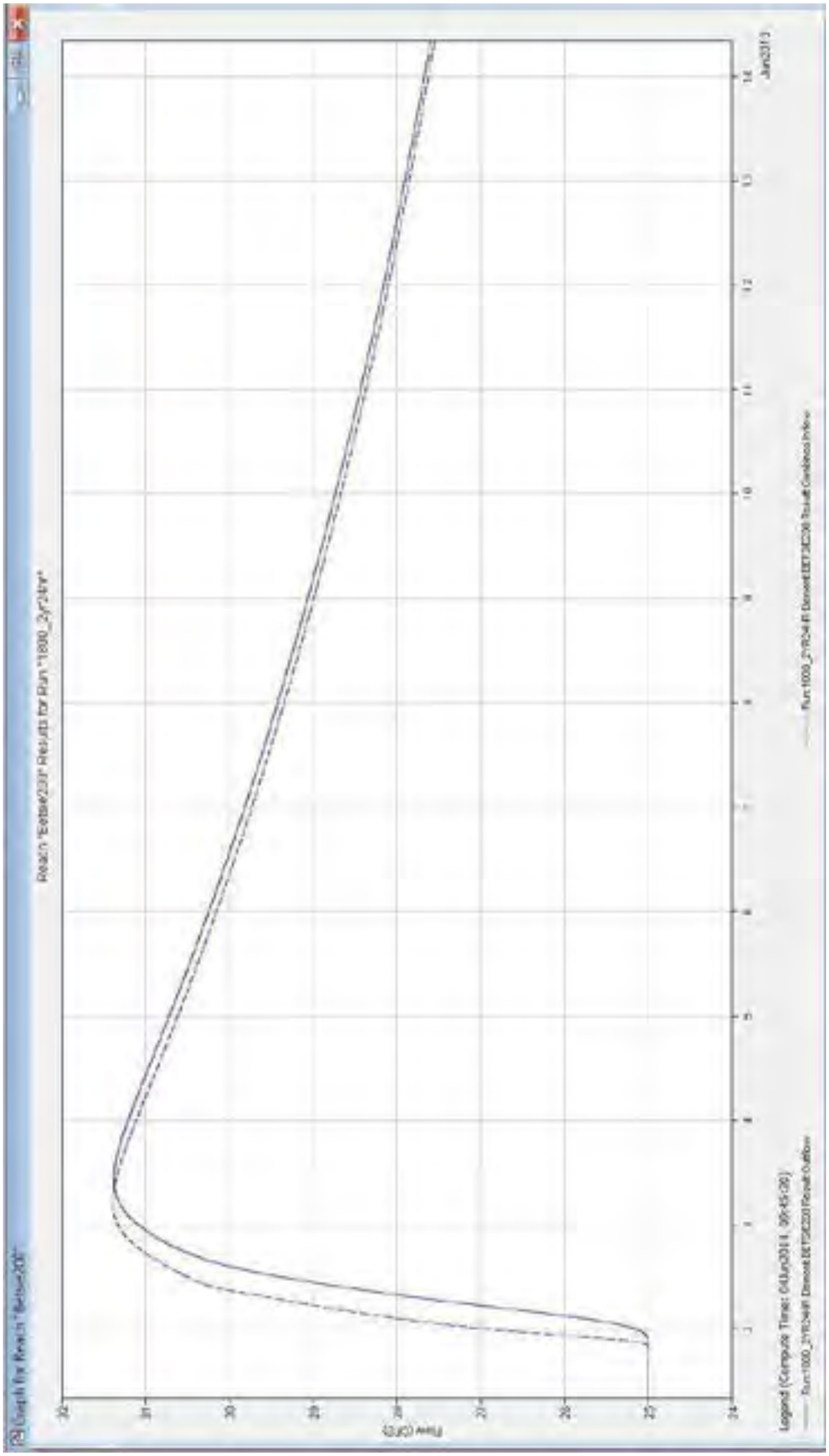


Figure 8b: Betsie River Mainstem Below Duck Lake

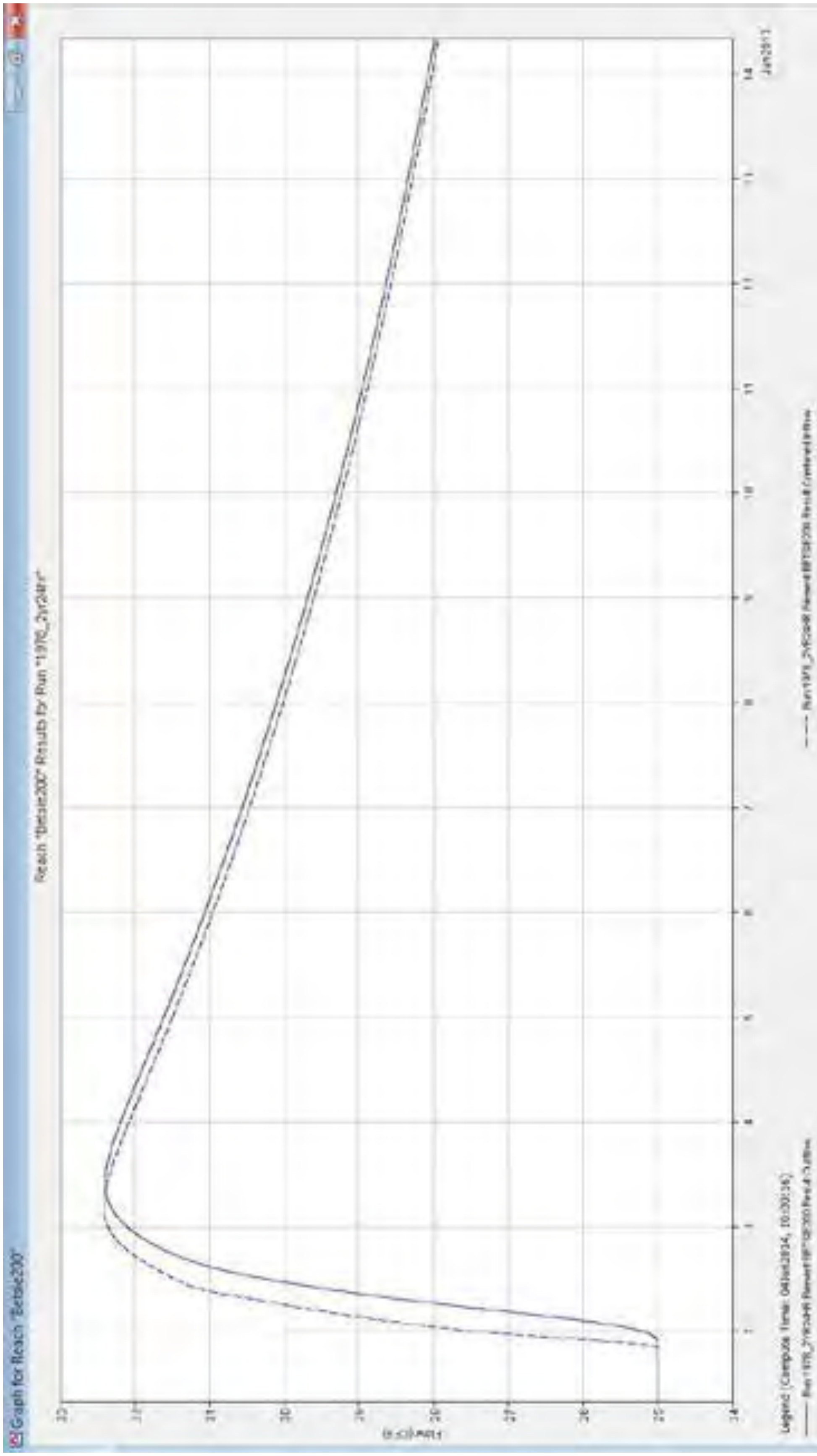


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Figure 8c: Betsie River Mainstem Below Duck Lake

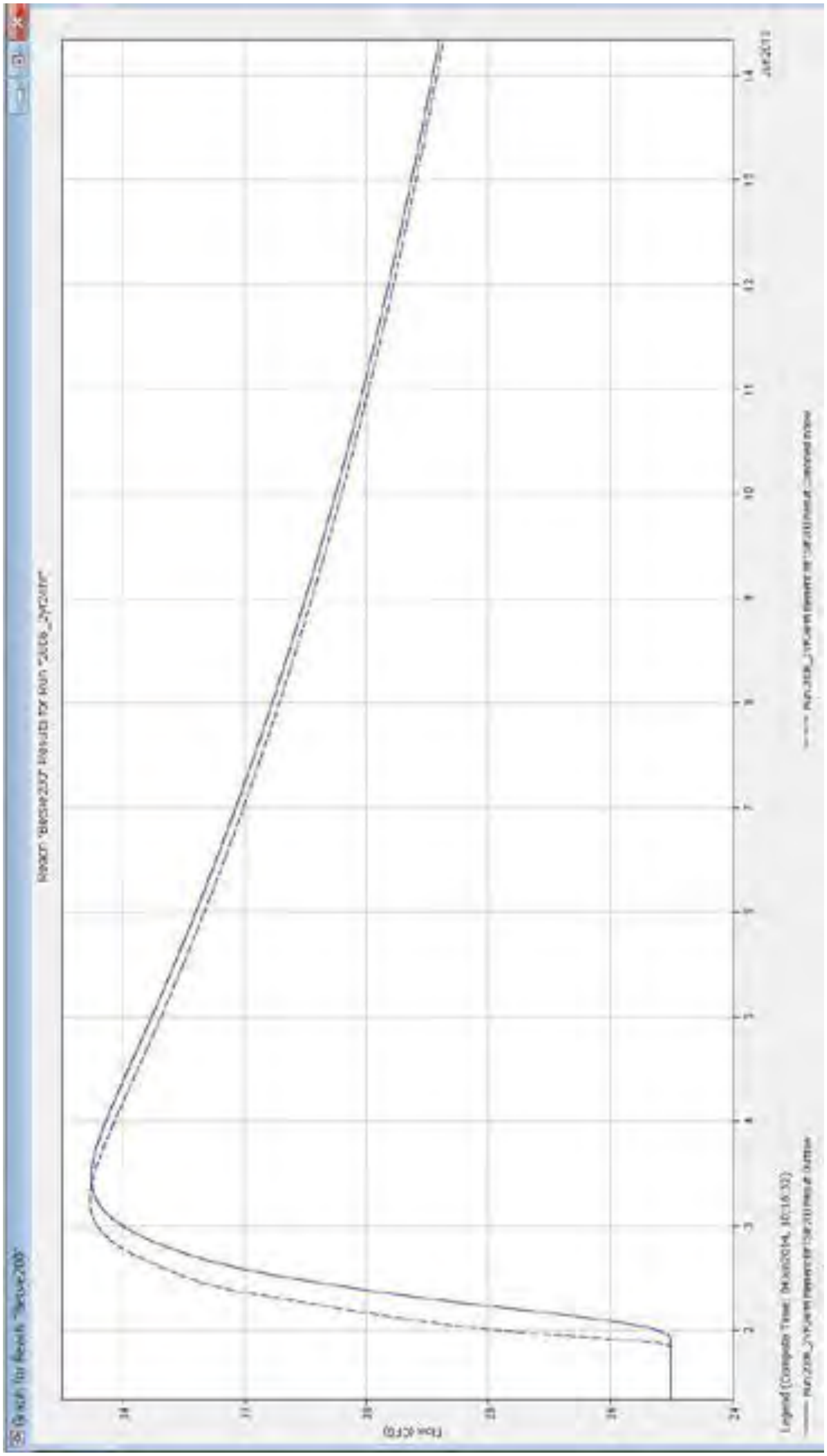

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Figure 9a: Betsie River Mainstem Below Green Lake

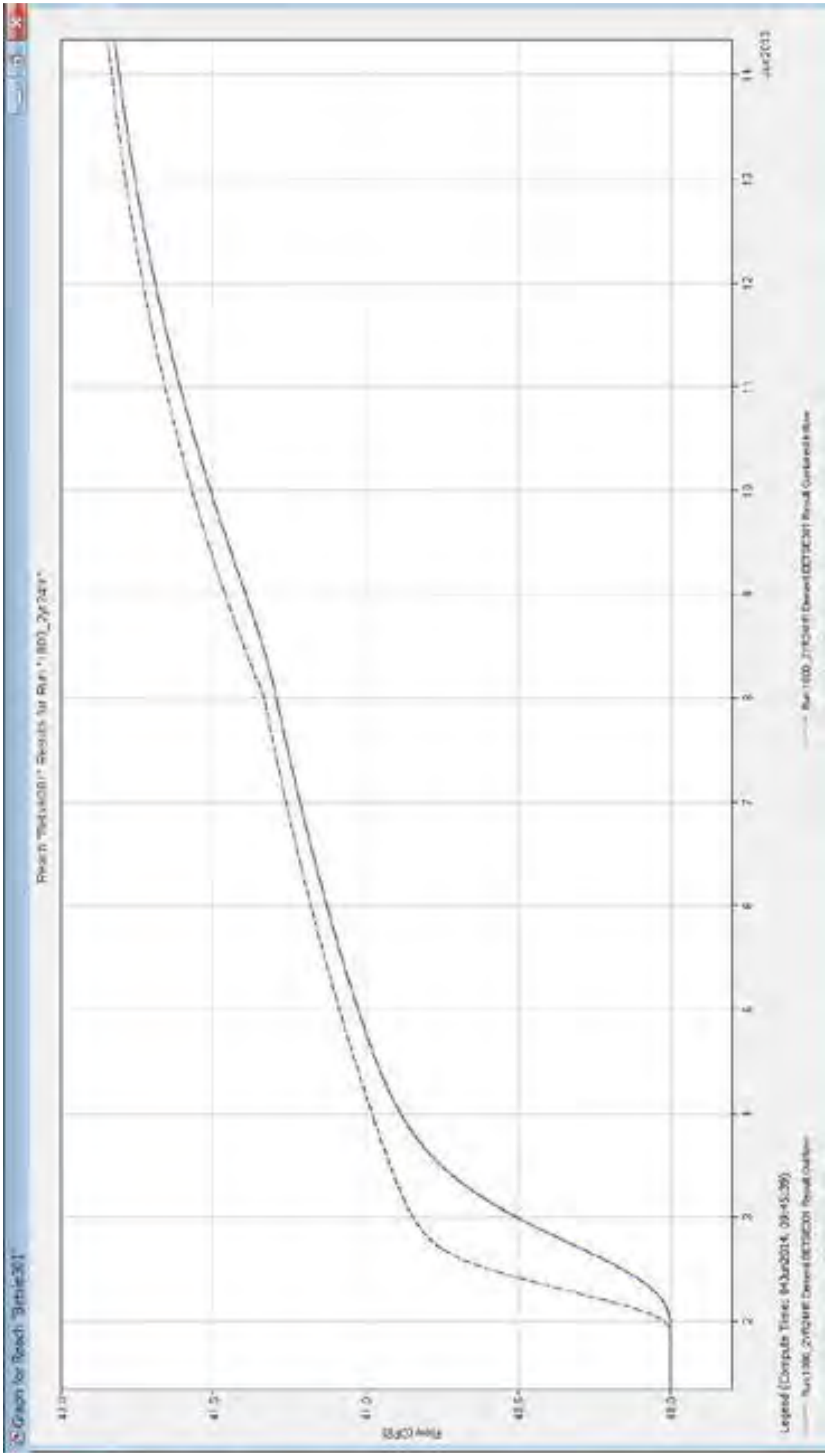

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Figure 9b: Betsie River Mainstem Below Green Lake

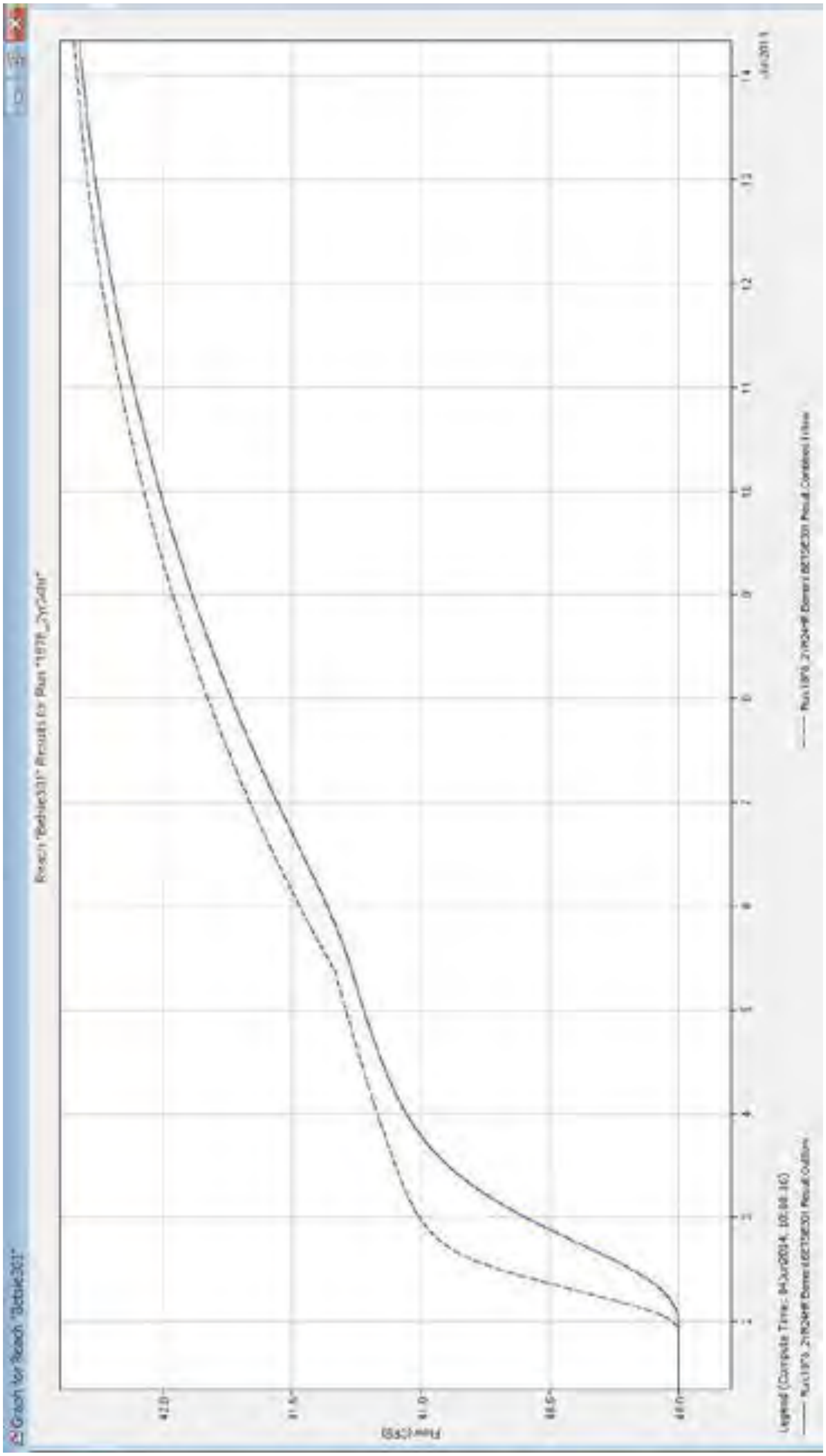

Figure 9c: Betsie River Mainstem Below Green Lake

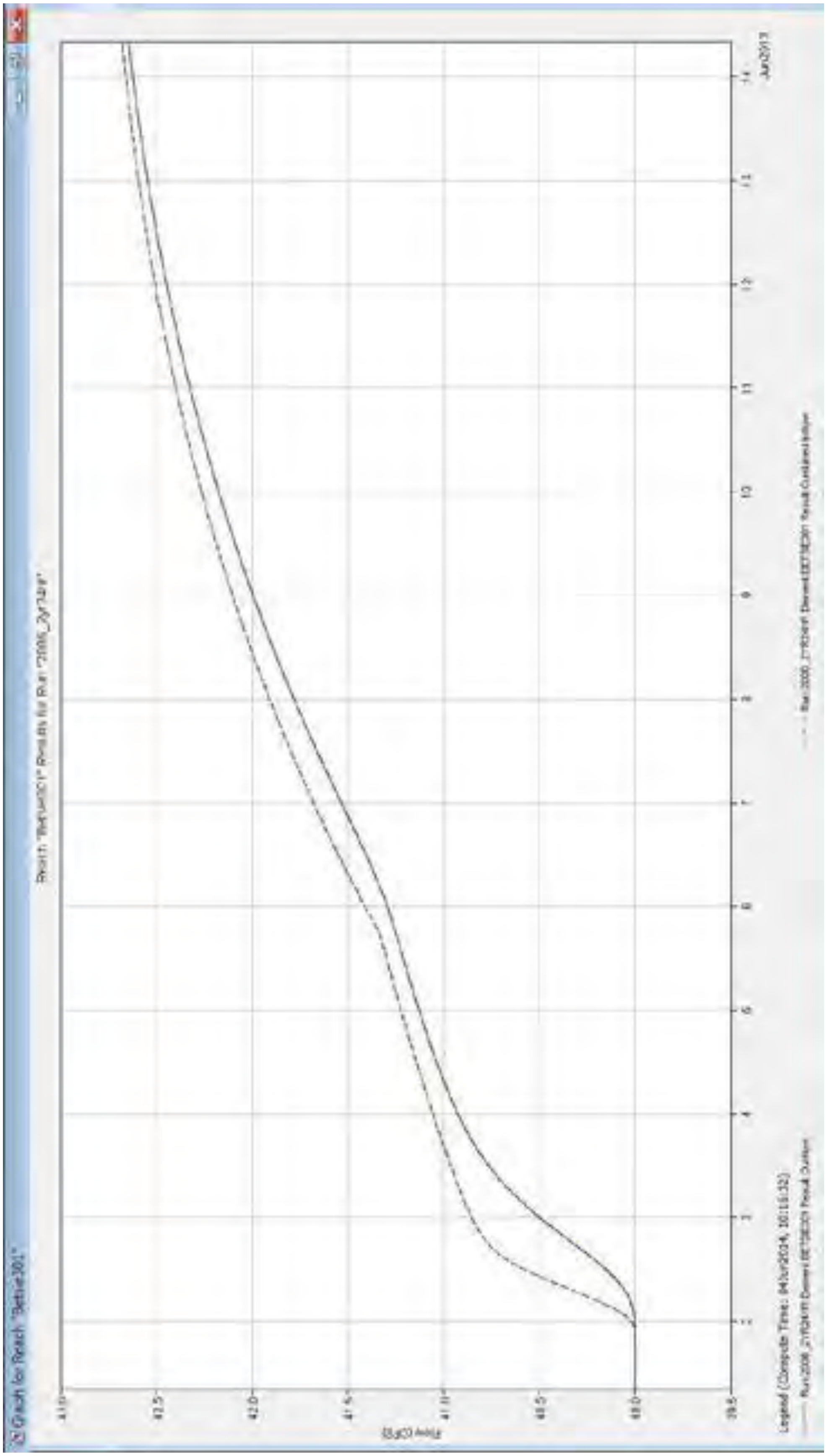

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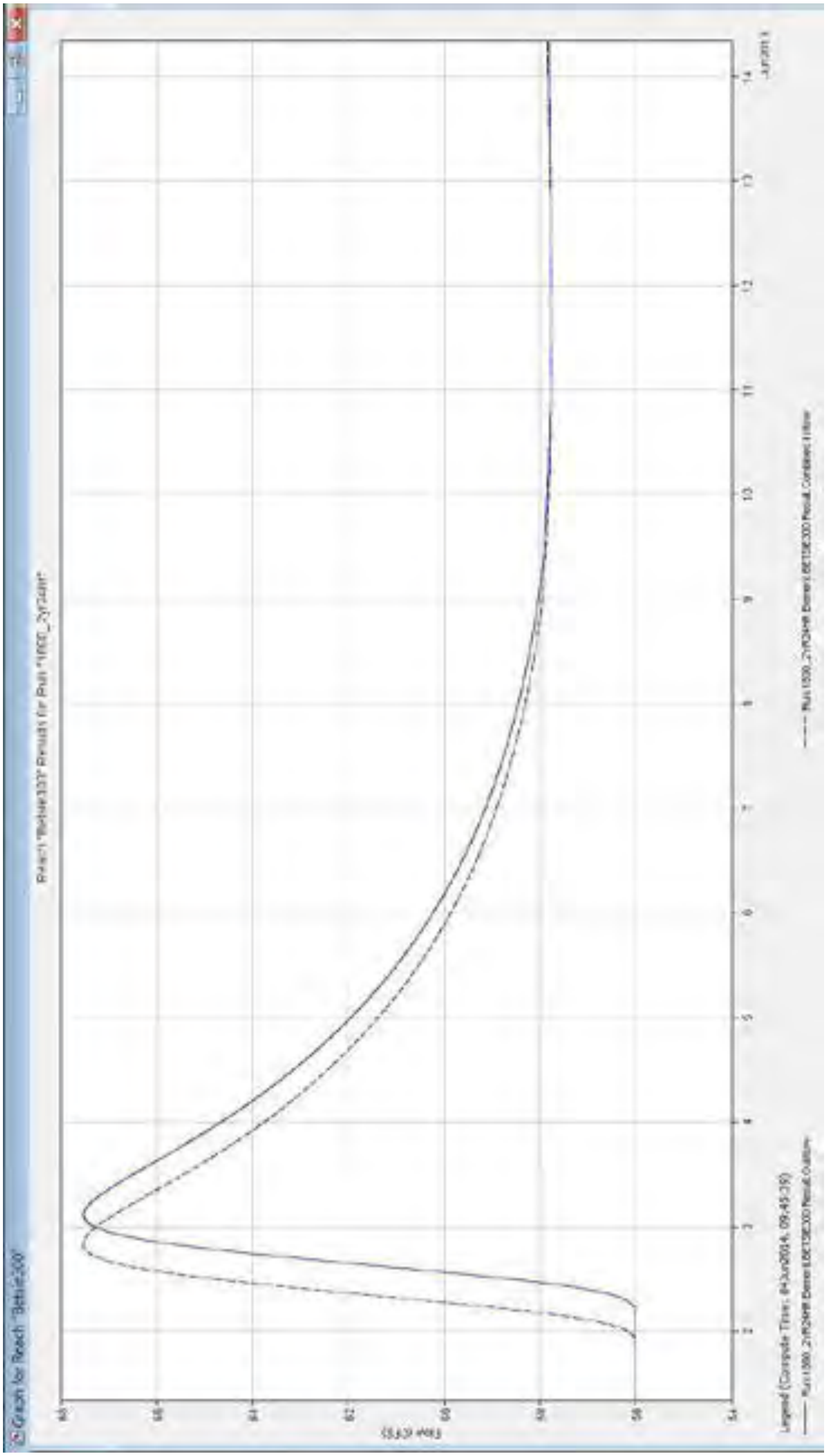
Figure 10a: Betsie River Mainstem Below Grass Lake



30

Figure 10b: Betsie River Mainstem Below Grass Lake

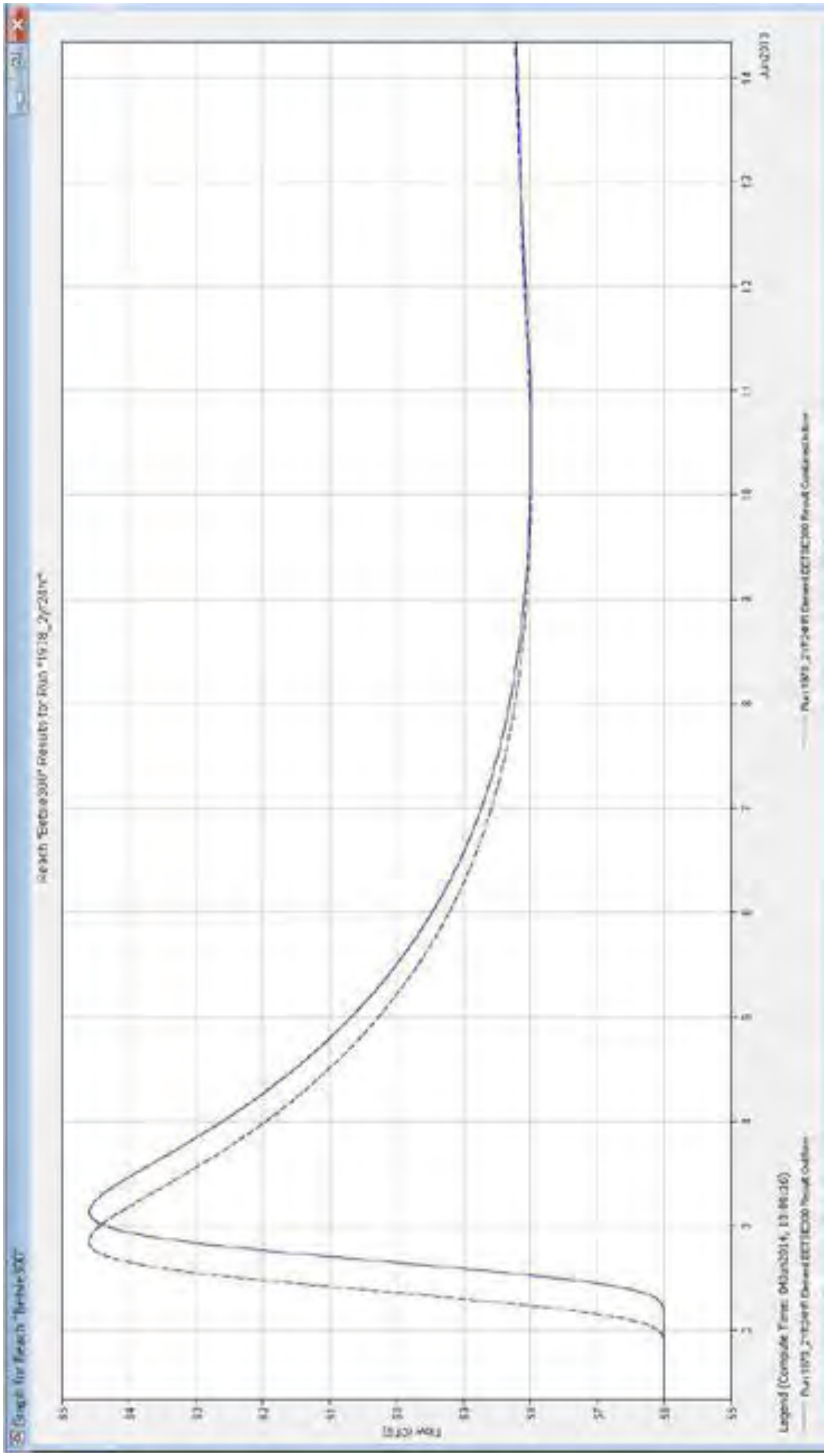


Figure 10c: Betsie River Mainstem Below Grass Lake

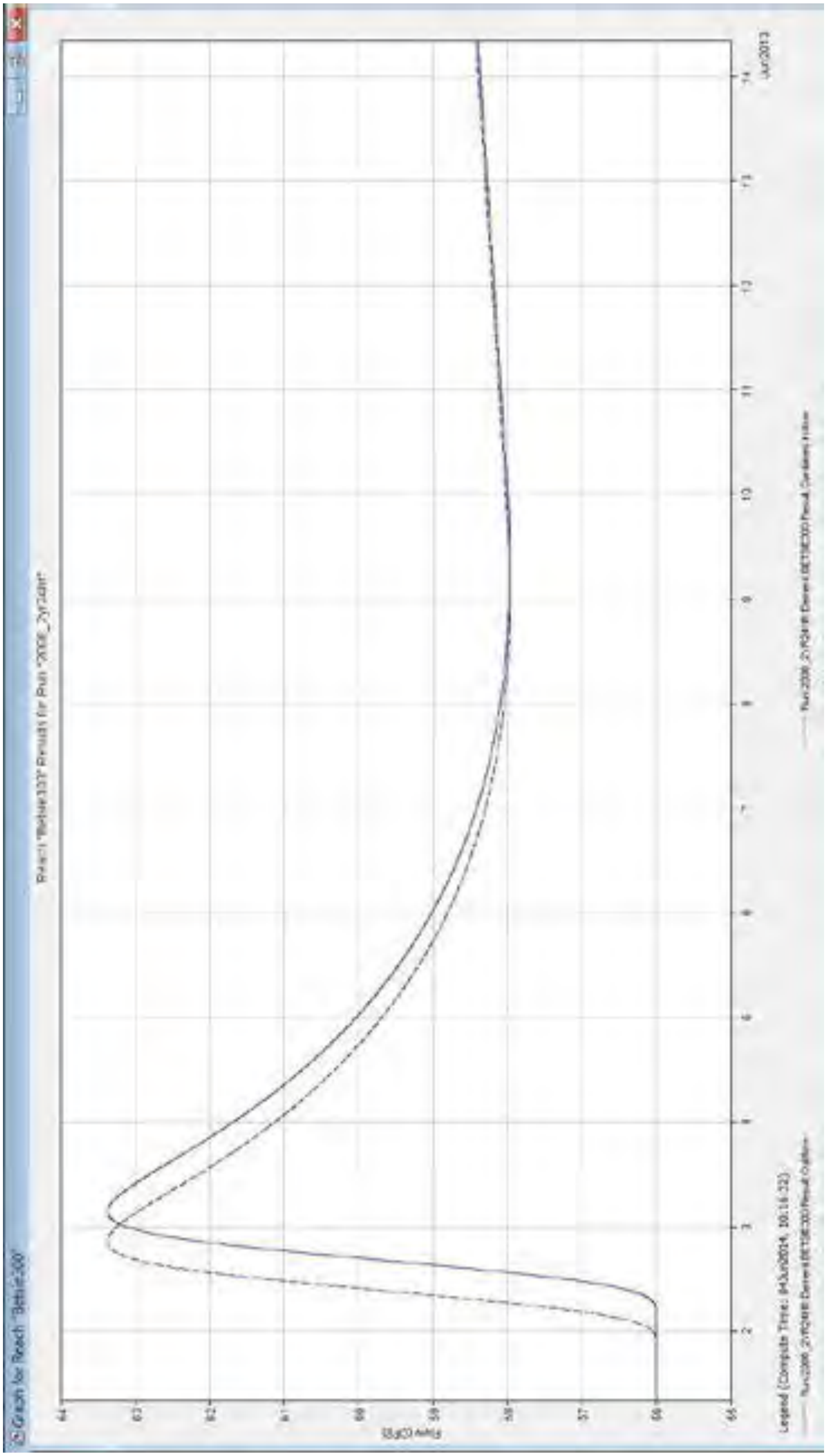


Figure 11a: Betsie River Mainstem Below Little Betsie River Junction

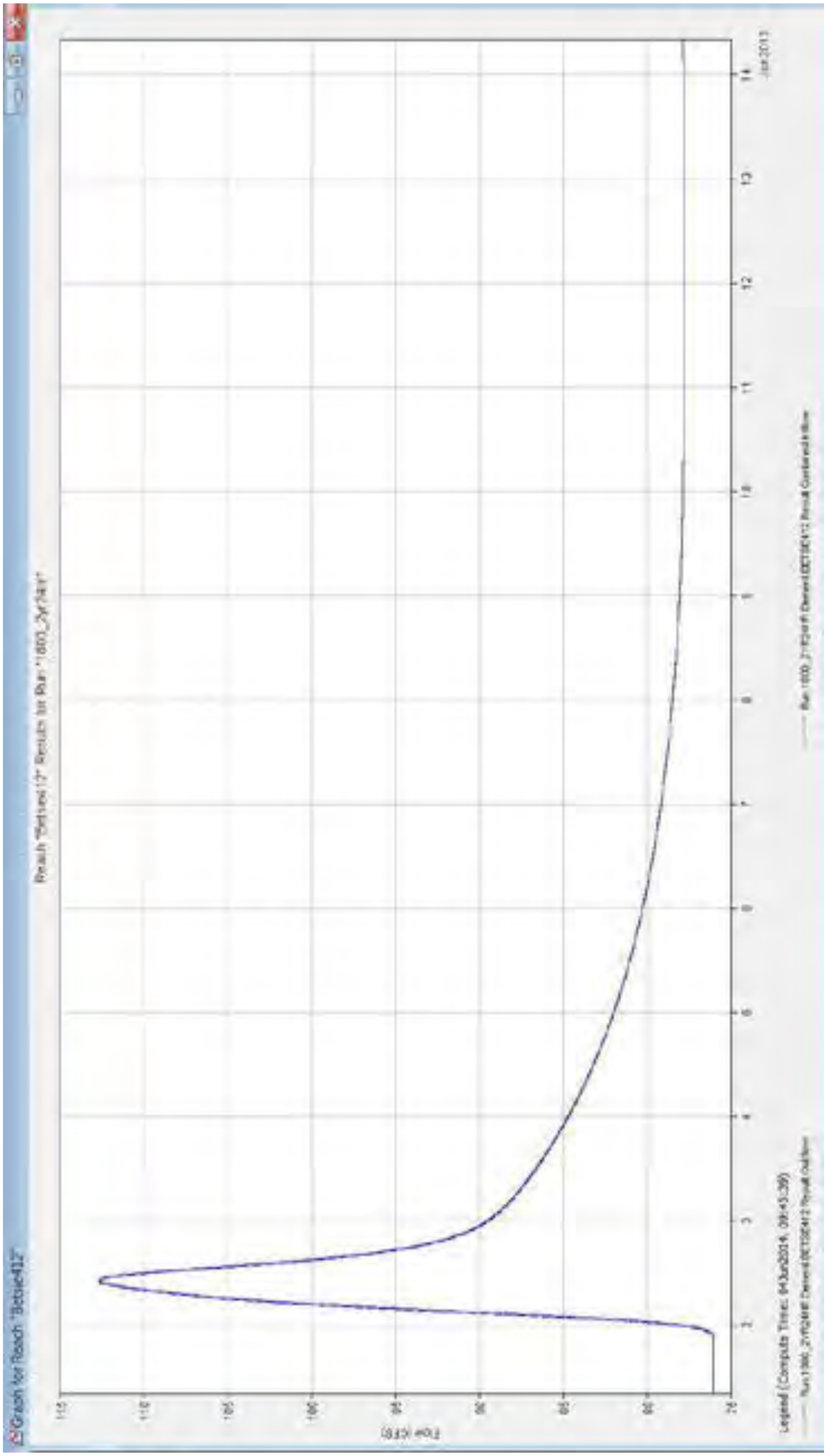


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Figure 11b: Betsie River Mainstem Below Little Betsie River Junction

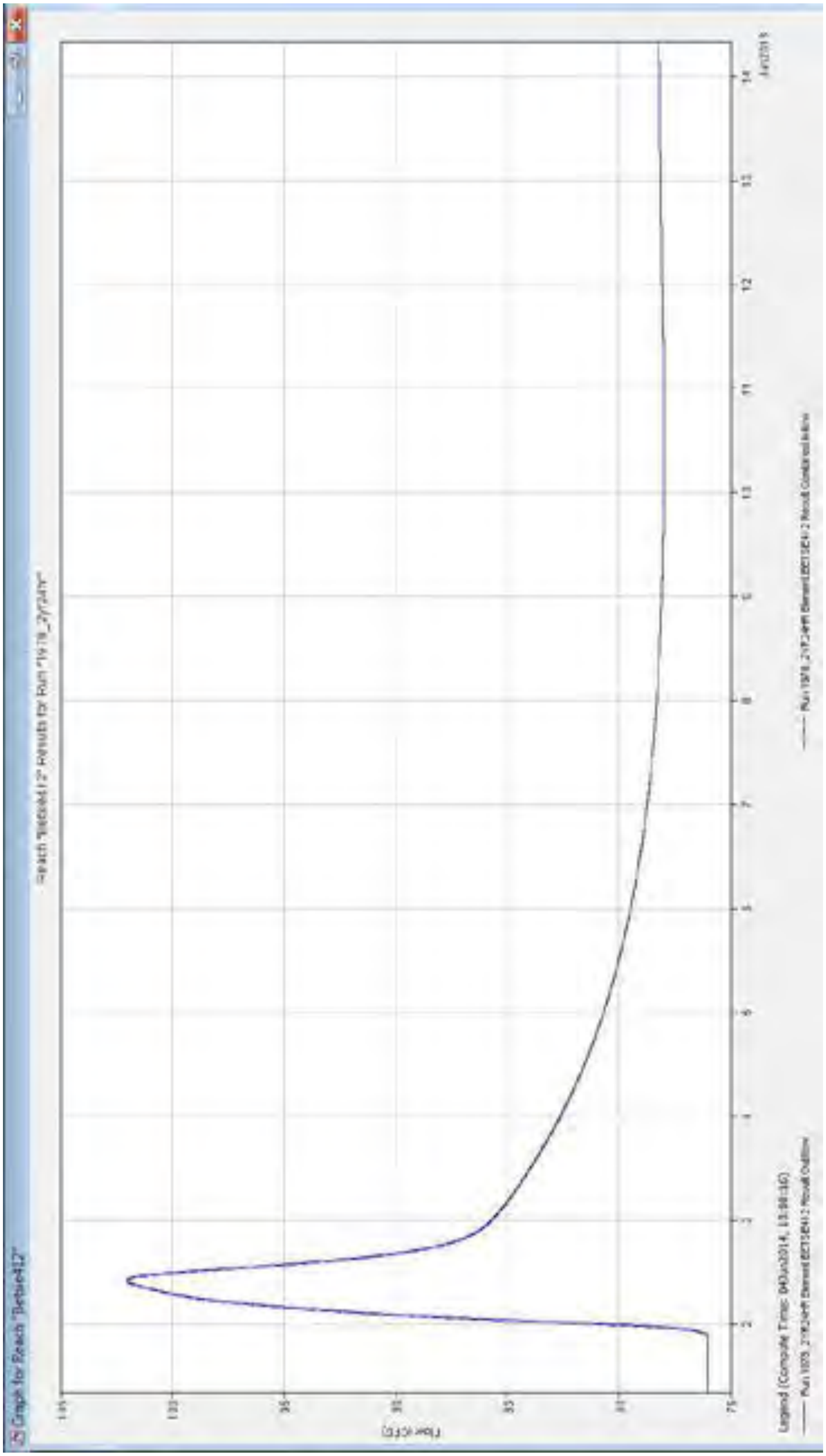

Figure 11c: Betsie River Mainstem Below Little Betsie River Junction

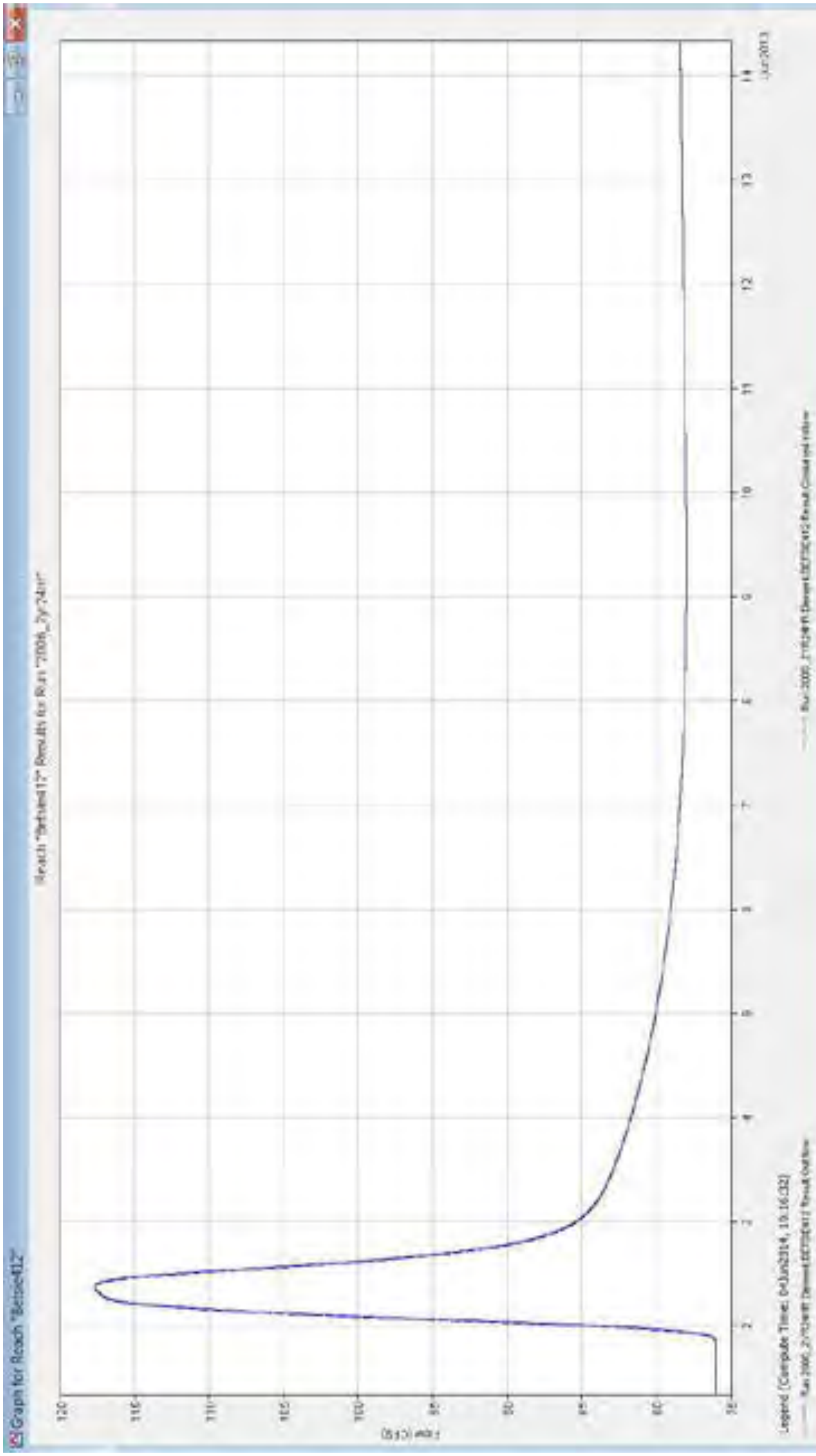

Figure 12a: Betsie River Mainstem Below Dair Creek Junction

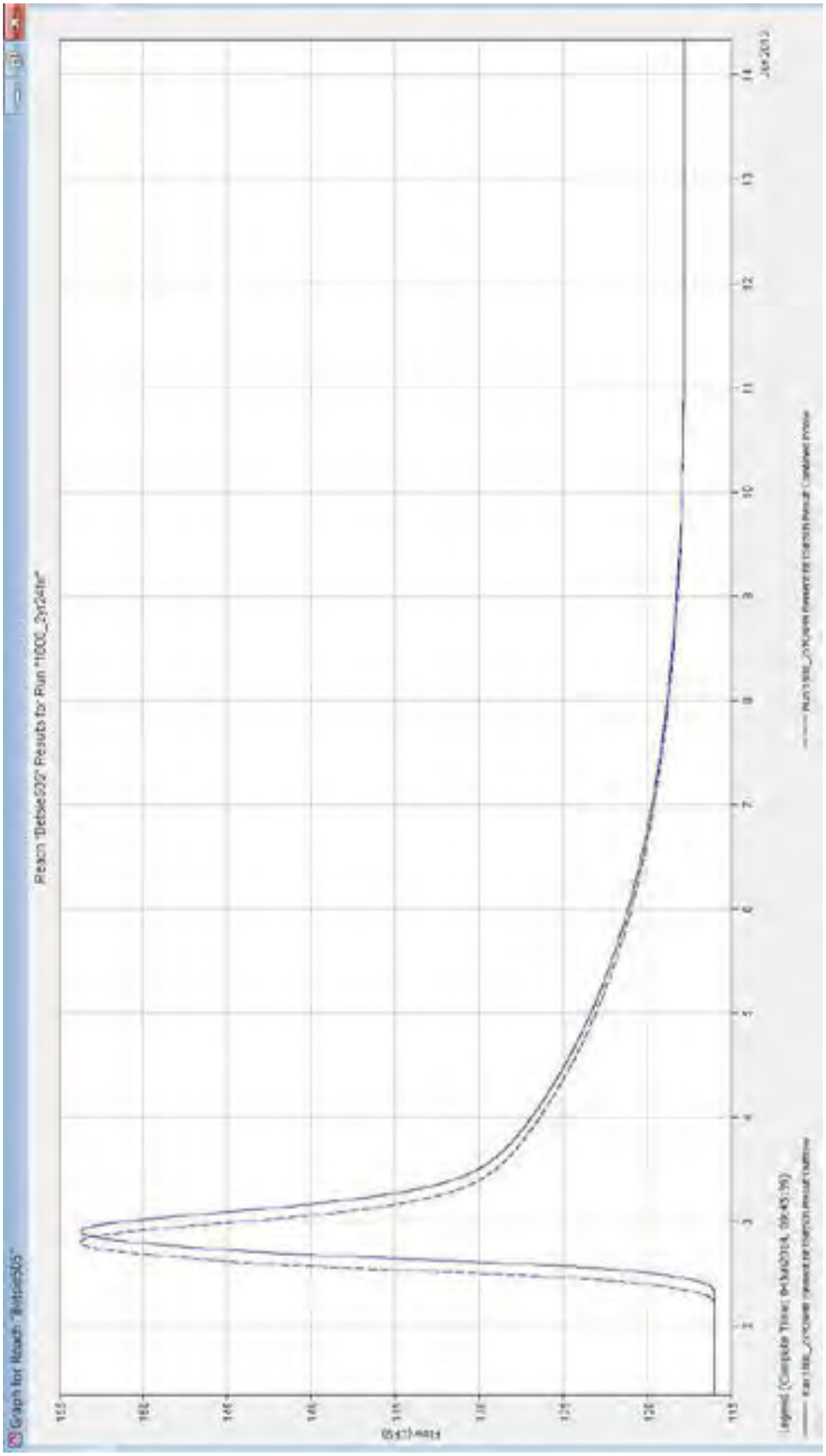

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Figure 12b: Betsie River Mainstem Below Dair Creek Junction

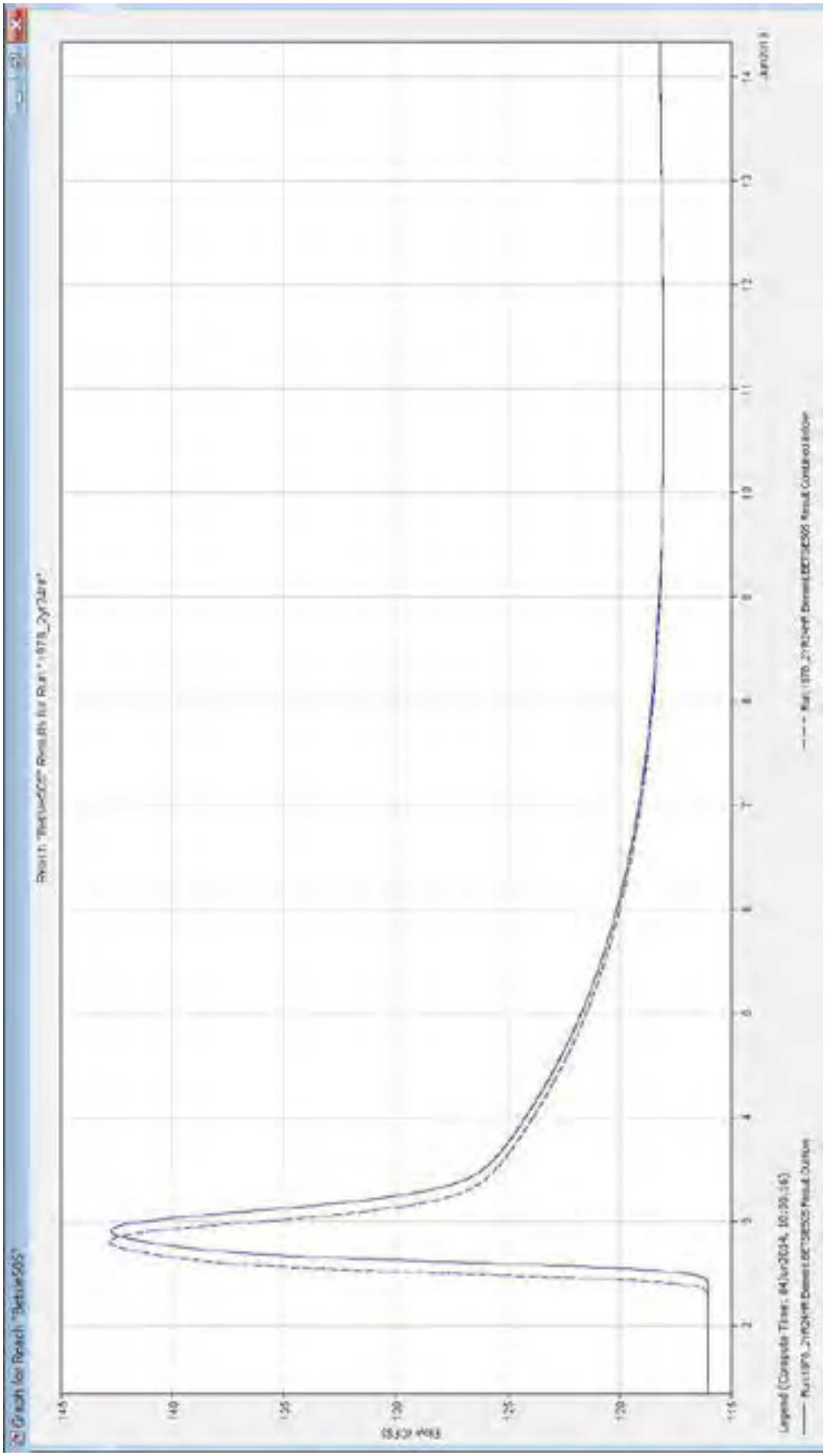

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Figure 12c: Betsie River Mainstem Below Dair Creek Junction

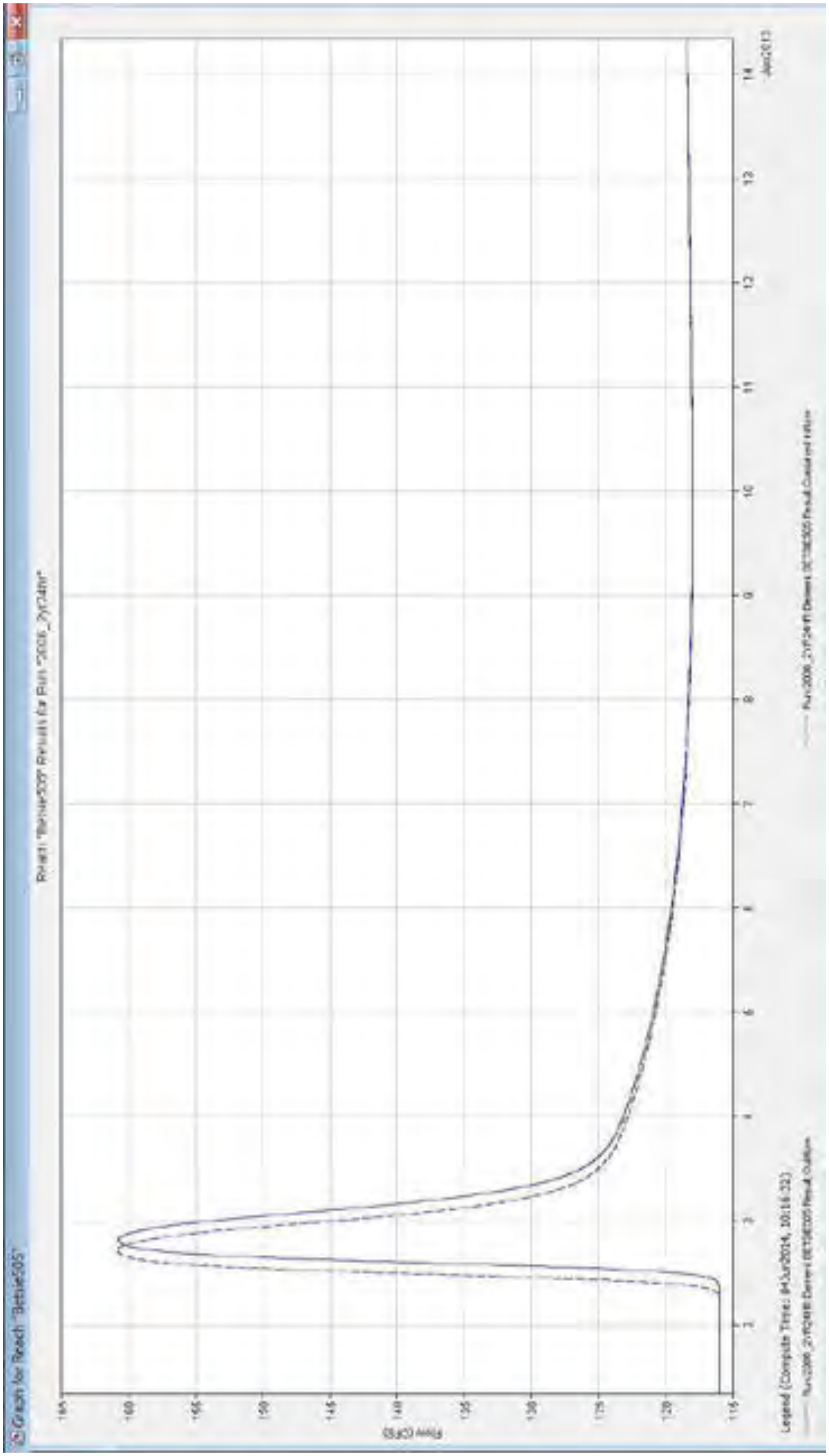

Figure 13a: Betsie River Mainstem Below Connection to Crystal Lake

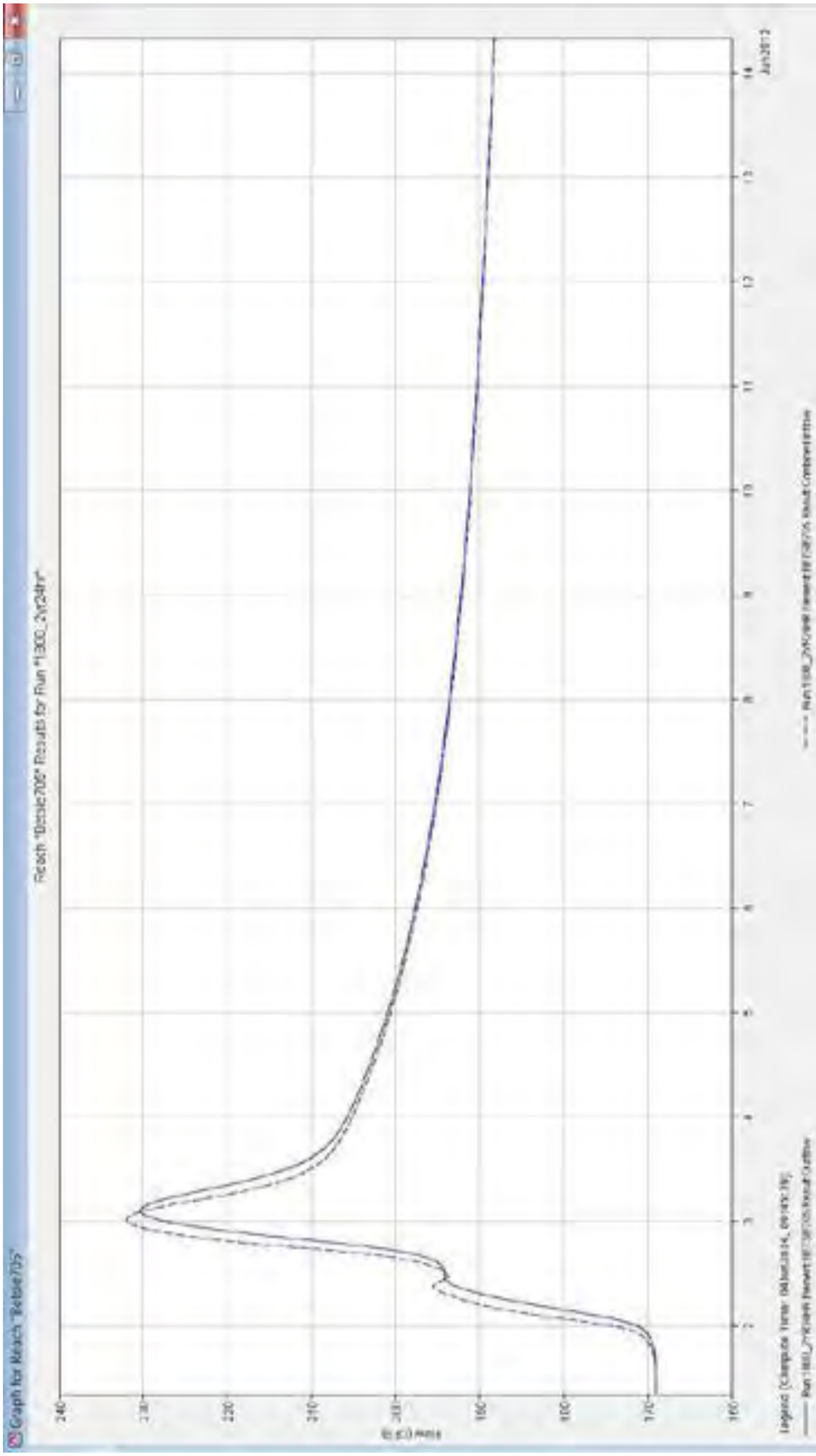

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Figure 13b: Betsie River Mainstem Below Connection to Crystal Lake

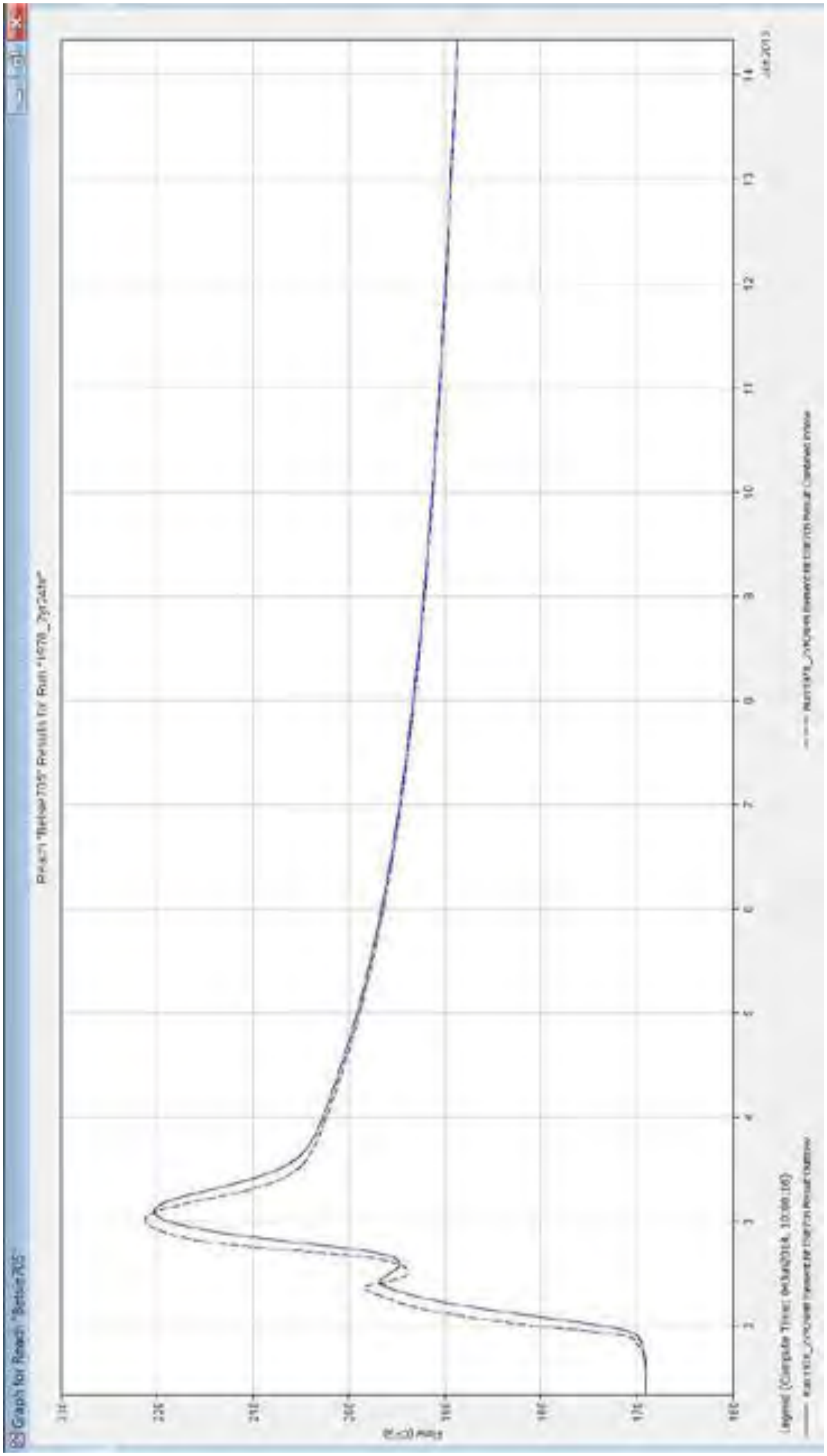

Figure 13c: Betsie River Mainstem Below Connection to Crystal Lake

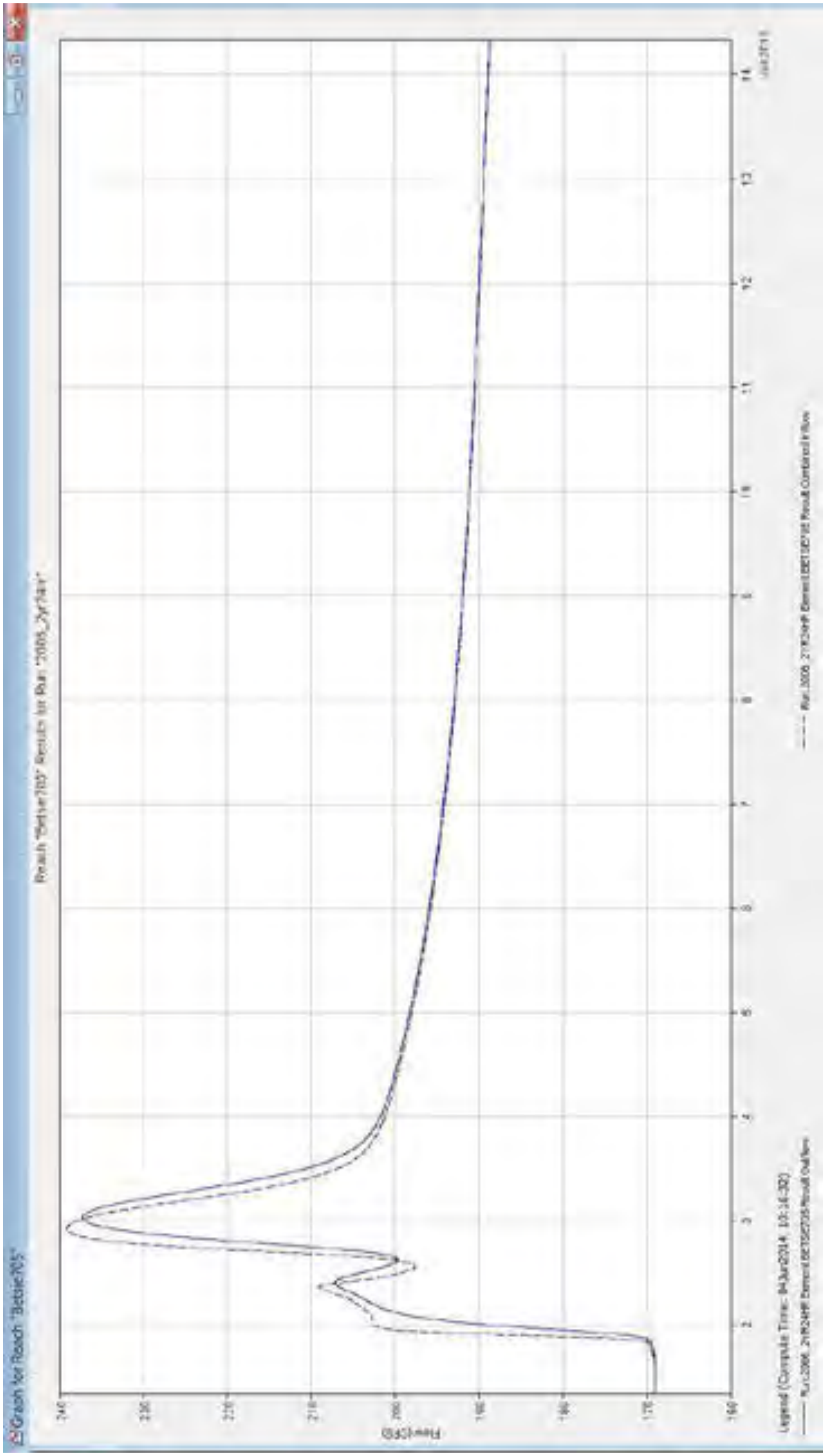

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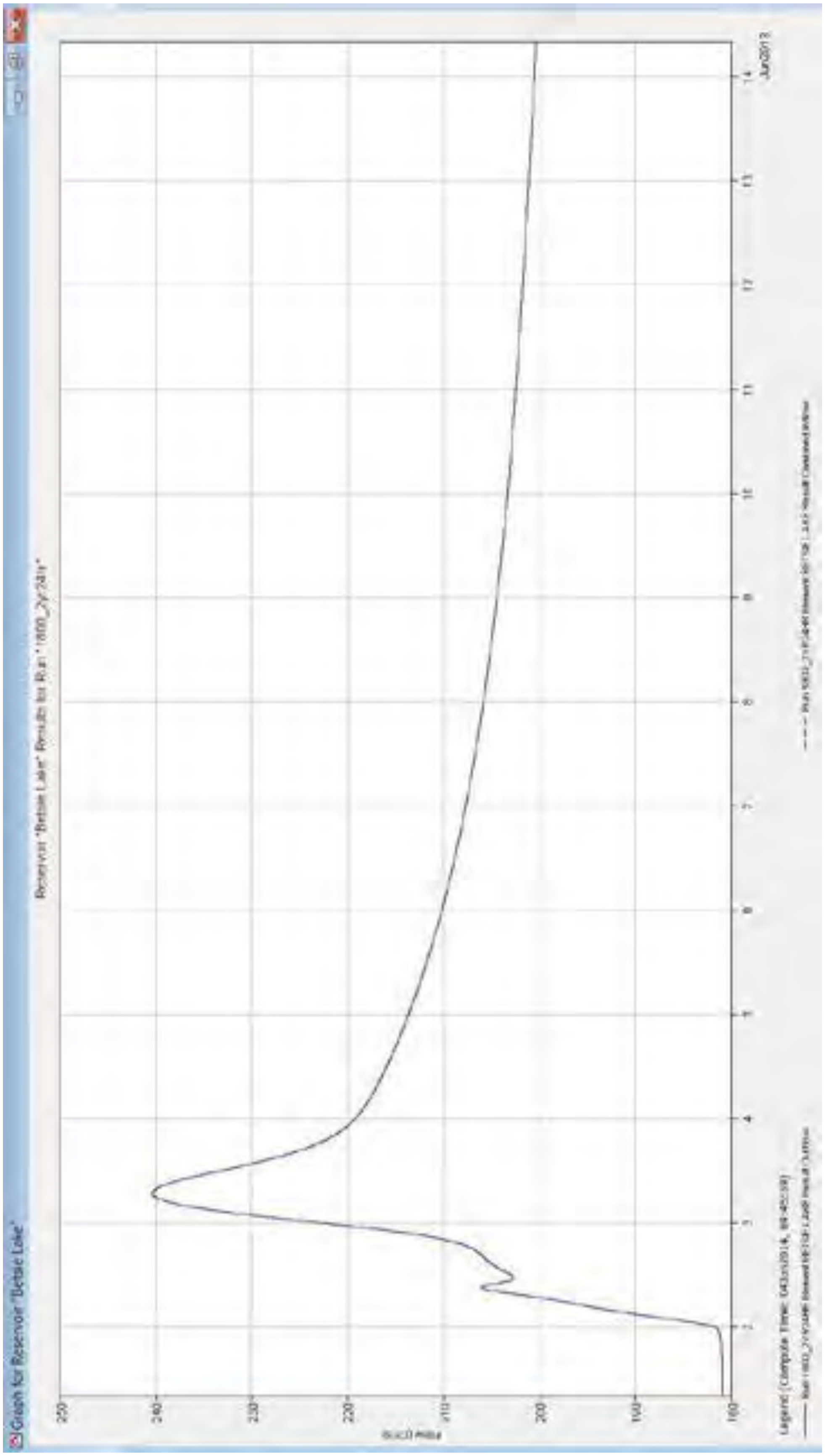
Figure 14a: Mouth of Betsie River at Betsie Lake



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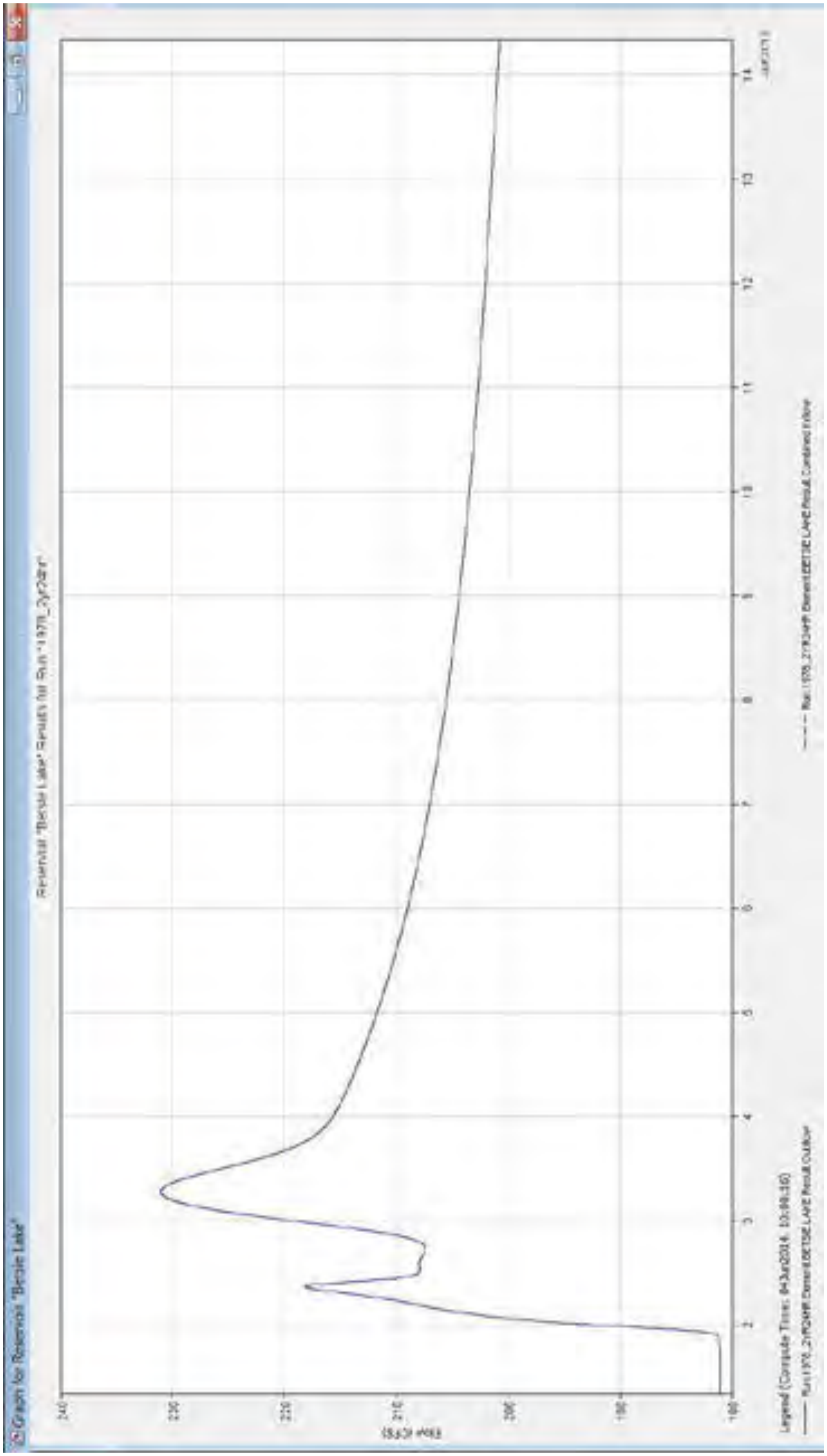
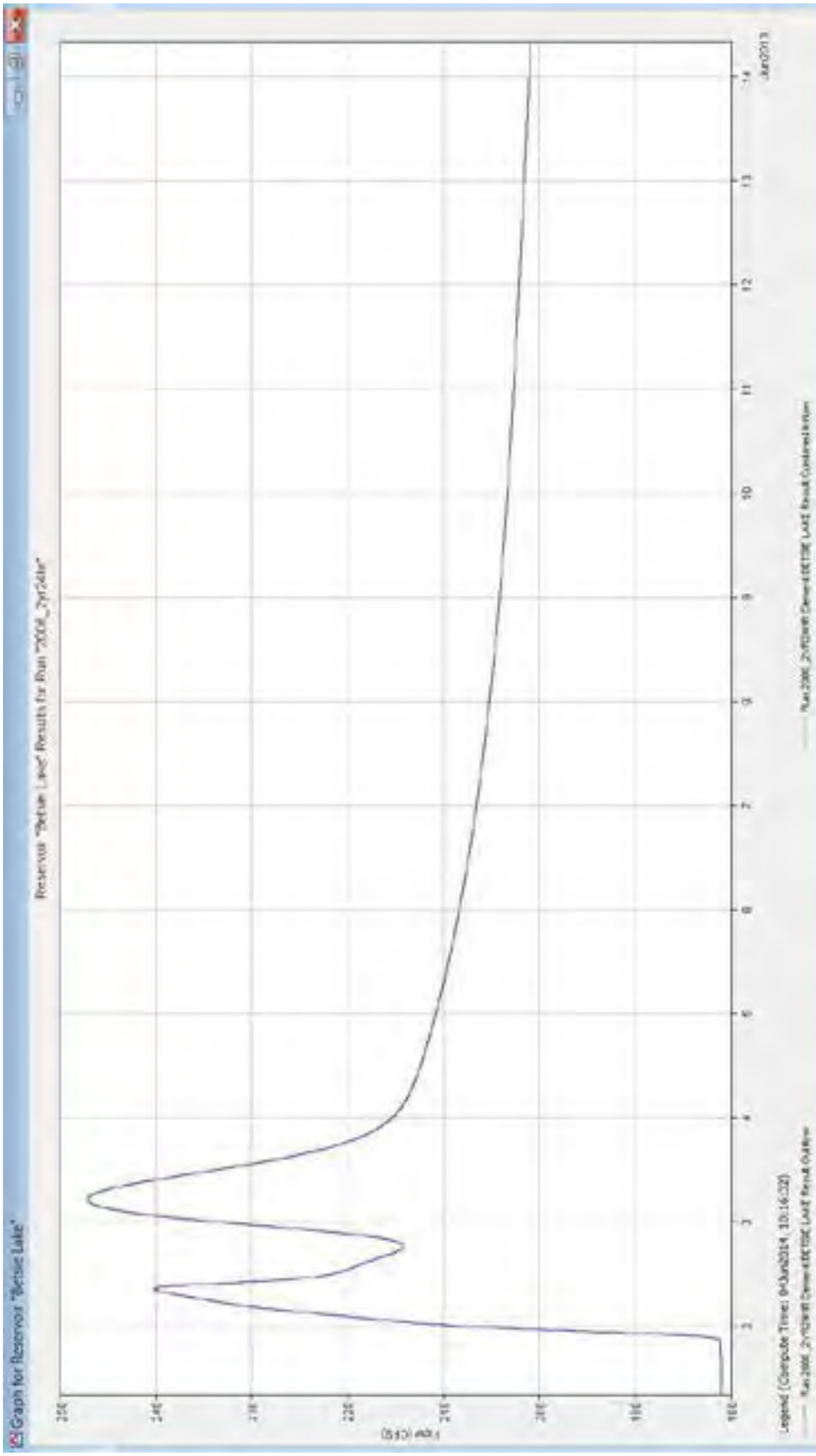


Figure 14b: Mouth of Betsie River at Betsie Lake

Figure 14c: Mouth of Betsie River at Betsie Lake



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Appendix C: Status of the Fishery Resource Reports

Betsie River Fishery

Michigan Department of Natural Resources
Status of the Fishery Resource Report
No. 2004-3, 2004

Betsie River

Benzie County (T25N, R13W, Section 17 and T25N, R14W, Sections 24, 35) and Manistee County (T24N, R14W, Section 2, 8)

Surveyed August, 1996; August, 1998; and August, 2003

Mark A. Tonello

Environment

The Betsie River watershed is located in Grand Traverse, Manistee, and Benzie counties (Figure 1), and drains roughly 155,026 acres (MDNR Wildlife Bureau, 1994). The Betsie River watershed begins with several small Designated Trout Streams, Horton Creek, Brigham Creek, and Mason Creek, that flow into Duck Lake in western Grand Traverse County. Duck Lake empties into Green Lake, and the Betsie River originates from Green Lake as the outflow. Shortly thereafter the Betsie River flows into Grass Lake Flooding. Below the Grass Lake Dam, the Betsie River flows for approximately 48 miles before entering Betsie Lake and then Lake Michigan at Frankfort and Alberta. The two largest tributaries are the Little Betsie River and Dair Creek (Figure 2). Both of these streams are top-quality trout streams with very cold, stable, flows and each contributes about 10% and 6%, respectively, of the total baseflow to the main channel (Newcomb 1998).

Two dams remain on the mainstem Betsie River, Grass Lake Dam, and Homestead Dam (Figure 2). Grass Lake Dam is approximately four miles downstream of Green Lake near the Grand Traverse County Line, and creates a 90 acre impoundment. Grass Lake Dam was constructed in 1951, primarily to improve waterfowl habitat and northern pike fishing (Newcomb and Coon 1997). Homestead Dam was largely removed in 1974, currently acts as a lamprey barrier, impounds little water, and does not impede salmonid migrations. A third dam, the Thompsonville Dam, failed in the spring of 1989 and was subsequently removed. Before that, it acted as the upstream barrier for most salmonids and warmed the river. Migrating salmon and trout currently have access to the entire river, even above Grass Lake Dam. Bonham (1976) studied the temperature effects of Grass Lake Dam and concluded that removing the dam would not significantly improve the temperature regime of the Betsie River. In contrast, Newcomb and Coon (1997) predicted that removal of the Grass Lake Dam would reduce water temperatures in the Grass Lake to Thompsonville reach by 2.2 ^{0}F in a typical flow year and 1.0 ^{0}F in low flow years.

Of the 155,026 acres that comprise the Betsie River watershed, about 55% of the land is forested, primarily with deciduous or mixed deciduous/coniferous forests. Other significant land uses for the portion of the watershed below the Grass Lake Dam include shrub/openlands (18%) and agriculture (11%). Only about 4% of the watershed is classified as urban (MDNR Wildlife Bureau 1994). The soils are 55% sand, 20% loam, and 34% wet soils (Gooding 1995). The Betsie River watershed receives about 31 inches of precipitation in an average year (Gooding 1995).

The Betsie River has been a state-designated Natural River since 1973. A Natural Rivers Zoning Board oversees development and other projects that are proposed within 400 feet of the riverbank on either side (Michigan Department of Natural Resources, 1973). The Natural Rivers Designation helps to protect the Betsie River ecosystem as development continues to occur at a rapid pace in the northwestern lower peninsula of Michigan.

Fishery Resource

The Betsie River is best known for its potamodromous fisheries, specifically for chinook salmon and steelhead. Some migratory brown trout and coho salmon are also caught. Chinook and coho salmon are not stocked in the Betsie system. These runs are comprised primarily of wild fish, or strays from other rivers. Little Manistee River strain steelhead have been stocked each year since 1990 (Table 1). Summer-run strains of steelhead (Rogue River and Skamania) were stocked in most years from 1984-90. These plantings of hatchery steelhead were made to enhance the fishery and supplement the low levels of steelhead naturally produced in the watershed. However, the plants of summer-run steelhead were then halted due to poor returns. Since 1991, about 540,000 winter-run (Little Manistee strain) steelhead smolts have been reared and released at the Orsini Hatchery by the Manistee County Sportfishing Association (Table 2). Annual stocking rates have ranged from 29,000 yearlings to almost 55,000 yearlings, averaging about 42,000 per year. Chinook salmon spawn extensively in the mainstem of the Betsie River. Steelhead and coho salmon spawning occurs throughout the mainstem and in the tributaries, although most of the wild smolts are produced in the Little Betsie River, Dair Creek, and other small tributaries throughout the watershed. In fact, Newcomb (1998) found that fully 50% of the wild steelhead smolts in the Betsie River came from the tributaries, even though they comprised only 11% of the channel area studied. The estimated number of wild steelhead smolts emigrating per year from the Betsie River system averaged less than 3,000 per year during 1993-96 (Newcomb 1998).

The Betsie River is heavily fished for steelhead and salmon, in the spring and fall. An angler census conducted from 1985-88 (Rakoczy and Rogers 1987, 1988, 1990) during April-October indicated that angler effort estimates on the Betsie River ranged from a high of 65,542 hours in 1986 to a low of 39,853 hours in 1987. Limited information exists on angler catch and harvest from the Betsie River, but during the same creel study, harvest ranged from a high of 2,600 steelhead in 1986 down to a low of 1,129 steelhead in 1988. Angler harvest for chinook salmon during the study ranged from 3,071 in 1986 to a low of 1,267 in 1988. Those creel surveys took place in the stretch from Homestead Dam to Betsie Lake, where most of the fishing effort for migratory salmonids is concentrated. Many anglers perceived a decline in steelhead catch rates during the late 1990's and early 2000's. Anglers also complain that steelhead run sizes have been highly variable between years with no apparent explanation. No angler census has been conducted since 1988 so the reported declines in fishing quality cannot be scientifically documented.

The fishery for resident trout is not nearly as popular or well known as the salmon and steelhead fisheries. Early in the 1900s, the Betsie was supposedly known as an excellent brook trout stream (Wicklund and Dean, 1957), although some experts question whether the Betsie ever could have been a top-notch trout stream due to the temperature problems that must have always existed. Resident trout populations are hampered by critically high summer water temperatures due primarily to modest summer groundwater input. Dams, competing fish species, and sand bedload fueled by erosion and poor road/stream crossings also impact trout populations. The brown trout fishery is maintained in the Betsie River primarily through stocking (Table 1). Throughout most of the 20th century, managers have struggled to improve resident trout fishing in the Betsie River. In 1965, rotenone was used to remove potential competing species such as suckers, chubs, and minnows (Bonham 1975), but these fish recolonized the river very quickly, so additional rotenone reclamations were not conducted. The washout and subsequent removal of Thompsonville Dam increased available trout habitat in the Betsie River system by allowing trout access to thermal refuge in the Little Betsie River and by reducing warming of the mainstem.

Since the early 1980s, MDNR Fisheries Division has stocked roughly 15,000 resident brown trout annually in the Betsie River (Table 1). Brown trout stocking sites in the 1990s included Long Rd., Carmean Rd., Black Bridge (Haze Rd.), Red Bridge (Lindy Rd.), Orsini (near the M-115 crossing in Manistee County), Kurick Rd., Psutka Rd., County Line Rd., and the M-115 crossing in Benzie County. Dair Creek and the Little Betsie River are not stocked. Michigan DNR Fisheries Division personnel conducted electrofishing surveys at multiple sites in 1957, 1965, 1968, 1974, 1990 (Hay 1990), and 1996 to assess the success of the brown trout plantings. Fish surveys aimed at assessing steelhead stocked by the Orsini Hatchery were conducted at several sites in 1998 and 2003.

Other habitat management actions have included the installation of fish habitat structures, stabilization of eroding streambanks, reducing erosion at poorly designed road/stream crossings, and excavation of sand traps. The Betsie River Watershed Restoration Committee (BRWRC) was formed in 1991 to oversee those activities. The Conservation Resource Alliance (CRA), a non-profit group out of Traverse City, administers the committee. The Partnership Agreement that formed the committee was signed by 34 private, public, and governmental organizations (Fleming and Kook 1997; Kim Balke, CRA, personal communication). Since 1991, the BRWRC has overseen work on 63 eroding streambanks, repaired four road/stream crossings, and assisted with the installation of a timber bridge and access site (Kim Balke, CRA, personal communication). One sand trap is currently being operated by MDNR at Kurick Rd. The BRWRC and the CRA are currently conducting a temperature study on the Betsie River with continuous recording thermometers. Newcomb and Coon (1997) conducted an extensive temperature study of the river, and the ongoing BRWRC/CRA study will build on those data.

Master Angler Data

Since 1995, a total of 45 fish caught in the Betsie River have been entered in the MDNR Fisheries Division Master Angler program. Chinook salmon were the most commonly entered species, with 15 individuals entered. Twelve steelhead, three brown trout, and two coho salmon were also entered. Other species entered included redhorse, white sucker, rock bass, and common carp. Of the 45 entries since 1995, 31 were Catch and Keep, while 14 were Catch and Release.

Recent Fisheries Surveys

The analysis below presents results of 1996, 1998, and 2003 electrofishing surveys and compares the results to those from prior surveys. Sample sites are identified in Figure 3. Data are presented sequentially starting with the most upstream site sampled in 1996 and proceeding downstream. All sampling was done using a tow barge electroshocking unit with three probes, using pulsed DC current up to 250 volts. In 1996, we sampled five sites, with two-pass mark and recapture surveys done at four of the sites. For those sites, the Bailey formula was used to derive population estimates. All sampling in 1996 was done from August 7-14. In 1998, we sampled two sites and in 2003 we sampled just one site.

Site 1- Al Serra property

1996

This site is located upstream of Carmean Rd., and downstream of Long Rd. This was the furthest upstream site sampled in 1996, and sampling had never been done here before. We made a single, 1,000-foot shocking run here to inventory the existing fish community. The crew estimated the river to average 55 ft. wide and one foot deep. Gradient was estimated at 11.3 ft/mile. Water temperature was 71°F at11:00a.m. Mean July temperatures upstream of this site but below Grass Lake ranged from 68.5 ^{0}F in a typical flow year up to 69.3^{o}F in a low flow year (Newcomb and Coon 1997). Woody cover and streamside vegetation are sparse in this area. The property is old pasture, and few trees are growing along the streambank. There is little shading on the river, which is very wide along this stretch. Stream morphology here is very homogenous, mostly riffles and runs, with few logjams or deep holes. The substrate consists mostly of gravel.

Only four brown trout were captured, ranging from 7-9 inches long. A total of sixteen steelhead parr from 1-7 inches long were captured. Four were unclipped and presumably wild, while the other twelve had right pectoral clips and most likely had been released from the Orsini Hatchery, which is located ten miles or so downstream in Manistee County (Figure 1). One chinook salmon parr was also captured. All trout were age-1, except for one 7" rainbow that was age-2. Other species collected here included common shiner, central mudminnow, blacknose dace, hornyhead chub, white sucker, and johnny darter.

Although this site had never been surveyed before, both Long Rd. (upstream) and Carmean Rd. (downstream) had been surveyed in 1957, 1968, and 1974. Catches of brown trout in those previous surveys were generally low. The best catch was at Long Rd. in 1968, when 18 brown trout up to 16" were caught.

Rainbow trout and chinook salmon were not caught in any previous surveys in the area, because Thompsonville Dam blocked migrations. Unlike previous surveys, we captured no warmwater or coolwater gamefish species in 1996. Warmwater and coolwater gamefish captured in previous surveys included smallmouth bass, largemouth bass, northern pike, rock bass, pumpkinseed sunfish, bluegill, and yellow perch. Bullheads were also collected in previous surveys. In the past, these species may have migrated downstream from the Grass Lake impoundment which has since largely filled in with sediment. Some may have also migrated upstream from the Thompsonville impoundment. The most likely explanation for the poor catch of trout at this site is high water temperature.

1998

The 1998 fisheries survey at the Al Serra property site again consisted of one electrofishing pass, done on August 7th. The catch in 1998 at the Al Serra property site was similar to that from 1996, although even fewer trout were observed. Five steelhead parr from 3-7 inches were captured, one of which had a right pectoral fin clip, indicating hatchery origin. The others were presumably wild. Only one 7" brown trout was captured. Other species observed included creek chubs, blacknose dace, rock bass, white suckers, sculpins, largemouth bass, johnny darters, common shiners, black bullhead, and brown bullhead. Water temperature was recorded as 68°.

Site 2-King Road

This site is located several miles north of Thompsonville. It is several miles downstream of the Al Serra property, ½ mile above the confluence with the Little Betsie River. This 1,200 foot long station was previously surveyed in 1957, 1968, 1974, and 1990. In 1990, stream width was estimated to average 37 feet, with a substrate composition of 70% sand and 30% gravel (Hay, 1990). Stream gradient was measured in 1996 at 4.38 ft/mile, and the water temperature was 74 °F at 10:30 am. No major changes in habitat from the 1990 survey were noted. Again, woody cover and large woody streamside vegetation are sparse in this area, and there are no logjams or deep holes. The streambanks at this site are forested, with a pine plantation on one side, and mixed hardwoods on the other side.

In 1996, a total of eight brown trout, from 7-9", were captured in the survey, resulting in an estimated density of 1.93 lbs/acre (Table 3), and a numerical density of 7.92/acre (Table 4). All brown trout were yearlings, except for one age 2 fish. There were 3.94 lbs/acre of rainbow trout at this site. Numerical density of rainbow trout was 55.45/acre. All rainbow trout were yearlings, except for one age 2 fish, and they ranged from 4 to 7 inches long. None of the rainbows had fin clips. One three-inch chinook salmon was captured, as was one two-inch coho parr. Other species captured included sculpin, blacknose dace, creek chub, common shiner, rock bass, white sucker, johnny darter, hornyhead chub, central mudminnow, longnose dace, and bluntnose minnow.

Previous surveys of this site had similar results, with very few holdover brown trout ever captured at this site. The main difference between the 1996 survey and the 1990 survey is that in 1996, more rainbow trout were captured.

Regardless, trout densities here were very low in 1996, as they were in 1990. This is most likely due to the high water temperatures found in this. The lack of instream habitat, pools or LWD may also contribute to the apparent low survival of stocked fish.

Site 3-Lindy Road (Red Bridge)

This site is located several miles west of Thompsonville, and several miles downstream of the old Thompsonville Dam Site. Previous surveys of this area were conducted in 1957, 1971, 1974, and 1990. The river here averages 52 feet wide and gradient was estimated at 7.9 ft/mile. The station is 1250 feet long. No estimate of substrate composition was recorded during the 1996 survey. Mean July water temperature at M-115, located about two miles downstream of this site, ranged from 66 ^{0}F in 1994 , to 67 ^{0}F in 1995 (Newcomb and Coon 1997). However, the mean temperature in August 1995, a low flow year, was 70.7 ^{0}F. The stream temperature during the 1996 survey was recorded as 70^{0} at 10:40 am. Instream cover is a little better here, in the form of some old DNR logjam habitat structures. Some deep runs which are very difficult to shock also provide cover.

Only six brown trout, ranging from seven to nine inches, were captured here during the 1996 survey. The estimated density of brown trout was 1.03 lbs/acre (Table 3), and the numerical density was 4.05/acre (Table 4). Rainbow trout density was 4.04 lbs/acre. Total numerical density of rainbow trout was 60.17/acre. Of these, all were yearlings except for one age 2 fish. Only one rainbow captured here had a right pectoral fin clip. Nine chinook salmon parr were captured, and their density was 0.15 lbs/acre. One coho parr was also captured in the survey. Other species collected here included creek chub, white sucker, central mudminnow, sculpin, blacknose dace, common shiner, rock bass, and johnny darter.

The brown trout population at this site declined dramatically from the 14.1 lbs/acre found in 1990. In that survey, 52 brown trout up to 22" were captured (Hay 1990). However, rainbow trout levels in 1996 were higher than in 1990, when the estimated rainbow trout density was only 0.3 lbs/acre. One of the rainbow trout captured here had a right pectoral fin clip, most likely indicating that it was stocked from the Orsini Hatchery. No salmon parr were found at this site in 1990. Although the 1957 survey found no trout in this area, the 1971 and 1974 surveys did find fair levels of brown trout. Populations were not estimated during the 1970's surveys so densities can not be directly compared to those from more recent surveys.

Site 4-Kurick Rd.

<u>1996</u>

This site is located in Manistee County, about four miles northwest of the Village of Copemish. It is roughly four miles downstream of the Lindy road site. Previous surveys of this area were conducted in 1965, 1968, 1971, 1974, and 1990. The river here averages about 54 feet in width, with 80% sand and 20% gravel substrate. There is some cover here, in the form of woody debris and a logjam or two. The stretch consists mostly of riffle habitat, with some pools and pocket water. The gradient is 14.2 ft/mile, which is the highest gradient of any site measured during this survey. During the 1996 survey, water temperature was 67 °F at 1:30 pm. This site is located about 1 stream mile downstream of M-115 where Newcomb and Coon (1997) reported that mean July water temperatures were 66 ^{0}F in a normal flow year and 67 ^{0}F in a low flow year. The Orsini Hatchery is located one mile upstream of the Kurick Road station.

As with the other sites, the brown trout catch here was very poor during the 1996 survey. Only 10 yearling brown trout ranging from 6-8" were captured in the 1,250 foot station, resulting in a density estimate of 1.48 lbs/acre (Table 3) and a numerical density of 9.74/acre (Table 4). The rainbow trout catch was better, as 404 individuals up to 9" were captured, resulting in a density estimate of 53.8 lbs/acre and a numerical density of 166.23/acre. However, about 75% of these fish had right pectoral clips, indicating that they were planted from the Orsini Hatchery. Of the rainbow trout sampled, 113 unclipped (and presumably naturally reproduced) individuals were captured, resulting in a density estimate of 7.48 lbs/acre. Approximately half of these unclipped rainbows were young of the year (YOY). The rest were yearlings. Five chinook salmon parr were also observed, resulting in a density estimate of .05 lbs/acre. Other species captured here included creek chub, rock bass, white sucker, bluegill, sculpin, blacknose dace, johnny darter, and one pumpkinseed sunfish.

As with the previous site, the brown trout population seems to have declined some since 1990. In 1990, brown trout density was 7.9 lbs/acre. Numerical density was 25.3/acre and the largest individual was over 21 inches long (Hay 1990). Only one brown trout from either the 1990 or 1996 survey was a young of the year. This indicates that although survival of stocked fish may be good at this site in some years, natural reproduction of brown trout here is not significantly contributing to the population. The 1990 density of brown trout age-2 and older was roughly 5.25/acre. Although this density is not great when compared to other rivers statewide, at least some planted fish survive. Earlier surveys also found a few holdover brown trout. Rainbow trout abundance in 1996 was substantially higher than in 1990, but the presence of so many hatchery fish is alarming. It suggests that a large percentage of the yearling steelhead planted in 1996 did not smolt and emigrate to Lake Michigan. Even so, the presence of so many rainbow trout at this site may indicate that there is better temperature and habitat near Kurick Rd. than in other areas of the river.

<u>1998</u>

On August 7, 1998, a one-pass electrofishing survey was conducted to investigate whether or not significant numbers of the stocked steelhead had remained in the river (Table 7). No population estimates were obtained. Four brown trout from 7-8" were caught, along with three chinook salmon parr and a few coho parr. A total of 298 steelhead parr from 1-9" were caught, along with one 24" adult steelhead. Of the 298 steelhead parr captured, 134 from 4-9" had right pectoral fin clips, indicating Orsini Hatchery origin. The majority of the steelhead parr larger than 6" had fin clips. The adult steelhead also had a right pectoral fin clip. Other species noted in the survey included sculpin, blacknose dace, white sucker, rock bass, green sunfish, pumpkinseed sunfish, and yellow perch. Water temperature was recorded as 63°.

<u>2003</u>

On August 12, 2003, another one-pass electrofishing survey was conducted, again to investigate whether or not significant numbers of the stocked steelhead had remained in the river (Table 7). Water temperature was recorded as 65° at 1:30 pm. As in 1998, no population estimates were obtained. A total of 22 brown trout were caught, ranging from 3-16" in length, along with one 6" brook trout, 68 chinook salmon parr from 2-4" in length, and 29 coho salmon parr, from 3-4" in length. One adult chinook salmon was also observed, but not captured. A total of 389 steelhead parr from 1-7" were collected, along with one 23" adult steelhead. Of the 389 steelhead parr captured, 141 bore right pectoral fin clips, indicating Orsini Hatchery origin. A total of 248 unclipped steelhead parr were caught, with many of those being YOY in the 1-3" range. The adult steelhead had dorsal-left ventral fin clips, indicating that it was a stray skamania (summer run) steelhead, from the 2001 Manistee River plant. The summer of 2003 was a cool, dry summer, which is likely the reason for the high number of naturally reproduced YOY steelhead seen in this survey.

Site 5-Psutka Rd.

This site was the most downstream site sampled in the 1996 survey. It is located about six miles west of the Village of Copemish, and is several miles downstream of Kurick Rd. Previous surveys of the area were conducted in 1957, 1965, 1968, 1971, 1974, and 1990. At this site, river width averages 46.5 feet, with 90% sand, 5% clay, and 5% gravel substrate in this 1,250 foot long station. During the 1996 survey, water temperature was 66° at 10:20 am. Habitat at this site was poor. The field notes indicate there is much less woody material and gravel here than at Kurick Rd. Gradient at this site was the lowest of any the five measured sites, at 2.6 ft/mile. There are no riffles in this station. This site was planted with 1,921 yearling brown trout in the spring of 1996.

As with the other sites, the brown trout catch here was very poor. Only 12 brown trout up to 9" were captured, resulting in an estimated density of 1.92 lbs/acre (Table 3) and a numerical density of 11.28/acre (Table 4). Eleven of the twelve brown trout were yearlings, while one was two years of age. The rainbow trout catch was poor here as well. Thirty-three individuals up to 9" were captured, resulting in an estimated density of 6.46 lbs/acre. Of those, 23 individuals had right pectoral fin clips, so only ten of the rainbow trout encountered here were wild, with an estimated density of 0.49 lbs/acre. Four of those wild rainbow trout were in the two-inch class, indicating that they were young of the year. No salmon were observed here. Other species captured included creek chub, blacknose dace, sculpin, rock bass, white sucker, common shiners, johnny darter, and pumpkinseed sunfish.

The brown trout population at this site in 1990 was also very poor, with six individuals up to 8 inches captured (Hay, 1990). The rainbow trout catch improved slightly in 1996, as only 11 individuals were seen in 1990. A few coho and chinook smolts were also observed in 1990. Very few trout and even fewer holdover brown trout have ever been captured at this site during past surveys.

Age and Growth

Age and growth analysis was conducted on 43 brown trout and 82 rainbow trout caught during the 1996 survey (Table 5). Growth for age-1 rainbow and brown trout appears to be exceptional, but the majority of those fish were most likely recently stocked fish. Trout that are reared in hatcheries typically show excellent growth in their first year, while they are in the hatchery. However, the age-2 rainbow and brown trout captured in this survey grew slowly. Age-2 brown trout and rainbow trout were 1.4 inches and 0.8 inches below the state of Michigan average, respectively. This is not an unexpected result, as studies have shown that trout growth can be inhibited at high water temperatures. We hypothesize that the extremely hot summer of 1995 and the resulting high water temperatures inhibited growth of Betsie River brown and rainbow trout.

Analysis

The brown trout catch in the 1996 survey was poor and very few "holdover" (fish that have survived at least one full year since being planted) brown trout were captured. Although the brown trout catch from the 1990 survey was not good, more were captured than in 1996. This may have been due to the extremely hot and dry weather during the summer of 1995. Newcomb and Coon (1997) found that the mean summer water temperatures in the Betsie River were warmer in 1995 than in 1993-94 or in 1996. They reported that mean June, July, and August 1995 exceeded 20.7 ^{0}C (69.3 ^{0}F) throughout the river reach from Green Lake to below the former Thompsonville dam. Thus, plantings of brown trout upstream of the old Thompsonville Dam site have low prospects for significant survival (A. Nuhfer, MDNR, Hunt Creek Research Station, personal communication). Similarly, Newcomb and Coon (1997) found significant negative correlations between the summer densities of age-0 and age-1 steelhead parr and the mean and maximum summer temperature. For the 1990 and 1996 surveys, the Betsie River was at 4-11 brown trout/acre, while other Michigan trout streams (Jordan River, Boardman River, Au Sable River, etc.) often have densities greater than 500/acre (A. Nuhfer, MDNR, Hunt Creek Research Station, personal communication). Very few yearling brown trout stocked in the spring of 1995 survived to the summer of 1996. No yearling trout stocked in 1994 were captured in 1996 (Table 6). Percent survival from one year to the next for both the 1990 and 1996 sampling efforts is shown in Table 6. Unfortunately, in very hot summers like 1995, we may expect significant mortality on stocked brown trout, with few surviving to the next year. In years with normal weather, we should be able to provide a respectable fishery with some holdover and some trophy potential. By altering the stocking locations, densities, and the strain of brown trout stocked we may be able to improve the fishery. For example, the stretch of river between the confluence of Dair Creek and Homestead Dam has some of the coldest temperatures on the mainstem of the Betsie, and may allow for better survival of stocked brown trout.

The catch of large numbers of juvenile Orsini Hatchery steelhead in the Betsie River in 1996, 1998, and 2003 (Table 7) indicates that the Orsini steelhead are not “smolting out” as they should. Typically, hatchery steelhead perform best when they smolt out within the first several months after stocking. According to Newcomb (1998), steelhead in the Betsie River typically smolt between early May and mid to late June. Therefore, any juvenile steelhead that have not left the river by late June will spend another full year in the river. In the Betsie River, this means that they will likely be subjected to temperature extremes and probably not survive. Therefore, strategies should be employed at the Orsini Hatchery to ensure that as many of the released juvenile steelhead successfully smolt out to Lake Michigan shortly after they are released from the hatchery.

Management Direction

Currently, Fisheries Division manages the 48 miles of the Betsie River below Grass Lake Dam for migratory Great Lakes trout and salmon and resident brown trout. Below the Grass Lake Dam, the Betsie River and its tributaries are Designated Trout Streams. Below Kurick Road in Manistee County, the Betsie River is currently regulated by Fisheries Division as a Type 4 stream, and is open to fishing all year. Minimum size limits for angler harvest are 8 inches for brook trout, 10 inches for all other trout and salmon species, except for Atlantic salmon, which must be 15 inches. Brook and brown trout or Atlantic salmon may not be harvested between September 30 and the last Saturday in April. Five fish may be kept per day, but only three of those may be 15 inches or larger. Rice Creek, Dair Creek, the Little Betsie River, and the Betsie River above Kurick Road are all regulated as Type 1 streams. Seasons for these waters follow the traditional trout season (last Saturday in April- September 30), and again, five fish may be harvested per day, but only three of those may be 15 inches or larger. Minimum size limits in Type 1 waters are 8 inches for brown and brook trout, and 10 inches for rainbow trout and other Pacific salmon species. In 2000, we moved the Type 4 boundary upstream to Wolf Rd., hoping to create more year-round fishing opportunity for steelhead anglers. However, due to public opposition, the boundary was moved back to Kurick Rd. in 2001.

The resident trout populations of the Betsie River will never rival those of other nearby rivers such as the Platte or Little Manistee. Salmonid survival and growth in the Betsie will continue to be limited by high summer temperatures, particularly in low-flow years. However, modifications to present stocking practices may improve the resident brown trout fishery and produce more trophy-sized individuals. We recommend that stockings be concentrated in thermally suitable areas identified by previous researchers (Newcomb, 1998; Newcomb and Coon 1997), and where holdover brown trout have been found in the past. Therefore, starting in 2001, stockings at Long Rd., Carmean Rd., and Psutka Rd. were discontinued. Plants at the five remaining sites (Black Bridge, Red Bridge, Orsini, Kurick Rd., and County Line Rd., Figure 4) were increased to 3,000 Seeforellen strain yearling brown trout per site. Also, one new stocking site was added.

Starting in 2002, 3,000 yearling brown trout were stocked at the M-115 crossing just downstream of the confluence with Dair Creek. This results in an overall stocking rate of 120 brown trout/acre in the Betsie River. In the past, Wild Rose strain brown trout were stocked in the Betsie River. According to Jim Dexter (MDNR, Plainwell, personal communication), Seeforellen strain brown trout have survived much better in southern Michigan trout streams that are limited by warm temperatures. Gilchrist Creek strain brown trout are unlikely to be adapted to survive well in warmer streams because their natal stream is cold (mean July 1995 water temperature was 62 ^{0}F). Moreover, their smaller size at planting requires that they survive about a year longer than the Seeforellen and Wild Rose strains before they grow to catchable size (Andy Nuhfer, MDNR Hunt Creek Research Station, personal communication). Therefore, when available, Seeforellen strain brown trout should be stocked into the Betsie River. The results of changes to the stocking program will be monitored by conversing with anglers and by repeating the population estimate surveys of 1990 and 1996.

Possible causes for the perceived decline in steelhead fishing are unknown. The washout of Thompsonville Dam in 1989 gave steelhead access to the entire river, including the Little Betsie, thus spreading the run over a larger area. Reduced densities per unit of stream area presumably could reduce angler catch rates. Small steelhead released from the Orsini hatchery in some years in the early to mid 1990's may not have been large enough to smolt the year they were planted. Studies have shown that survival for stocked steelhead smolts is much higher when they are larger than 200 mm or 7.9 inches (Seelbach et al. 1994). In recent years however, the average size of the yearling steelhead planted by the Orsini hatchery has increased. Since 1998, steelhead smolts planted in the Betsie River have averaged over 7.0 inches long. The Orsini Hatchery should have a target size of 8.0 inches for steelhead smolts, even if it requires a reduction in the numbers of steelhead smolts raised and stocked. In an attempt to increase the average size of the stocked steelhead, the number of fish supplied to the Orsini Hatchery for the 2004 plant was reduced from 40,000 to 35,000. Hopefully, decreasing the density of steelhead in the raceways will allow them to grow to a larger size.

Another potential problem in the past with the Orsini Hatchery operation has been date of release. In many previous years, the Orsini steelhead were not released from the hatchery until mid-June. This may have been too late, dooming the juvenile steelhead to spend another entire year in the Betsie River, and thus possibly subjecting them to lethal temperatures. In 2003, the Orsini steelhead were released in mid-May, hopefully early enough so that at least those big enough successfully smolted out. In 2004, the Orsini steelhead will be released from the hatchery in early April. Interestingly enough, no hatchery steelhead larger than 7" were captured in the 2003 survey of the Kurick Road site (Table 7.). In the previous two surveys in 1996 and 1998, there were larger, 8 and 9 inch hatchery steelhead caught. Hopefully, the lack of larger hatchery steelhead in the 2003 survey indicated that they were released early enough, and that they successfully smolted out to Lake Michigan. Another management action that will help to assess the Orsini Hatchery program is fin clipping. Starting in 2005, the Orsini steelhead will be marked with their own individual fin clip, instead of the generic right pectoral fin clip used to mark all winter-run steelhead stocked into Michigan tributaries. This will help us assess the survival and return of the Orsini steelhead to the Betsie River.

Although the Orsini Hatchery operation has not been without problems, it should still be viewed as a successful cooperative venture with the Manistee County Sportfishing Association. In the early 1980s, the Betsie River was being planted with an average of about 20,000 steelhead fingerlings, and they were often very small, even as small as 3.2" in 1982. These stocked fish could not have provided much benefit to the Betsie River steelhead fishery. Also, recent research (Jory Jonas, MDNR, Charlevoix Research Station, unpublished data) has shown that steelhead imprint and return to several Michigan rivers much better when they are planted at upstream sites. In the Jonas study, fish planted at harbor sites had much higher straying rates. Michigan DNR hatchery personnel have monitored the condition of the Orsini steelhead in recent years (Martha Wolgamood, MDNR Wolf Lake Hatchery, personal communication) and the condition of the Orsini fish has been as good as from hatcheries operated by MDNR. In summary, the Orsini hatchery operation has allowed the Betsie River to be stocked with higher numbers of steelhead at an upstream site, which should provide better imprinting and homing to the river. Therefore, MDNR Fisheries Division will continue to supply the Orsini Hatchery with 35,000 fall fingerling steelhead annually. Fisheries Division will also fund up to $3,000 per cycle of the hatchery power needs as well as providing staff to inspect and review the Orsini hatchery capacity and operating conditions.

The perceived decline in steelhead fishing on the Betsie River may be just that, perception. It is entirely possible that steelhead fishing on the

Betsie has actually not declined, or was never really as good as some say. The available data seem to support this conclusion. According to Rakoczy and Rogers (1987, 1988, and 1990), total catch per hour for steelhead on the Betsie River below Homestead Dam was .0397 in 1986 (April-November), .0303 in 1987 (April-October), and .0270 in 1988 (April-October). While these catch rates are respectable, they are not exceptional. For example, in 1986, catch rates were higher in the Grand River (.0553), the Muskegon River (.0484), and the Bear River (.0428). In recent years, total catch per hour for steelhead on the Manistee River below Tippy Dam was .0419 in 1999 and .0418 in 2000 (Rakoczy, unpublished data). While fishing may have been good on the Betsie in those years, it does not appear to have been better than that on many other Michigan rivers, then or now. Michigan west coast steelhead runs and angler catch rates can be extremely variable from year to year. The run size and timing is dependent on many different factors, including weather, water temperature, rainfall, Lake Michigan conditions, and so on.

Fisheries Division personnel will continue to work with the BRWRC and the Conservation Resource Alliance to halt sand inputs from eroding streambanks and poorly constructed road/stream crossings. As sand inputs are eliminated, the focus of the BRWRC should turn to the installation of various types of habitat, including large woody material, lunker structures, boulders, and shading (tree planting). We should continue to maintain the sand trap at Kurick Rd. and should make sure it is emptied in a timely manner. The combined effects of reducing sand erosion, removing excess sand already in the channel, and tree plantings are management actions that will help reduce temperatures in the Betsie River. Streams with heavy sand bedloads tend to widen and become shallower, allowing them to warm at a faster rate. Fisheries Division personnel should also work with the BRWRC and CRA to interpret the results of the temperature study currently being conducted by those groups. Although the upper Betsie River is not presently suitable for year-round brown trout survival, habitat improvement work should still continue there. The upper Betsie River is much wider than it should be, most likely due to turn-of-the-century logging practices. Therefore, we should continue to work to narrow and deepen the channel as much as possible. This may help to moderate stream temperatures somewhat. Even as it is now, the upper Betsie River is moderate-gradient water with abundant gravel, which allows for outstanding natural reproduction of chinook salmon.

MDNR Wildlife Division is currently in the process of evaluating the function of the Grass Lake Flooding (Rich Earle, MDNR Wildlife Division, Traverse City, personal communication). If it is determined that the Grass Lake Flooding is not providing the appropriate benefits to wildlife populations, then we should work with Wildlife Division to remove the dam. While this will likely not drastically affect the watershed, it may moderate water temperatures somewhat in the upper Betsie River and allow for better survival of stocked trout and possibly some natural reproduction as well.

One other situation that needs to be addressed is the old Dair Mill site on Dair Creek. Sometime around 1900, a mill and dam were constructed on Dair Creek. The mill is long since gone, but half of the flow of Dair Creek continues to flow into the Betsie River through an artificial channel. This diminishes the flow in the natural channel of lower Dair Creek. The result is that steelhead may have difficulty accessing the upper portions of Dair Creek. Newcomb (1998) identified Dair Creek as critical spawning and rearing habitat for wild steelhead in the Betsie River. To remedy the situation, the artificial channel should be filled in and all the flow returned to the natural channel of Dair Creek. This will ensure that steelhead and other migratory salmonids will be able to access the upstream portions of Dair Creek.

Since a large portion of the Betsie River, Little Betsie River, and Dair Creek watersheds are within the Pere Marquette State Forest, Best Management Practices and Natural Rivers buffers need be followed by DNR Forest Management personnel when they propose timber harvests. Fisheries Division personnel should analyze and comment if necessary on

Forest Compartment Reviews that pertain to the Betsie River watershed. Forested areas along important tributary streams like Dair Creek, the Little Betsie River, and others should not be managed for young successional aspen. Instead, coniferous species should be encouraged, and Old-Growth designations pursued. Young aspen is a prime food source for beaver, and beavers have the potential to severely degrade and even completely block small streams like the Little Betsie River and Dair Creek. Newcomb (1997) identified these tributary streams as important contributors of cold water to the Betsie River, as well as critical producers of wild steelhead smolts. Therefore, every possible effort should be made to discourage beavers from colonizing and blocking these tributary streams. Beaver dams degrade small trout streams by blocking upstream fish migrations, warming the water, blocking woody debris and organic material downstream movements, and interfere with insect drift.

Fisheries Division personnel should also work with the Michigan Department of Environmental Quality to protect the Betsie River watershed from unwise land use and improper development. Improper development and poor land-use practices have the potential to further degrade the Betsie River (through increased runoff, less shade, more erosion at crossings, etc.). Newcomb (1997) found a negative relationship between spring flow and the number of age-0 steelhead present. Therefore, stormwater runoff from any new developments should not be allowed to enter the river. The larger tributaries, particularly the Little Betsie River and Dair Creek, are critical for wild steelhead reproduction. Newcomb (1998) also found that small tributaries and springs also provided good thermal refuge and habitat for juvenile steelhead. Therefore, all tributaries should be protected with extra diligence from improper land use and poor logging practices. Natural Rivers designation should also continue to help with this management goal.

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Table 1.-Michigan DNR fish plantings into the Betsie River from 1980-2003.

Year	Species and Strain	Long Rd.	Carmean Rd.	King Rd.	Black Bridge	Red Bridge	Orsini	Kurick Rd.	Psutka Rd.	County Line Rd.	M-115	River Rd.	Frankfort
1980	Brown Trout	1,000	1,000		1,000			1,000	1,000	1,000	500		
	Rainbow Trout (MI steelhead)												20,000
1981	Brown Trout	1,000	1,000		1,000	1,000		1,000	1,000	1,000	500		8,400
	Rainbow Trout (MI steelhead)												20,004
1982	Brown Trout	1,400	1,400		1,400	1,400		1,500		1,500	750		
	BNT fall fingerlings												20,000
	Rainbow Trout (MI steelhead)												15,000
1983	Brown Trout	2,000	2,000		2,000	2,000		2,000		2,000	1,000		10,000
	BNT fall fingerlings												20,000
	Rainbow Trout (MI steelhead)												23,359
1984	Brown Trout	2,000	2,000		2,000	2,000		2,000	2,000	2,000	1,000		15,000
	BNT fall fingerlings												17,000
	Rainbow Trout (MI steelhead)												15,000
	RBT (Rogue R. steelhead)												8,000
1985	Brown Trout	1,910	1,910			1,910		1,810	1,810	1,810	810		11,300
	BNT fall fingerlings												20,000
	Rainbow Trout (MI steelhead)												13,000
1986	Brown Trout	1,930	1,930		1,930	1,930		1,850	1,850	1,850	850		15,000
	BNT fall fingerlings												20,000
	Rainbow Trout (Skamania)												20,001
1987	Brown Trout	1,940	1,940		1,940	1,940		1,880	1,880	1,880	880		14,900
	BNT fall fingerlings												11,500
	Rainbow Trout (Shasta, fall fingerlings)												4,560
	Rainbow Trout (Skamania)												17,500
1988	Brown Trout	2,000	2,000		2,000	2,000		2,000	2,000	2,000	1,000		15,000
	BNT fall fingerlings			10,000		10,000					10,000		
	Rainbow Trout (Skamania)												15,000

Table 1.-Continued

Year	Species and Strain	Long Rd.	Carmean Rd.	King Rd.	Black Bridge	Red Bridge	Orsini	Kurick Rd.	Psutka Rd.	County Line Rd.	M-115	River Rd.	Frankfort
1989	Brown Trout	2,000	2,000		2,000	2,000		2,000	2,000	2,000		1,000	15,000
	BNT fall fingerlings	14,000	14,000		14,000	14,000						14,000	57,000
	Rainbow Trout (MI steelhead fry)				110,875								
	Rainbow Trout (Skamania)				15,000							15,000	
1990	Brown Trout	2,000	2,000		2,000	2,000		2,000	2,000	1,999	1,000		14,998
	BNT fall fingerlings										10,000		
	Rainbow Trout (MI steelhead)											10,000	
	Rainbow Trout (Skamania)											10,360	
1991	Brown Trout	2,000	2,000		1,999	2,000		1,990	1,990	1,990	998		15,738
	Rainbow Trout (MI steelhead)						29,171						
	Rainbow Trout (Skamania)											10,000	
1992	Brown Trout (Wild Rose)	1,990	1,990		1,990	1,990		1,990	1,990	1,990	990		14,700
	Rainbow Trout (MI steelhead)						32,141						
1993	Brown Trout (Wild Rose)	2,000	2,000		2,000	2,000		2,000	2,000	2,000	1,000		14,900
	Rainbow Trout (MI steelhead)						44,125						
1994	Brown Trout (Wild Rose)	1,999	1,999		2,000	1,999		2,000	1,996	1,999	998		15,000
	Rainbow Trout (MI steelhead)						48,560						
1995	Brown Trout (Wild Rose)	1,970	1,970		1,970	1,970		1,940	1,940	1,940	940		14,900
	Rainbow Trout (MI steelhead)						49,206						
1996	Brown Trout (Wild Rose)	1,980	1,980		1,980	1,980		1,921	1,921	1,921	970		13,500
	Rainbow Trout (MI steelhead)						54,916						
1997	Brown Trout (Wild Rose)	2,057	2,058		2,058	2,060	1,058	2,059	2,059	2,058			14,170
	Rainbow Trout (MI steelhead)						49,279						
1998	Brown Trout (Wild Rose)	1,990	1,990		1,975	1,990	980	1,980	1,980	1,980			14,500
	Rainbow Trout (MI steelhead)						38,700						
1999	Brown Trout (Wild Rose)						1,000	2,000	2,000	2,000			
	Brown Trout (Gilchrist Creek)	2,000	2,000		2,000	2,000							
	Brown Trout (Seeforellen)												15,000
	Rainbow Trout (MI steelhead)						38,700						

Table 1.-Continued

Year	Species and Strain	Long Rd.	Carmean Rd.	King Rd.	Black Bridge	Red Bridge	Orsini	Kurick Rd.	Psutka Rd.	County Line Rd.	M-115	River Rd.	Frankfort
2000	Brown Trout (Wild Rose)	2,100	2,100		2,100	2,100	1,100	2,100	2,100	2,100			20,000
	Rainbow Trout (MI steelhead)						39,991						
2001	Brown Trout (Wild Rose)												15,800
	Brown Trout (Seeforellen)				3,070	3,070	3,070	3,070		3,070			
	Rainbow Trout (MI steelhead)						39,400						
2002	Brown Trout (Wild Rose)												15,800
	Brown Trout (Gilchrist Creek)				3,040	3,040	3,040	3,040		3,040	3,040		
	Rainbow Trout (MI steelhead)						38,560						
2003	Brown Trout (Wild Rose)				3,050	3,050	3,050	3,050		3,050	3,050		15,500
	Rainbow Trout (MI steelhead)						38,725						

Table 2.-Orsini Hatchery Steelhead Production, 1991-2003

Year	# Stocked	Size (cm)	Size (inches)
1991	29,171	17.4	6.9
1992	32,141	20.4	8.0
1993	44,125	15.2	6.0
1994	48,560	13.7	5.4
1995	49,206	17.6	6.9
1996	54,916	15.5	6.1
1997	49,279	16.8	6.6
1998	38,700	17.8	7.0
1999	40,400	18.3	7.2
2000	39,991	18.2	7.2
2001	39,400	17.4	6.9
2002	38,560	18.5	7.3
2003	38,725	16.7	6.6

Table 3.-1990 and 1996 Betsie River salmonid population estimates, in lbs/acre.

	Brown trout	Rainbow trout	Coho salmon	Chinook salmon
King Rd.				
1990	1.7	0.23	None obs.	**
1996	1.93	3.94	0.01	0.01
Lindy Rd.				
1990	14.1	0.3	None obs.	None obs.
1996	1.03	4.04	0.01	0.15
Kurick Rd.				
1990	7.9	4.6	2.8	None obs.
1996	1.48	53.8*	None obs.	0.05
Psutka Rd.				
1990	0.8	1.5	0.4	**
1996	1.92	6.46	None obs.	None obs.
Homestead Dam				
1990	0.9	0.7	**	**
1996				

* Many of the rainbow trout captured at this station had right pectoral fin clips and were most likely stocked from the Orsini Hatchery.

** Indicates that although a few individuals were observed at the station, not enough were captured for a reliable estimate.

Table 4.-1990 and 1996 Betsie River salmonid population estimates, in number/acre.

	Brown trout	Rainbow trout	Coho salmon	Chinook salmon
King Rd.				
1990	11.9	4.0	None obs.	0.5
1996	7.92	55.45	0.99	0.99
Lindy Rd.				
1990	64.9	9.5	None obs.	None obs.
1996	4.05	60.17	0.68	10.14
Kurick Rd.				
1990	25.3	236.4	149.3	None obs.
1996	9.74	624.68*	None obs.	3.25
Psutka Rd.				
1990	6.8	9.8	97.7	2.3
1996	11.28	41.6	None obs.	None obs.
Homestead Dam				
1990	2.2	49.3	1.8	**
1996				

* Many of the rainbow trout captured at this station had right pectoral fin clips and were most likely stocked from the Orsini Hatchery.

** Indicates that although a few individuals were observed at the station, not enough were captured for a reliable estimate.

Table 5.-Average total length (inches) at age, and growth relative to the state average, for fish sampled from the Betsie River during August, 1996.

Species	Age Group	Number of fish	Length range in inches	Mean length in inches	State average length	Growth index* (by age group)
Brown trout	I	38	6.4-10.1	8.1	6.2	1.8
	II	5	7.1-9.1	7.8	9.2	-1.4
Rainbow trout	I	75	4.3-9.1	6.5	5.7	0.8
	II	7	7.0-9.1	7.9	8.7	-0.8
Rock bass	I	9	2.7-4.2	3.3	3.5	-0.2
	II	1	5.8	5.8	4.8	
	V	1	8.8	8.8	10	

* Growth index is the deviation from the state average length.

Table 6.-Betsie River brown trout numbers by age, percent by age, and annual survival. Data were combined for 4 stations where populations were estimated in 1990 and 1996.

Betsie River brown trout numbers by age group for 4 stations where populations were estimated								
in 1990 and 1996.								
	Number by age							
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	Total number
1990	3.0	172.6	10.6	1.5	1.0	0.0	4.0	192.7
1996	0.0	45.7	7.0	0.0	0.0	0.0	0.0	52.7
Betsie River brown trout percent of population by age group for 4 stations where populations were estimated								
in 1990 and 1996.								
	Percent by age							
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	Total Percent
1990	1.6	89.6	5.5	0.8	0.5	0.0	2.1	100
1996	0.0	86.7	13.3	0.0	0.0	0.0	0.0	100
Percent survival to the next age (assumming uniform recruitment)								
Year	**0**	**1**	**2**	**3**	**4**	**5**	**6+**	
1990		6.2	14.1	66.7	0.0			
1996		15.3	0.0					

***Note: Brown trout scales from South Branch Au Sable used for inch groups that had no readable scales.**

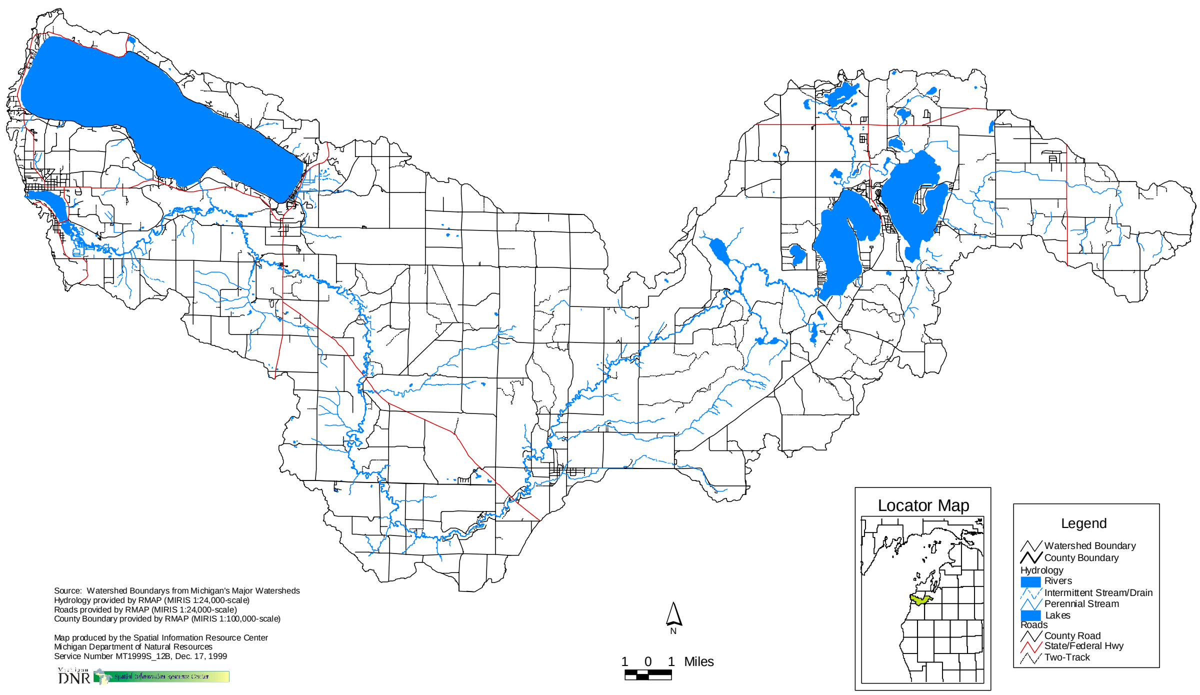
Table 7.-Catch of brown trout and juvenile steelhead from sampling at the Kurick Road station.

1996 Marking run only	Inch Class	# Brown trout	# Steelhead (RP)	# Steelhead (no clip)	# Brook trout
	1"			6	
	2"			21	
	3"			8	
	4"		9	5	
	5"		51	16	
	6"	3	81	6	
	7"	6	52		
	8"	1	12		
	9"		1		
Total		10	206	62	0

1998	Inch Class	# Brown trout	# Steelhead (RP)	# Steelhead (no clip)	# Brook trout
	1"			8	
	2"			69	
	3"			46	
	4"		1	6	
	5"		12	17	
	6"		35	16	
	7"	1	60	2	
	8"	3	22		
	9"		4		
Total		4	134	164	0

2003	Inch Class	# Brown trout	# Steelhead (RP)	# Steelhead (no clip)	# Brook trout
	1"			30	
	2"			125	
	3"	4		48	
	4"		12	4	
	5"		57	30	
	6"		52	8	1
	7"	5	20	3	
	8"	8			
	9"	4			
	16"	1			
Total		22	141	163	1

Figure 1. Betsie River Watershed



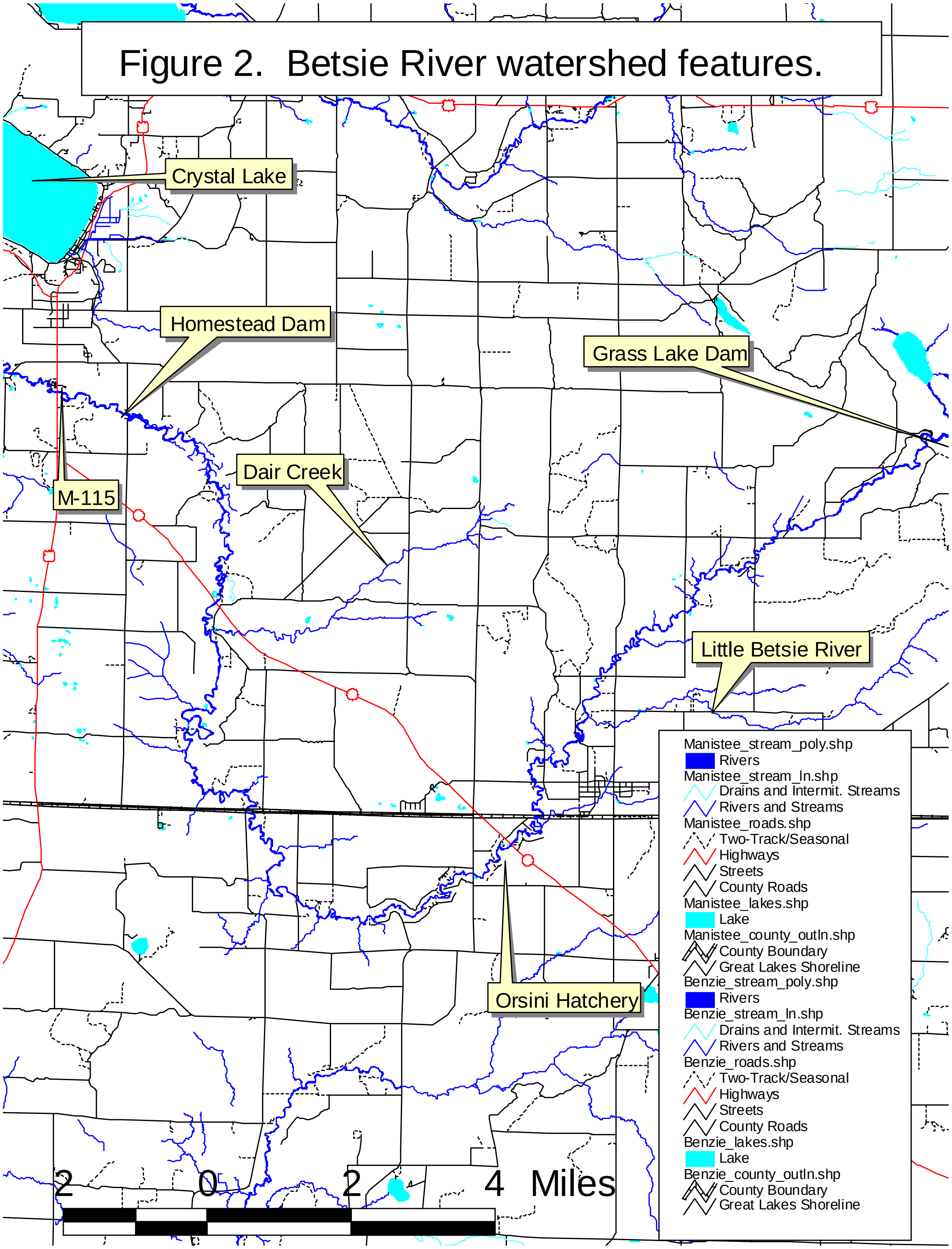


Figure 2. Betsie River watershed features.
Crystal Lake
Homestead Dam
Grass Lake Dam
Dair Creek
M-115
Little Betsie River
Orsini Hatchery
2 0 2 4 Miles
Manistee_stream_poly.shp
Rivers
Manistee_stream_ln.shp
Drains and Intermit. Streams
Rivers and Streams
Manistee_roads.shp
Two-Track/Seasonal
Highways
Streets
County Roads
Manistee_lakes.shp
Lake
Manistee_county_outln.shp
County Boundary
Great Lakes Shoreline
Benzie_stream_poly.shp
Rivers
Benzie_stream_ln.shp
Drains and Intermit. Streams
Rivers and Streams
Benzie_roads.shp
Two-Track/Seasonal
Highways
Streets
County Roads
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Lake
Benzie_county_outln.shp
County Boundary
Great Lakes Shoreline

Figure 3. Betsie River 1996 sampling locations.

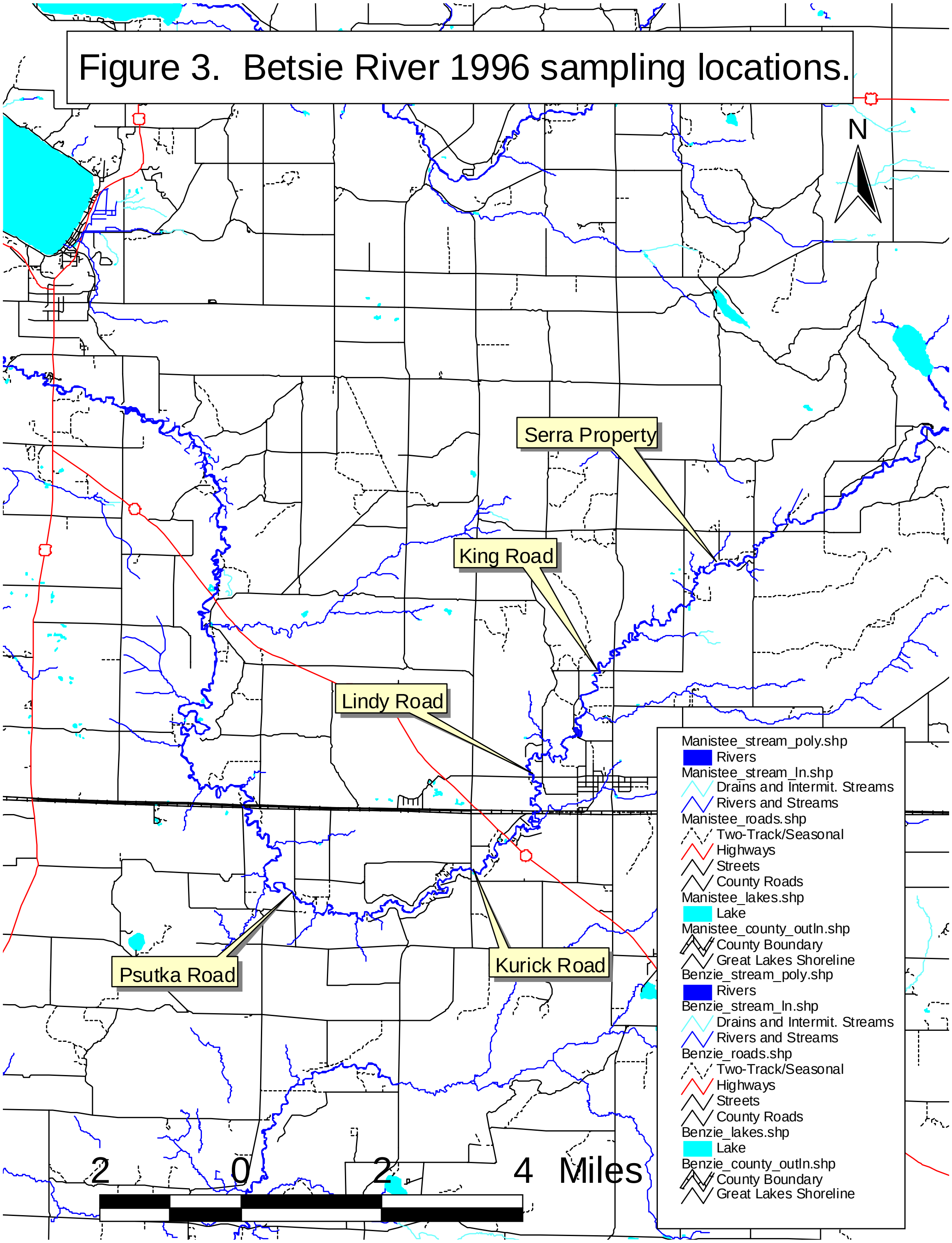
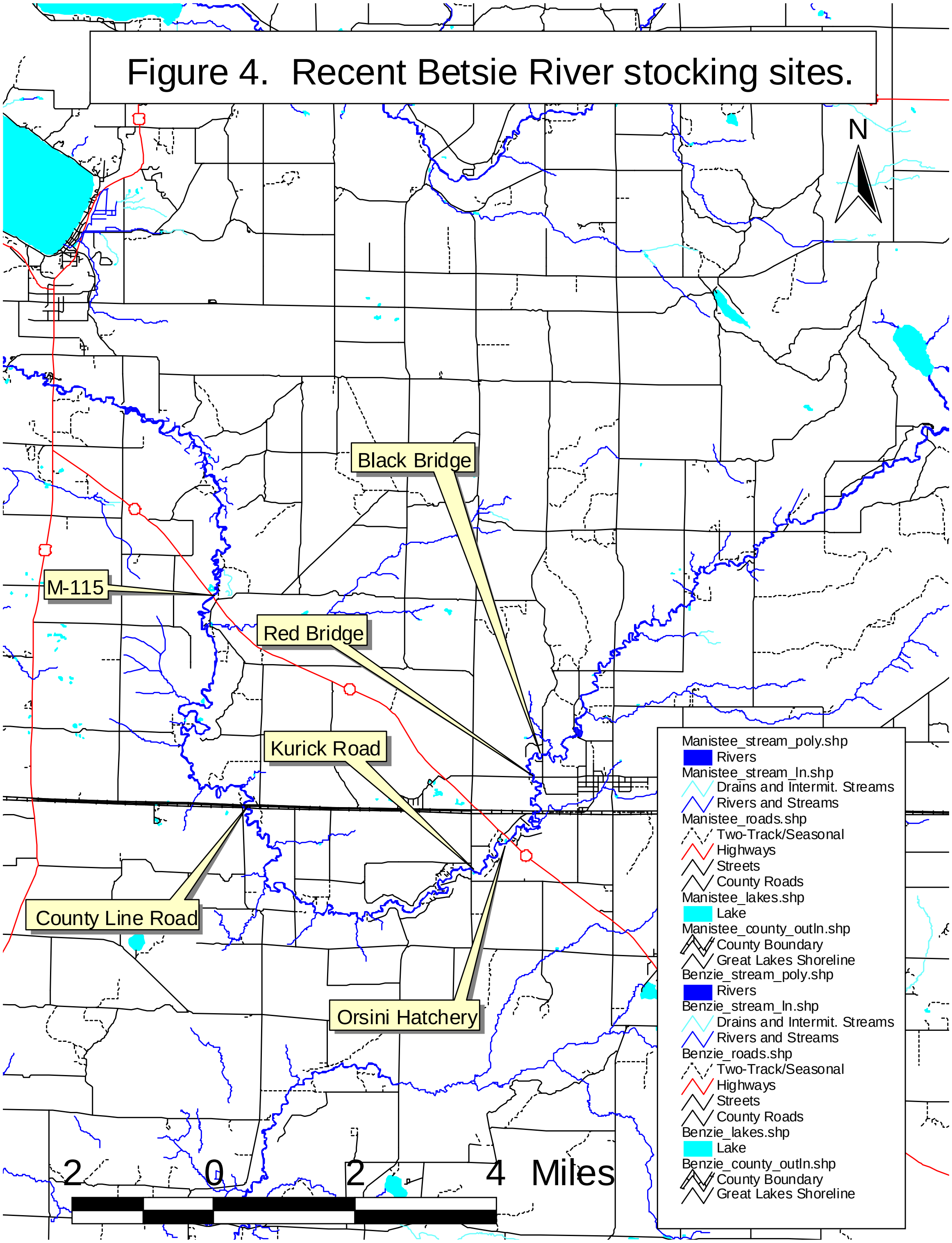


Figure 4. Recent Betsie River stocking sites.



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Betsie Lake Fishery

Betsie Lake
Benzie County (T26N, R16W, Section 27)
Betsie River Watershed; last surveyed 2008

Heather L. Seites and Mark A. Tonello

Environment

Betsie Lake is 289 acres in size and is located between the villages of Elberta and Frankfort in Benzie County, Michigan, in the northwestern Lower Peninsula. Betsie Lake is the drowned river mouth of the Betsie River, which flows into the southeastern end of the lake and drains out into Lake Michigan at the western end. The total drainage area for Betsie Lake is 244.6 square miles, including 2.6 square miles from the immediate drainage and minor tributaries (Grant 1978). The land encompassed by the Betsie Lake watershed is primarily deciduous forest or mixed deciduous/ coniferous forest, with minimal development. The maximum depth of the lake is 34 feet, though approximately 80% of the lake is less than 10 feet deep. The western end of the basin was frequently dredged while the Ann Arbor Railroad Car Ferries were in operation (Grant 1978), and is currently dredged on a 5 to 10 year cycle to maintain navigation (U.S. Army Corp of Engineers 2009). The Village of Frankfort occupies most of the north shore of the lake, which is moderately developed with marinas, or armored with rocks and steel seawall. On the south shore of Betsie Lake is the village of Elberta, which is lightly developed with marinas, or public parks and green space armored with rocks or steel seawall. The southeastern shoreline is mostly undeveloped marshy lowland, with a few private residences.

Historically, the land adjacent to Betsie Lake has been utilized by various industries. In the late 1800's the Frankfort Iron Works operated a blast furnace and railroad lines along the Elberta shoreline, which were sold to the Ann Arbor Railroad near the turn of the century (Blacklock 1975). Grain elevators, a petroleum facility, and coal docks were constructed, and car ferries operated along the lake until the Ann Arbor Railroad operations ceased in approximately 1982. During this time, oil spills on the lake were common (Grant 1978). Logging operations and sawmills operated on the Frankfort and Elberta shores from the time the harbor was opened in 1867 until 1905 (Blacklock 1975). Today, and going back as far as the early 1900's, frozen food packing companies, marine engineering firms and shipyards, manufacturing plants, and fruit processing plants have operated on the Frankfort side of the lake.

There is one citizen-based group that is active on Betsie Lake, the Friends of Betsie Bay (FOBB). The FOBB was established in 1998 (Fred Stransky, personal communication). Since then, they have initiated a water quality monitoring program for Betsie Lake (in cooperation with the Benzie Conservation District), as well as drafting of a management plan for the watershed. The FOBB are strong advocates of area land uses that promote a community in harmony with the natural environment of Betsie Lake.

Public boat ramps are available on Betsie Lake at the Frankfort municipal boat launch on the north side of the lake, or the Elberta Marina in the southeastern corner of the lake. The are also seven marinas on the lake, six private and one municipal, that provide dockage to transient Lake Michigan or Betsie Lake boaters. Public fishing piers are located at the Frankfort Green Space and the Elberta Waterfront Park.

History

The first documented biological survey of Betsie Lake was conducted by the Water Quality Division of the Michigan Department of Conservation in 1966. This survey was initiated following complaints from local residents about poor water quality throughout the lake. The goal of this survey was to determine what type of effects local point source waste discharges were having on the macroinvertebrate community and physical appearance of the lake (Bryant and Seeburger 1966). Bottom dwelling macroinvertebrates were collected in single dredge hauls using a Ponar dredge, then sieved and fixed with formalin (Bryant and Seeburger 1966). Twenty-seven samples were collected in six regions of the lake, and each species collected in the sample was assigned a tolerance level (intolerant, facultative, and tolerant) based upon their ability to survive in poor environmental conditions (Bryant and Seeburger 1966). Many of these sampling sites were located near four known point source waste water discharges. In all of these stations, tolerant bloodworms and sludgeworms were the predominant organisms collected, indicating poor water quality conditions (Bryant and Seeburger 1966).

In 1972 the U.S Environmental Protection Agency surveyed Betsie Lake in conjunction with the National Eutrophication Survey, and at this time sampling results showed the lake to be eutrophic (U.S. EPA 1975). Samples from various water depths were collected at a single fixed location three times from June to November (U.S. EPA 1975). Water chemistry, phytoplankton, and chlorophyll a data was collected during each sampling period. Collectively, the villages of Frankfort and Elberta were found to contribute 48% of the total phosphorous load while the Betsie River contributed 52% of the total phosphorous load (U.S. EPA 1975). Based on these results, the U.S. Environmental Protection Agency (1975) recommended that point source phosphorous inputs to the lake be reduced to the lowest practical levels.

The Water Quality Division sampled the macroinvertebrate community, as well as sediment chemistry, in Betsie Lake during July of 1975. Macroinvertebrate dredge sampling was replicated at twenty-one of the original 1966 sampling locations in six regions of the lake. As observed in the 1966 survey, two tolerant species of aquatic oligochates dominated the samples (Grant 1978) despite the fact that one of the point source waste water discharges had ceased operations and another had lowered its discharge rate since the 1966 survey. Therefore, the residual wastes in the lake continued to affect the water quality of the lake (Grant 1978). While the lake was still considered to have low water quality, some improvements such as an increase in the numbers of oligochates and the increased presence of mayflies were noted in this survey (Grant 1978). Sediment samples were also collected at four of the sampling locations using a Ponar dredge (Grant 1978). Heavy metals were analyzed using atomic absorption followed by nitric acid digestion, while chlorinated hydrocarbons were analyzed using gas chromatography (Grant 1978). Copper, zinc, lead, and chromium levels were all considered to be slightly elevated compaired to U.S. EPA standards, while polychlorinated biphenyls (PCB's) and chlorinated hydrocarbon levels were low enough to be below the limits of analytical sensitivity (Grant 1978).

In 2007, the Friends of Betsie Bay, in cooperation with the Benzie Conservation District, conducted water quality assessments in the lake. A Hydrolab was used to collect information regarding pH, dissolved oxygen levels, and temperatures, and phosphorous, chlorophyll a, and Escherichia coli (E.

coli) levels were also testing using collected water samples (Benzie Conservation District 2009). The 2007 data showed that the overall water quality in Betsie Bay is good, and has improved over the original 1972 U.S. Environmental Protection Agency study (U.S. EPA 1975). Secchi disk readings have improved from an average of 2 to 4.5 feet in 1972, to 5 to 7 feet in 2007. This increase in visibility may be attributed to improving water quality, as well as the presence of zebra mussels inside the lake. Chlorophyll a levels were higher in 2007, and increased water clarity noted in the Secchi disk readings supports this. Phosphorous levels determined in 2007 are very similar to those from 1972. E.coli levels were very low in the lake and surrounding areas and pH and dissolved oxygen levels have remained very stable over time.

Fish have been stocked into Betsie Lake by the State of Michigan for many years. The U.S. Coast Guard Station on Betsie Lake has been used as a stocking location for lake run brown trout and rainbow trout (steelhead). From 1972 to 2009, MDNR Fisheries Division has annually planted from 8,400 to 44,300 spring yearling brown trout (Table 1). Fall fingerling brown trout were also added at a rate of 11,500 to 57,000 annually from 1983 to 1989 (Table 1). In the years 1981-1985, Michigan strain winter run steelhead were planted at a rate of 13,000 to 23,359, and in 1986-1987 from 20,001 to 22,060 summer run steelhead were stocked (Table 1). In 1988 the Orsini Fish Hatchery began operating upstream on the Betsie River producing winter run steelhead, and the stocking of steelhead ceased in the lake.

The MDNR Fisheries Division Master Angler program has had six entries from Betsie Lake since 1996. These entries include one rock bass, one northern pike, one brown trout, one Chinook salmon, and two common carp.

Current Status

The first comprehensive fisheries survey conducted on Betsie Lake occurred in May of 2008. This was a discretionary survey conducted using Status and Trends protocols (Kevin Wehrly, Institute for Fisheries Research, Ann Arbor; unpublished data). Net sampling occurred from May 5 through May 8, and included the use of one large-mesh fyke net (3 net-nights), one inland gill net (1 net-night), two experimental gill nets (4 net-nights), and three trap nets (9 net-nights). The survey plan also called for an electrofishing effort, but budgetary issues prevented this effort from being completed. The intent of the survey was to determine the current status of all fish populations in the lake.

During the survey, a total of 708 fish by number representing 22 species were caught (Table 2). Rock bass, white sucker, and yellow perch comprised the largest portion of the catch. A total of 292 rock bass made up 41% of the total catch, ranging in size from 4 to 10 inches. White suckers represented 43% of the catch by weight with 124 individuals ranging in size from 12 to 23 inches. Fifty-four yellow perch from 5 to 11 inches were caught, with 52% exceeding nine inches in length. Brown bullhead, bowfin, and gizzard shad were also observed.

Game fish caught included northern pike, smallmouth bass, largemouth bass, and walleye (Table 2). A total of 33 northern pike were caught ranging from 15 to 31 inches, and comprised 12% of the weight by catch. In addition, five walleye were also caught, ranging in size from 19 to 26 inches. The presence of walleye in Betsie Lake was not surprising, as anglers have reported catching them in the past. Walleye were stocked up river in the Homestead Pond in 1966, and anglers reported good catches of walleye in the Betsie River from 1973 to 1976. This return of fish may have been the result of the planted walleye leaving the pond while the dam was being removed in 1973 and 1974, then returning to spawn. There has been no documented evidence of a spawning run of walleye in the Betsie River before or since this planting. According to Hanchin et al. (2007), adult walleye tagged in the Muskegon River during spawning were subsequently recaptured at many different locations around Lake Michigan, including other drowned rivermouth lakes. Therefore, since no walleye are stocked in the Betsie River system or Betsie Lake, it is likely that the walleye in Betsie Lake are migrants from other systems, potentially from the Herring Lakes, Portage Lake, or Platte Lake. Although only five walleye were caught in this survey, they were all growing at rates well above the state of Michigan average length at age. They were likely post-spawn adult walleye that had spawned elsewhere and were taking advantage of the diverse forage opportunities in Betsie Lake.

Most species caught showed above average growth (Table 3). Age -2,-3,-4, and-5 northern pike were growing well at 1.6 inches above the state of Michigan average length at age. Smallmouth bass (Ages 4 and 5) were also growing well at 1.3 inches about the state of Michigan average length at age. Rock bass (Ages 3, 4, 6, and 7) also slightly exceeded state average lengths at age at 0.6 inches. Not enough (less than five) black crappie, largemouth bass, steelhead, or walleye were collected from any one inch class to make statistical inferences about their age and growth.

At certain times of the year, Betsie Lake receives considerable fishing pressure. In the spring, Betsie Lake is very popular with anglers trolling for brown trout and steelhead as they migrate in and out of the lake from Lake Michigan. Pier fishing and shore fishing along the Elberta shoreline for steelhead is also popular. Additionally, Chinook and coho salmon provide Betsie Lake anglers with excellent trolling, shore, and pier fishing opportunities from August through October as they stage in Betsie Lake, prior to heading upstream into the Betsie River. Though currently undocumented, angling for these migratory species likely accounts for the majority of the fishing pressure that occurs on Betsie Lake. In the summer, Betsie Lake receives some fishing pressure from anglers seeking smallmouth bass and northern pike. Some ice fishing also takes place on Betsie Lake, with steelhead, northern pike and yellow perch being the most sought-after species in the winter.

Analysis and Discussion

The 2008 MDNR fisheries survey showed that Betsie Lake has a generally healthy fish community, and that the species composition of the lake is similar to that found in other drowned river mouth lakes, including Manistee and Pere Marquette Lakes (MDNR Fisheries Division, unpublished data). Game fish captured included smallmouth bass, northern pike, and walleye. Smallmouth bass were also represented by eight year classes (Ages 3 through 10) and were growing well. The northern pike population appears to be healthy, as evident by the five year classes captured and above average growth rates exhibited.

Additional gamefish species that were captured in low numbers in the 2008 survey included rainbow trout (likely steelhead migrating to and from the Betsie River), brown trout, and menominee whitefish. Largemouth bass were notably absent from the 2008 survey. It is likely that they are present in Betsie Lake, at least in low numbers.

With the exception of rock bass and yellow perch, Betsie Lake does not have strong panfish populations. Rock bass were the most numerous species found in the survey, with 292 individuals representing eight year classes (Ages 2 through 9). Yellow perch were also well-represented in the survey, with most fish larger than seven inches in length. It is likely that the yellow perch population of Betsie Lake is heavily influenced by the yellow perch population of Lake Michigan, as there is likely movement of yellow perch back and forth between Betsie Lake and Lake Michigan particularly when spawning (Schnieder at al. 2007). One black crappie was also captured in the survey. The lack of other panfish species, including bluegill and pumpkinseed sunfish in the catch was somewhat surprising. While Betsie Lake is not known for its bluegill or pumpkinseed sunfish fishing, it is likely that both species are present, at least in low numbers.

Other fish collected in the 2008 Betsie Lake survey in significant numbers included bowfin, brown bullhead, white sucker, gizzard shad, and two species of redhorse. Gizzard shad represented 4.8% of the total catch by number with 34 individuals. While gizzard shad potentially provide an excellent forage base for bass, northern pike, and walleye, they also have been known to compete heavily with juvenile largemouth and bluegill (Aday et al. 2003). Juvenile brown bullhead, white sucker, and redhorse also provide forage for smallmouth bass, largemouth bass, and northern pike, but as adults they may have negative impacts on more desirable species like walleye or yellow perch, as they compete with panfish and juvenile game fish for forage (Hayes 1990). These three species comprised 22% of the total species caught by number. Very low numbers of longnose gar, burbot, alewife, sea lamprey, and common carp were also collected.

Management Direction

Another fisheries survey of Betsie Lake should be conducted within the next five years. In the next fisheries survey, electrofishing and seining should be conducted along with trap and gill nets in order to obtain a more representative sample of fish. Electrofishing is less species-specific than netting and has the potential to collect more data on bass, panfish, and salmonids, while seining will provide better insight into the minnow and juvenile game fish populations in the lake. Both of these techniques will allow for the sampling of shallower, more diverse near-shore areas that may have been missed in the 2008 survey.

The overall goal for Betsie Lake is to maintain a stable and sustainable fisheries community. Movement of fish such as walleye, whitefish, and gizzard shad from Lake Michigan provides for increased species diversity and angling opportunity, as does the migratory movements of salmonids such as steelhead, brown trout, coho salmon, and Chinook salmon. Species such as rock bass, smallmouth bass, yellow perch, northern pike, white sucker, and redhorse that are native to the lake should continue to thrive. Currently, none of these species are stocked by the MDNR Fisheries Division, and they appear to be reproducing well on their own.

One of the goals for Betsie Lake should be to sustain the salmonid fishery in Betsie Lake and in the Lake Michigan waters of the Frankfort area. In particular, the stocking of brown trout into Betsie Lake should be continued at the current rates of 15,000 to 20,000 fish annually. These stocking rates are necessary in order to sustain the current fishery, and will allow Betsie Lake to continue to be one of the better brown trout fisheries along the Lake Michigan shoreline. The Betsie River is also stocked with yearling steelhead, and in some years supports high levels of steelhead natural reproduction. No Chinook or coho salmon are stocked in the Betsie River, so the salmon fisheries of the Betsie River and Betsie Lake are entirely dependent on natural reproduction and migration. The steelhead and salmon pass through Betsie Lake as smolts on their way downstream to Lake Michigan, and return through Betsie Lake as adults on their way upstream to spawn. Good water quality in both the Betsie River system and Betsie Lake is necessary to ensure optimal spawning habitat, improve survival rates of natural and stocked fish, and to encourage fish to return to the system to reproduce. Therefore, maintaining and improving water quality in the Betsie River and in Betsie Lake should be one of the highest priorities for the Betsie River watershed.

Another goal for Betsie Lake should be the conservation of the remaining undeveloped riparian areas, in particular those containing wetlands. Riparian areas along the lake should be protected, as these areas are important to fish community health and continued improvement of the lake's water quality. A large percentage of the lake's shoreline is heavily armored with rocks, docks, or steel seawall, so the protection of any remaining natural riparian areas near the southeastern end of the lake and the mouth of the Betsie River should continue to be a priority. Also, marina development on Betsie Lake should be completed with the Betsie Lake sport fishery in mind. Betsie Lake is less than 300 acres in size, so new marina development potentially could take place on canals dredged inland instead of on the limited open water of Betsie Lake itself.

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Table 1. Michigan DNR fish plantings in Betsie Lake 1972-2009

Year	Species and Strain/Type	Number
1971	Rainbow trout (*Michigan)*	10,000
1972	Brown trout (Fall fingerlings)	35,000
1973	Brown trout (Spring yearlings)	20,000
1974	Brown trout (Spring yearlings)	44,300
1975	Brown trout (Spring yearlings)	10,000
1976	Brown trout (Spring yearlings)	19,621
	Rainbow trout *(Michigan)*	17,086
1977	Brown trout (Spring yearlings)	20,000
1978	Brown trout (Spring yearlings)	25,038
1979	Brown trout (Spring yearlings)	10,000
1980	Rainbow trout *(Michigan)*	20,000
1981	Brown trout *(Harrietta)*	8,400
	Rainbow trout *(Michigan)*	20,004
1982	Brown trout *(Harrietta)*	20,000
	Rainbow trout *(Michigan)*	15,000
1983	Brown trout *(Harrietta)*	10,000
	Brown trout (Fall fingerlings)	20,000
	Rainbow trout *(Michigan)*	23,359
1984	Brown trout *(Harrietta)*	15,000
	Brown trout (Fall fingerlings)	17,000
	Rainbow trout *(Michigan)*	15,000
1985	Brown trout *(Wild Rose)*	11,300
	Brown trout (Fall fingerlings)	20,000
	Rainbow trout *(Michigan)*	13,000
1986	Brown trout *(Wild Rose)*	15,000
	Brown trout (Fall fingerlings)	20,000
	Rainbow trout *(Skamania)*	20,001
1987	Brown trout *(Soda Lake)*	14,900
	Brown trout (Fall fingerlings)	11,500
	Rainbow trout *(Skamania)*	17,500
	Rainbow trout *(Shasta)*	4,560
1988	Brown trout *(Plymouth rock)*	15,000
	Rainbow trout *(Skamania)*	15,000
1989	Brown trout *(Plymouth rock)*	15,000
	Brown trout (Fall fingerlings)	57,000
1990	Brown trout *(Soda Lake)*	14,998
1991	Brown trout *(Plymouth rock)*	15,738
1992	Brown trout *(Wild Rose)*	14,700
1993	Brown trout *(Wild Rose)*	14,900
1994	Brown trout *(Wild Rose)*	15,000
1995	Brown trout *(Wild Rose)*	14,900
1996	Brown trout *(Wild Rose)*	13,500
1997	Brown trout *(Wild Rose)*	14,170
1998	Brown trout *(Wild Rose)*	14,500
1999	Brown trout *(Seeforellen)*	15,000
2000	Brown trout *(Wild Rose)*	20,000
2001	Brown trout *(Wild Rose)*	15,800
2002	Brown trout *(Wild Rose)*	15,800
2003	Brown trout *(Wild Rose)*	15,500
2004	Brown trout *(Wild Rose)*	15,100
2005	Brown trout *(Wild Rose)*	16,000
2006	Brown trout *(Wild Rose)*	16,100
2007	Brown trout *(Wild Rose)*	13,800
2008	Brown trout (*Gilchrist Creek)*	16,000
2009	Brown trout (*Gilchrist Creek)*	20,000

Table 2. Number, weight, and length of fish collected from Betsie Lake with large mesh fyke nets, trap nets, inland gill nets, and experimental gill nets May 5-8, 2008.

Species	Number	Percent by number	Weight (lbs)	Percent by weight	Length Range (inches)	Average length
Alewife	4	1%	0.37	0%	6 to 8	6.5
Black crappie	1	0%	0.14	0%	6	6
Brown trout	1	0%	0.12	0%	6	6
Bowfin	31	4%	0	0%	14 to 28	23.7
Brown bullhead	41	6%	16.3	2%	6 to 12	8.6
Burbot	7	1%	5.6	1%	11 to 16	13.5
Common carp	1	0%	11.48	1%	29	29
White sucker	124	18%	350.02	43%	12 to 23	18.5
Gizzard shad	34	5%	47.93	6%	12 to18	15.2
Largemouth bass	2	0%	4.33	1%	15 to 16	15.5
Longnose gar	2	0%	3.09	0%	19 to 30	24.5
Northern pike	33	5%	99.54	12%	15 to 31	22.7
Rainbow trout	2	0%	4.22	1%	7 to 22	14.5
Rock bass	292	41%	71.86	9%	4 to 10	6.2
Round whitefish	1	0%	0.7	0%	13	13
Sea lamprey	1	0%	0.54	0%	19	19
Shorthead redhorse	13	2%	35.12	4%	18 to 23	20.5
Silver redhose	19	3%	44.73	6%	5 to 27	16.5
Smallmouth bass	38	5%	78.16	10%	9 to 20	15
Walleye	5	1%	19.38	2%	19 to 26	22
Mudpuppy	2	0%	0	0%	10 to 13	21.7
Yellow perch	54	8%	16.08	2%	5 to 11	8.1
Total	708	100%	809.71	100%		

Table 3. Average total weighted length (inches) at age and growth relative to the state average for fish sampled from Betsie Lake with large mesh fyke nets, trap nets, inland gill nets, and experimental gill nets May 5-8, 2008.

	Age										Mean Growth
Species	I	II	III	IV	V	VI	VII	VIII	IX	X	Index
Black crappie	…	…	6.5 (1)	…	…	…	…	…	…	…	**
Largemouth bass	…	…	…	…	15.9 (1)	16.6 (1)	…	…	…	…	**
Northern pike	15.7 (1)	19.0 (5)	21.5 (16)	26.2 (16)	28.5 (5)	…	…	…	…	…	+ 1.6
Rock bass	…	4.3 (3)	6.0 (19)	7.0 (8)	7.6 (4)	8.1 (9)	8.7 (7)	9.7 (2)	9.00 (1)		+ 0.6
Smallmouth bass	…	…	11.5 (2)	13.9 (13)	15.7 (12)	17.4 (2)	17.3 (2)	11.6 (1)	18.6 (4)	20.2 (1)	+ 1.3
Walleye	…	…	…	21.5 (2)	23.7 (1)	23.0 (2)	…	…	…	…	**
Rainbow trout (steelhead)	…	…	22 (1)	…	…	…	…	…	…	…	**

** Mean growth index can only be calculated for age groups with five or more individuals.

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Crystal Lake Fishery

Crystal Lake

Benzie County
Betsie River Watershed, last surveyed 2014

Mark A. Tonello

Environment

Crystal Lake is the ninth-largest inland lake in Michigan, at 9,854 acres. It is located in western Benzie County, just north of the city of Frankfort (Figure 1). The village of Beulah is located along the eastern shore of Crystal Lake, with the village of Benzonia just to the south. Crystal Lake is a deep, oligotrophic lake with a maximum depth of approximately 165 feet and an average depth of 70 feet. Substrates consist primarily of sand and marl. Crystal Lake is part of the Betsie River watershed. An outlet stream flows out of the south shore and directly feeds the Betsie River. Although there is a lake-level control dam on the outlet, jumping migratory fish from Lake Michigan such as salmon and steelhead can clear the dam and enter the lake. At base flow, the outlet discharges approximately 34 cubic feet per second (cfs; Anonymous 2015).

Crystal Lake lies just east of Lake Michigan, approximately ½ mile from the coast. It has a relatively small watershed for a lake of its size, at just over 28,000 acres (Anonymous 2015). This is due to the topography of the landscape surrounding the lake. Directly to the south and north of Crystal Lake are large glacial moraines that reach elevations 200-300 feet higher than that of the lake. Because of this, there are only a few tributaries to Crystal Lake, most of which are very small spring creeks. The surrounding landscape is hilly and mostly forested with northern hardwoods, although there is a large wetland complex located directly east of the lake, locally known as the Trapp Farm. Point Betsie and its associated sand dunes lie directly west of Crystal Lake, and the Sleeping Bear Dunes National Lakeshore lies to the north. There are also a number of fruit orchards and golf courses in the Crystal Lake watershed.

The shoreline of Crystal Lake (approximately 21 miles) is heavily developed with homes and cottages, and boasts some of the highest property values in the region (Anonymous 2015). Crystal Lake is an extremely popular tourist destination, with fishing, boating, sailing, and swimming all being popular activities. The local economies of Frankfort, Beulah, and Benzonia all benefit significantly from Crystal Lake-based tourism.

The largest tributary to Crystal Lake is Cold Creek, which flows into the eastern end of the lake in the village of Beulah (Figure 1). Cold Creek is a Designated Trout Stream that supports migratory runs of Coho Salmon and steelhead from Crystal Lake, in addition to hosting populations of resident Brown Trout and Brook Trout (Tonello 2007). Cold Creek flows through a wetland area known as the Trapp Farm area before entering the Village of Beulah. On the Trapp Farm property, Cold Creek was significantly affected by historical agricultural practices, including ditching, dredging, and stream re-routing. Cold Creek historically had several dams on it, including the Case Dam (a sawmill dam that dated back to the 1800s). Unfortunately, the Case Dam failed in 1973, releasing sawdust and sediment into Cold Creek. A large sediment trap was then constructed on Cold Creek in 1975 (Daniels and Murphy 2003) to keep the sediment and sawdust from reaching Crystal Lake. The basin is approximately 90 feet by 350 feet and is emptied as needed by the Village of Beulah. The basin continues to intercept sediment, including that coming off the Trapp Farm property.

There are several different opportunities for public access on Crystal Lake (Figure 2). The largest public access site is the Michigan Department of Natural Resources (MDNR) site located off Mollineaux Road on the south shore, just east of Railroad Point. This site was completed in late 2011 and was first open to the public for the 2012 boating season. The site offers four launch ramps, with paved parking for 36 vehicles with trailers and another 20 vehicles without trailers, plus ample unpaved overflow parking. There are also two ADA car/trailer spaces. The Crystal Lake and Watershed Association co-operatively operates a boat-wash station at the site.

The other primary boat launch on Crystal Lake lies in the village of Beulah, on the east end of the lake (Figure 2). That launch has two ramps and parking for 8-10 vehicles and trailers. Also at this site is an accessible fishing pier, which was installed in the summer of 2014. The Beulah beach area is also popular in the spring and fall for surf-style fishing for Rainbow Trout, Lake Trout, and Coho Salmon. Boat launches with parking for a few vehicles and trailers are also available at the end of Lobb Road on the south shore of the lake, and at the end of Nichols Road on the north shore. Although most of the shoreline of Crystal Lake is privately owned and developed, the Railroad Point Natural Area provides nearly 200 acres and over 3,000 feet of undeveloped shoreline. The Natural Area is owned by Benzie County and jointly administered by the Grand Traverse Regional Land Conservancy.

Crystal Lake is a Designated Trout Lake, and is regulated under Type E fishing regulations. This means that Crystal Lake is open to year-round fishing, with a year-round possession season on trout and salmon. The minimum size limits for Lake, Brook, Brown, and Rainbow Trout are 15 inches, while the minimum size limit for Coho or Chinook Salmon is 10 inches. The daily possession limit is 3 trout or salmon of one species or in combination.

The Crystal Lake and Watershed Association (CLWA) is the primary citizen-based advocacy group for Crystal Lake, and is a 501(c)(3) organization. The CLWA was founded in 2004 through the merger of two groups: the Crystal Lake Association and the Crystal Lake Watershed Fund. Both groups originated back in the 1960s (Anonymous 2015). The CLWA supports a number of programs including water quality sampling, landowner education, student education, operation of the boat wash station at the MDNR boat launch and others.

History

Because of its east-west orientation and susceptibility to Lake Michigan winds, Crystal Lake was originally known as "Cap" Lake, referring to the whitecaps which were and still are, very common on the lake (Case 1915, Brown and Funk 1940). Historically the lake level of Crystal Lake was approximately 20 feet higher than it currently is today. In 1873, an ill-conceived project by a local businessman named Archibald Jones to allow steamboat navigation between Lake Michigan and Crystal Lake via the Betsie River went awry. The project called for straightening and dredging the Betsie River and the Crystal Lake outlet stream, but did not take into account the differences in elevation between Crystal Lake and those waterbodies. When the construction crew attempted to enlarge the Crystal Lake outlet, the force of the water took over and carved a large opening that drained the lake down to its current level over the span of approximately two weeks (Case 1915).

The incident caused Crystal Lake to lose approximately 25% of its volume and surface area, reducing its size by approximately 3,093 acres (Anonymous 2012). The current water level is controlled by a dam that is operated by the Benzie County Drain Commissioner. The court mandated legal lake level was set in 1980. The winter level is six inches lower than the summer level, in order to protect infrastructure from ice damage. The sheer volume of water in Crystal Lake combined with the limited ability of the small outlet stream to convey water makes it difficult at times to meet the legally mandated levels.

One historical fisheries issue on Crystal Lake was that of fish (Rainbow Smelt and Rainbow Trout) supposedly exiting the lake through the outlet (Shetter and Reynolds 1942). Several attempts were made at blocking downstream fish passage, but each time the screens were demolished or broken, either by vandalism or natural conditions (storms, ice floes, etc.). Eventually it became clear that downstream migration, if it was occurring, was not having any impact on the overall fish populations in Crystal Lake.

Other fisheries management of Crystal Lake included the installation of brush shelters in 1958 (DNR files, Cadillac) in an attempt to add fish cover. In the 1960s there was some discussion regarding possible installation of a spawning reef for Lake Trout spawning. Eventually this idea was abandoned as impractical and Lake Trout populations continue to be supported by stocking.

Fish Stocking

The first recorded fish stocking in Crystal Lake was in 1890 when Lake Trout were stocked (Table 1). Since then, Crystal Lake has had a long and varied stocking history. Lake Trout were again stocked in 1895, 1897, and 1905. Between 1905 and 1944, various warmwater and coolwater species were stocked, including Largemouth Bass, Smallmouth Bass, Bluegill, and Yellow Perch. Walleye and Warmouth each were stocked in one instance as well. The first successful introduction of Rainbow Smelt in the Great Lakes region occurred in Crystal Lake in 1912 (Van Oosten 1937). It is believed that the Rainbow Smelt populations in the upper Great Lakes originated from fish that migrated out of Crystal Lake and into Lake Michigan (Beckman 1941).

Since 1945, fish stocking in Crystal Lake has been limited to salmonids, primarily Lake and Rainbow Trout (Table 1). Splake, Brown Trout, and Atlantic Salmon were each stocked in a few years. Since 1993, only Lake and Rainbow Trout have been stocked. Recent stocking regimes have consisted of approximately 60,000 yearling Lake Trout and 20,000 yearling Rainbow Trout annually. Surplus fall-fingerling steelhead (a genetic strain of Rainbow Trout) have also been stocked several times in recent years.

Fisheries Surveys

The first fisheries survey of Crystal Lake was conducted in 1940 by the Michigan Department of Conservation (MDOC; the precursor to today's Department of Natural Resources (MDNR)). In that survey (Brown and Funk 1940) the researchers used seines, experimental gill nets, and fyke nets. Yellow Perch absolutely dominated the catch (at 98.3% by number), with most of those taken in the gill nets. Other species caught included Rock Bass, White Sucker, Lake Whitefish, Cisco (Lake Herring), Lake Trout, Burbot, Northern Pike, Bluegill, Rainbow Smelt, Spottail Shiner, Emerald Shiner, Iowa Darter, Johnny Darter, Logperch, and Bluntnose Minnow (Table 2). The researchers also caught a species they called "straw-colored shiner". There is no species known as "straw-colored shiner", so it is unknown what species they were actually referring to. Burbot, Northern Pike, and Bluegill were each represented by one individual. Other species not caught in the 1940 survey but reported as being observed or caught by anglers in Crystal Lake included Black Crappie, Bullhead, Redhorse, and Smallmouth Bass.

The 1940 survey report (Brown and Funk 1940) marks the first acknowledgement by MDOC that Crystal Lake is best suited to coolwater and coldwater species. To that point, MDOC had been stocking species like Bluegill, Largemouth Bass, Smallmouth Bass, and Yellow Perch (Table 1). The authors correctly pointed out that stocking of Yellow Perch and Smallmouth Bass was unnecessary, as those species would be able to propagate themselves naturally. They recommended halting the stocking of all but coldwater species, and specifically recommended stocking rainbow trout and lake trout.

The next MDOC fisheries survey was conducted in 1948 (MDNR files, Cadillac) by Fisheries Biologist Stanley Lievense. The 1948 survey was a short effort conducted with experimental gill nets and some seining. The only species captured were Yellow Perch, Rock Bass, White Sucker, and Smallmouth Bass, and Rainbow Smelt (Table 2). Another short gill net effort was conducted in 1956, also by Fisheries Biologist Lievense (MDNR files, Cadillac). Species caught in this effort included Lake Trout, Lake Whitefish, Burbot, Yellow Perch, Rainbow Smelt, and White Sucker (Table 2).

In November of 1960, a fyke net effort was conducted on Crystal Lake, the goal of which was to catch Lake Whitefish for stocking into Glen Lake in Leelanau County. Unfortunately, only one Lake Whitefish was captured in the effort, so no transfer was conducted. Other species caught included Rainbow Trout, Cisco, Burbot, and White Sucker (Table 2).

In 1976, several MDNR Fisheries Biologists took note that no recent comprehensive surveys had been conducted on Crystal Lake. In the report (MDNR files, Cadillac), MDNR Biologist Bernie Ylkanen detailed the existing sparse fisheries knowledge of Crystal Lake. He mentioned that Lake Trout and Rainbow Trout fishing were only fair. He mentioned that the Yellow Perch fishery was good year-round. He also discussed the Lake Whitefish fishery, including the good ice fishery, and spring/fall nearshore fishery, and the November/December spear fishery. Laarman (1976) also recommended surveying the lake with appropriate fisheries sampling gear and forming management recommendations from the results.

In response, in June of 1977, MDNR conducted a fisheries survey of Crystal Lake with Great Lakes gill nets (Hay 1980). Species collected included Lake Trout, Lake Whitefish, Cisco, Yellow Perch, Rainbow Smelt, Burbot, White Sucker, and Slimy Sculpin (Table 2). The survey showed robust populations of Lake Trout, Lake Whitefish, and Cisco. The Lake Trout ranged from 10 to 36 inches in length, with nine different age groups represented. Hay surmised that some natural reproduction was occurring, presumably based on the lack of fin clips on some of the Lake Trout from certain age groups. Four different age classes of Lake Whitefish and nine different year classes of Cisco were present in the catch. While the Yellow Perch catch was very numerous, the vast majority was only six inches in length and came from just two year classes. Age and growth analysis indicated that they were growing slowly.

Subsequent fisheries surveys of Crystal Lake were conducted in 1989 (Hay 1989) and 1997 (MDNR files, Cadillac). Like the 1977 survey, these surveys consisted only of Great Lakes gill nets. Large numbers of Lake Trout representing numerous year classes were caught in both surveys. As in 1977, robust populations of Lake Whitefish and Cisco were present, as were large numbers of Yellow Perch. In the 1989 survey, the yellow perch size structure was better (a larger percentage of the catch was over 7 inches), and growth was improved over 1977. However, in 1997, the vast majority of the Yellow Perch catch was smaller than seven inches. The 1989 survey marked the first documentation of Coho Salmon in Crystal Lake (which had never been stocked). Coho Salmon were also present in 1997. Four Rainbow Trout were caught in 1989, and one was caught in 1997. Seven Brown Trout were caught in 1989, and one was caught in 1997. No Atlantic Salmon were caught in either survey.

The next comprehensive fisheries survey of Crystal Lake was conducted in 2003. The 2003 survey was conducted over an extended time period (May through August) and utilized a number of different gear types, including small and large mesh fyke nets, trap nets, inland gill nets, and Great Lakes gill nets. In the 2003 survey, a total of 7,128 fish representing 16 species and weighing nearly 10,000 lbs. were caught (Table 3). By far, White Sucker and Rock Bass were the most numerous species caught. White Suckers comprised 53.6% of the catch by number and 78.6% by weight. Rock Bass comprised approximately 30% of the catch by number and 10.8% of the catch by weight. Other well-represented species included Yellow Perch, Cisco, and Lake Trout. The contrast between the 2003 survey and the previous three surveys was the use of trapping gear (fyke nets and trap nets). The vast majority of the White Suckers and Rock Bass were captured in the fyke nets and trap nets. Age and growth data from the 2003 survey efforts are in Tables 4-6. Some creel census was conducted during the summer of 2003 as well. Although the catch and effort data is unavailable, age and growth data from fish sampled by creel census is included in Tables 4 and 6.

An ice fishing creel census survey was conducted on Crystal Lake in the winter of 2004 (MDNR Fisheries Division unpublished data; Table 7). During the ice season an estimated 31,703 fish were harvested and 9,831 fish were released by ice anglers. Yellow Perch were the most commonly caught species, with 23,916 kept and 9,520 released. Other species encountered during the winter creel survey included Rainbow Trout, Brown Trout, Lake Trout, Cisco, Lake Whitefish, White Sucker, and Rainbow Smelt. The winter 2004 ice fishery on Crystal Lake generated a total estimate of 41,794 angler hours (10,155, angler trips). Based on a value of $39/day for daily angler expenditures (U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau 2011) the Crystal Lake ice fishery conservatively generates $400,000 to the local economy on an annual basis.

In the summer of 2004, an experimental hydro acoustic survey was conducted on Crystal Lake. As part of the survey, Great Lakes gill nets were set to help verify the hydroacoustic fisheries data. The verification nets were set May 17-18, and August 16-17, 2004. A total of 136 fish representing eight species were caught in the Great Lakes gill nets (Tables 2 and 8). Age and growth data was collected from the netted fish (Tables 9 and 10). The results of the hydroacoustic survey showed that Crystal Lake had 1,316 fish/hectare. This result is comparable with that of hydroacoustic surveys of other large, oligotrophic inland lakes in Michigan. According to Claramunt (MDNR, unpublished data), Higgins Lake had 1,181 fish/hectare, and the main body of Lake Charlevoix had 836 fish/hectare in similar hydroacoustic surveys that were conducted in 2011.

Although Lake Sturgeon have never been captured in any of the Crystal Lake fisheries surveys, they have been documented in the lake. In 2005 and 2007 we received reports from riparian landowners of several Lake Sturgeon in the shallows of Crystal Lake. The reports were accompanied by photos. Some of the landowners mentioned that they see Lake Sturgeon in the shallows every spring. The Lake Sturgeon observed and photographed included large adults that were possibly exhibiting spawning behavior. The overall population level of Lake Sturgeon in Crystal Lake is unknown, but it must be assumed that natural reproduction is supporting this population.

From 1994-2015, a total of 121 exceptional fish caught from Crystal Lake have been entered into the DNR Fisheries Division Master Angler program (Table 11). The species with the most entries is Rock Bass, with 43 entries. Smallmouth Bass, Rainbow Smelt, and Burbot were also well-represented with more than 20 entries each. Eleven Lake Trout were entered over the years, along with one Brown Trout. The large number of Master Angler entries for Crystal Lake speaks to the popularity and quality of fishing on Crystal Lake.

Current Status

The most recent comprehensive fisheries survey of Crystal Lake was conducted by MDNR in the summer and fall of 2014. The summer netting portion of the survey took place from June 23 through June 27. Survey gear used included four Great Lakes gill nets (15 net-nights), two straight run gill nets (four net-nights), two experimental graded-mesh inland gill nets (six net-nights), and six trap nets (16 net-nights). The fall netting portion of the survey took place from November 5-7, and it included three Great Lakes gill nets (six net-nights), two straight run gill nets (four net-nights), and two large-mesh fyke nets (two net-nights). The primary purpose of this survey was to assess the status of all fish populations in Crystal Lake, with additional focus on the Lake Trout and Rainbow Trout populations.

During the 2014 June netting survey, a total of 4,263 fish were caught, representing 10 different species (Table 12). Rock Bass were the most frequently collected species, with a total of 3,206 caught. They represented 75.2% of the total catch by number and ranged from 3 to over 12 inches in length. Yellow Perch were also numerous in the June catch, with 784 caught, ranging from 4 to 13 inches in length. Other fish species caught in the 2014 June netting survey included Burbot, Coho Salmon, Lake Trout, Lake Whitefish, Northern Pike, Rainbow Trout, Smallmouth Bass, and White Sucker. A total of 85 Smallmouth Bass were caught, with individuals ranging up to 21 inches. Thirty Lake Trout were caught, averaging 21.5 inches in length and ranging up to 32 inches.

In the November portion of the survey, a total of 197 fish were caught, representing 9 species (Table 13). The one new species encountered was Longnose Sucker, with one caught. No Coho Salmon or Rainbow Trout were caught. The Lake Trout caught in the November portion of the survey averaged over five inches longer than those caught in June (26.7 inches vs. 21.5 inches). Also, the Yellow Perch caught in the November effort were larger than those caught in June (11.3 inches vs. 8.0).

Most species caught in the 2014 Crystal Lake survey showed growth near the State of Michigan length at age average (Tables 14 and 15). In both portions of the survey, Lake Trout exceeded the State Average growth rate. Yellow Perch were growing slightly slower than the State Average in both portions of the survey, although not dramatically so.

Analysis and Discussion

Crystal Lake is a daunting and sometimes dangerous lake to conduct fisheries surveys on. At nearly 10,000 acres, it is a very large lake, and its proximity to Lake Michigan means that it is often subjected to storms and heavy winds coming off Lake Michigan. In both the 2003 and 2014 surveys, weather played a role, sometimes forcing the fisheries crews off the lake and preventing the tending of nets. Despite this, both surveys provided valuable information regarding the fish populations of Crystal Lake.

One of the reasons for conducting the 2014 survey of Crystal Lake was to evaluate the Lake Trout stocking program, which has been ongoing for decades (Table 1). The catch of 55 Lake Trout representing twelve different age classes verifies that the stocking program is successful. Lake Trout exhibit growth rates well above the State average (Tables 14 and 15). This is likely due to the abundant forage available in Crystal Lake in the form of Rainbow Smelt. In the 2004 winter creel survey, effort showed the popularity of Lake Trout fishing in Crystal Lake, with an estimated 3,438 harvested and another 100 released (Table 7).

The 2014 fisheries survey showed that most native fish populations in Crystal Lake are healthy. Rock Bass and Yellow Perch were particularly abundant, with many year classes represented. Many Rock Bass of Master Angler proportions are present in Crystal Lake. Smallmouth Bass were also well-represented in the catch, with 12 different year classes present. Crystal Lake has a reputation as a very good Smallmouth Bass fishing lake, with trophy potential. Yellow Perch are also very popular among Crystal Lake anglers and are heavily pursued in both the open water and ice fishing seasons. Northern Pike are present in the lake and grow very well, but population levels are relatively low.

Crystal Lake is somewhat unique in that it hosts a self-sustaining population of Coho Salmon (Tonello 2007). Glen Lake in Leelanau County is the only other inland lake in Michigan that is also known to host "landlocked" Coho Salmon (Seites et al. 2010). The 2014 fisheries survey was not particularly effective in catching either Coho Salmon or Rainbow Trout (which are stocked into Crystal Lake annually and may also reproduce naturally in Cold Creek and other tributaries). Perhaps different survey methods or a different time of year might be more successful in catching Rainbow Trout and Coho Salmon in assessment gear. Creel census might also be a better method for assessing the Rainbow Trout stocking program and the size of the Coho Salmon population.

Although not native, Rainbow Smelt are a very important species on Crystal Lake, both as a sport fishery and as a forage base for large salmonid predators. No Rainbow Smelt were caught in the 2014 survey. Although the survey gear used is not designed to catch Rainbow Smelt, they had been caught by similar gear in many previous surveys (Table 2). Again, creel census is likely a better tool for assessing the Rainbow Smelt population and fishery. Rainbow Smelt are heavily pursued on Crystal Lake by ice anglers in the winter. Another species that was noticeably absent in the 2014 fisheries survey catch was Cisco. They had been caught in most previous fisheries surveys of Crystal Lake (Table 2). Most recently, 221 were caught in the 2003 fisheries survey and another 67 caught in the 2004 survey.

Management Direction

Crystal Lake is an extremely popular lake for sportfishing. It is well-known for multiple fisheries, including a very popular Rainbow Smelt fishery, the likes of which can only be found on a handful of other inland lakes in Michigan. The large number of Master Angler entries (Table 11) speaks to the quality and popularity of Crystal Lake for anglers. The 2004 creel survey showed that the Crystal Lake fishery was worth nearly $400,000 to the local economy (U. S. Department of the Interior 2011). Due to inflation rates in the 10+ years since the survey was conducted, it can easily be assumed that the fishery today generates well over $500,000 to the economy of Benzie County and the Beulah area.

Crystal Lake is a rare natural resource in that it has deep, cold water that can harbor species like Lake Trout, Cisco, and Rainbow Smelt. For over 50 years, Crystal Lake has had a reputation as a good lake for catching Lake Trout. The Lake Trout population is likely entirely dependent on stocking. Therefore, we should continue to annually stock 60,000 yearling Lake Trout (a rate of 6.1 yearlings per acre). Subsequent fisheries surveys should be conducted to monitor Lake Trout growth rates. If Lake Trout growth rates were to drop, then stocking rates should be examined and possibly reduced. Although Rainbow Trout were virtually nonexistent in the 2014 catch, a well-regarded sport fishery exists for this species. For that reason, we should continue to stock 20,000 yearling Eagle Lake strain Rainbow Trout annually.

Native species like Yellow Perch, Rock Bass, Lake Whitefish, and Smallmouth Bass should continue to thrive in Crystal Lake without direct management efforts. Although not native, Rainbow Smelt are very popular with anglers, and they also should continue to provide a quality sportfishery. However, the lack of Cisco in the catch of the 2014 survey is concerning, especially considering that Cisco had been caught in most previous surveys (Table 2). Similar results occurred in surveys of nearby Duck Lake (2008; Tonello 2012) and Green Lake (2013; Tonello 2014). Both lakes have had historically robust Cisco populations, but none were found in the most recent surveys of both of those respective lakes. Future fisheries surveys should make a concerted effort to sample Cisco in particular on Crystal Lake. Cisco are a listed as a "Threatened" species by the Michigan Department of Natural Resources.

A year-round creel census survey should be conducted on Crystal Lake as soon as possible. Although the 2004 winter creel census provided valuable data, more recent angler effort, catch, and harvest data from all four seasons would provide more information. Also, the MDNR Public Access Site did not exist in 2004, so access to Crystal Lake was more difficult at that time. A modern creel census survey could incorporate some new components to estimate the economic value of the fishery to the local economy.

Any remaining riparian wetlands adjacent to Crystal Lake should be protected as they are critical to the continued health of the aquatic community. Future riparian development and wetland loss may result in deterioration of the water quality and aquatic habitat. Healthy biological communities in inland lakes require suitable natural habitat. Human development within the lake watershed, along the shoreline, and in the lake proper has a tendency to change and diminish natural habitat. Appropriate watershed management is necessary to sustain healthy biological communities, including fish, invertebrates, amphibians, reptiles, birds and aquatic mammals. For lakes this includes best management practices (BMP's) that ensure high water quality, especially for nutrients; preservation of natural shorelines, particularly shore contours and vegetation; and preservation of bottom contours, vegetation, and wood structure within a lake. Guidelines for protecting fisheries habitat in inland lakes can be found in Fisheries Division Special Report 38 (O'Neal and Soulliere 2006).

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Figure 1. Crystal Lake, Benzie County, Michigan.

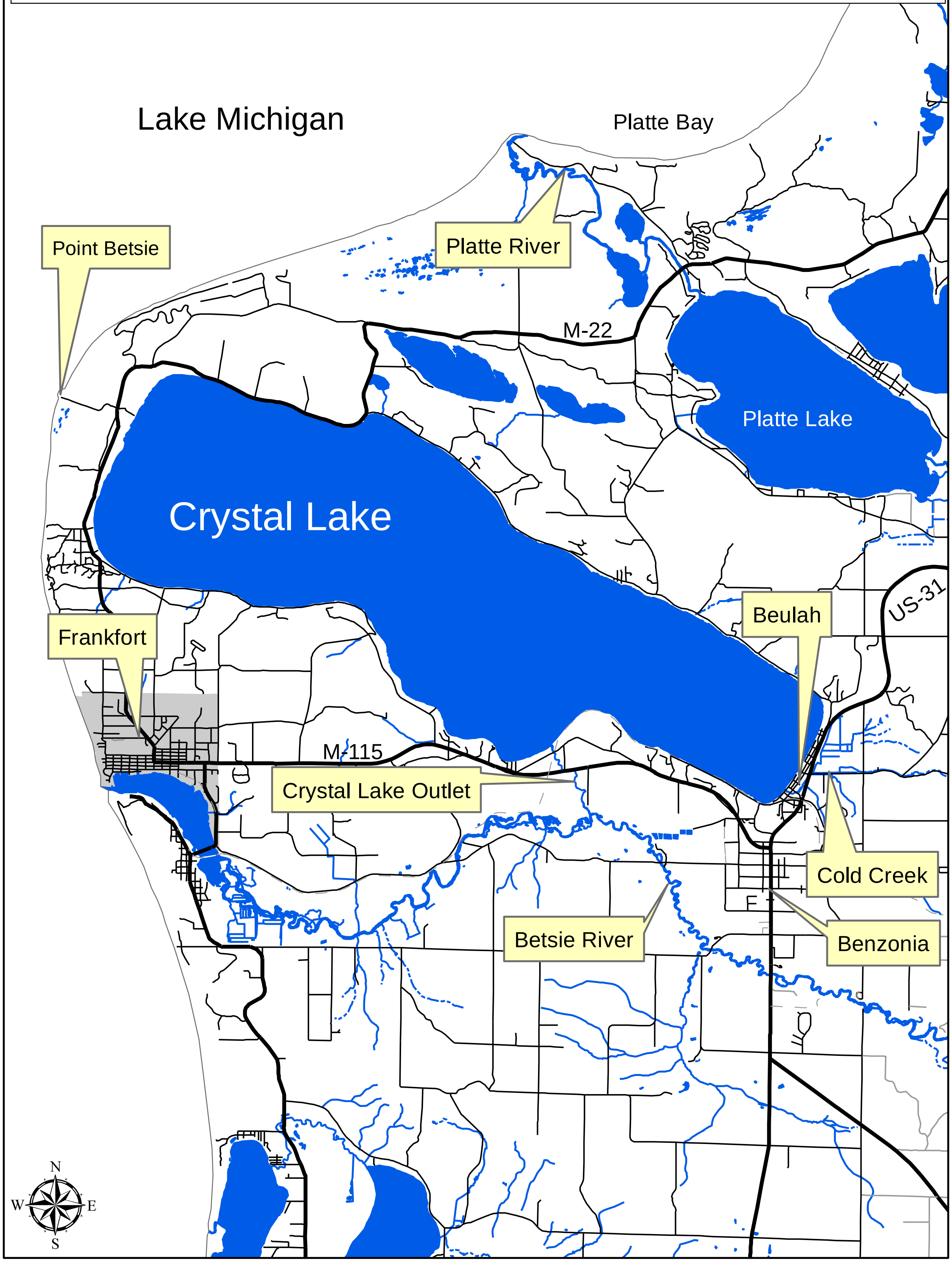

Figure 2. Features and access points of Crystal Lake, Benzie County, Michigan.

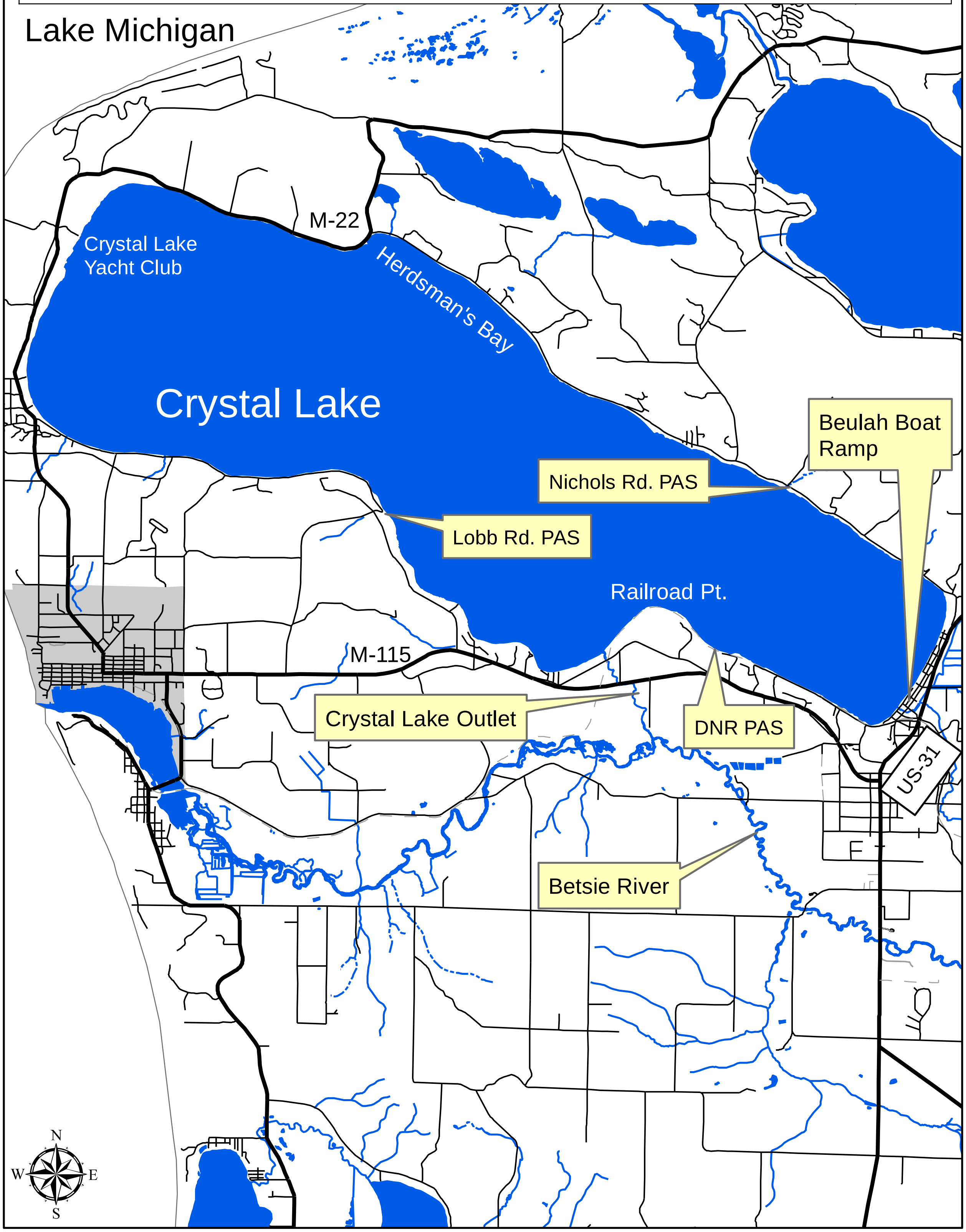

Table 1. Fish stocked in Crystal Lake, Benzie County, 1890-2015.

Year	Species	Number	Size/age	Strain
1890	Lake Trout	460	2 yr.	
1895	Lake Trout	25,000		
1897	Lake Trout	80,000		
	Walleye	800,000	fry	
1905	Lake Trout	30,000	fry	
	Largemouth Bass	600	fingerlings	
1910	Smallmouth Bass	1,000	fingerlings	
	Yellow Perch	500	fingerlings	
	Warmouth	1,000	yearlings and 2 yr.	
1912	Rainbow Smelt	16,400,000	eggs	
1930	Bluegill	280	yearlings	
1932	Largemouth Bass	1,000		
1934	Bluegill	10,000	3 mo.	
1935	Bluegill	10,000	4 mo.	
	Lake Trout	9,000	8 mo.	
	Smallmouth Bass	2,000	4 mo.	
1936	Bluegill	200	yearlings	
	Largemouth Bass	200	yearlings	
1937	Bluegill	10,000	5 mo.	
	Lake Trout	20,000	fry	
	Smallmouth Bass	2,500	5 mo.	
1938	Lake Trout	16,000	3 mo.	
	Yellow Perch	180,000	7 mo.	
1939	Smallmouth Bass	2,100	4 mo.	
	Yellow Perch	30,000	7 mo.	
1940	Lake Trout	5,000	yearlings	
	Smallmouth Bass	1,100	4 mo.	
1941	Lake Trout	7,335	2 yr.	
	Rainbow Trout	9,990	adults	
	Smallmouth Bass	300	4 mo.	
1942	Lake Trout	6,800	2 yr.	
	Rainbow Trout	5,000	yearlings	
	Smallmouth Bass	1,625	4-5 mo.	
1943	Smallmouth Bass	1,200	3 mo.	
1944	Smallmouth Bass	470	4 mo.	
1945	Lake Trout	2,000	2 yr.	
1946	Lake Trout	7,000	2 yr.	
1947	Lake Trout	5,000	adults	
1948	Lake Trout	3,000	9"	
1949	Lake Trout	5,000	7.5"	
1950	Lake Trout	5,000	9"	
1951	Lake Trout	13,400	7.8"	
1952	Lake Trout	3,350	8"	
1953	Lake Trout	8,673	7-8"	
1955	Lake Trout	5,000	legal	
1956	Lake Trout	11,500	legal	
	Rainbow Trout	12,000	sublegal	
1957	Lake Trout	6,500	legal	

Table 1 continued. Fish stocked in Crystal Lake, Benzie County, 1890-2014.

	Rainbow Trout	10,000	legal	
	Rainbow Trout	65,000	sublegal	
1958	Lake Trout	15,000	legal	
	Rainbow Trout	92,000	sublegal	
1959	Lake Trout	15,100	legal	
1960	Lake Trout	15,000	legal	
	Rainbow Trout	10,000	legal	
1961	Lake Trout	15,000	legal	
	Rainbow Trout	10,000	legal	
1962	Lake Trout	5,100	legal	
	Rainbow Trout	10,000	legal	
1963	Lake Trout	6,000	legal	
	Rainbow Trout	10,000	legal	
1964	Lake Trout	400	legal	
	Rainbow Trout	20,000	legal	
1965	Lake Trout	10,000	legal	
	Lake Trout	5,000	sublegal	
	Rainbow Trout	10,000	sublegal	
1966	Rainbow Trout	50,017	spring fingerlings	
	Splake	50,000	spring fingerlings	
1967	Lake Trout	9,330	adults	
	Rainbow Trout	10,000	yearlings	
1968	Lake Trout	2,231	adults	
	Rainbow Trout	47,118	yearlings	
	Rainbow Trout	2,431	adults	
	Rainbow Trout (steelhead)	1,543	adults	Little Manistee
1969	Rainbow Trout	5,000	yearlings	
	Rainbow Trout (steelhead)	10,000	yearlings	Little Manistee
1970	Lake Trout	10,000	fall fingerlings	
	Rainbow Trout	20,017	yearlings	
	Rainbow Trout	2,102	adults	
1971	Lake Trout	10,100	yearlings	
	Rainbow Trout	40,000	yearlings	
	Rainbow Trout	1,850	adults	
1972	Lake Trout	20,000	yearlings	
	Lake Trout	75	adults	
1973	Rainbow Trout	20,000	yearlings	
	Rainbow Trout (steelhead)	20,350	yearlings	Little Manistee
	Splake	100,000	fry	
1974	Lake Trout	100,000	yearlings	
	Lake Trout	8,420	adults	
	Rainbow Trout	561	adults	
1975	Brown Trout	306	adults	
	Lake Trout	131,852	yearlings	
	Rainbow Trout	170	adults	
1976	Lake Trout	88,000	yearlings	
1977	Lake Trout	90,000	yearlings	
1978	Lake Trout	50,000	yearlings	
1979	Lake Trout	65,000	yearlings	

Table 1 continued. Fish stocked in Crystal Lake, Benzie County, 1890-2014.

1980	Lake Trout	50,000	yearlings	
1981	Lake Trout	50,000	yearlings	Marquette
1982	Lake Trout	55,000	yearlings	Marquette
1983	Lake Trout	60,000	yearlings	Marquette
	Lake Trout	30,000	fall fingerlings	
1984	Brown Trout	30,000	yearlings	Harrietta
	Lake Trout	200	adults	Marquette
1985	Brown Trout	25,330	yearlings	Harrietta
	Lake Trout	15,000	yearlings	Marquette
1986	Atlantic Salmon	21,000	fall fingerlings	Landlocked
	Brown Trout	2,000	yearlings	Soda Lake
	Brown Trout	1,600	yearlings	Wild Rose
	Lake Trout	60,000	yearlings	Lake Superior
1987	Brown Trout	26,900	yearlings	Soda Lake
	Brown Trout	3,100	yearlings	Plymouth Rock
	Lake Trout	190,000	fall fingerlings	Marquette
	Lake Trout	59,630	yearlings	Marquette
1988	Brown Trout	30,000	yearlings	Plymouth Rock
	Lake Trout	150,000	spring fingerlings	Marquette
1989	Brown Trout	30,000	yearlings	Plymouth Rock
	Rainbow Trout	20,000	yearlings	Shasta
1990	Atlantic Salmon	19,278	fall fingerlings	Penobscot
	Brown Trout	29,997	yearlings	Soda Lake
	Lake Trout	90,920	yearlings	Marquette
	Rainbow Trout	8,495	yearlings	Shasta
1991	Brown Trout	46,225	yearlings	Plymouth Rock
	Lake Trout	48,700	yearlings	Lake Superior
1992	Atlantic Salmon	50,137	fall fingerlings	Landlocked
	Lake Trout	80,000	yearlings	Lake Superior
	Rainbow Trout	20,000	yearlings	Eagle Lake
1993	Lake Trout	80,000	yearlings	Marquette
	Rainbow Trout	19,500	yearlings	Eagle Lake
1994	Lake Trout	71,000	yearlings	Marquette
	Rainbow Trout	20,000	yearlings	Eagle Lake
1995	Rainbow Trout	20,000	yearlings	Eagle Lake
1996	Lake Trout	90,660	yearlings	Marquette
	Rainbow Trout	9,990	yearlings	Kamloops
	Rainbow Trout	10,000	yearlings	Eagle Lake
1997	Lake Trout	60,850	yearlings	Marquette
	Rainbow Trout	40,000	fall fingerlings	Eagle Lake
	Rainbow Trout	20,436	yearlings	Eagle Lake
	Rainbow Trout	11,118	fall fingerlings	Shasta
1998	Lake Trout	79,008	yearlings	Marquette
	Rainbow Trout	19,975	yearlings	Eagle Lake
1999	Lake Trout	80,800	yearlings	Marquette
	Rainbow Trout	19,500	yearlings	Eagle Lake
2000	Lake Trout	70,500	yearlings	Marquette
	Rainbow Trout	20,700	yearlings	Eagle Lake

Table 1 continued. Fish stocked in Crystal Lake, Benzie County, 1890-2014.

2001	Lake Trout	82,000	yearlings	Marquette
	Rainbow Trout	19,000	yearlings	Eagle Lake
2002	Lake Trout	80,470	yearlings	Marquette
	Rainbow Trout	31,900	yearlings	Eagle Lake
2003	Lake Trout	80,000	yearlings	Marquette
	Rainbow Trout	21,120	yearlings	Eagle Lake
2004	Lake Trout	60,000	yearlings	Marquette
	Rainbow Trout	22,000	yearlings	Eagle Lake
2005	Lake Trout	60,000	yearlings	Marquette
	Rainbow Trout	45,932	yearlings	Eagle Lake
2006	Lake Trout	62,250	yearlings	Marquette
	Rainbow Trout	20,000	yearlings	Eagle Lake
2007	Lake Trout	60,536	yearlings	Marquette
	Rainbow Trout	21,500	yearlings	Eagle Lake
2008	Lake Trout	50,880	yearlings	Lewis Lake
	Rainbow Trout	22,000	yearlings	Eagle Lake
2009	Lake Trout	63,617	yearlings	Lewis Lake
	Rainbow Trout	21,600	yearlings	Eagle Lake
	Rainbow Trout	93,200	fall fingerlings	Eagle Lake
2010	Lake Trout	63,199	yearlings	Lake Superior
	Rainbow Trout	25,008	yearlings	Eagle Lake
2011	Lake Trout	58,798	yearlings	Lake Superior
	Rainbow Trout	31,761	yearlings	Eagle Lake
2012	Lake Trout	48,971	yearlings	Lake Superior
	Rainbow Trout	21,802	yearlings	Eagle Lake
	Rainbow Trout (steelhead)	55,214	fall fingerlings	Little Manistee
2013	Lake Trout	59,228	yearlings	Seneca Lake
	Rainbow Trout	20,452	yearlings	Eagle Lake
	Rainbow Trout (steelhead)	74,061	fall fingerlings	Little Manistee
2014	Lake Trout	40,000	yearlings	Lake Superior
	Rainbow Trout	20,600	yearlings	Eagle Lake
2015	Lake Trout	54,340	yearlings	Lake Superior
	Rainbow Trout	20,700	yearlings	Eagle Lake

Table 2. Presence/absence of fish species in historical fisheries surveys of Crystal Lake, Benzie County, MI.

Species	1940	1948	1956	1960	1977	1989	1997	2003	2004	2014
Black Crappie	x*									
Bluegill	x									
Bluntnose Minnow	x							x		
Brown Bullhead								x		
Brown Trout						x	x			
Bullhead spp.	x*									
Burbot	x		x	x	x		x	x	x	x
Cisco	x			x	x	x	x	x	x	
Coho Salmon						x	x		x	x
Common Shiner								x		
Emerald Shiner	x									
Iowa Darter	x									
Johnny Darter	x									
Lake Trout	x		x		x	x	x	x	x	x
Lake Whitefish	x		x	x	x		x	x	x	x
Logperch	x							x		
Longnose Sucker										x
Mudpuppy								x		
Northern Pike	x									x
Pumpkinseed	x*									
Redhorse spp.	x*									
Rainbow Smelt	x	x	x		x	x	x	x	x	
Rainbow Trout				x		x	x	x		x
Rock Bass	x	x				x	x	x		x
Slimy Sculpin					x					
Smallmouth Bass	x*	x				x	x	x		x
Spottail Shiner	x							x		
White Sucker	x	x	x	x	x	x	x	x	x	x
Yellow Perch	x	x	x		x	x	x	x	x	x

*Reported as present but not caught in the survey.

Table 3. Number, weight, and length of fish collected from Crystal Lake with fyke nets (small and large mesh), trap nets, Great Lakes gill nets, and inland gillnets from May 4 through August 27, 2003.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
Bluntnose Minnow	1	0.0	0.0	0.00	3-3	3.5	
Brown Bullhead	1	0.0	0.9	0.01	12-12	12.5	100 (7")
Burbot	24	0.3	76.7	0.82	13-27	22.0	
Common Shiner	65	0.9	2.1	0.02	3-4	3.7	
Lake Trout	130	1.8	432.7	4.63	10-34	20.1	79 (15")
Cisco	221	3.1	102.6	1.10	7-17	12.2	
Logperch	21	0.3	0.4	0.00	3-4	3.6	
Lake Whitefish	43	0.6	124.8	1.33	13-22	19.5	
Mudpuppy	8	0.1	0.0	0.00	13-14	13.2	
Rainbow Smelt	12	0.2	0.6	0.01	4-7	5.7	
Rainbow Trout	31	0.4	44.1	0.47	5-23	16.2	35 (15")
Rock Bass	2,133	29.9	1,013.1	10.83	1-12	8.1	89 (6")
Smallmouth Bass	55	0.8	106.6	1.14	4-20	14.1	62 (14")
Spottail Shiner	18	0.3	0.2	0.00	3-3	3.5	
White Sucker	3,819	53.6	7,351.6	78.61	10-20	16.5	
Yellow Perch	546	7.7	96.0	1.03	2-13	8.0	43 (7")
Total	7,128	100	9,352.4	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., 5=5.0 to 5.9 inch, 12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 4. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Crystal Lake with trap nets and fyke nets May 5-7, 2003, and by creel census during April and May, 2003. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	Age II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Mean Growth Index
Brown Trout	17.5 (1)					28.4 (1)								-
Coho Salmon	17.3 (4)													-
Lake Trout			18.0 (6)	21.0 (5)	22.9 (2)	26.2 (3)	27.8 (5)	29.9 (2)		33.8 (3)				+0.8
Lake Whitefish							18.2 (1)		19.4 (1)	21.9 (3)		21.8 (1)		*
Rainbow Trout	16.4 (8)	22.2 (17)	23.2 (1)											+6.6
Rock Bass					9.4 (1)	9.7 (1)		10.6 (1)	11.0 (3)	10.8 (2)	11.5 (7)**	11.9 (5)*	12.2 (1)	-
Smallmouth Bass	9.9 (1)		14.1 (3)	15.3 (1)	16.3 (1)	17.5 (1)	18.9 (1)		19.5 (1)					-
Yellow Perch												13.2 (1)		-

*No State of Michigan average has been calculated.

**No State of Michigan average has been calculated for rock Bass older than age VIII.

Table 5. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Crystal Lake with trap nets, inland gill nets, straight run gill nets, and Great Lakes gill nets June 9 - July 30, 2003. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

				Age											Mean
Species	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Growth Index
Cisco				9.9 (12)	11.6 (8)	12.8 (27)	15.2 (10)	14.2 (9)	15.5 (3)						*
Lake Trout			14.0 (20)	17.6 (26)	21.1 (17)	23.0 (15)	27.3 (8)	27.7 (5)	34.3 (2)	31.8 (2)			34.2 (1)		+0.2
Lake Whitefish				14.7 (2)	13.0 (1)	15.3 (2)	14.8 (1)	19.6 (3)	22.1 (5)	19.4 (6)	20.8 (5)	21.3 (2)	21.2 (2)	22.2 (1)	*
Rock Bass		3.3 (12)	5.3 (18)	6.5 (10)	8.2 (9)	8.5 (14)	9.0 (2)	10.0 (1)	10.3 (4)	10.9 (9)*	11.3 (4)	11.4 (6)*	12.1 (7)*	12.6 (1)	+0.1
Smallmouth Bass	5.5 (4)	9.6 (3)	11.7 (10)	14.2 (7)	15.4 (5)	17.0 (6)	17.7 (4)	19.5 (4)	20.1 (1)		19.5 (1)				+1.0
Yellow Perch		3.2 (10)	5.7 (13)	6.3 (20)	8.8 (23)	10.0 (11)	11.1 (11)	11.5 (3)	11.8 (2)	12.6 (1)	13.3 (1)		12.7 (1)		-0.7

*No State of Michigan average has been calculated.

Table 6**.** Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Crystal Lake with Great Lakes gill nets August 25 - 27, 2003 and by creel census during August and September, 2003. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

			Age											
Species	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Mean Growth Index
Lake Trout	12.0	14.5	19.0	21.7	23.7	26.2		29.6	33.2					-0.4
	(4)	(10)	(3)	(11)	(3)	(4)		(1)	(1)					
Lake Whitefish							18.5	20.0	19.4	20.6	21.5			-*
							(1)	(2)	(3)	(2)	(4)			
Rainbow Trout	17.6													-
	(2)													

*No State of Michigan average has been calculated

Table 7. Results of the winter 2004 MDNR creel survey of Crystal Lake (Benzie County), including an evening component targeting Rainbow Smelt anglers.

Species	Estimated harvest, winter 2004	Estimated released, winter 2004
Rainbow Trout	48	9
Brown Trout	11	0
Lake Trout	3,438	100
Cisco	21	0
Lake Whitefish	776	0
Yellow Perch	23,916	9,520
White Sucker	882	202
Rainbow Smelt	2,611	0

Total winter 2004 angler trips: 10,155
Total winter 2004 angler hours: 41,794

Table 8. Number, weight, and length of fish collected from Crystal Lake with Great Lakes gill nets, May 17-18 and August 16-17, 2004, as verification for an experimental hydroacoustic survey.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
Burbot	2	1.5	4.7	2.2	18-21	19.6	
Cisco	67	49.3	19.1	9.0	7-17	9.5	
Coho Salmon	1	0.7	0.6	0.3	12-12	12.5	100 (10")
Lake Trout	32	23.5	115.8	54.9	14-30	21.3	97 (15")
Lake Whitefish	22	16.2	51.2	24.3	10-21	18.9	
Rainbow Smelt	2	1.5	0.1	0.0	4-5	5.0	
White Sucker	9	6.6	19.5	9.2	16-19	17.6	
Yellow Perch	1	0.7	0.2	0.1	7-7	7.5	100 (7")
Total	136	100	211.0	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., 5=5.0 to 5.9 inch, 12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 9. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Crystal Lake with Great Lakes gill nets May 17-18, 2004. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	II	III	Age IV	V	VI	VII	VIII	IX	X	Mean Growth Index
Cisco				14.5 (3)						*
Lake Trout		16.0 (4)	20.1 (6)	25.3 (6)						+4.1
Lake Whitefish	10.3 (1)		17.0 (1)	20.9 (1)	20.4 (4)					*

*No State of Michigan average has been calculated.

Table 10. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Crystal Lake with Great Lakes gill nets August 16-17, 2004. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	I	II	III	Age IV	V	VI	VII	Mean Growth Index
Cisco	7.3 (1)		11.9 (4)	12.1 (4)	13.1 (9)	15.5 (1)	17.2 (2)	*
Coho salmon	12.0 (1)							-
Lake Trout			16.8 (3)	19.9 (7)	25.6 (4)		30.5 (1)	-0.4
Lake Whitefish				17.2 (7)	20.0 (8)	19.8 (1)		*

*No State of Michigan average has been calculated.

Table 11. Michigan DNR Master Angler awards issued for fish caught from Crystal Lake, Benzie County, 1994-2015.

Species	Number of Master Angler awards issued
Rock Bass	43
Smallmouth Bass	22
Burbot	21
Rainbow Smelt	21
Lake Trout	11
Bluegill	1
Brown Trout	1
Northern Pike	1
Total:	121

Table 12. Number, weight, and length of fish collected from Crystal Lake with experimental gill nets, Great Lakes gill nets, straight run gill nets, trap nets, and inland gillnets on June 23-27, 2014.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
Burbot	10	0.2	35.5	2.1	17-26	22.9	
Coho Salmon	5	0.1	0.8	0.0	7-9	8.5	0 (10")
Lake Trout	30	0.7	124.0	7.4	10-32	21.5	80 (15")
Lake Whitefish	28	0.7	78.9	4.7	14-23	19.1	
Northern Pike	8	0.2	39.3	2.3	20-32	28.2	88 (24")
Rainbow Trout	1	0.0	0.3	0.0	9-9	9.5	0 (15")
Rock Bass	3,206	75.2	899.2	53.4	3-12	8.0	67 (6")
Smallmouth Bass	85	2.0	138.0	8.2	7-21	14.4	45 (14")
White Sucker	106	2.5	256.6	15.2	12-20	17.8	
Yellow Perch	784	18.4	111.4	6.6	4-13	8.0	17 (7")
Total	4,263	100	1684.0	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., 5=5.0 to 5.9 inch, 12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 13. Number, weight, and length of fish collected from Crystal Lake with Great Lakes gill nets, straight run gill nets, and large mesh fyke nets on November 5-7, 2014.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
Burbot	9	4.6	37	7.6	21-26	24.0	
Lake Trout	25	12.7	183.8	37.7	20-36	26.7	100 (15")
Lake Whitefish	5	2.5	11.9	2.4	18-19	19.0	
Longnose Sucker	1	0.5	3.4	0.7	19-19	19.5	
Northern Pike	5	2.5	31.0	6.4	18-36	28.4	80 (24")
Rock Bass	22	11.2	12.5	2.6	6-12	9.4	100 (6")
Smallmouth Bass	1	0.5	0.8	0.2	11-11	11.5	0 (14")
White Sucker	67	34.0	161.9	33.2	14-21	18.4	
Yellow Perch	62	31.5	45.4	9.3	9-12	11.3	100 (7")
Total	197	100	487.7	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., 5=5.0 to 5.9 inch, 12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 14. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Crystal Lake with trap nets, inland gill nets, straight run gill nets, and Great Lakes gill nets June 23-27, 2014. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	Age I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVIII	Mean Growth Index
Burbot				21.1 (1)													-
Lake Trout		10.8 (1)	15.3 (7)	18.0 (5)	18.2 (2)	25.2 (3)	23.9 (4)	24.9 (2)	28.8 (2)			32.9 (1)	28.7 (1)	28.9 (1)	32.0 (1)		+0.4
Lake Whitefish					14.3 (1)	16.8 (1)	18.3 (5)	18.2 (5)	20.4 (3)	20.2 (4)	20.8 (4)	21.1 (1)		22.1 (3)		23.1 (1)	*
Northern Pike		20.0 (1)	26.8 (4)	30.1 (1)	30.5 (2)												-
Rainbow Trout	9.2 (1)																-
Rock Bass			4.5 (7)	5.6 (15)	6.8 (12)	7.7 (6)	8.7 (19)	9.5 (10)	10.5 (7)	11.6 (6)	11.4 (7)	11.9 (8)	12.4 (2)				-0.4
Smallmouth Bass		7.8 (12)	11.6 (25)	14.7 (18)	16.0 (9)	17.6 (3)	18.8 (5)	18.3 (1)	18.2 (1)	17.4 (1)	20.6 (4)	19.8 (2)	20.1 (1)				+0.9
Yellow Perch		4.6 (8)	6.0 (13)	6.5 (27)	7.9 (23)	8.8 (16)	10.2 (11)	10.6 (10)	12.0 (6)	12.2 (7)	12.0 (8)	12.5 (3)					-0.6

*No State of Michigan average has been calculated.

Table 15. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Crystal Lake with fyke nets, straight run gill nets, and Great Lakes gill nets, November 5-7, 2014. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

			Age										
Species	I	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XV	Mean Growth Index
Lake Trout			21.9 (9)	23.6 (6)	27.6 (1)	31.3 (1)	31.6 (1)	31.0 (1)	28.7 (1)	31.6 (3)		35.8 (2)	+2.0
Lake Whitefish						18.7 (3)	18.3 (1)	19.7 (1)					*
Northern Pike	18.5 (1)	27.1 (1)	30.8 (2)	36.1 (1)									-
Smallmouth Bass		11.1 (1)											-
Yellow Perch				9.9 (1)	10.2 (2)	12.1 (3)	11.5 (9)	11.9 (12)	11.8 (5)	11.4 (4)	12.3 (2)		-0.2

*No State of Michigan average has been calculated.

Duck Lake Fishery

Duck Lake
Grand Traverse County
Betsie River Watershed

Mark Tonello, Fisheries Management Biologist, Cadillac

Environment

Duck Lake (Fig. 1) is 1,930 acres in size and located approximately 15 miles southwest of Traverse City, near the Village of Interlochen in western Grand Traverse County, Michigan. The maximum depth of Duck Lake is about 98 feet, with the average depth being about 35 feet. Approximately one quarter of the lake is shallower than 15 feet. Substrates in Duck Lake consist mostly of sand, marl, and organic matter. The surrounding area is hilly and mostly forested, although some subdivisions are present as well. There are also some large wetland complexes nearby. The shoreline of Duck Lake is fairly developed with homes and cottages, although not as heavily developed as other nearby lakes like Long and Silver. Many private parcels on Duck Lake are larger in size and with more shoreline than lots on the other nearby lakes.

Interlochen State Park, a very popular campground, is located on the western shore, between Duck and Green Lakes. Interlochen State Park was the first state park in Michigan, dedicated by the Michigan legislature in 1917. The Interlochen Center for the Arts, a privately-owned camp and boarding school is located just north of the State Park, and is also between the two lakes. The only other publicly owned land on Duck Lake is some State-owned forest land near the southern tip of the lake. Public access to Duck Lake is available at Interlochen State Park, which hosts two boat launches.

Duck Lake is in the headwaters of the Betsie River watershed. Several small streams including Brigham, Horton, and Mason Creeks flow into Duck Lake. Brigham and Mason Creek are brook trout streams, while Horton Creek is warm and does not support trout. One other unnamed warm water stream flows into the northern part of Duck Lake after emerging from Bass Lake and flowing through Saunders Lake, Ellis Lake, and Tonawanda Lake. The outlet stream flows out of the northwestern shore of Duck Lake and flows into nearby Green Lake. The Betsie River begins as it flows out of Green Lake.

History

The first recorded fish stocking in Duck Lake was in 1905 when walleye fry were stocked (Table 1). Since then, Duck Lake has had a long and varied stocking history. Other species stocked in the early 1900s included smallmouth bass. From 1929 through 1938, intensive stocking of bluegill, largemouth bass, smallmouth bass, walleye, and yellow perch occurred. Lake trout were first stocked into Duck Lake in 1951. Since then, lake trout have been the most commonly stocked species. Other species stocked since then have included splake, rainbow trout, and brown trout. Lake trout and brown trout were stocked annually from 1990 through 2009. Since 2009, only lake trout have been stocked into Duck Lake.

The first fisheries survey of Duck Lake was conducted in 1950 by the Michigan Department of Conservation (MDOC; the precursor to today's Department of Natural Resources (DNR)). The researchers used experimental gill nets and seines in the survey. Species caught in the 1950 survey included northern pike, yellow perch, smallmouth bass, largemouth bass, bluegill, longear sunfish, pumpkinseed sunfish, rock bass, longnose gar, white sucker, lake herring, rainbow smelt, mimic shiner, common shiner, bluntnose minnow, and logperch. Limnological investigations determined that oxygen was present even in the deepest portions of the lake, which likely led to lake trout stocking beginning in 1951.

DNR file correspondence from the 1950s indicates that anglers were regularly catching lake trout, some in excess of 10 lbs. Apparently the lake trout stocked in the early 1950s were marked with fin clips, and angler catches seemed to indicate that multiple year classes of the stocked lake trout were surviving and thriving.

Other fisheries surveys of Duck Lake were conducted by the MDOC and DNR in 1967, 1975, 1981 (Hay 1981), 1991 (Hay 1991), and 1997. The 1967, 1975, and 1981 surveys utilized only gill nets. The fish species composition of these surveys did not differ appreciably from the 1950 survey. Species caught that had not been observed in 1950 included bowfin, brown trout, bullhead (species not indicated), and redhorse (species not indicated). Lake trout and splake were first caught in the 1981 survey (Hay 1981). Fin clips indicated that the lake trout caught in the 1981 survey were survivors from the 1965 stocking effort. Age and growth analysis from the 1981 survey indicated that lake herring and yellow perch were growing slowly, while northern pike were growing well in excess of the State average.

The 1991 survey was the first in which fyke nets were used in addition to gill nets (Hay 1991). This allowed for better surveying of shallow waters, leading to greater numbers of panfish and bass caught. The survey revealed good populations of smallmouth bass, bluegill, and pumpkinseed sunfish. These species showed average growth, with each being near the state average. Good numbers of yellow perch, rock bass, northern pike, splake and lake herring were also caught, along with lesser numbers of lake trout, brown trout, and rainbow smelt. One lake whitefish was caught in the 1981 survey, the first ever documented from Duck Lake. As in 1981, yellow perch were growing slowly. Northern pike, which had been growing rapidly in 1981, were now growing 1.3 inches slower than the State average. Lake herring were not aged in 1981.

In 1997, a general fisheries survey of the Duck Lake fish community was completed using fyke and inland gill nets. A total of 577 fish weighing 507.6 lbs were caught (Table 2). Bluegill, rock bass, lake herring, and pumpkinseed sunfish were the most numerous species caught. Other species present in good numbers included lake trout, largemouth bass, northern pike, smallmouth bass, and yellow bullhead. Smaller numbers of alewife, brown trout, bowfin, brown bullhead, white sucker, longnose gar, splake, and yellow perch were also caught. This was the first time that alewife had been documented in Duck Lake. As in the 1991 survey, one lake whitefish was caught. Also as in the 1991 survey, northern pike growth was poor in 1997 (Table 3). Lake herring were also growing slowly, at 2 inches slower than the State average. Lake trout growth however, was outstanding, as they were growing nearly seven inches faster than the State average. Twelve of the 20 lake trout caught in 1997 were from the 1992 year class. Other species from the 1997 survey showed growth that was near the State average.

From 1994-2011, a total of 65 exceptional fish caught from Duck Lake have been entered into the DNR Fisheries Division Master Angler program (Table 4). Of those 65 fish, the vast majority were rock bass. Other species, each represented by one entry, included bluegill, lake herring, longnose gar, northern pike, pumpkinseed sunfish, smallmouth bass and splake. The large number of Master Angler entries for Duck Lake speaks to the popularity of fishing on Duck Lake.

Current Status

The most recent comprehensive fisheries survey of Duck Lake was conducted by the DNR in the summer of 2008. The netting portion of the survey took place from June 19 through June 22. Survey gear used included one large-mesh fyke net (3 net-nights), three trap nets (9 net-nights), and three experimental graded-mesh inland gill nets (9 net-nights). The primary purpose of this survey was to assess the status of all fish populations in Duck Lake, with additional focus on the brown trout and lake trout populations.

During the 2008 June netting survey, a total of 921 fish were caught, representing 14 different species (Table 5). Rock bass were the most frequently collected species, with a total of 511 caught. They represented 55.4% of the total catch by number and ranged from 3 to over 12 inches in length. Other panfish species collected included bluegill (115 from 4-8 inches), green sunfish (3 at 3 inches), pumpkinseed sunfish (15 from 4-6 inches), and yellow perch (139 from 5-12 inches).

Game fish species caught in the 2008 June netting survey primarily included largemouth bass, smallmouth bass, and northern pike (Table 5). Totals of 35 largemouth and 33 smallmouth bass were caught, with the largemouth ranging up to 17 inches and the smallmouth up to 19 inches. The smallmouth bass averaged 15.4 inches, with 73% over 14 inches in length. The northern pike catch consisted of 16 individuals from 13 to 33 inches, averaging 24.6 inches. Other fish species caught in the 2008 survey included 1 brown trout (6 inches), 27 brown bullhead (7-14 inches), 1 longnose gar (34 inches), 2 sticklebacks (not identified to species, both were 2 inches), 21 white suckers (9-20 inches), and 4 yellow bullhead (9-11 inches). Noticeably absent from the 2008 survey were lake trout and lake herring.

Most species caught in the 2008 Duck Lake survey showed growth near the State of Michigan length at age average (Table 6). Largemouth and smallmouth bass in particular were growing well, with both species growing 1.1 inches faster than the State average. Not enough (fewer than five of any one age class) northern pike were collected to make statistical inferences regarding age and growth.

Fish species that were not caught in the 2008 survey of Duck Lake but had been reported in previous surveys included alewife, bowfin, lake herring, lake trout, lake whitefish, longear sunfish, longnose gar, rainbow smelt, and redhorse.

Limnological sampling on Duck Lake was conducted by the DNR in 93 feet of water on August 28, 2008. On that day, Secchi depth was recorded as 16 feet, and the thermocline was relatively deep at 33 feet. The temperature profile showed oxygen concentrations of less than 3 ppm in water deeper than 81 feet. Shoreline data was also collected on Duck Lake by DNR Fisheries personnel on August 28, 2008 (Table 7). Data collected included the number of docks, submerged trees, and houses found per kilometer of shoreline, as well as how much of the shoreline is armored or hardened with a structure in order to prevent erosion. Duck Lake averaged 13.0 docks per kilometer (20.8 docks per mile), 21.4%

shoreline armoring, 175 submerged trees per kilometer (280 submerged trees per mile), and 15.4 houses per kilometer (24.6 houses per mile).

Analysis and Discussion

One of the reasons for conducting the 2008 survey of Duck Lake was to evaluate the brown trout stocking program, which had been underway since 1989 (Table 1). However, only six brown trout were caught in the three fisheries surveys conducted (1991, 1997, 2008) since that program began. That fact, combined with a lack of positive angler catch reports of brown trout in Duck Lake, led to the discontinuation of the brown trout stocking program. Brown trout were last stocked into Duck Lake in 2009.

The 2008 DNR fisheries survey showed that Duck Lake has generally healthy gamefish populations. Largemouth and smallmouth bass in particular were numerous and are keystone predators. In the 1997 survey, the average sizes and percentage exceeding the minimum legal size were much lower for both largemouth and smallmouth bass than in 2008. The 2008 survey showed that the bass populations of Duck Lake are well balanced, with good growth, multiple year classes represented in the catch, and many individuals exceeding the minimum legal-size limit of 14 inches. Duck Lake has a reputation for providing excellent bass fishing opportunities, and the 2008 survey confirmed that. The northern pike catch in the 2008 survey was fair, with eight of the sixteen caught exceeding the minimum legal length of 24 inches.

The lack of lake trout and lake herring in the catch of the 2008 survey of Duck Lake is concerning, considering that lake trout are annually stocked and these two species have been present in most previous surveys of Duck Lake. However, angler reports indicate that lake trout fishing has remained robust since the 2008 survey. Future fisheries surveys should make a concerted effort to sample these two species in particular.

The panfish populations in Duck Lake appear to be healthy, for the most part. Although the bluegill and pumpkinseed sunfish populations in Duck Lake are not overly large, they grow well and can attain "keeper" sizes. The rock bass population in Duck Lake is robust, including many individuals exceeding the minimum Master Angler length of 11 inches. The yellow perch population of Duck Lake is also healthy, averaging 8.1 inches in length, with individuals present up to 12 inches.

Duck Lake is more heavily developed with docks and dwellings than other lakes in Michigan (Table 7). Duck Lake had 13.0 docks per kilometer of shoreline, while the average large deep lake in Michigan had only 4.3 docks per kilometer (Wehrly et al. 2010). Duck Lake also had 15.4 dwellings per kilometer, compared to 9.2 dwellings per kilometer for other large deep lakes in Michigan. Duck Lake however, had much more woody debris (175 trees per kilometer) than other large lakes in Michigan (average = 8.4 trees per kilometer). Duck Lake also had slightly less shoreline armoring (21.4%) than other large, deep, inland lakes in Michigan (average = 24.2%). Dwelling and submerged wood densities indicate shoreline development has negatively affected habitat in Duck Lake when compared to undeveloped lakes in northern Michigan and Wisconsin.

Management Direction

Native species like bluegill, pumpkinseed sunfish, rock bass, northern pike, largemouth bass, and smallmouth bass should continue to thrive in Duck Lake without direct management efforts. However, no lake herring were caught in the 2008 survey. Lake herring are a state-threatened species. Future fisheries surveys should place extra emphasis on studying the lake herring population of Duck Lake.

Duck Lake is a rare resource in that it has deep, cold water that can harbor lake trout. For the last 50+ years, Duck Lake has had a reputation as a good lake trout fishing lake. However, the Duck Lake lake trout population is likely entirely dependent on stocking. Therefore, we should continue to stock lake trout annually at a rate of 6 yearlings per acre.

Any remaining riparian wetlands adjacent to Duck Lake should be protected as they are critical to the continued health of the lake's aquatic community. Future riparian development and wetland loss may result in deterioration of the water quality and aquatic habitat. Healthy biological communities in inland lakes require suitable natural habitat. Human development within the lake watershed, along the shoreline, and in the lake proper has a tendency to change and diminish natural habitat. Appropriate watershed management is necessary to sustain healthy biological communities, including fish, invertebrates, amphibians, reptiles, birds and aquatic mammals. Generally for lakes this includes maintenance of good water quality, especially for nutrients; preservation of natural shorelines, especially shore contours and vegetation; and preservation of bottom contours, vegetation, and wood structure within a lake. Guidelines for protecting fisheries habitat in inland lakes can be found in Fisheries Division Special Report 38 (O'Neal and Soulliere 2006).

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Figure 1. Duck Lake, Grand Traverse County, MI.

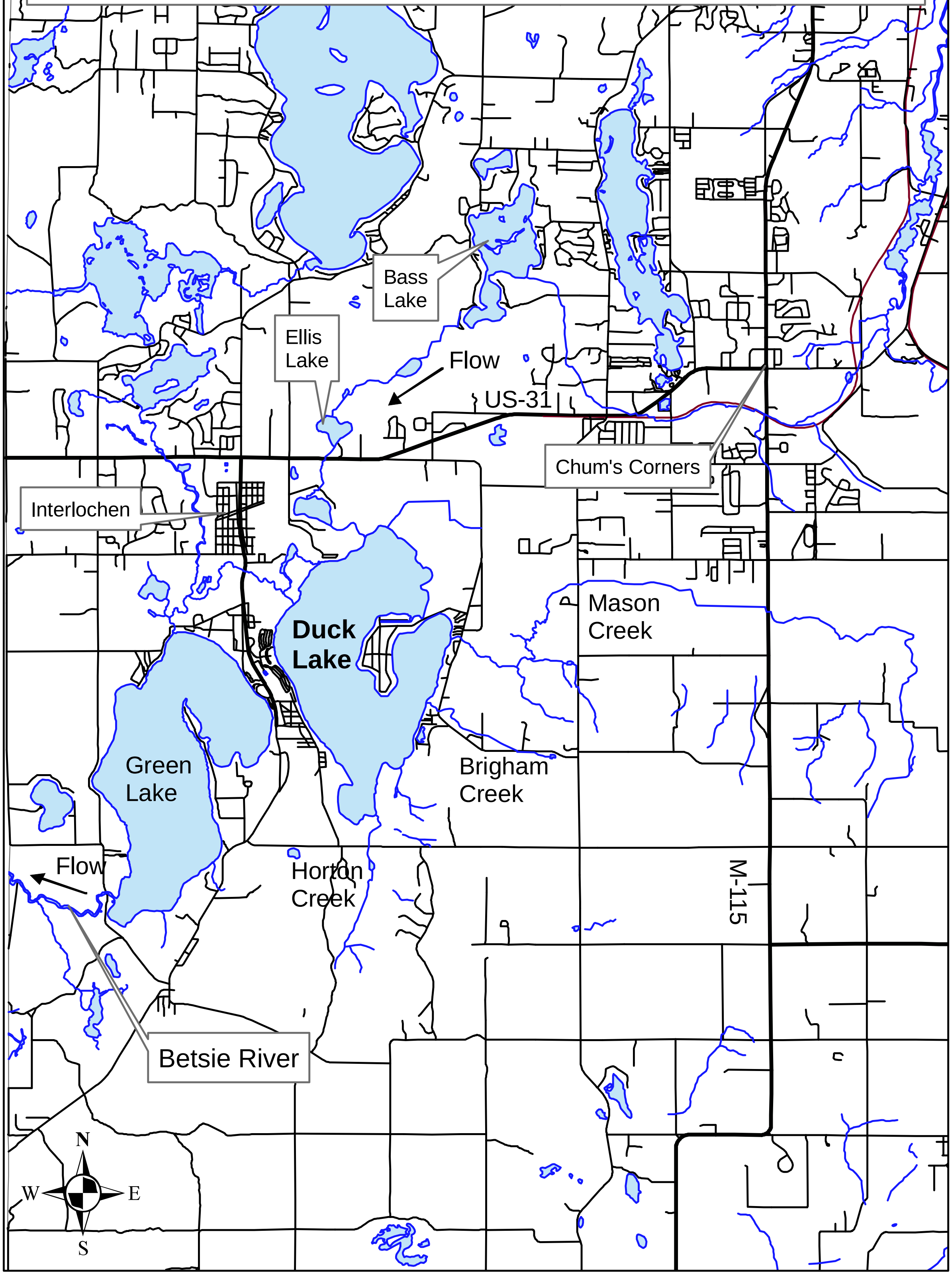

Table 1. Fish stocked in Duck Lake, Grand Traverse County, 1905-2011.

Year	Species	Number	Size/age	Strain
1905	walleye	125,000	fry	
1909	smallmouth bass	6,000	fry	
	walleye	100,000	fry	
1910	walleye	100,000	fry	
1929	bluegill	12,000	3-5 months	
	largemouth bass	1,000	2 months	
1930	bluegill	6,000	unknown	
	walleye	200,000	fry	
1931	bluegill	6,000	5 months	
	smallmouth bass	750	4 months	
1932	bluegill	1,000	unknown	
	largemouth bass	500	unknown	
1933	bluegill	3,000	6 months	
	largemouth bass	1,000	6 months	
	walleye	200,000	fry	
1934	bluegill	12,000	unknown	
	largemouth bass	1,000	unknown	
	yellow perch	5,000	unknown	
1935	bluegill	5,000	unknown	
	walleye	170,000	fry	
	yellow perch	25,000	unknown	
1936	bluegill	150	yearlings	
	largemouth bass	150	yearlings	
	largemouth bass	1,000	fingerlings	
	shiners	27,000	unknown	
	walleye	300,000	fry	
	yellow perch	3,250	unknown	
1937	bluegill	20,000	unknown	
	largemouth bass	400	fingerlings	
	walleye	240,000	fry	
	yellow perch	10,000	unknown	
1938	bluegill	20,000	unknown	
	largemouth bass	2,000	unknown	
	walleye	200,000	fry	
1951	lake trout	3,300	yearlings	
1952	lake trout	5,000	sub-legal	
1953	lake trout	3,000	yearlings	
1954	lake trout	5,000	yearlings	
1955	lake trout	5,000	yearlings	
1956	lake trout	5,000	yearlings	
1957	lake trout	5,000	yearlings	
1961	lake trout	5,000	yearlings	
1964	lake trout	3,000	legal	
1965	brook trout	10,000	sub-legal	
	lake trout	34,100	sub-legal	
	lake trout	1,900	legal	
1966	splake	50,000	spring fingerlings	
1969	rainbow trout	23,318	yearlings	
1970	brown trout	700	adults	
	brown trout	20,000	yearlings	

Table 1 continued. Fish stocked in Duck Lake, Grand Traverse County, 1905-2011.

1970	rainbow trout	1,345	adults	
1976	splake	14,004	yearlings	
1977	splake	30,000	yearlings	
1978	lake trout	25,000	yearlings	
1981	splake	15,000	yearlings	
1982	lake trout	10,000	yearlings	Marquette
1983	lake trout	5,000	yearlings	Marquette
1985	lake trout	4,000	yearlings	
1987	splake	7,000	yearlings	
1988	splake	6,200	yearlings	
1989	brown trout	5,000	yearlings	Plymouth Rock
	splake	10,000	fall fingerlings	
1990	brown trout	7,000	yearlings	Soda Lake
	lake trout	6,800	yearlings	Marquette
1991	lake trout	6,900	yearlings	Lake Superior
1992	brown trout	6,900	yearlings	Wild Rose
	lake trout	7,000	yearlings	Lake Superior
1993	brown trout	6,900	yearlings	Wild Rose
	lake trout	7,000	yearlings	Marquette
1994	brown trout	6,998	yearlings	Saint Croix
	lake trout	6,100	yearlings	Marquette
1995	brown trout	7,000	yearlings	Soda Lake
1996	brown trout	6,527	yearlings	Wild Rose
	lake trout	7,000	yearlings	Marquette
1997	brown trout	6,990	yearlings	Wild Rose
	lake trout	5,090	yearlings	Marquette
1998	brown trout	6,800	yearlings	Seeforellen
	lake trout	6,900	yearlings	Marquette
1999	brown trout	7,000	yearlings	Seeforellen
	lake trout	8,000	yearlings	Marquette
2000	brown trout	7,950	yearlings	Seeforellen
	lake trout	10,600	yearlings	Marquette
2001	brown trout	7,150	yearlings	Seeforellen
	lake trout	8,000	yearlings	Marquette
2002	brown trout	7,070	yearlings	Gilchrist Creek
	brown trout	520	yearlings	Wild Rose
	lake trout	7,240	yearlings	Marquette
2003	brown trout	7,100	yearlings	Wild Rose
	lake trout	8,000	yearlings	Marquette
2004	brown trout	7,100	yearlings	Wild Rose
	lake trout	11,000	yearlings	Marquette
2005	brown trout	8,000	yearlings	Wild Rose
	lake trout	10,000	yearlings	Marquette
2006	brown trout	8,600	yearlings	Wild Rose
	lake trout	12,000	yearlings	Marquette
	lake trout	1,000	adults	Lake Superior
2007	brown trout	6,400	yearlings	Wild Rose
	lake trout	7,000	yearlings	Marquette
2008	brown trout	8,100	yearlings	Wild Rose
	lake trout	6,000	yearlings	Lewis Lake
2009	brown trout	9,500	yearlings	Wild Rose

Table 1 continued. Fish stocked in Duck Lake, Grand Traverse County, 1905-2011.

2009	lake trout	7,500	yearlings	Seneca Lake
2010	lake trout	11,400	yearlings	Lake Superior
2011	lake trout	11,200	yearlings	Lake Superior

Table 2. Number, weight, and length of fish collected from Duck Lake with large mesh fyke nets and inland gillnets on June 18-22, 1997.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
alewife	1	0.2	0.2	0.0	8-8	8.5	
bluegill	145	25.1	22.1	4.4	3-10	5.9	32 (6")
brown trout	3	0.5	11.8	2.3	8-29	15.8	100 (8")
bowfin	1	0.2	4.6	0.9	23-23	23.5	
brown bullhead	5	0.9	4.0	0.8	10-12	11.9	100 (7")
lake herring	51	8.8	12.6	2.5	7-16	9.3	
lake trout	20	3.5	133.6	26.3	16-30	26.2	100 (8")
lake whitefish	1	0.2	2.6	0.5	19-19	19.5	
largemouth bass	39	6.8	36.9	7.3	8-15	12.1	13 (14")
longnose gar	9	1.6	29.8	5.9	30-34	32.7	
northern pike	21	3.6	67.3	13.3	21-26	24.3	62 (24")
pumpkinseed sunfish	59	10.2	11.8	2.3	5-8	6.2	61 (6")
rock bass	148	25.6	51.0	10.0	4-11	7.1	66 (6")
smallmouth bass	27	4.7	37.6	7.4	8-19	12.6	41 (14")
splake	3	0.5	27.4	5.4	26-29	27.8	100 (8")
white sucker	11	1.9	36.6	7.2	8-22	19.8	
yellow perch	8	1.4	0.7	0.1	5-6	6.0	0 (7")
yellow bullhead	25	4.3	17.0	3.3	8-13	11.2	
Total	577	100	507.6	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., "5"=5.0 to 5.9 inch, 12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 3. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Duck Lake with fyke nets and inland gill nets, June 18-22, 1997. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	Age										Mean Growth Index
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Bluegill		3.0 (1)	5.4 (6)	5.7 (23)	7.9 (3)	8.25 (4)	7.9 (1)		10.0 (2)		-0.2
Brown trout		9.1 (2)			29.0 (1)						
Lake trout			17.9 (2)	20.9 (2)	27.7 (13)	28.6 (3)					+6.9
Lake herring		7.7 (1)	8.3 (6)	12.8 (2)		13.9 (2)					-2.0
Largemouth bass			11.0 (12)	11.7 (12)	12.7 (5)	13.3 (4)	14.7 (2)	15.7 (1)			-0.3
Northern pike					23.5 (8)	24.2 (3)	24.8 (6)	26.3 (2)	24.6 (1)		-3.9
Pumpkinseed sunfish			5.3 (1)	6.0 (19)	7.2 (1)	7.8 (3)					+0.2
Rock bass			5.4 (7)	6.5 (25)	8.9 (3)	9.5 (12)	10.1 (3)	10.7 (3)	11.1 (8)	11.1 (1)	+0.8
Smallmouth bass		9.0 (12)	10.2 (4)		14.8 (1)	17.2 (3)	17.6 (3)	18.2 (3)	19.3 (1)		+0.2
Splake					28.6 (2)	26.5 (1)					
Yellow perch				6.0 (3)	5.8 (3)	6.4 (2)					

Table 4. Michigan DNR Master Angler awards issued for fish caught from Duck Lake, Grand Traverse County, 1994-2011.

Species	Number of Master Angler awards issued
Bluegill	1
Lake herring	1
Longnose gar	1
Northern pike	1
Pumpkinseed sunfish	1
Rock bass	58
Smallmouth bass	1
Splake	1
Total:	65

Table 5. Number, weight, and length of fish collected from Duck Lake with large mesh fyke nets, trap nets, and inland gillnets on June 18-22, 2008.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
bluegill	115	12.5	16.7	3.7	4-8	5.8	37 (6")
brown trout	1	0.1	0.1	0.0	6-6	6.5	0 (8")
brown bullhead	27	2.9	15.3	3.4	7-14	10.3	100 (7")
green sunfish	2	0.2	0.1	0.0	3-3	3.5	
largemouth bass	35	3.8	60.7	13.4	11-17	14.7	60 (14")
longnose gar	1	0.1	3.9	0.9	34-34	34.5	
northern pike	16	1.7	60.1	13.3	13-33	24.6	50 (24")
pumpkinseed sunfish	15	1.6	2.0	0.4	4-6	5.4	20 (6")
rock bass	511	55.5	133.9	29.6	3-12	6.6	57 (6")
smallmouth bass	33	3.6	70.9	15.7	7-19	15.4	73 (14")
stickleback	1	0.1	0.0	0.0	2-2	2.5	
white sucker	21	2.3	51.9	11.5	9-20	17.9	
yellow bullhead	4	0.4	2.2	0.5	9-11	10.5	
yellow perch	139	15.1	34.7	7.7	5-12	8.1	70 (7")
Total	921	100	452.5	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., "5"=5.0 to 5.9 inch, 12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 6. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Duck Lake with trap nets, fyke nets, and inland gill nets, June 18-22, 2008. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	I	II	III	Age IV	V	VI	VII	VIII	IX	X	XI	Mean Growth Index
Bluegill			4.9 (14)	5.5 (8)	6.1 (7)	6.8 (16)	8.2 (3)	8.4 (1)				-0.4
Largemouth bass				13.1 (9)	14.0 (11)	15.6 (7)	16.3 (3)	16.4 (3)	17.3 (3)	17.4 (1)		+1.1
Northern pike	13.9 (1)	20.3 (1)	21.0 (3)	23.3 (3)	24.4 (2)	29.2 (4)	27.6 (1)	33.7 (1)				
Pumpkinseed sunfish			5.1 (7)	5.3 (7)	6.3 (1)	6.3 (1)						-0.1
Rock bass			5.0 (15)	6.0 (23)	7.1 (17)	9.2 (14)	10.3 (4)	10.5 (8)	11.1 (6)	11.4 (3)	12.0 (2)	+0.7
Smallmouth bass		7.7 (3)	11.4 (1)	14.2 (12)	14.7 (1)	16.8 (1)	17.5 (5)	18.0 (3)	18.5 (7)			+1.1
Yellow perch				7.0 (6)	7.5 (29)	8.9 (13)	10.2 (7)	10.6 (2)	11.4 (2)	12.3 (2)		-0.5

Table 7. Shoreline data for Duck Lake, Grand Traverse County. Sampling was conducted by DNR Fisheries personnel on August 28, 2008.

	Total docks per km	Percent shoreline armoring	Submerged trees per km	Dwellings per km
Duck Lake	13.0	21.4	175.0	15.4

Green Lake Fishery

Green Lake

Grand Traverse County
Betsie River Watershed, Surveyed 2013

Mark A. Tonello and Todd G. Kalish, DNR Fisheries Division

Environment

Green Lake (Fig. 1) is 2,000 acres in size and located approximately 15 miles southwest of Traverse City, near the Village of Interlochen in western Grand Traverse County, Michigan. The maximum depth of Green Lake is about 102 feet, with the average depth being about 35 feet. Approximately one eighth of the lake is shallower than 15 feet. Substrates in Green Lake consist mostly of marl, sand, and organic matter. The surrounding area is hilly and mostly forested, although some development is present as well. There are also some large wetland complexes nearby. The shoreline of Green Lake is fairly developed with homes and cottages, although not quite as heavily developed as other nearby lakes like Long and Silver. Duck Lake, a similarly sized lake, is located directly to the east of Green Lake, with less than ¼ mile of land separating the two lakes. Duck Lake was most recently surveyed in 2008 (Tonello 2012) and hosts good fishing for panfish, largemouth bass, smallmouth bass, northern pike, and stocked lake trout. Both Duck and Green Lakes are regulated as Type B Trout Lakes. This means that they are open to year-round fishing, with minimum size limits of 10 inches for brook trout, coho salmon, and Chinook salmon, 12 inches for brown and rainbow trout, and 15 inches for lake trout. The daily possession limit is five trout or salmon, with no more than three 15 inches or greater in size.

Interlochen State Park, a very popular campground, is located on the western shore, between Duck and Green Lakes. Interlochen State Park was the first state park in Michigan, dedicated by the Michigan legislature in 1917. The Interlochen Center for the Arts, a privately-owned camp and boarding school is located just north of the State Park, and is also between the two lakes. Public access to Green Lake is available at Interlochen State Park, which hosts a boat launch. There is also another DNR boat launch on Green Lake on the west shore of the Green Lake.

Green Lake is in the headwaters area of the Betsie River watershed. It has one stream flowing into it, which enters Green Lake at its northern tip. That stream is the outlet flow from Duck Lake, and also has outlet flows from other small lakes in the area, including Round, Cedar Hedge, Tuller's, and Bridge Lakes. The Betsie River begins as it flows out of the southern tip of Green Lake (Fig. 1).

History

The first recorded fish stocking in Green Lake was in 1933 when bluegill and largemouth bass fingerlings were stocked (Table 1). Since then, Green Lake has had a long and varied stocking history. Other species stocked in the early 1900s included "Great Lakes Shiners" (likely emerald shiners), walleye, and yellow perch. Stockings of warm water species ceased in 1944, and rainbow trout were first stocked in 1949. Rainbow trout were stocked in most years through 1962, and then in 1965 lake trout and brown trout were first stocked. Through the 1970s and 1980s, brown trout were heavily stocked, joined in some years by lake trout. Splake were also stocked several times in the late 1980s. Since 1992, only lake trout have been stocked into Green Lake.

The first fisheries survey of Green Lake was conducted in 1947 by the Michigan Department of Conservation (MDOC; the precursor to today's Department of Natural Resources (DNR)). The researchers used seines in the survey and also observed fish with an underwater light at night. Species caught or observed included yellow perch, bluegill, rock bass, largemouth bass, white sucker, lake herring (cisco), longnose gar, northern pike, bowfin, common shiner, bluntnose minnow, logperch, and Johnny darter (Table 2). A file report from MDOC Biologist Stanley Lievense discusses the lack of walleye survival, which had been stocked as fry in a number of different years prior to 1947 (Table 1). Mr. Lievense attributed the lack of survival to predation. He recommended against further walleye stocking and instead called for the stocking of rainbow trout.

In 1950, an extensive survey of Green Lake was conducted using gill nets and seines. In addition to the species captured in 1944, other species caught included rainbow trout, smallmouth bass, spottail shiner, brook silverside, and hornyhead chub. The survey file also contains a number of angler reports regarding the stocked rainbow trout from the early 1950s, with anglers routinely catching rainbow trout up to 24 inches in length.

Other fisheries surveys of Green Lake were conducted by the MDOC and DNR in 1967, 1975, 1981 (Hay 1981), 1989 (Hay 1989), 1997 (Hay 1997), and 2003 (Kalish 2003). The 1967, 1975, and 1981 surveys utilized only gill nets. The fish species composition of these surveys did not differ appreciably from the 1947 and 1950 surveys (Table 2). Species caught that had not been observed in prior surveys included brown trout, rainbow smelt, splake, yellow bullhead, and brown bullhead. Hay (1981) indicates that the splake caught in 1981 were caught near the inlet and were likely migrants from Duck Lake (since splake had not yet been stocked into Green Lake). Age and growth analysis from the 1981 survey indicated that yellow perch were growing slowly, brown trout were growing rapidly, and most other species were growing at rates near the State average.

The 1989 and 1997 surveys were the first in which fyke nets were used in addition to gill nets (Hay 1989, 1997). This allowed for better surveying of shallow waters, leading to greater numbers of panfish and bass caught. The surveys revealed good populations of bluegill, cisco, smallmouth bass, and rock bass. Lesser numbers of largemouth bass, pumpkinseed sunfish, northern pike, splake lake trout, yellow perch, bowfin, white sucker, longnose gar, black bullhead, and brown bullhead were also caught. Two lake trout were also caught in the 1989 survey, the first ever caught in a fisheries survey of Green Lake. Seven more lake trout were caught in the 1997 survey. In both of those surveys, both bluegill and yellow perch were growing slower than the State average.

The 2003 fisheries survey also utilized fyke nets and experimental gill nets, but also saw the first use of electrofishing and seining on Green Lake (Kalish, 2004). In the 2003 survey, a total of 2,076 fish weighing 759.4 lbs were caught. Bluegill, rock bass, and spottail shiner were the most numerous species caught. Other species present in good numbers included yellow perch, largemouth bass, smallmouth bass, common shiner, longnose gar, and pumpkinseed sunfish. Seventeen lake trout from 7 to 35 inches in length were caught, indicating continues success with the lake trout stocking program. One warmouth was recorded in the catch, but this fish may have been a misidentified longear sunfish.

Green Lake is substantially north of the known range of warmouth in Michigan. Bluegill, largemouth bass, and yellow perch from the 2003 survey were growing slower than the State average.

Creel census surveys were conducted on Green Lake in the summer of 2003 and the winter of 2004 (DNR Fisheries Division, unpublished data; Table 8). In the summer creel survey, it was estimated that 40,608 fish were caught, with 29,578 of those released. Bluegill was the most commonly caught species, with 4,541 kept and 15,507 released. One striking feature of the summer creel survey was the relatively small number of sport fish that were kept: only 469 smallmouth bass were kept while 3,928 were released; only 157 largemouth bass were kept while 1,943 were released. The total summer angler effort was 23,697 angler hours (7,943 angler trips).

For the winter 2004 Green Lake creel survey, the daytime and nighttime (mostly targeting rainbow smelt) were separated. For the winter daytime effort, an estimated 4,436 fish were caught, with 2,168 released. Yellow perch were the most commonly caught species, with 2,037 kept and 2,093 released. The winter daytime ice fishery on Green Lake generated a total of 18,279 angler hours (5,781 angler trips). The winter nighttime ice creel effort resulted in an estimated catch of 54,938 rainbow smelt and generated 29,766 angler hours (9,260 angler trips). In total, the 2004 Green Lake fishery generated 71,742 angler hours (22,984 angler trips). Based on a value of $39/day for daily angler expenditures (U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau 2011) the Green Lake fishery is worth at least $896,376 to the local economy on an annual basis.

From 1994-2013, a total of 87 exceptional fish caught from Green Lake have been entered into the DNR Fisheries Division Master Angler program (Table 3). Of those 87 fish, the vast majority were rock bass (49 entries). Smallmouth bass were also well-represented with 22 entries. Other species, each represented by five entries or less, included bluegill, bowfin, longnose gar, northern pike, lake trout, and rainbow smelt. The large number of Master Angler entries for Green Lake speaks to the popularity of fishing on Green Lake.

Current Status

The most recent comprehensive fisheries survey of Green Lake was conducted by the DNR in the summer of 2013. The netting portion of the survey took place from May 20th through May 24th. Survey gear used included two large-mesh fyke nets (7 net-nights), two trap nets (8 net-nights), one small-mesh fyke net (four net-nights), two experimental graded-mesh inland gill nets (6 net-nights), and two straight-run gill nets (7 net-nights). The seining and electrofishing portion of the survey took place on the evening of July 30th. In that effort, six seine hauls were conducted, and three ten minute transects were electrofished. The primary purpose of this survey was to assess the status of all fish populations in Green Lake, with additional focus on the lake trout population.

During the 2013 May netting survey, a total of 1,072 fish were caught, representing 14 different species (Table 4). Rock bass were the most frequently collected species, with a total of 499 caught. They represented 46.5% of the total catch by number and ranged from 3 to over 12 inches in length. Other panfish species collected included bluegill (80 from 2-10 inches), pumpkinseed sunfish (7 from 4-9 inches), and yellow perch (103 from 5-13 inches).

Game fish species caught in the 2013 May netting survey included largemouth bass, smallmouth bass, northern pike, and lake trout (Table 4). Totals of 76 largemouth and 68 smallmouth bass were caught, with both species ranging up to 20 inches. The largemouth bass averaged 14.7 inches, with 74% over 14 inches in length. The smallmouth bass averaged 15.6 inches, with 58% over 14 inches in length. The northern pike catch consisted of 49 individuals from 11 to 32 inches, averaging 23.7 inches. A total of 16 lake trout were caught, ranging from 23-32 inches.

In the July 2013 seining and electrofishing portion of the survey, a total of 536 fish were caught, representing 18 species (Table 5). Spottail shiners, mimic shiners, and bluegill were the most commonly collected species from this portion of the survey.

Most species caught in the 2013 Green Lake survey showed growth near the State of Michigan length at age average (Tables 6 and 7). The exceptions were lake trout, which were growing much faster than the State average, and smallmouth bass, which were also growing well. Young largemouth bass (ages -2 and -3) from the seining and electrofishing portion of the survey were growing slowly, but older age classes (ages -5 through -9) from the netting portion of the survey were growing at rates nearer to the State average.

Fish species that were not caught in the 2013 survey of Green Lake but had been reported in previous surveys included black bullhead, blackside darter, brown trout, hornyhead chub, cisco, logperch, rainbow smelt, rainbow trout, and splake. New species documented in the 2013 survey included Iowa darter, longear sunfish, and mimic shiner.

Analysis and Discussion

One of the reasons for conducting the 2013 survey of Green Lake was to evaluate the lake trout stocking program, which had been underway since 1982 (Table 1). The catch of 16 lake trout representing four different age classes verifies that the stocking program is successful. Also, the lake trout are exhibiting phenomenal growth rates, much higher than the State average. This is likely due to the abundant forage available in Green Lake in the form of rainbow smelt. However, the 2003/2004 creel effort showed very low catch of lake trout, both in summer and winter (Table 8).

The 2013 DNR fisheries survey showed that Green Lake has generally healthy gamefish populations. Largemouth and smallmouth bass in particular were numerous and are keystone predators. In the 2003 survey, both species were much less abundant than in 2013. The 2013 survey showed that the bass populations of Green Lake are well balanced, with good growth, multiple year classes represented in the catch, and many individuals exceeding the minimum legal-size limit of 14 inches. Green Lake has a reputation for providing excellent bass fishing opportunities, and the 2013 survey confirmed that. The northern pike catch in the 2013 survey was also much more numerous than in previous surveys, nearly half of the fish caught exceeding the minimum legal length of 24 inches.

The panfish populations in Green Lake also appear to be healthy, for the most part. Although the bluegill and pumpkinseed sunfish populations in Green Lake are not overly large, they grow well and can attain "keeper" sizes. The rock bass population in Green Lake is robust, including many individuals exceeding the minimum Master Angler length of 11 inches. The yellow perch population of Green Lake is also healthy, averaging nearly 8 inches in length, with individuals present up to 13 inches.

Management Direction

Green Lake is an extremely popular lake for sportfishing. It is well-known for multiple fisheries, including a very popular rainbow smelt fishery, the likes of which can only be found on a handful of other inland lakes in Michigan. The large number of Master Angler entries for Green Lake speaks to the quality and popularity of Green Lake for anglers. The 2003/2004 creel survey showed that the Green Lake fishery was worth nearly $900,000 to the local economy. Due to inflation rates in the 10+ years since the survey was conducted, it can easily be assumed that the Green Lake fishery today is worth well over $1,000,000 to the economy of Grand Traverse County and the Interlochen area.

Green Lake is a rare natural resource in that it has deep, cold water that can harbor species like lake trout, cisco, and rainbow smelt. For the last 30+ years, Green Lake has had a reputation as a good lake for catching lake trout. The Green Lake lake trout population is likely entirely dependent on stocking. Therefore, we should continue to stock 12,000 yearling lake trout into Green Lake annually (a rate of 6 yearlings per acre). However, the extremely low catch of lake trout in the 2003/2004 creel effort is disturbing. It is questionable whether many anglers are actively targeting lake trout on Green Lake. If it is determined that lake trout stocking in Green Lake is not being adequately utilized by the angling public, then the stocking program should be cut.

Native species like bluegill, pumpkinseed sunfish, rock bass, northern pike, largemouth bass, and smallmouth bass should continue to thrive in Green Lake without direct management efforts. However, the lack of cisco in the catch of the 2013 survey of Green Lake is concerning, especially considering that cisco had been caught in virtually all previous surveys of Green Lake (Table 2). Additionally, cisco were noticeably absent in a 2008 MDNR fisheries survey of Duck Lake as well (Tonello 2012). Future fisheries surveys should make a concerted effort to sample cisco in particular on both Duck and Green Lakes. Cisco are a listed as a "Threatened" species by the Michigan Department of Natural Resources.

Any remaining riparian wetlands adjacent to Green Lake should be protected as they are critical to the continued health of the aquatic community of Green Lake. Future riparian development and wetland loss may result in deterioration of the water quality and aquatic habitat. Healthy biological communities in inland lakes require suitable natural habitat. Human development within the lake watershed, along the shoreline, and in the lake proper has a tendency to change and diminish natural habitat. Appropriate watershed management is necessary to sustain healthy biological communities, including fish, invertebrates, amphibians, reptiles, birds and aquatic mammals. Generally for lakes this includes maintenance of good water quality, especially for nutrients; preservation of natural shorelines, especially shore contours and vegetation; and preservation of bottom contours, vegetation, and wood structure within a lake. Guidelines for protecting fisheries habitat in inland lakes can be found in Fisheries Division Special Report 38 (O'Neal and Soulliere 2006).

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Figure 1. Green Lake, Grand Traverse County, MI.

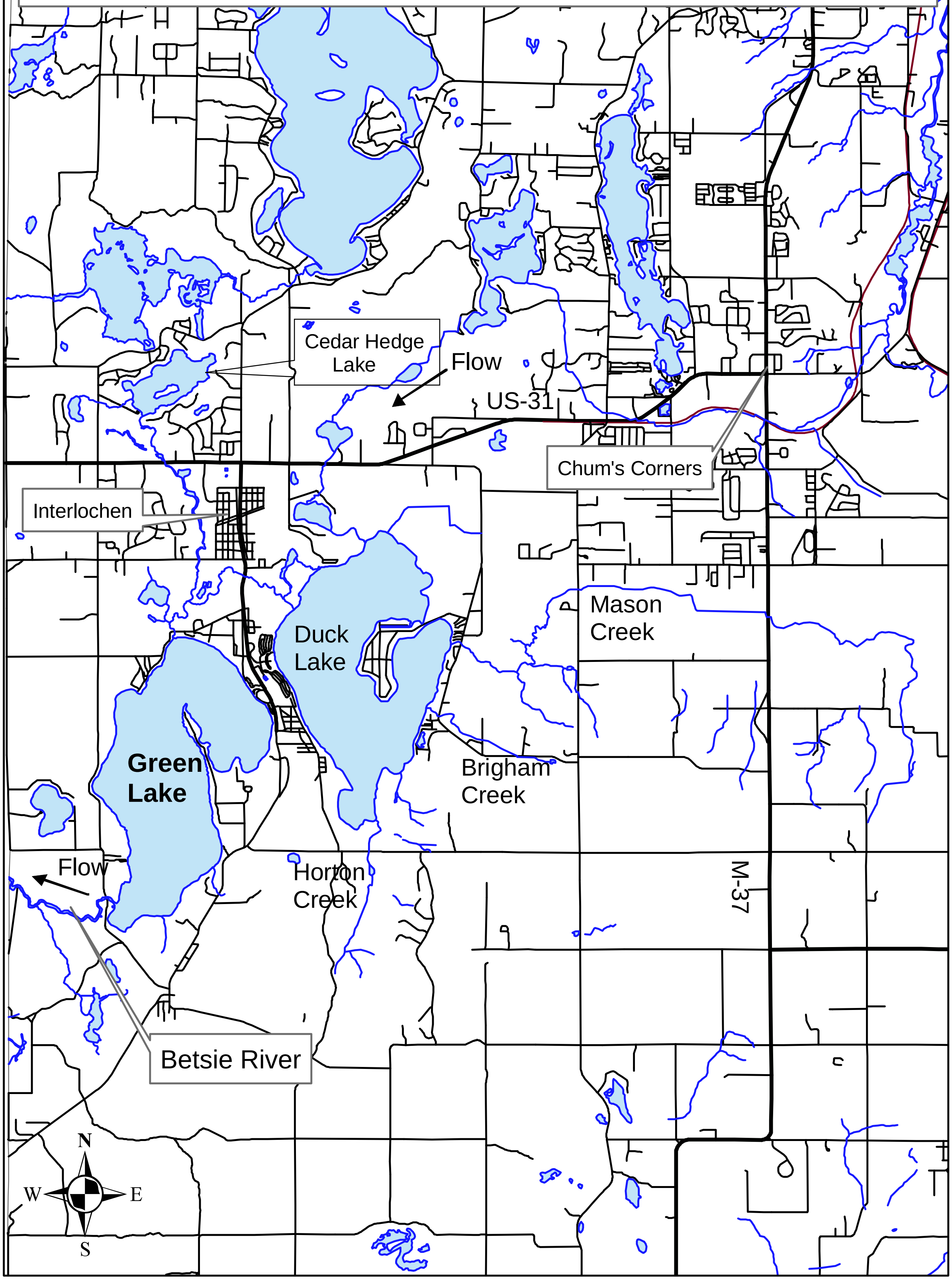

Table 1. Fish stocked in Green Lake, Grand Traverse County, 1933-2013.

Year	Species	Number	Size/age	Strain
1933	bluegill	3,000	6 mo.	
	largemouth bass	1,000	6 mo.	
1935	bluegill	6,000	4 mo.	
	shiners	250,000	fry	
	walleye	170,000	fry	
	yellow perch	25,000	7 mo.	
1936	bluegill	150	yearlings	
	largemouth bass	150	yearlings	
	largemouth bass	1,000	4 mo.	
	shiners	27,000	fry	
	walleye	300,000	fry	
	yellow perch	3,250	8 mo.	
1937	bluegill	20,000	5 mo.	
	walleye	255,000	fry	
	yellow perch	10,000	7 mo.	
1938	bluegill	20,000	4 mo.	
	largemouth bass	200	3 mo.	
	walleye	200,000	fry	
1939	bluegill	25,000	5 mo.	
	largemouth bass	1,000	5 mo.	
	walleye	200,000	fry	
	yellow perch	8,000	7 mo.	
1940	bluegill	600	yearlings	
	largemouth bass	2,400	3-7 mo.	
	walleye	180,000	fry	
1941	bluegill	10,000	4 mo.	
	largemouth bass	800	4 mo.	
1942	bluegill	20,000	4 mo.	
	largemouth bass	800	4 mo.	
	walleye	200,000	fry	
1943	bluegill	1,000	yearlings	
	largemouth bass	800	4 mo.	
1944	bluegill	1,000	yearlings	
	largemouth bass	800	3 mo.	
1949	rainbow trout	2,000	yearlings	
1950	rainbow trout	2,000	yearlings	
1951	rainbow trout	2,000	yearlings	
	rainbow trout	7,000	fall fingerlings	
1952	rainbow trout	5,000	yearlings	
1953	rainbow trout	5,000	yearlings	
1954	rainbow trout	5,000	yearlings	
1955	rainbow trout	62,000	fall fingerlings	
1957	rainbow trout	5,000	yearlings	
1958	rainbow trout	6,000	yearlings	
1961	rainbow trout	5,000	yearlings	
1962	rainbow trout	5,000	yearlings	
1965	brown trout	25,000	yearlings	
	lake trout	31,300	yearlings	

Table 1 continued. Fish stocked in Green Lake, Grand Traverse County, 1933-2013.

1968	brown trout	10,000	yearlings	
1969	rainbow trout	10,000	yearlings	
1970	brown trout	1,000	adults	
	rainbow trout	20,000	yearlings	
1971	brown trout	13,559	adults	
1972	brown trout	20,467	yearlings	
1973	brown trout	23,225	yearlings	
1974	brown trout	20,000	yearlings	
1975	brown trout	20,000	yearlings	
1976	brown trout	20,000	yearlings	
1977	brown trout	4,811	adults	
	brown trout	20,006	yearlings	
1978	brown trout	10,000	yearlings	
1979	brown trout	10,000	yearlings	
1981	brown trout	8,000	yearlings	Harrietta
1982	brown trout	5,000	yearlings	Harrietta
	lake trout	10,000	yearlings	Marquette
1983	brown trout	10,000	yearlings	Harrietta
	lake trout	10,000	yearlings	Marquette
	lake trout	11,400	fall fingerlings	Marquette
1984	brown trout	10,000	yearlings	Harrietta
1985	brown trout	10,330	yearlings	Wild Rose
	lake trout	4,000	yearlings	
	splake	18,000	yearlings	
1986	brown trout	11,400	yearlings	Wild Rose
1987	brown trout	3,100	yearlings	Plymouth Rock
	brown trout	11,900	yearlings	Soda Lake
	splake	12,000	yearlings	
1988	brown trout	15,000	yearlings	Plymouth Rock
	splake	12,000	yearlings	
1989	brown trout	15,000	yearlings	Plymouth Rock
1990	brown trout	18,593	yearlings	Soda Lake
	lake trout	11,700	yearlings	Marquette
1991	brown trout	36,000	yearlings	Plymouth Rock
1992	lake trout	15,700	yearlings	Lake Superior
1993	lake trout	15,900	yearlings	Marquette
1994	lake trout	10,600	yearlings	Marquette
1996	lake trout	16,000	yearlings	Marquette
1997	lake trout	9,130	yearlings	Marquette
1998	lake trout	11,900	yearlings	Marquette
1999	lake trout	16,000	yearlings	Marquette
2000	lake trout	6,100	yearlings	Marquette
2001	lake trout	16,000	yearlings	Marquette
2002	lake trout	16,950	yearlings	Marquette
2003	lake trout	16,000	yearlings	Marquette
2004	lake trout	16,500	yearlings	Marquette
2005	lake trout	15,000	yearlings	Marquette
	lake trout	8,896	fall fingerlings	Lake Superior
2006	lake trout	15,000	yearlings	Marquette

Table 1 continued. Fish stocked in Green Lake, Grand Traverse County, 1933-2013.

2007	lake trout	12,000	yearlings	Marquette
2008	lake trout	10,200	yearlings	Lewis Lake
2009	lake trout	12,500	yearlings	Seneca Lake
2010	lake trout	12,000	yearlings	Lake Superior
2011	lake trout	11,800	yearlings	Lake Superior
2012	lake trout	10,000	yearlings	Lake Superior
2013	lake trout	10,440	yearlings	Seneca Lake

Table 2. Presence/absence of fish species in historical fisheries surveys of Green Lake.

Species	1947	1950	1967	1975	1981	1989	1997	2003	2013
Banded killifish								x	x
Black bullhead						x			
Blackside darter								x	
Bluegill	x	x		x			x	x	x
Bluntnose minnow	x	x						x	x
Bowfin	x	x		x	x	x	x	x	x
Brook silverside		x							x
Brown bullhead					x	x		x	x
Brown trout			x	x	x			x	
Common shiner	x	x						x	x
Creek chub								x	x
Hornyhead chub		x						x	
Iowa darter									x
Johnny darter	x	x						x	
Lake herring (cisco)	x	x		x	x	x	x	x	
Lake trout						x	x	x	x
Largemouth bass	x	x		x	x		x	x	x
Logperch	x	x						x	
Longear sunfish									x
Longnose gar	x	x				x		x	x
Mimic shiner									x
Northern pike	x	x	x	x	x	x	x	x	x
Pumpkinseed sunfish						x	x	x	x
Rainbow smelt				x	x		x	x	
Rainbow trout		x							
Rock bass	x	x	x	x	x	x	x	x	x
Smallmouth bass	x	x		x	x	x	x	x	x
Splake					x	x			
Spottail shiner		x						x	x
Warmouth								x	
White sucker	x	x		x	x	x	x	x	x
Yellow bullhead				x					x
Yellow perch	x	x	x	x	x	x	x	x	x

Table 3. Michigan DNR Master Angler awards issued for fish caught from Green Lake, Grand Traverse County, 1994-2013.

Species	Number of Master Angler awards issued
Bluegill	5
Bowfin	3
Lake trout	2
Longnose gar	4
Northern pike	1
Rainbow smelt	1
Rock bass	49
Smallmouth bass	22
Total:	87

Table 4. Number, weight, and length of fish collected from Green Lake with large mesh fyke nets, small mesh fyke nets, trap nets, and inland gillnets on May 20-24, 2013.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
bluegill	80	7.5	20.7	1.5	2-12	6.5	60 (6")
bowfin	34	3.2	120.6	9.0	11-28	20.5	
brown bullhead	48	4.5	44.3	3.3	10-14	12.5	100 (7")
lake trout	16	1.5	156.3	11.7	23-32	29.8	100 (15")
largemouth bass	76	7.1	139.5	10.4	7-20	14.7	74 (14")
longnose gar	2	0.2	6.4	0.5	23-37	30.0	
northern pike	49	4.6	155.9	11.6	11-32	23.7	49 (24")
pumpkinseed sunfish	7	0.7	2.8	0.2	4-9	7.4	86 (6")
rock bass	499	46.5	365.3	27.2	3-12	9.6	88 (6")
smallmouth bass	68	6.3	150.4	11.2	7-20	15.6	58 (14")
spottail shiner	42	3.9	1.5	0.1	3-5	4.3	
white sucker	47	4.4	152.9	11.4	17-22	20.2	
yellow bullhead	1	0.1	0.4	0.0	9-9	9.5	100 (7")
yellow perch	103	9.6	23.9	1.8	5-13	7.8	51 (7")
Total	1,072	100	1340.9	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., "5"=5.0 to 5.9 inch,12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 5. Number, weight, and length of fish collected from Green Lake with electrofishing and seining on July 30, 2013.

Species	Number	Percent by number	Weight (Pounds)	Percent by weight	Length range (inches)[1]	Average length	Percent legal size[2]
banded killifish	15	2.8	0.1	0.2	2-2	2.5	
bluegill	98	18.3	6.0	10.5	1-6	4.3	2 (6")
bluntnose minnow	28	5.2	0.0	0.0	1-2	1.7	
bowfin	3	0.6	15.1	26.4	22-26	24.2	
brook silverside	3	0.6	0.0	0.0	1-3	2.5	
creek chub	1	0.2	0.0	0.0	2-2	2.5	
common shiner	1	0.2	0.0	0.0	3-3	3.5	
Iowa darter	1	0.2	0.0	0.0	2-2	2.5	
largemouth bass	26	4.9	13.8	24.2	1-17	8.2	12 (14")
longnose gar	1	0.2	0.6	1.1	20-20	20.5	
longear sunfish	6	1.1	0.2	0.4	2-4	3.5	
mimic shiner	139	25.9	0.6	1.1	1-2	2.4	
northern pike	1	0.2	2.5	4.4	22-22	22.5	0 (24")
pumpkinseed sunfish	10	1.9	1.1	1.9	4-6	5.2	10 (6")
rock bass	37	6.9	11.0	19.3	2-10	6.8	70 (6")
smallmouth bass	10	1.9	5.1	8.9	1-19	6.1	10 (14")
spottail shiner	152	28.4	0.3	0.5	1-2	1.8	
yellow perch	4	0.7	0.7	1.2	5-8	7.3	75 (7")
Total	536	100	57.1	100			

[1]Note some fish were measured to 0.1 inch, others to inch group: e.g., "5"=5.0 to 5.9 inch, 12=12.0 to 12.9 inches; etc.

[2]Percent legal size or acceptable size for angling. Legal size or acceptable size for angling is given in parentheses.

Table 6. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Green Lake with trap nets, fyke nets, and inland gill nets, May 20-23, 2013. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	Age I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Mean Growth Index
Bluegill	3.0 (1)		4.3 (10)	5.4 (5)	6.2 (2)	6.9 (8)	8.2 (9)	9.3 (5)					0
Lake trout				25.3 (4)	30.6 (3)	31.2 (5)	31.8 (4)						+8.4
Largemouth bass		8.2 (2)	8.7 (3)	11.5 (4)	13.5 (9)	14.4 (8)	15.2 (15)	16.2 (12)	17.4 (5)	20.3 (2)	19.9 (1)		-0.6
Northern pike		12.0 (2)	16.6 (2)	22.9 (17)	24.2 (17)	26.3 (7)	28.7 (3)	26.0 (1)					-1.0
Pumpkin-seed sunfish			4.1 (1)		6.6 (3)		8.7 (2)		9.1 (1)				-
Rock bass			4.1 (5)	5.6 (3)	6.0 (15)	7.0 (8)	9.0 (14)	9.5 (12)	10.4 (7)	11.1 (9)	11.5 (7)	11.8 (6)	-0.3
Smallmouth bass		8.0 (4)	11.6 (7)	14.0 (19)	15.6 (7)	16.4 (6)	17.9 (5)	18.5 (8)	19.7 (4)	19.9 (4)			+1.2
Yellow perch		6.2 (5)	7.1 (18)	7.3 (7)	8.2 (10)	9.5 (6)	11.1 (6)	10.7 (2)	12.2 (4)				+0.4

Table 7. Average total weighted length (inches) at age, and growth relative to the state average, for fish sampled from Green Lake with seining and electrofishing, July 30, 2013. Number of fish aged is given in parenthesis. A minimum of five fish per age group is statistically necessary for calculating a Mean Growth Index, which is a comparison to the State of Michigan average.

Species	Age I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Mean Growth Index
Bluegill			5.2 (19)	5.2 (3)									-0.1
Largemouth bass	7.0 (3)	7.3 (10)	9.0 (5)		13.9 (2)	17.5 (2)							-1.5
Longear sunfish				4.2 (1)	4.8 (1)								-
Northern pike					22.6 (1)								-
Pumpkin-seed sunfish		4.2 (2)	5.4 (8)										+0.2
Rock bass			4.8 (4)	5.1 (4)	7.1 (15)	8.0 (6)	8.8 (1)	10.2 (1)	10.4 (2)	10.4 (1)			-0.1
Smallmouth bass	5.8 (2)	8.4 (1)	11.6 (1)					19.9 (1)					-
Yellow perch		7.4 (2)	8.4 (1)	7.5 (1)									-

Table 8. Results of the summer 2003 and winter 2004 MDNR creel survey, including an evening component targeting rainbow smelt anglers.

Species	Estimated harvest, summer 2003	Estimated released, summer 2003	
lake trout	9	0	
smallmouth bass	469	3,928	
yellow perch	2,920	3,231	
northern pike	291	831	Summer 2003 angler hours: 23,697
bluegill	4,541	15,507	
largemouth bass	157	1,943	
pumpkinseed	320	399	Summer 2003 angler trips: 7,943
rock bass	216	3,630	
green sunfish	12	0	
bowfin	0	95	
cisco	0	0	
rainbow smelt	0	0	
white sucker	0	14	

Species	Estimated harvest, winter 2004	Estimated released, winter 2004	
lake trout	0	37	Winter 2004 angler hours (non smelt): 18,279
smallmouth bass	0	0	
yellow perch	2,037	2,093	
northern pike	226	38	Winter 2004 angler trips (non smelt): 5,781
bluegill	0	0	
largemouth bass	0	0	
pumpkinseed	0	0	Winter 2004 smelt angler hours: 29,766
rock bass	0	0	
green sunfish	0	0	
bowfin	0	0	Winter 2004 smelt angler trips: 9,260
cisco	5	0	
rainbow smelt	54,891	46	
white sucker	0	0	

Total summer 2003/winter 2004 angler hours: 71,742
Total summer 2003/winter 2004 angler trips: 22,984

Appendix D: Road Stream Crossing Inventory Tables

ROAD STREAM CROSSING INVENTORY TABLE - PART A							
SITE ID	STREAM	ROAD	COUNTY	TOWNSHIP	TOWN	RANGE	SECT
B-005	Betsie River	Reynolds Rd	Benzie	Colfax	25N	13W	9
B-006	Betsie River	Wallin Rd	Benzie	Colfax	25N	13W	9
B-007	Betsie River Tributary	South Carmean	Benzie	Colfax	25N	13W	19
B-008	Betsie River	South Carmean	Benzie	Colfax	25N	13W	19
B-009	Betsie River Tributary	South Carmean	Benzie	Colfax	25N	13W	19
B-010	Peppermint Creek	Lindy Rd	Benzie	Colfax	24N	13W	34
B-011	Peppermint Creek	Karlin Rd	Benzie	Colfax	25N	13W	33
B-013	Little Betsie Tributary	Long Rd	Benzie	Colfax	25N	13W	29
B-019	Betsie River	Thompsonville Rd	Benzie	Colfax	25N	13W	19
B-021	Little Betsie River	Thompsonville Rd	Benzie	Colfax	25N	13W	30
B-022	Peppermint Creek Tributary	Thompsonville Rd	Benzie	Colfax	25N	13W	31
B-023	Peppermint Creek Tributary	Railroad Grade off Thompsonville Rd	Benzie	Weldon	25N	14W	36
B-024	Peppermint Creek Tributary	Lindy Rd	Benzie	Weldon	25N	14W	36
B-025	Peppermint Creek Tributary	Thompson Rd	Benzie	Weldon	25N	14W	36
B-026	Peppermint Creek	Thompsonville Rd	Benzie	Weldon	25N	14W	36
B-027	Peppermint Creek	Railroadgrade off Lindy Rd	Benzie	Weldon	25N	14W	36
B-028	Peppermint Creek	Lindy Rd	Benzie	Colfax	25N	13W	31
B-029	Peppermint Creek	Thurman Rd	Benzie	Colfax	25N	13W	31
B-030	Peppermint Creek	Lindy Rd	Benzie	Colfax	25N	13W	32
B-031	Peppermint Creek	Wells Rd	Benzie	Weldon	25N	14W	36
B-032	Betsie River	Wolf Rd	Benzie	Weldon	25N	14W	25
B-035	Betsie River	Lindy Rd	Benzie	Weldon	25N	14W	35
B-041	Dair Creek	Pioneer Rd	Benzie	Weldon	25N	14W	16
B-042	Dair Creek Tributary	Pioneer Rd	Benzie	Weldon	25N	14W	21
B-056	Betsie River Tributary	North County Line Rd	Benzie	Weldon	24N	14W	6
B-057	Betsie River Tributary	North County Line Rd	Benzie	Weldon	24N	14W	6
B-058	Betsie River	North County Line Rd	Benzie	Weldon	24N	14W	6
B-062	Dair Creek	M-115	Benzie	Weldon	25N	14W	19
B-063	Betsie River	M-115	Benzie	Weldon	25N	14W	19
B-064	Betsie River Tributary	Joyfield Rd	Benzie	Joyfield	25N	15W	36
B-065	Betsie River Tributary	Wallaker Rd	Benzie	Joyfield	25N	15W	25
B-066	Rice Creek	Highway-31	Benzie	Joyfield	25N	15W	11
B-067	Rice Creek Tributary	Ballard Rd	Benzie	Joyfield	25N	15W	9
B-068	Rice Creek Tributary	Ballard Rd	Benzie	Benzonia	25N	15W	4
B-069	Rice Creek	Grace Rd	Benzie	Benzonia	26N	15W	34
B-070	Betsie River	Grace Rd	Benzie	Benzonia	26N	15W	34
B-071	Betsie River	US 31	Benzie	Benzonia	26N	15W	3
B-072	Betsie River	River Rd	Benzie	Benzonia	26N	15W	33
B-073	Cold Creek	Homestead Rd	Benzie	Benzonia	26N	15W	35
B-074	Cold Creek	Case Rd	Benzie	Benzonia	26N	15W	26
B-075	Cold Creek	US 31	Benzie	Benzonia	26N	15W	26
B-076	Cold Creek	Clark St	Benzie	Benzonia	26N	15W	26
B-077	Cold Creek	S. Benzie Blvd.	Benzie	Benzonia	26N	15W	26
B-078	Cold Creek	Center St	Benzie	Benzonia	26N	15W	26
B-079	Crystal Lake Tributary	Crystal Dr	Benzie	Benzonia	26N	15W	16
B-080	Crystal Lake Tributary	Crystal Dr	Benzie	Lake	26N	16W	1
B-081	Crystal Lake Tributary	M-22	Benzie	Crystal Lake	26N	16W	16
B-082	Crystal Lake Tributary	Bellows Rd	Benzie	Crystal Lake	26N	16W	15
B-083	Crystal Lake Tributary	Thomas Rd	Benzie	Crystal Lake	26N	16W	15
B-084	Crystal Lake Tributary	Thomas Rd	Benzie	Crystal Lake	26N	16W	15
B-085	Crystal Lake Tributary	South Shore Rd	Benzie	Crystal Lake	26N	16W	16

ROAD STREAM CROSSING INVENTORY TABLE - PART B									
SITE ID	LON	LAT	CROSSING TYPE	ROAD SURFACE	SEVERITY	INVENTORY YEAR	SEDIMENT LOADING	PHOS LOADING	LOADING METHOD
B-005	-85.877873	+44.574673	Bridge	Sand	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-006	-85.893136	+44.570467	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-007	-85.918221	+44.559070	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-008	-85.918906	+44.555047	Bridge	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-009	-85.918344	+44.549171	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-010	-85.867055	+44.520169	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-011	-85.878430	+44.521648	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-013	-85.898488	+44.538588	Culvert(S)	Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-019	-85.938205	+44.546416	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-021	-85.938563	+44.531718	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-022	-85.938784	+44.522175	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-023	-85.940706	+44.521039	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-024	-85.940020	+44.520483	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-025	-85.940824	+44.519441	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-026	-85.938884	+44.517839	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-027	-85.940439	+44.518060		Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-028	-85.920946	+44.520361	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-029	-85.918619	+44.520492	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-030	-85.904929	+44.520654	Culvert(S)	Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-031	-85.944174	+44.515934	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-032	-85.948908	+44.528856	Bridge	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-035	-85.961478	+44.520474	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-041	-85.997943	+44.567971	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-042	-85.998324	+44.554324	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-056	-86.059226	+44.514771	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-057	-86.049933	+44.514568	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-058	-86.044670	+44.514453	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-062	-86.047055	+44.551377	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-063	-86.053430	+44.557268	Bridge	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-064	-86.076631	+44.529697	Culvert(S)	Sand & Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-065	-86.080103	+44.531306	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-066	-86.099462	+44.580077	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-067	-86.134675	+44.587576	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-068	-86.124473	+44.593582	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-069	-86.115039	+44.603492	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-070	-86.112399	+44.604420	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-071	-86.099250	+44.600650	Bridge	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-072	-86.123358	+44.618110	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-073	-86.088752	+44.617580	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-074	-86.088426	+44.626547	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-075	-86.091601	+44.629997	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-076	-86.093794	+44.629145	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-077	-86.094983	+44.629064	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-078	-86.096052	+44.629480	Bridge	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-079	-86.115050	+44.657191	Bridge	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-080	-86.184535	+44.688152	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-081	-86.245612	+44.658551	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-082	-86.233278	+44.657634	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-083	-86.226441	+44.657868	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-084	-86.233942	+44.659785	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-085	-86.240748	+44.662818	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated

ROAD STREAM CROSSING INVENTORY TABLE - PART A							
SITE ID	STREAM	ROAD	COUNTY	TOWNSHIP	TOWN	RANGE	SECT
B-086	Crystal Lake Tributary	South Shore Rd	Benzie	Crystal Lake	26N	16W	15
B-087	Crystal Lake Tributary	South Shore Rd	Benzie	Crystal Lake	26N	16W	15
B-088	Betsie River Tributary	M-115	Benzie	Crystal Lake	26N	15W	20
B-089	Betsie River Tributary	Betsie Valley Trail	Benzie	Crystal Lake	26N	15W	20
B-090	Betsie River Tributary	Mollineaux Rd	Benzie	Crystal Lake	26N	15W	20
B-091	Betsie River Tributary	Outlet Rd	Benzie	Crystal Lake	26N	15W	20
B-092	Betsie River	River Rd	Benzie	Crystal Lake	26N	15W	31
B-093	Betsie River	Access off River Rd	Benzie	Crystal Lake	26N	15W	31
B-094	Betsie River Tributary	River Rd	Benzie	Crystal Lake	26N	15W	29
B-095	Betsie River Tributary	Grace Rd	Benzie	Gilmore	25N	16W	1
B-096	Betsie River Tributary	Ellis Rd	Benzie	Gilmore	25N	16W	1
B-097	Betsie River Tributary	Grace Rd	Benzie	Gilmore	25N	16W	1
B-098	Betsie River/Lake	M-22	Benzie	Crystal Lake	26N	16W	27
B-099	Betsie River/Lake	Railroad trail	Benzie	Crystal Lake	26N	16W	34
B-100	Betsie Lake tributary	Didrickson Rd	Benzie	Crystal Lake	26N	16W	26
B-101	Betsie Lake tributary	Didrickson Rd	Benzie	Crystal Lake	26N	16W	26
B-102	Betsie Lake tributary	M-22	Benzie	Crystal Lake	26N	16W	26
B-103	Betsie River Tributary	Carlson Rd	Benzie	Crystal Lake	26N	16W	25
B-104	Betsie River Tributary	River Rd	Benzie	Crystal Lake	26N	16W	36
B-105	Betsie River Tributary	Railroad Trail	Benzie	Crystal Lake	26N	16W	36
B-106	Betsie River Tributary	River Rd	Benzie	Crystal Lake	26N	16W	31
G-001	Green Lake Tributary	Diamond Park Rd	Grand Traverse	Green Lake	26N	12W	20
G-002	Tributary of Green Lake	M-137	Grand Traverse	Grant	25N	12W	4
G-003	Betsie River	Betsie River Rd	Grand Traverse	Grant	25N	12W	6
G-004	Hall Creek	Hall Creek Rd	Grand Traverse	Grant	25N	12W	7
M-043	Betsie River	M-115	Manistee	Springdale	24N	14W	2
M-044	Betsie River	Kurick Rd	Manistee	Springdale	24N	14W	3
M-045	Betsie River Tributary	Old Grade	Manistee	Springdale	24N	14W	10
M-046	Betsie River Tributary	Old Grade	Manistee	Springdale	24N	14W	10
M-047	Betsie River Tributary	Old Grade	Manistee	Springdale	24N	14W	9
M-048	Betsie River Tributary	Springdale Rd	Manistee	Springdale	24N	14W	9
M-049	Betsie River Tributary	Willis Rd	Manistee	Springdale	24N	14W	5
M-050	Betsie River Tributary	Psutka Rd	Manistee	Springdale	24N	14W	5
M-051	Betsie River	Psutka Rd	Manistee	Springdale	24N	14W	8
M-052	Betsie River Tributary	Psutka Rd	Manistee	Springdale	24N	14W	8
M-053	Betsie River Tributary	Springdale Rd	Manistee	Springdale	24N	14W	7
M-054	Betsie River Tributary	Big Four Rd	Manistee	Springdale	24N	14W	7
M-055	Betsie River Tributary	Moore Rd	Manistee	Springdale	24N	14W	7
BT_B014	Unknown (Betsie Tributary)	Long Rd	Benzie	Colfax	25N	13W	20
BT_B015	Unknown (Betsie Tributary)	Long Rd	Benzie	Colfax	25N	13W	17
BT_B016	Betsie River	Long Rd	Benzie	Colfax	25N	13W	17
BT_B033	Red Creek	Haze Rd	Benzie	Weldon	25N	14W	26
BT_B034	Betsie River	Haze Rd	Benzie	Weldon	25N	14W	35
BT_B036	Dair Creek	S. Weldon Rd	Benzie	Weldon	26N	14W	15
BT_B037	Dair Creek	Weldon Rd	Benzie	Weldon	25N	14W	15
BT_B037A	Dair Creek	Weldon Rd	Benzie	Weldon	25N	14W	15
BT_B038	Dair Creek	Weldon Rd	Benzie	Weldon	25N	14W	10
BT_B039	Dair Creek	Weldon Rd	Benzie	Weldon	25N	14W	10
BT_B040	Dair Creek	Landis Rd	Benzie	Weldon	25N	14W	16
BT_B059	Dair Creek	Dair Mill Rd	Benzie	Weldon	25N	14W	19
BT_B060	Dair Creek	Old King Rd	Benzie	Weldon	25N	14W	19

ROAD STREAM CROSSING INVENTORY TABLE - PART B									
SITE ID	LON	LAT	CROSSING TYPE	ROAD SURFACE	SEVERITY	INVENTORY YEAR	SEDIMENT LOADING	PHOS LOADING	LOADING METHOD
B-086	-86.232984	+44.660961	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-087	-86.223635	+44.660409	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-088	-86.144858	+44.632366	Bridge	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-089	-86.146404	+44.634314	Bridge	Gravel	Minor	2011	0.41 T	0.35 lbs	Estimated
B-090	-86.146821	+44.635304	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-091	-86.146880	+44.636237		Sand & Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-092	-86.167754	+44.618234	Bridge	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-093	-86.168356	+44.618902		Sand & Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-094	-86.149817	+44.620557	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-095	-86.184753	+44.604659	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-096	-86.190195	+44.600737	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-097	-86.189590	+44.604670	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-098	-86.221607	+44.620272	Bridge	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-099	-86.220405	+44.619150	Bridge	Gravel	Minor	2011	0.41 T	0.35 lbs	Estimated
B-100	-86.217792	+44.625892	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-101	-86.219951	+44.625576	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
B-102	-86.220637	+44.625870	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-103	-86.196210	+44.619047	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-104	-86.190164	+44.614933	Culvert(S)	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
B-105	-86.189874	+44.613992	Culvert(S)		Minor	2011	0.41 T	0.35 lbs	Estimated
B-106	-86.174092	+44.616756	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
G-001	-85.781846	+44.633149	Bridge	Paved	Minor	2011	0.41 T	0.35 lbs	Estimated
G-002	-85.772789	+44.593409	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
G-003	-85.796668	+44.592893	Bridge	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
G-004	-85.803084	+44.578371	Culvert(S)	Sand	Minor	2011	0.41 T	0.35 lbs	Estimated
M-043	-85.968382	+44.507461	Bridge	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-044	-85.979264	+44.501520		Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-045	-85.989545	+44.495410	Culvert(S)	Sand & Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-046	-85.995774	+44.491565	Culvert(S)		Severe	2011	6.64 T	5.64 lbs	Estimated
M-047	-86.006951	+44.491273	Culvert(S)	Sand & Gravel	Severe	2011	6.64 T	5.64 lbs	Estimated
M-048	-86.011006	+44.485402	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-049	-86.019863	+44.508559	Culvert(S)	Sand & Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-050	-86.029892	+44.507118	Culvert(S)	Sand & Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-051	-86.029970	+44.496213	Bridge		Severe	2011	6.64 T	5.64 lbs	Estimated
M-052	-86.029728	+44.487153	Culvert(S)	Sand & Gravel	Minor	2011	0.41 T	0.35 lbs	Estimated
M-053	-86.048373	+44.486189	Culvert(S)	Sand & Gravel	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-054	-86.040912	+44.493198	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
M-055	-86.044070	+44.500150	Culvert(S)	Paved	Moderate	2011	1.18 T	1.01 lbs	Estimated
BT_B014	-85.898250	+44.553220	Culvert(S)	Gravel	Severe	2014	3.77 T	3.20 lbs	Calculated
BT_B015	-85.898220	+44.562860	Culvert(S)	Gravel	Moderate	2014	3.07 T	2.61 lbs	Calculated
BT_B016	-85.898065	+44.565289	Other	Sand	Restored	2015	0.49 T	0.42 lbs	Estimated
BT_B033	-85.958830	+44.528310	Culvert(S)	Gravel	Severe	2014	2.39 T	2.03 lbs	Calculated
BT_B034	-85.958800	+44.525070	Bridge	Gravel	Severe	2014	6.64 T	5.64 lbs	Estimated
BT_B036	-85.977620	+44.568650	Culvert(S)	Sand	Severe	2014	1.58 T	1.34 lbs	Calculated
BT_B037	-85.977550	+44.570370	Culvert(S)	Gravel	Moderate	2014	0.20 T	0.17 lbs	Calculated
BT_B037A	-85.977650	+44.571700	Culvert(S)	Sand	Moderate	2014	0.21 T	0.18 lbs	Calculated
BT_B038	-85.977380	+44.574420	Culvert(S)	Sand	Moderate	2014	0.74 T	0.63 lbs	Calculated
BT_B039	-85.977440	+44.575360	Culvert(S)	Gravel	Minor	2014	0.47 T	0.40 lbs	Calculated
BT_B040	-86.015680	+44.557510	Culvert(S)	Gravel	Restored	2014	1.12 T	0.96 lbs	Calculated
BT_B059	-86.054290	+44.551830	Culvert(S)	Paved	Restored	2014	0.49 T	0.42 lbs	Calculated
BT_B060	-86.054760	+44.552000	Culvert(S)	Paved	Restored	2014	0.10 T	0.08 lbs	Calculated

ROAD STREAM CROSSING INVENTORY TABLE - PART A							
SITE ID	STREAM	ROAD	COUNTY	TOWNSHIP	TOWN	RANGE	SECT
BT_B061	Betsie River	Old King Rd	Benzie	Weldon	25N	14W	19
BT_B107A	Cold Creek	US-31	Benzie	Benzonia	26N	15W	23
BT_B107B	Cold Creek	East St	Benzie	Benzonia	26N	15W	23
BT_B108A	Cold Creek	Elderidge Rd	Benzie	Benzonia	26N	15W	24
BT_B108B	Cold Creek	Narrow Gauge Rd	Benzie	Benzonia	26N	15W	24
BT_B109	Cold Creek	Eastman Rd	Benzie	Benzonia	26N	15W	25
BT_B110	Cold Creek	Narrow Gauge Rd	Benzie	Benzonia	26N	15W	24
BT_G005	Mason Creek	M-37	Grand Traverse	Blair	26N	11W	20
BT_G006	Mason Creek	Mill Rd	Grand Traverse	Blair	26N	11W	27
BT_G007	Mason Creek	Co. 633	Grand Traverse	Green Lake	26N	12W	24
BT_G008A	Mason Creek	Co. 633	Grand Traverse	Green Lake	26N	12W	25
BT_G008B	Mason Creek	Co. 633	Grand Traverse	Green Lake	26N	12W	25
BT_G009	Brigham Creek	E Duck Lake Rd	Grand Traverse	Green Lake	26N	12W	25
BT_G010	Brigham Creek	E Duck Lake Rd	Grand Traverse	Green Lake	26N	12W	25
BT_G011	Brigham Creek	Hulett Rd	Grand Traverse	Green Lake	26N	12W	26
BT_G012	Brigham Creek	E Duck Lake Rd	Grand Traverse	Green Lake	26N	12W	26
BT_G013	Mason Creek	E Duck Lake Rd	Grand Traverse	Green Lake	26N	12W	23
BT_G015	Duck Lake/Green Lake connector stream	M-137	Grand Traverse	Green Lake	26N	12W	21
BT_G017	Unknown (Near Tullers Lake)	Riley Rd	Grand Traverse	Green Lake	26N	12W	16
BT_G018	Unknown	Cedar Hedge Lake Access Rd	Grand Traverse	Green Lake	26N	12W	8
BT_G019	Unknown (Near Cedar Hedge Lake)	US-31	Grand Traverse	Green Lake	26N	12W	8
BT_G020	Unknown (Near Tonowanda Lake)	Birch Rd.	Grand Traverse	Green Lake	26N	12W	15
BT_G021	Unknown (Near Ellis Lake)	US-31	Grand Traverse	Green Lake	26N	12W	10
B-012	Little Betsie River	Nessen Rd	Benzie	Colfax	25N	13W	28
B-017	Little Betsie River	Bentley Rd	Benzie	Colfax	25N	13W	29
B-018	Little Betsie River	Bentley Rd	Benzie	Colfax	25N	13W	30
B-020	Betsie River	King Rd	Benzie	Weldon	25N	14W	24
BT_G014	Horton Creek	Youker Rd	Grand Traverse	Green Lake	26N	12W	34

ROAD STREAM CROSSING INVENTORY TABLE - PART B									
SITE ID	LON	LAT	CROSSING TYPE	ROAD SURFACE	SEVERITY	INVENTORY YEAR	SEDIMENT LOADING	PHOS LOADING	LOADING METHOD
BT_B061	-86.055833	+44.551362	Other	Paved	Restored	2014	0.23 T	0.19 lbs	Calculated
BT_B107A	-86.090190	+44.632320	Culvert(S)	Paved	Moderate	2014	1.40 T	1.19 lbs	Calculated
BT_B107B	-86.090300	+44.632180	Culvert(S)	Paved	Minor	2014	0.10 T	0.09 lbs	Calculated
BT_B108A	-86.078850	+44.632240	Culvert(S)	Paved	Moderate	2014	0.99 T	0.84 lbs	Calculated
BT_B108B	-86.078850	+44.632240	Culvert(S)	Paved	Moderate	2014	0.39 T	0.33 lbs	Calculated
BT_B109	-86.070070	+44.631970	Culvert(S)	Paved	Moderate	2014	0.59 T	0.50 lbs	Calculated
BT_B110	-86.063060	+44.632410	Culvert(S)	Paved	Moderate	2014	0.38 T	0.32 lbs	Calculated
BT_G005	-85.655920	+44.635110	Culvert(S)	Paved	Moderate	2014	1.00 T	0.85 lbs	Calculated
BT_G006	-85.627460	+44.618340	Culvert(S)	Gravel	Severe	2014	3.63 T	3.08 lbs	Calculated
BT_G007	-85.696400	+44.639410	Culvert(S)	Paved	Moderate	2014	0.79 T	0.67 lbs	Calculated
BT_G008A	-85.696570	+44.623090	Culvert(S)	Paved	Severe	2011	2.91 T	2.48 lbs	Calculated
BT_G008B	-85.696570	+44.623630	Culvert(S)	Paved	Severe	2014	2.91 T	2.48 lbs	Calculated
BT_G009	-85.709480	+44.614180	Culvert(S)	Paved	Moderate	2014	1.13 T	0.96 lbs	Calculated
BT_G010	-85.712350	+44.614300	Culvert(S)	Paved	Severe	2014	0.26 T	0.22 lbs	Calculated
BT_G011	-85.716840	+44.616360	Culvert(S)	Gravel	Moderate	2014	0.52 T	0.44 lbs	Calculated
BT_G012	-85.726180	+44.620190	Culvert(S)	Paved	Moderate	2014	0.36 T	0.31 lbs	Calculated
BT_G013	-85.721290	+44.631310	Culvert(S)	Paved	Severe	2014	40.27 T	34.23 lbs	Calculated
BT_G015	-85.767340	+44.641460	Bridge	Paved	Moderate	2014	0.63 T	0.54 lbs	Calculated
BT_G017	-85.776880	+44.644070	Culvert(S)	Paved	Moderate	2014	0.98 T	0.83 lbs	Calculated
BT_G018	-85.793370	+44.667520	Culvert(S)	Gravel	Moderate	2014	5.65 T	4.80 lbs	Calculated
BT_G019	-85.783590	+44.658860	Bridge	Paved	Moderate	2014	1.77 T	1.51 lbs	Calculated
BT_G020	-85.751274	+44.654034	Culvert(S)	Gravel	Severe	2014	2.02 T	1.72 lbs	Calculated
BT_G021	-85.750120	+44.658540	Bridge	Paved	Moderate	2014	1.67 T	1.42 lbs	Calculated
B-012	-85.878270	+44.533170	Bridge	Paved	Restored		0.00 T	0.00 lbs	Calculated
B-017	-85.910420	+44.534780	Culvert(S)	Paved	Restored		0.10 T	0.08 lbs	Calculated
B-018	-85.930150	+44.534970	Culvert(S)	Paved	Restored		0.06 T	0.05 lbs	Calculated
B-020	-85.942460	+44.542210	Bridge	Paved	Restored		1.85 T	1.57 lbs	Calculated
BT_G014	-85.740900	+44.599750	Culvert(S)	Paved	Minor		0.66 T	0.56 lbs	Calculated

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Appendix E: Streambank Erosion Site Inventory Tables

STREAMBANK EROSION SITE INVENTORY TABLE																	
SITE ID	STREAM	COUNTY	TOWNSHIP	OWNER	TOWN	RANGE	SECTION	LON	LAT	SCORE	SEVERITY	BANK	TREND	% VEGETATION	CURRENT	SEDIMENT LOADING	PHOS LOADING
BTS-001	Betsie River	Benzie	Colfax Twp	State	25N	13W	2	-85.848950	+44.589490	30	Moderate	Left	Increasing	0-10%	Slow	8.80 T	7.48 lbs
BTS-002	Betsie River	Benzie	Colfax Twp	State	25N	13W	2	-85.849090	+44.589310	22	Minor	Left	Stable	11-50%	Slow	4.23 T	3.59 lbs
BTS-003	Betsie River	Benzie	Colfax Twp	Private	25N	13W	9	-85.882810	+44.572770	25	Minor	Right	Stable	11-50%	Fast	0.91 T	0.78 lbs
BTS-004	Betsie River	Benzie	Colfax Twp	Private	25N	13W	9	-85.888620	+44.572740	26	Minor	Right	Stable	51-100%	Fast	1.34 T	1.14 lbs
BTS-005	Betsie River	Benzie	Colfax Twp	Private	25N	13W	9	-85.889710	+44.572140	28	Moderate	Right	Increasing	11-50%	Fast	5.32 T	4.52 lbs
BTS-006	Betsie River	Benzie	Colfax Twp	Private	25N	13W	9	-85.893070	+44.570670	31	Moderate	Right	Increasing	10-50%	Slow	2.23 T	1.89 lbs
BTS-007	Betsie River	Benzie	Colfax Twp	Private	25N	13W	16	-85.892420	+44.569950	24	Minor	Left	Stable	11-50%	Fast	2.88 T	2.88 lbs
BTS-008	Betsie River	Benzie	Colfax Twp	State	25N	13W	16	-85.893940	+44.569410	29	Moderate	Left	Increasing	51-100%	Fast	7.42 T	6.31 lbs
BTS-009	Betsie River	Benzie	Colfax Twp	State	25N	13W	16	-85.897480	+44.567030	29	Moderate	Right	Increasing	11-50%	Fast	1.80 T	1.53 lbs
BTS-010	Betsie River	Benzie	Colfax Twp	Private	25N	13W	17	-85.912520	+44.562530	31	Moderate	Left	Increasing	10-50%	Slow	18.56 T	15.78 lbs
BTS-011	Betsie River	Benzie	Colfax Twp	Private	25N	13W	17	-85.913850	+44.563210	36	Severe	Right	Increasing	0-10%	Slow	53.46 T	45.44 lbs
BTS-012	Betsie River	Benzie	Colfax Twp	Private	25N	13W	17	-85.913860	+44.562710	24	Minor	Right	Stable	11-50%	Fast	0.61 T	0.52 lbs
BTS-013	Betsie River	Benzie	Colfax Twp	Private	25N	13W	17	-85.913860	+44.562710	24	Minor	Right	Stable	11-50%	Fast	0.68 T	0.58 lbs
BTS-014	Betsie River	Benzie	Colfax Twp	Private	25N	13W	19	-85.922630	+44.553910	28	Moderate	Right	Stable	11-50%	Fast	22.54 T	22.54 lbs
BTS-015	Betsie River	Benzie	Colfax Twp	Private	25N	13W	19	-85.923410	+44.552310	29	Moderate	Right	Stable	11-50%	Fast	14.42 T	14.42 lbs
BTS-016	Betsie River	Benzie	Colfax Twp	Private	25N	13W	19	-85.923520	+44.551720	31	Moderate	Left	Increasing	11-50%	Slow	16.23 T	16.23 lbs
BTS-017	Betsie River	Benzie	Colfax Twp	Private	25N	13W	19	-85.927450	+44.551570	29	Moderate	Left	Increasing	0-10%	Fast	11.74 T	9.98 lbs
BTS-018	Betsie River	Benzie	Colfax Twp	Private	25N	13W	19	-85.932980	+44.549280	20	Minor	Left	Stable	51-100%	Fast	0.74 T	0.63 lbs
BTS-019	Betsie River	Benzie	Colfax Twp	Private	25N	13W	19	-85.933320	+44.550010	26	Moderate	Right	Increasing	11-50%	Slow	18.56 T	15.78 lbs
BTS-020	Betsie River	Benzie	Colfax Twp	Private	25N	13W	19	-85.934230	+44.548050	31	Moderate	Left	Increasing	11-50%	Slow	9.28 T	7.89 lbs
BTS-021	Betsie River	Benzie	Weldon Twp	Private	25N	14W	25	-85.943560	+44.539900	31	Moderate	Left	Increasing	10-50%	Fast	29.70 T	25.24 lbs
BTS-022	Betsie River	Benzie	Weldon Twp	Private	25N	14W	25	-85.942820	+44.538590	41	Severe	Left	Increasing	0-10%	Fast	155.92 T	132.53 lbs
BTS-023	Betsie River	Benzie	Weldon Twp	Private	25N	14W	25	-85.946030	+44.534130	31	Moderate	Left	Increasing	11-50%	Fast	4.56 T	3.88 lbs
BTS-024	Betsie River	Benzie	Weldon Twp	Private	25N	14W	25	-85.946850	+44.533190	34	Severe	Left	Increasing	11-50%	Fast	40.73 T	37.67 lbs
BTS-025	Betsie River	Benzie	Weldon Twp	Private	25N	14W	25	-85.947190	+44.533080	35	Severe	Right	Increasing	0-10%	Fast	23.76 T	20.19 lbs
BTS-026	Betsie River	Benzie	Weldon Twp	Private	25N	14W	25	-85.949320	+44.532240	31	Moderate	Right	Stable	0-10%	Fast	18.24 T	15.51 lbs
BTS-027	Betsie River	Benzie	Weldon Twp	Private	25N	14W	25	-85.949130	+44.531410	37	Severe	Left	Increasing	0-10%	Fast	42.77 T	36.35 lbs
BTS-028	Betsie River	Benzie	Weldon Twp	Private	25N	14W	36	-85.955810	+44.523480	25	Moderate	Left	Increasing	10-50%	Slow	8.22 T	6.98 lbs
BTS-029	Betsie River	Benzie	Weldon Twp	State	25N	14W	36	-85.956860	+44.524610	30	Moderate	Left	Increasing	0-10%	Fast	3.04 T	2.58 lbs
BTS-030	Betsie River	Benzie	Weldon Twp	Private	25N	14W	35	-85.960520	+44.525310	26	Minor	Right	Stable	11-50%	Fast	4.16 T	3.53 lbs
BTS-031	Betsie River	Benzie	Weldon Twp	Private	25N	14W	35	-85.963410	+44.522590	32	Severe	Right	Increasing	10-50%	Slow	42.26 T	35.92 lbs
BTS-032	Betsie River	Benzie	Weldon Twp	Private	25N	14W	35	-85.960480	+44.516670	32	Severe	Left	Increasing	10-50%	Fast	23.76 T	20.19 lbs
BTS-033	Betsie River	Benzie	Weldon Twp	Private	25N	14W	35	-85.962040	+44.516040	25	Minor	Right	Stable	51-100%	Fast	13.68 T	11.63 lbs

STREAMBANK EROSION SITE INVENTORY TABLE

SITE ID	STREAM	COUNTY	TOWNSHIP	OWNER	TOWN	RANGE	SECTION	LON	LAT	SCORE	SEVERITY	BANK	TREND	% VEGETATION	CURRENT	SEDIMENT LOADING	PHOS LOADING
BTS-034	Betsie River	Benzie	Weldon Twp	Private	25N	14W	35	-85.959520	+44.513410	31	Moderate	Left	Increasing	11-50%	Slow	11.88 T	10.10 lbs
BTS-035	Betsie River	Manistee	Springdale Twp	Private	24N	14W	2	-85.961530	+44.511280	35	Severe	Left	Increasing	0-10%	Fast	9.12 T	7.75 lbs
BTS-036	Betsie River	Manistee	Springdale Twp	Private	24N	14W	2	-85.961760	+44.510710	23	Minor	Left	Stable	11-50%	Fast	2.43 T	2.07 lbs
BTS-037	Betsie River	Manistee	Springdale Twp	Private	24N	14W	2	-85.960310	+44.510240	36	Severe	Right	Increasing	0-10%	Fast	12.77 T	10.85 lbs
BTS-038	Betsie River	Manistee	Springdale Twp	Private	24N	14W	2	-85.959920	+44.509870	35	Severe	Left	Increasing	11-50%	Fast	142.55 T	121.17 lbs
BTS-039	Betsie River	Manistee	Springdale Twp	Private	24N	14W	2	-85.970110	+44.506820	30	Moderate	Left	Increasing	11-50%	Slow	5.05 T	4.29 lbs
BTS-040	Betsie River	Manistee	Springdale Twp	Private	24N	14W	2	-85.973920	+44.504330	31	Moderate	Right	Stable	0-10%	Fast	45.08 T	45.08 lbs
BTS-041	Betsie River	Manistee	Springdale Twp	Private	24N	14W	2	-85.975420	+44.503140	25	Minor	Right	Stable	11-50%	Fast	4.81 T	4.81 lbs
BTS-042	Betsie River	Manistee	Springdale Twp	State	24N	14W	2	-85.978210	+44.500840	36	Severe	Right	Increasing	11-50%	Fast	47.52 T	40.39 lbs
BTS-043	Betsie River	Manistee	Springdale Twp	State	24N	14W	3	-85.980140	+44.501610	32	Severe	Right	Increasing	0-10%	Slow	24.04 T	24.04 lbs
BTS-044	Betsie River	Manistee	Springdale Twp	Private	24N	14W	3	-85.981980	+44.501500	27	Moderate	Left	Stable	50-100%	Fast	47.89 T	47.89 lbs
BTS-045	Betsie River	Manistee	Springdale Twp	Private	24N	14W	3	-85.984770	+44.501360	27	Minor	Right	Stable	51-100%	Fast	9.50 T	9.50 lbs
BTS-046	Betsie River	Manistee	Springdale Twp	Private	24N	14W	10	-85.985820	+44.497610	30	Moderate	Left	Increasing	11-50%	Fast	3.56 T	3.03 lbs
BTS-047	Betsie River	Manistee	Springdale Twp	Private	24N	14W	10	-85.986850	+44.496460	28	Moderate	Left	Increasing	0-10%	Fast	4.45 T	4.12 lbs
BTS-048	Betsie River	Manistee	Springdale Twp	Private	24N	14W	10	-85.994230	+44.493720	28	Moderate	Left	Stable	11-50%	Fast	20.79 T	17.67 lbs
BTS-049	Betsie River	Manistee	Springdale Twp	Private	24N	14W	10	-85.999010	+44.493660	27	Minor	Left	Increasing	11-50%	Fast	2.55 T	2.35 lbs
BTS-050	Betsie River	Manistee	Springdale Twp	Private	24N	14W	10	-85.998610	+44.493990	31	Moderate	Right	Increasing	0-10%	Fast	2.39 T	2.21 lbs
BTS-051	Betsie River	Manistee	Springdale Twp	Private	24N	14W	9	-86.001980	+44.494740	31	Moderate	Left	Increasing	11-50%	Slow	20.54 T	17.46 lbs
BTS-052	Betsie River	Manistee	Springdale Twp	Private	24N	14W	9	-86.013730	+44.492490	38	Severe	Right	Increasing	0-10%	Fast	57.70 T	57.70 lbs
BTS-053	Betsie River	Manistee	Springdale Twp	Private	24N	14W	9	-86.018230	+44.492650	33	Severe	Right	Increasing	11-50%	Fast	36.66 T	33.91 lbs
BTS-054	Betsie River	Manistee	Springdale Twp	Private	24N	14W	8	-86.020220	+44.492910	26	Minor	Left	Increasing	50-100%	Slow	2.84 T	2.41 lbs
BTS-055	Betsie River	Manistee	Springdale Twp	Private	24N	14W	9	-86.019080	+44.493480	31	Moderate	Right	Increasing	11-50%	Fast	45.08 T	45.08 lbs
BTS-056	Betsie River	Manistee	Springdale Twp	Private	24N	14W	8	-86.023980	+44.493310	28	Moderate	Right	Stable	11-50%	Fast	19.09 T	17.66 lbs
BTS-057	Betsie River	Manistee	Springdale Twp	Private	24N	14W	8	-86.027440	+44.494870	28	Moderate	Right	Stable	11-50%	Fast	36.06 T	36.06 lbs
BTS-058	Betsie River	Manistee	Springdale Twp	State	24N	14W	8	-86.035930	+44.497060	35	Severe	Right	Increasing	0-10%	Fast	14.85 T	12.62 lbs
BTS-059	Betsie River	Manistee	Springdale Twp	State	24N	14W	5	-86.035210	+44.503230	27	Minor	Right	Stable	11-50%	Fast	14.26 T	12.12 lbs
BTS-060	Betsie River	Manistee	Springdale Twp	Private	24N	14W	5	-86.034670	+44.505770	20	Minor	Right	Increasing	11-50%	Fast	2.27 T	1.93 lbs
BTS-061	Betsie River	Manistee	Springdale Twp	Private	24N	14W	6	-86.042560	+44.513720	23	Minor	Right	Stable	11-50%	Fast	3.04 T	2.58 lbs
BTS-062	Betsie River	Benzie	Weldon Twp	Private	25N	14W	31	-86.042680	+44.516240	24	Moderate	Right	Stable	11-50%	Fast	132.07 T	112.26 lbs
BTS-063	Betsie River	Benzie	Weldon Twp	Private	25N	14W	31	-86.044230	+44.518830	33	Severe	Right	Increasing	11-50%	Fast	23.76 T	20.19 lbs
BTS-064	Betsie River	Benzie	Weldon Twp	Private	25N	14W	31	-86.051390	+44.517670	27	Minor	Right	Stable	0-10%	Fast	3.65 T	3.10 lbs
BTS-065	Betsie River	Benzie	Joyfield Twp	Private	25N	15W	36	-86.062010	+44.526180	31	Moderate	Right	Stable	0-10%	Fast	84.15 T	84.15 lbs
BTS-066	Betsie River	Benzie	Joyfield Twp	Private	25N	15W	36	-86.060230	+44.528950	37	Severe	Right	Increasing	0-10%	Fast	96.17 T	96.17 lbs

STREAMBANK EROSION SITE INVENTORY TABLE																	
SITE ID	STREAM	COUNTY	TOWNSHIP	OWNER	TOWN	RANGE	SECTION	LON	LAT	SCORE	SEVERITY	BANK	TREND	% VEGETATION	CURRENT	SEDIMENT LOADING	PHOS LOADING
BTS-067	Betsie River	Benzie	Weldon Twp	Private	25N	14W	30	-86.058940	+44.531060	28	Moderate	Left	Stable	11-50%	Fast	59.40 T	59.40 lbs
BTS-068	Betsie River	Benzie	Weldon Twp	Private	25N	14W	30	-86.054030	+44.535670	33	Severe	Right	Increasing	11-50%	Fast	25.46 T	23.55 lbs
BTS-069	Betsie River	Benzie	Weldon Twp	State	25N	14W	19	-86.056280	+44.550590	29	Moderate	Left	Stable	51-100%	Fast	72.12 T	72.12 lbs
BTS-081	Betsie River	Benzie	Benzonia Twp	State	25N	15W	2	-86.082090	+44.598240	20	Minor	Right	Stable	51-100%	Fast	8.17 T	8.17 lbs
BTS-082	Betsie River	Benzie	Benzonia Twp	Private	25N	15W	2	-86.096530	+44.599830	27	Minor	Left	Stable	0-10%	Fast	3.61 T	3.61 lbs
BTS-083	Betsie River	Benzie	Benzonia Twp	State	25N	15W	2	-86.098560	+44.600770	24	Moderate	Right	Stable	50-100%	Slow	25.83 T	21.95 lbs
BTS-084	Betsie River	Benzie	Benzonia Twp	Private	25N	15W	3	-86.102080	+44.602990	29	Moderate	Right	Increasing	11-50%	Fast	27.84 T	25.75 lbs
BTS-085	Betsie River	Benzie	Benzonia Twp	Private	26N	15W	34	-86.104080	+44.603480	38	Severe	Right	Increasing	10-50%	Fast	91.64 T	84.77 lbs
BTS-086	Betsie River	Benzie	Benzonia Twp	Private	26N	15W	34	-86.107910	+44.603890	30	Moderate	Right	Increasing	10-50%	Fast	19.23 T	19.23 lbs
BTS-087	Betsie River	Benzie	Benzonia Twp	State	26N	15W	34	-86.113020	+44.606270	29	Moderate	Right	Increasing	10-50%	Slow	22.54 T	22.54 lbs
BTS-070	Betsie River	Benzie	Weldon Twp	Private	25N	14W	18	-86.052150	+44.558120	29	Moderate	Right	Increasing	11-50%	Fast	35.15 T	32.52 lbs
BTS-071	Betsie River	Benzie	Weldon Twp	Private	25N	14W	18	-86.052440	+44.558810	30	Moderate	Right	Increasing	11-50%	Slow	6.31 T	5.36 lbs
BTS-072	Betsie River	Benzie	Weldon Twp	Private	25N	14W	18	-86.052810	+44.561290	36	Severe	Left	Increasing	0-10%	Fast	16.63 T	14.14 lbs
BTS-073	Betsie River	Benzie	Weldon Twp	State	25N	14W	18	-86.053410	+44.564660	31	Moderate	Left	Increasing	11-50%	Slow	21.13 T	17.96 lbs
BTS-074	Betsie River	Benzie	Weldon Twp	State	25N	14W	18	-86.050030	+44.569210	26	Moderate	Right	Increasing	10-50%	Fast	3.08 T	2.62 lbs
BTS-075	Betsie River	Benzie	Weldon Twp	State	25N	14W	18	-86.052190	+44.572090	29	Moderate	Left	Increasing	10-50%	Slow	44.02 T	37.42 lbs
BTS-076	Betsie River	Benzie	Weldon Twp	Private	25N	14W	7	-86.052510	+44.573290	31	Moderate	Left	Increasing	10-50%	Fast	14.85 T	12.62 lbs
BTS-077	Betsie River	Benzie	Weldon Twp	Private	25N	14W	7	-86.051170	+44.576470	29	Moderate	Right	Increasing	50-100%	Fast	29.94 T	25.45 lbs
BTS-078	Betsie River	Benzie	Weldon Twp	Private	25N	14W	6	-86.056940	+44.587840	30	Moderate	Right	Increasing	10-50%	Slow	8.91 T	7.57 lbs
BTS-079	Betsie River	Benzie	Benzonia Twp	Private	25N	15W	1	-86.077840	+44.595770	31	Moderate	Right	Increasing	0-10%	Slow	12.73 T	11.77 lbs
BTS-080	Betsie River	Benzie	Benzonia Twp	Private	25N	15W	1	-86.078760	+44.595570	33	Severe	Left	Increasing	0-10%	Slow	26.93 T	26.93 lbs

STREAMBANK EROSION SEVERITY INDEX (SCORE)

Items from site data sheet are used in determining severity index.

1. Condition of the bank
   1 pt. – Toe is stable, upper bank eroding
   3 pts. – Toe is undercutting
   5 pts. – Both toe and upper bank are eroding

2. Condition trend
   1 pt. – Stable
   1 pt. – Decreasing
   5 pts. – Increasing

3. Amount of vegetative cover on bank slope
   1 pt. – 50 to 100%
   3 pts. – 10-50%
   5 pts. – 1 to 10%

4. Apparent cause of bank erosion (can use more than one)
   1 pt. – Obstruction in river
   2 pts. – Bend in river
   1 pt. – Bank seepage
   1 pt. – Gullying from side channels
   1 pt. – Foot traffic

5. Depth of river
   1 pt. – 0 to 2 ft.
   2 pts. – 3 ft. or greater

6. Current
   1pt – Slow
   2 pts – Medium
   3 pts – Fast

7. Length of eroded bank
   1 pt – 0 to 20 ft
   3 pts – 21 to 50 ft
   5 pts – 51 ft or greater

8. Height of eroded bank
   1 pt – 0 to 5 ft
   3 pts – 5 to 10 ft
   5 pts – 10 to 20 ft
   7 pts – 20ft or greater

9. Slope of eroded bank
   1 pt – 4:1 or greater
   2 pts – 2:1 or 3:1
   5 pts – Vertical or 1:1

10. Soil texture of bank
   1 pt. – Clay or loam
   2 pts – Gravel or stratified
   3 pts – Sand

SEVERITY

The total assigned points determine the erosion severity as follows:

Minor erosion – less than 28 points

Moderate erosion – 28 to 31 points

Severe erosion – 32 points & greater

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Appendix F: Landscape Level Functional Wetland Assessment Methodology Report

LANDSCAPE LEVEL WETLAND FUNCTIONAL ASSESSEMENT (LLWFA)

Version 1.0

Methodology Report

Updated October 1, 2013

Michigan Department of Environmental Quality

Wetland Program Development Grant 2008: Landscape Level Wetland Functional Assessment Final Report

Abstract: The emergence of watershed management planning is driving an interest in understanding the relationship between wetland loss and degraded surface water quality. In addition to quantifying wetland loss, there has been a strong push recently to interpret loss of wetland function on a landscape level, and to incorporate that information into a watershed management context. In a 1990 report to Congress, the Michigan Department of Natural Resources (MDNR) and the U.S. Department of the Interior estimated that Michigan had lost approximately 50% of its original wetland resource base.

Though calculations on wetland quantity can give us an idea of overall impact, studies in the Northeast have shown the available spatial information can be enhanced to estimate qualitative loss of wetland function. Based on a technique developed in the US Fish and Wildlife Service's (USFWS) Northeast Region additional information can be added to the National Wetland Inventory (NWI) database to characterize 13 general wetland functions at a landscape level. In cooperation with the Michigan Nonpoint Source Unit, this technique was applied to assist with watershed management plans with wetland conservation and restoration strategies for their watershed projects. Thirty separate 319 watershed groups around the state have either completed LLWFA analysis, or are slated for completion in the next 2 years. Several municipalities have incorporated these efforts into part of their master planning process.

As part of the LLWFA efforts, watershed stakeholders receive the latest in geographic information system (GIS) technology, allowing groups that formerly had no GIS expertise in house to make the best possible use of the wetland mapping information.

Working closely with an advisory group of Michigan biologists, ecologists, and other specialists from numerous other relevant wetland-related fields, the LLWFA methods have been refined and updated to reflect the regional differences in wetland ecosystems from the northeast to the Midwest.

Training of local watershed planners, GIS outputs, and refining of documentation have been a major focus of this project.

INTRODUCTION

The USFWS has been conducting the NWI for over 25 years. The NWI Program has produced wetland maps for 91% (78% final) of the lower 48 states, all of Hawaii, and 35% of Alaska. Wetlands are classified according to the Service's official wetland classification system (Cowardin et al. 1979). This classification describes wetlands by ecological system (marine, estuarine, lacustrine, riverine, and palustrine), by subsystem (e.g., water depth, exposure to tides), class (vegetative life form or substrate type), subclass, water regimes (hydrology), water chemistry (pH and salinity), and special modifiers (e.g., alterations by humans). The availability of digital data and GIS technology make it possible to use NWI data for various geospatial analyses.

In the 1990s, the NWI Program for the Northeast Region recognized the potential application of NWI data for watershed assessments, but realized that other attributes would have to be added to the data to facilitate functional analysis. Dr. Mark Brinson had recently developed a hydrogeomorphic (HGM) approach to wetland functional assessment (Brinson, 1993). This approach provided the impetus for developing other attributes to expand the NWI database and make it more useful for functional assessment.

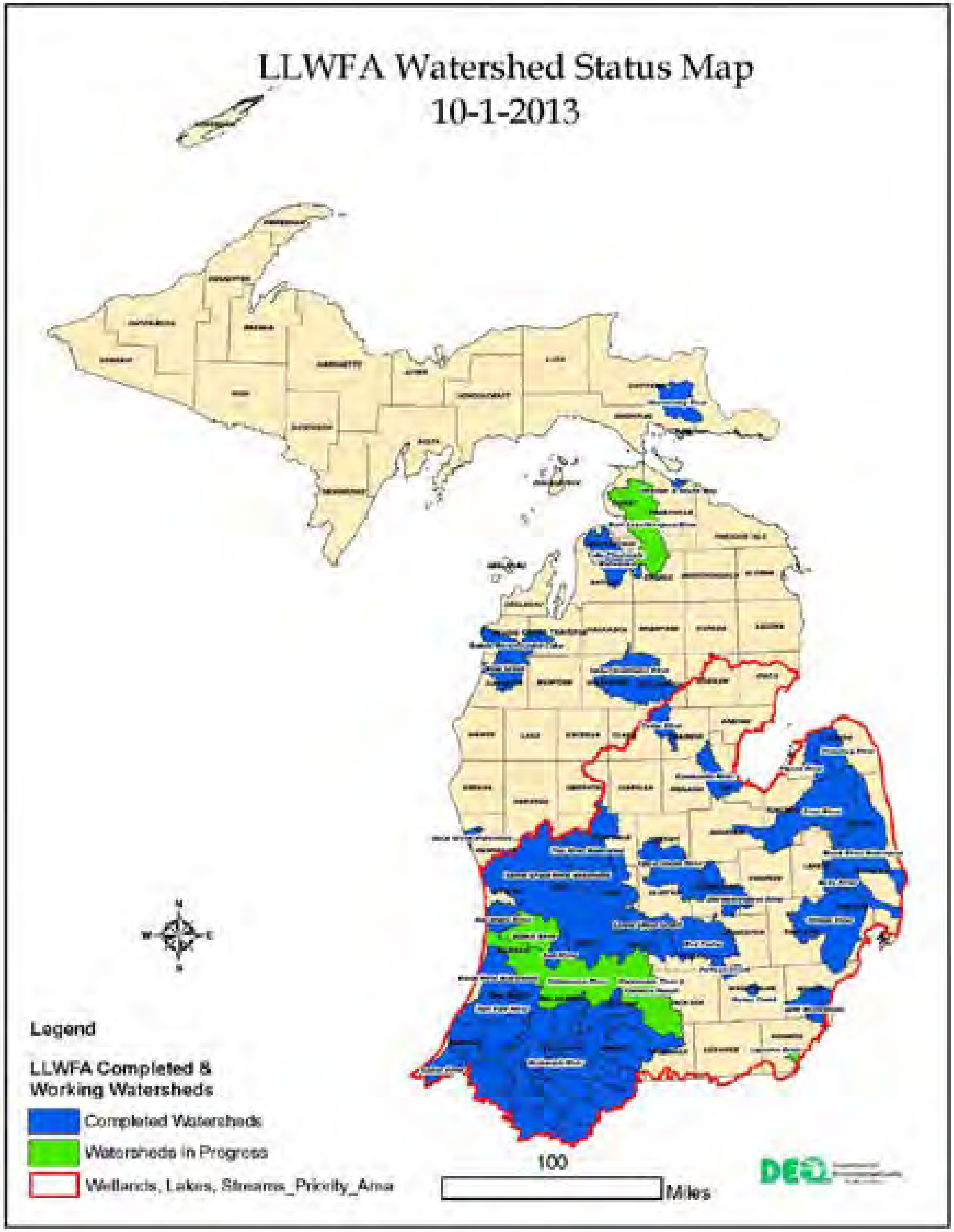
In the mid-1990s, a set of HGM-type descriptors were developed to describe a wetland's landscape position, landform, and water flow path (Tiner, 2002). These projects were watershed characterizations that included a preliminary assessment of wetland functions as a main component or the prime component of the study. Of the 4 LLWW descriptors (landscape position, landform, water flow path and waterbody type), as they're referred to in Tiner's Nanticoke Watershed study in Maryland (Tiner, 2004), three were derived from the three core components in Brinson's (Brinson, 1993) approach to wetland functional classification. Geomorphic Setting (landscape position) refers to the topographic location of the wetland within the surrounding landscape. Water source and its transport (relates to landform) refers to the hydrologic input into a given wetland, which has been adapted and refined in this analysis. Hydrodynamics (water flow path) refers to the motion of water and the capacity of that water to do work (i.e., transport sediments, transport nutrients to root surfaces) (Brinson, 1993).

In conducting these studies, USFWS worked with local and regional wetland experts to develop correlations between these wetland characteristics as recorded in the NWI database and wetland functions. These correlations reflect the best approximation of what types of wetlands are likely to perform certain functions at significant levels based on the characteristics we have in the NWI database (Tiner, 2003b). Given that the functional correlations were developed for the Northeast Region of the country, an advisory group was convened in Michigan to address regional differences and develop functional correlations that better fit Michigan's diverse wetland resource base. Though the information contained within a LLWFA analysis is intended to be an approximation of wetland function across a landscape, there is defensible logic in connecting fundamental wetland properties with ecological significance (Brinson, 1993). This type of analysis assumes that given sufficient information on geomorphic setting, water source, and water movement, it should be possible to make reasonable judgments on how these physical properties can be translated into wetland functions.

Background

The Michigan Department of Environmental Quality (MDEQ) has been working since 2006 on refining and expanding the use of the LLWFA across much of the state. Each year, the MDEQ Nonpoint Source Unit is the main entity which distributes 319 watershed planning funds to local units of government, non-profit organizations, and numerous other state, federal, and local partners to reduce nonpoint source pollution statewide. Their yearly prioritization of watershed planning efforts directly influenced the completion of LLWFA efforts, and the scale at which they work is a perfect fit for this landscape level wetland information. Twenty watersheds have been through the complete LLWFA process, and another ten watersheds are in some phase of completion. This approach addresses both a current (2005) wetland inventory and a Pre-European Settlement inventory, to approximate change over time, and provide the best information possible on wetland status and trends from original condition through today. These watershed planning organizations have utilized these tools to help them better evaluate projects for preserving or enhancing their current wetland resources and planning for restoration of lost resources. Restoring lost wetland functionality shows great promise in addressing the systemic cause of much of the non-point source pollution occurring in the state. The following map illustrates completed watersheds, and those in various phases of completion:

Figure 1: LLWFA Status Map as of 10/1/2013



METHODS-General

The LLWFA involved the completion of 5 major tasks:

1. Spatial Data Collection and Integration
2. Classification and Enhancement of NWI data with LLWW descriptors
3. Functional Correlations and Assessment
4. GIS Tool Development and Status and Trends Report
5. Training and Outreach

The first task assigned was to collect and integrate all GIS spatial data for the watershed that could be used to attempt an automated classification of the NWI polygons from a HGM and functional perspective. This data collection included:

Layer Name	Data Source	Description
National Wetlands Inventory	USFWS Service, National Wetlands Inventory	2005 National Wetland Inventory competed by Ducks Unlimited (Great Lakes/Atlantic Regional Office)
National Hydrography Dataset-High Resolution	US Geological Survey and the United States Environmental Protection Agency	Based upon Digital Line Graph (DLG) hydrography at 1:24,000 scale
Digital Raster Graphic (DRG) topography and DEM	US Geological Survey	Scanned USGS Topo quads
SSURGO Soil Surveys	Natural Resource Conservation Service	Digitized from Paper Soil Surveys at 1:24000
NAPP 1998 Digital Orthophoto Mosaics	US Geological Survey	Color Infra-Red Aerial Imagery
NAIP 2005 & 2010 Digital Orthophoto Mosaics	Natural Resource Conservation Service (NRCS)	Natural Color Aerial Imagery
CGI Framework Data	MI Center for Geographic Information	Includes roads, political boundaries, hydrography, census figures, etc
Michigan Natural Features Inventory Land Cover 1800	Michigan Natural Features Inventory (MNFI)	Land Cover data derived from General Land Office (GLO) Surveys from early to mid 1800's
DARCY Groundwater Movement Model	MDNR Institute for Fisheries Research	Predicts groundwater recharge/discharge based on topography and soils
Michigan Natural Features Inventory Biorarity Index	MNFI	Known sightings of threatened, endangered, or special concern species and high quality natural communities based on a 40 acre grid

Each dataset was necessary to complete one piece of the HGM classification. Of these datasets, topography and hydrography were the most utilized to determine the LLWW descriptors for each wetland in NWI. Results of this classification were then checked against the National Aerial Photography Program (NAPP) and National Agriculture Imagery Program (NAIP) photography to ensure consistency with current conditions. These datasets were integrated into a Geodatabase for use in ESRI ArcINFO 9.3 software. A geodatabase is a GIS data format that allows integration of disparate data sources into one centralized database, from which, all data can be accessed independently. This approach eases the difficulty in managing multiple GIS datasets concurrently.

The second task involved the actual LLWW classification of NWI polygons for various watersheds. Classification of HGM (LLWW) descriptors included populating the NWI database with information on; landscape position, landform, water flow path, and waterbody type. (Tiner, 2003a). Rivers, lakes, and ponds present in the NWI spatial data were classified in terms of waterbody type, and waterflow path. The method for classifying these LLWW descriptors involves a trained interpreter individually analyzing each and every polygon within each of the wetland inventories. The general methodology for determining values for each of the LLWW descriptors are determined as follows:

LANDFORM

Landform values are derived explicitly from Cowardin water regime information. A detailed breakdown of this classification is explained in more detail in Figure 7.

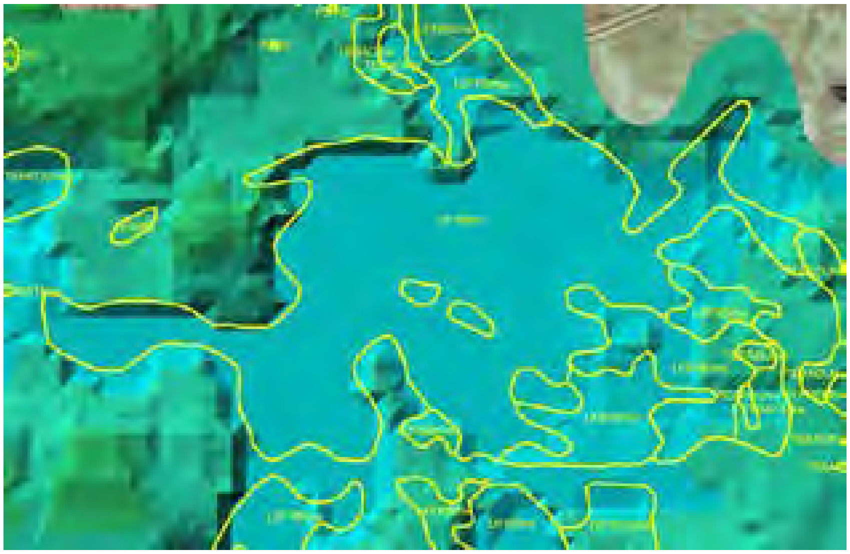
LANDSCAPE POSITION

Landscape position values are determined by cross referencing NWI with hydrology and topography. NWI polygons that spatially intersect a stream/river in the National Hydrography Dataset (NHD) are classified as lotic. Lotic type wetlands can be further refined to indicate their adjacency to a stream or a river (lotic stream or lotic river). High resolution NHD data was used to differentiate rivers from streams in this analysis. A NHD classification completed by MDNR, Institute for Fisheries Research separated rivers by temperature gradient (cold, cool, warm) and size, based on average water flows (cubic feet per second or CFS). This dataset was used in the LLWFA analysis to mark this distinction. An example of a lotic stream wetland is shown in Figure 2 below.

Figure 2: Lotic Stream Wetland Example

NWI Polygons that are determined to be within the basin of a lake are classified as lentic. Identifying the extent of a lake basin, and thus which wetlands fall within it, is done with the assistance of digital elevation models (DEM). An example of a lake basin shown on a DEM and wetlands falling within and outside of that basin is illustrated in Figure 3.

Figure 3: Lake Basin and adjacent wetlands shown on a DEM



NWI Polygons that don't intersect surface water features or aren't spatially located within a lake basin are classified as terrene. An example of a terrene wetland is shown in Figure 4 below.

Figure 4: Terrene wetland example

These automations of the classification process are sometimes limited by the source data used to make the determinations. It is then necessary for a trained interpreter to make a classification call based on best professional judgment. For example, if a wetland polygon is located within an area that is influenced by the hydrology of an adjacent stream, but the location of the linework misrepresents the spatial location of the actual stream on the ground, the wetland polygon will be misclassified as terrene. For a clear illustration of this concept, see Figure 5.

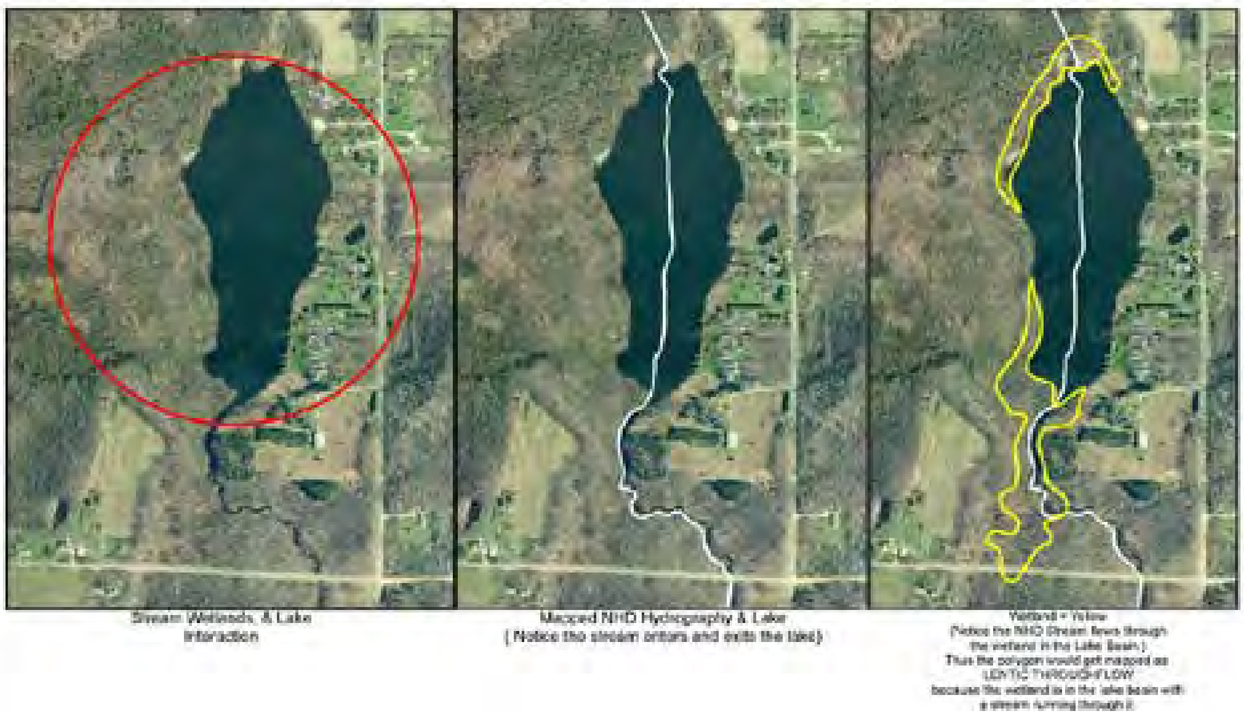
Figure 5: Hydrologic Mapping Error Resulting in Misclassification of a Wetland

WATER FLOW PATH

Water flow path, otherwise known as hydrodynamics, is classified by automated and manual interpretation of the intersection of NHD surface water features and NWI. Automated methods include intersecting NHD and NWI to capture throughflow wetlands (in-stream wetlands), both natural and artificial. A distinction is drawn in NHD between natural stream/river features and artificial canal/ditch features. Vegetated NWI wetlands that don't intersect any surface water body are classified as isolated. Detailed coding was developed in an effort to differentiate intermittent, artificial, and perennial connections between wetlands and other surface waterbodies. Any wetland classified as lentic (Landscape Position) is automatically assigned a water flow path of bidirectional, accounting for the tidal effects of lakes on adjacent wetlands.

Wetlands located at the terminus of a stream entering a lake are a special exception in that they are coded as lentic throughflow to account for the hydrologic influence the stream is having on that wetland, even though the wetland is also located in the lake basin. See Figure 6 for a detailed explanation of this exception:

Figure 6: Lentic Throughflow



WATERBODY TYPE

Waterbody type classification is the simplest of the 4 LLWW descriptors. Ponds, lakes, and rivers are classified as such based explicitly on NWI Cowardin code. Lakes and ponds were separated at the 5-acre mark, all open-water polygons less than or equal to 5 acres were classified as ponds, while all open-water polygons larger than 5 acres were classified as lakes. The 5 acre cutoff was chosen to remain consistent with previously existing MDEQ regulations. High resolution NHD data was used to differentiate rivers from streams in this analysis. A NHD classification completed by MDNR, Institute for Fisheries Research separated rivers by temperature gradient (cold, cool, warm) and size, based on average water flows (CFS) This dataset was used in the LLWFA analysis to mark this distinction.

Figure 7: LLWW Classification Detail

Landscape Position	Landform	Waterbody Type	Waterflow Path
Terrene (TE) Wetland that is: 1. Surrounded by upland 2. Borders a pond that is surrounded by upland. (*Modifier pd)* 3. Is adjacent to but is not affected by the stream/river.	**Slope (SL)** Wetlands occurring on a slope of 5% or greater.	**Natural Pond (PD1)** A natural pond that is less than 5 acres in size.	**Isolated (IS)** Wetland is typically surrounded by upland (non-hydric soil); receives precipitation and runoff from adjacent areas with no apparent outflow.
Lentic (LE) Wetland lies along a lake or within its basin (i.e., the relatively flat plain contiguous to the lake).	**Island (IL)** A wetland completely surrounded by water.	**Dike/Impounded Pond (PD2)** A pond that is diked/impounded and less than 5 acres in size.	**Inflow (IN)** Wetland is a sink receiving water from a river, stream, or other surface water source, lacking surface-water outflow.
Lotic River (LR) Wetland that is periodically flooded by a river.	**Fringe (FR)** Wetland occurs in the shallow water zone of a permanent waterbody. **NWI water regime F, G, and H*	**Excavated Pond (PD3)** A pond that is excavated and less than 5 acres in size.	**Outflow (OU)** Water flows out of the wetland naturally, but does not flow into this wetland from another source.
Lotic Stream (LS) Wetland that is periodically flooded by a stream.	**Floodplain (FP)** Wetland occurs on an active alluvial plain along a river and some streams. **Modifiers FPba (Basin) and FPfl (Flat)*	**Natural Lake (LK1)** A natural lake that is greater than 5 acres in size.	**Outflow Intermittent (OI)** Water flows out of the wetland intermittently, but does not flow into this wetland from another source.
	Basin (BA) Wetland occurs in a distinct depression. **NWI water regime C and E*	**Dammed River Valley (LK2)** A lake created by damming a river valley and greater than 5 acres in size.	**Outflow Artificial (OA)** Water flows out of the wetland, in a channel that was manipulated or artificially created.
	Flat (FL) Wetland occurs on a nearly level landform. **NWI water regime A and B*	**Excavated Lake (LK3)** A lake that is excavated and is greater than 5 acres in size.	**Throughflow (TH)** Water flows through the wetland, often coming from upstream sources (typically wetlands along rivers and streams).
		River (RV) A polygonal feature on a U.S. Geological Survey map (DRG) or a National Wetlands Inventory Map.	**Throughflow Intermittent (TI)** Water flows through the wetland intermittently, often coming from upstream sources (typically wetlands along streams).
			Throughflow Artificial (TA) Water flows through the wetland, in a channel that was manipulated or artificially created.

**** hw Modifier: Any landscape position or waterbody type associated with a 1st order stream*			**Bidirectional (BI)** Wetland along a lake and not along a river or stream entering this type of waterbody; its water levels are subjected to the rise and fall of the lake levels

Task number three involved connecting the HGM-coded NWI polygons with the functional correlations prepared by MDEQ with input from the LLWFA Advisory Council. Certain functions rely solely on the LLWW descriptors, others rely mainly on the NWI (Cowardin, 1979) Classification, and a third subset relies on a combination of the two. The functional correlations and the Watershed-based Preliminary Assessment of Wetland Functions (W-PAWF) will be discussed in greater detail later in this report.

The fourth task in the LLWFA process involves the products and reports that accompany the GIS classification and functional correlation, and present this information to an audience that typically has little to no exposure to these types of wetland concepts. Final deliverables for this effort include hard-copy maps illustrating wetland extent during Pre-European Settlement and 2005 eras, and predicted wetlands of significance for 13 functions. A status and trends document contrasting Pre-European Settlement wetlands to 2005 wetlands is also created for each watershed. A final statistical report is also included in the status and trends document illustrating approximate functional loss, wetland loss, and general information on how the LLWFA work was completed. Also provided for each watershed is a customized GIS tool that presents the totality of the information generated during the LLWW classification, functional correlations, and all source data used to complete the effort. This mapping tool allows for customized map creation utilizing aerial photography, hydrography, and any other relevant data to be overlain and utilized along with the wetland information. This free GIS product gives users the freedom to utilize the data for creation of maps intended for site specific application. Given the high cost of GIS software, and the expertise necessary to operate a comprehensive GIS, this particular piece of the LLWFA effort is a simple, valuable, and informative tool to local planning groups that are too often short of resources, monetary and otherwise.

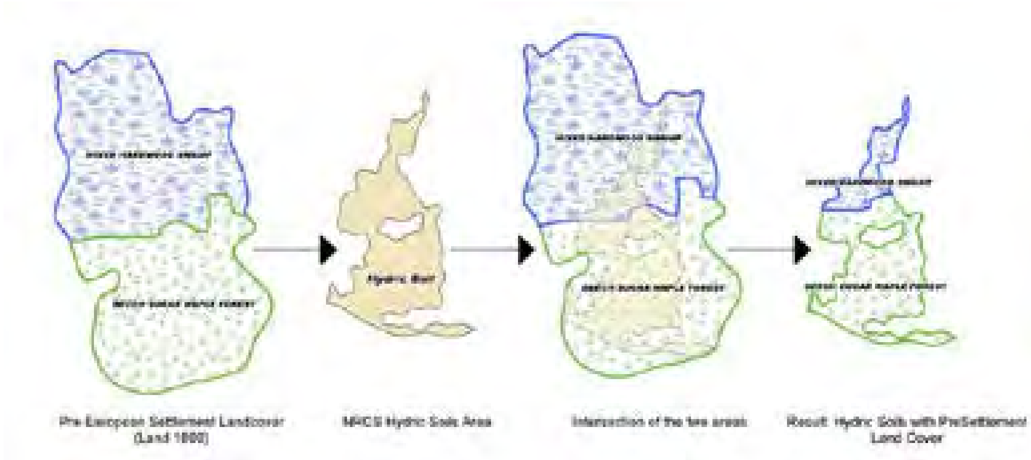
Finally, training and outreach has been an integral part of the LLWFA process. Given the relative complexity of this type of wetland assessment effort, significant time has been spent presenting the results of this analysis to watershed groups and other interested organizations, as well as in-depth training given to stakeholders likely to utilize this type of tool in their professional capacity. Twenty watersheds have been presented with information about their watershed and many have found this to be helpful on a planning scale as well as helpful in educating local stakeholders on the benefits of wetland functions and values. In 2010, a presentation was given at the semi-annual drain commissioner's conference, to highlight the potential of this type of landscape level assessment in restoring and protecting hydrologic condition. This audience was receptive to this type of planning tool, and showed significant interest in adapting this sort of approach in their activities. These types of additional applications for the LLWFA process are still being cultivated and explored, and represent part of the potential future for this tool.

METHODS - Pre-European Settlement Wetland Inventory (Presettlement NWI)

Estimating the extent of historic wetlands was completed through the use of several data sources, all of which required a level of assumption to ascertain the information needed for a useful and accurate functional classification. Given that fact, it is obvious that this dataset represents a best-guess approximation of wetland extent and condition in Pre- European Settlement times. The location and condition of Pre- European Settlement wetlands were derived from two major sources: (1) soil survey data from the United States Department of Agriculture Natural Resource Conservation Service (NRCS) based on 1:15,840 soil maps and (2) Michigan Natural Features Inventory (MNFI) Pre- European Settlement vegetation maps derived from General Land Office (GLO) Survey maps created between 1816 and 1856 (Comer, 1996). The former source was relied upon much more heavily with the secondary source filling in gaps in the classification of wetland type.

Hydric soil map units were culled from the soil survey data, including all major hydric units as well as complexes where hydric soils were deemed to be a significant part of the soils series (<15%). All hydric soil polygons were deemed historic wetland polygons for the purposes of this analysis. These polygons were then cross-referenced (overlain) with the Pre-European Settlement Land Cover Layer so that differing vegetation types were denoted as separate polygons within a single hydric soil unit. This intersection between the two layers is shown in Figure 8:

Figure 8: Diagram illustrating intersection of Hydric Soil Polygons with Pre- European Settlement Land Cover



The process shown in Figure 8 was automated using GIS tools and programming expertise to simplify and accelerate the speed at which this lengthy geoprocessing technique could be completed. This automation method is shown in detail in Appendix 1.

Because the spatial location of Pre-European Settlement wetlands are derived from soil polygons that have no accompanying Cowardin classification codes, these codes had to be created to facilitate comparison with the current NWI. Completion of this 'Presettlement Cowardin code' was possible through the use of auxiliary data sources, including; Pre-European Settlement Land Cover, GLO Survey Plats, current hydrology, and topography. The methodology for creating this attribution is outlined below.

Vegetative class of Pre-European Settlement wetland polygons is determined using the Pre-European Settlement Land Cover dataset. A crosswalk between Land Cover types in the Pre-European Settlement Land Cover dataset and NWI Cowardin Vegetative Classes is provided in Appendix 2 at the end of this report. Water Regime (flooding/ponding frequency) information for Pre-European Settlement polygons is derived from a crosswalk document prepared for the LLWFA process by the State Soil Scientist. This document assigns a Cowardin water regime to each unique Map Unit Symbol (soil type) that is considered by NRCS to be hydric. This document creates a crosswalk from one dataset to the other, allowing an 'apples to apples' comparison of current NWI and our derived Pre-European Settlement NWI. This crosswalk is essential in the LLWW coding process, as water regime is directly utilized to arrive at landform. This document is presented in a spreadsheet, and attached to this report digitally on the accompanying DVD. For a generalized Correlation Legend Scheme of the NWI Water Regime - NRCS Hydric Soils Map Unit List prepared by NRCS, see Appendix 3.

Pre-European Settlement hydrology was approximated using current surface water data, topography, and checked against GLO Surveys. Original GLO survey plats were obtained from the MNFI, and georectified to section corners to be spatially explicit in the LLWFA system. This allowed original stream course locations to be verified with current hydrology and topography information. Streams that appeared to occupy their original undisturbed channel, or were denoted as undisturbed in the attribution were included in the Pre-European Hydrology dataset.

Once the 'Presettlement Cowardin Code' has been created for each Pre-European Settlement wetland polygon, the LLWW process could be applied to each in the same manner it is applied to the current NWI.

Because of assumptions made during the presettlement attribution process, there are some issues of scale created when comparing Pre-European Settlement NWI with Current NWI. The result of these assumptions is a dataset that is very simplified in comparison to the 2005 NWI, however it provides an adequate base at the landscape level to perform a basic assessment of lost wetland function.

METHODS-2005 Enhanced National Wetland Inventory

The distribution, extent, and classification of 2005 wetlands were based on NWI mapping. Wetlands were classified according to the FWS's official wetland classification system (Cowardin et al. 1979). The LLWW descriptors were added to the digital NWI database to provide HGM-type information for each wetland polygon. In addition to the four LLWW descriptors, information was gathered on wetlands in a headwater position relative to the watershed as a whole. Wetlands polygons adjacent to ponds had this relationship noted in the database. A distinction was drawn when dealing with floodplain wetlands in terms of landform. Depending on the assigned water regime of the NWI polygon, the floodplain wetland was further classified as either basin or flat.

When enhancing the current NWI with the LLWW descriptors, significant effort goes into mapping hydrologic connection between wetlands, and connections between wetlands and other surface water features. Extensive artificial drainage networks have been added to the landscape since Pre-European Settlement, many times in former wetland areas. This has resulted in formerly isolated wetlands being connected to the overall hydrologic network, significantly changing the functional role that wetland plays in the overall watershed. These types of functional changes are important to note in this type of analysis.

As part of this effort, while the HGM descriptors were being added to the NWI database, MDEQ, Water Resources Division (WRD) staff also performed quality assurance/quality control on the Ducks Unlimited 2005 NWI update. This resulted in significant acreage of wetland being added to the updated NWI, and erroneous mapping being corrected in many instances.

The WRD also made every effort to add features to the NHD surface water inventory if a feature was located that was not otherwise mapped in the NHD hydrology dataset. Due to the scale at which the interpreters are working on this effort, significant stream miles have been added to NHD that were otherwise omitted. These features were generally mapped only if they had a hydrologic impact on wetlands within the watershed.

Preliminary Assessment of Wetland Functions

This study employed a landscape-level wetland assessment approach called W-PAWF. W-PAWF applies general knowledge about wetlands and their functions to produce a watershed profile highlighting wetlands of potential significance for numerous functions. The method was developed to predict wetland functions for large geographic areas, particularly watersheds, from NWI data. To do this, two steps must be undertaken: (1) the digital NWI database must be expanded by adding LLWW descriptors, and (2) correlations between wetland characteristics in the database and wetland functions must be developed. Many wetland functions are related to physical properties, while others are dependent on a combination of biological and physical characteristics. For example, floodplain and depressional wetlands temporarily store surface water, whereas slope wetlands do not; wetlands that are sources of streams are vital for streamflow maintenance; marshes provide habitat for waterfowl and waterbirds (Tiner, 2003b).

Once the digital databases had been constructed for both eras, including LLWW descriptors, correlations were applied to both datasets to produce a preliminary assessment of wetlands performing functions at significant levels. The correlations are applied to the databases with analyses that take into account NWI classification as well as HGM codes constructed from the LLWW descriptors.

Thirteen total functions are evaluated in the W-PAWF approach; (1) Flood Water Storage, (2) Streamflow Maintenance, (3) Nutrient Transformation, (4) Sediment and Other Particulate Retention, (5) Shoreline Stabilization, (6) Fish Habitat, (7) Stream Shading, (8) Waterfowl and Waterbird Habitat, (9) Shorebird Habitat,

(10) Interior Forest Bird Habitat, (11) Amphibian Habitat, (12) Conservation of Rare and Imperiled Wetlands and Species, (13) Ground Water Influence. Each of the functions is discussed in more detail below. Many of the criteria where initially developed by Ralph Tiner from the USFWS based on his knowledge of wetland characteristics and functions, while others have been devised by the MDEQ and incorporated into the analysis. An advisory group was formed of Michigan biologists, wetland specialists, and others to modify the criteria to better fit the characteristics of Michigan wetlands.

The enhanced NWI provides knowledge about each wetland area and the significance at which each particular wetland performs one or more of the thirteen evaluated functions. The functional characteristics of each wetland help to provide valuable information on what ecological services an existing wetland is providing on the landscape as well as what services could be replaced by wetland restoration activities. In evaluating each of the functions, upland conditions adjacent to the wetland are not considered, and it should be emphasized that this preliminary assessment should be viewed as a first cut at identifying wetlands performing various functions at a significant rate based on the identified criteria and detailed information established for each wetland.

After completing the NWI enhancement and the Functional Correlation analyses, maps can be produced to highlight wetlands that are performing these functions at significant levels. Two classes of significance were used to cull out wetlands performing functions at high and moderate levels based on their physical and biological characteristics. Significance is a relative term and is used in this analysis to identify wetlands that are likely to perform a given function at a level above that of wetlands not designated (Tiner, 2003b).

Flood Water Storage

This function is important for reducing downstream flooding and lowering flood heights, both of which aid in minimizing property damage and personal injury from such events *(*Tiner, 2003b*)*. All wetlands perform some type of flood water storage; however we have tried to identify areas that are performing this function at a significant level. Wetlands capturing flood water at significant levels would include wetlands along streams and rivers. These wetland types hold excess water until the river or stream can re-stabilize and move the excess water down stream. Once the water levels recede the water stored in these wetlands also recedes back to normal levels. Wetlands located on islands in lakes or rivers also provide this function significantly, as do ponds that are not being artificially drained. Isolated basin wetlands are also a very important wetland type for this function. These depressions or bowl-shaped wetlands provide a storage area for adjacent upland run off during rain events preventing the water from flooding surrounding areas. Wetlands performing this function at a moderate level include wetlands with natural hydrologic connections as opposed to wetlands that are being drained artificially. Ponds that are not ranked as high for this function are included in the moderate category, as are wetlands adjacent to lakes. This function does not take into consideration the size of the wetland being analyzed, although generally accepted principles would indicate that size should make a difference in the amount of water stored.

Flood Water Storage	***High***	• Wetlands along Streams and Rivers • Island Wetlands • Ponds that are Throughflow & Throughflow Intermittent • Terrene Basin Isolated
	Moderate	• Terrene & Outflow or Outflow Intermittent wetlands • Other Ponds • Terrene wetlands that are associated with Ponds • All Lake side wetlands not already High

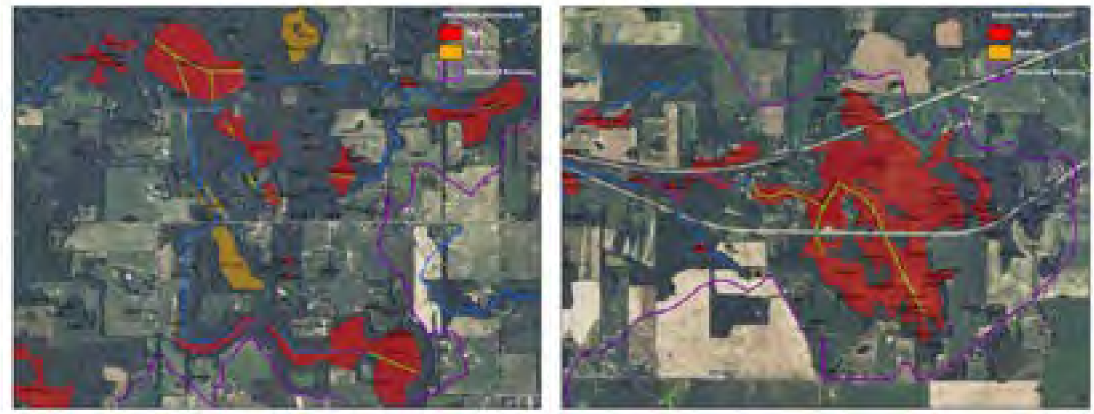
Figure 9: Examples of NWI Wetlands Rated High and Moderate for Flood Water Storage

Streamflow Maintenance

Wetlands that are sources of groundwater discharge that sustain streamflow in the watershed. Such wetlands are critically important for supporting aquatic life in streams. All wetlands classified as headwater wetlands are important for streamflow (Tiner, 2002). Headwater wetlands are very important when it comes to maintaining base flows of streams. All wetlands classified as headwater are rated as performing this function at a significant rate. Specific wetland types also perform this function, but generally at a more moderate rate. Wetlands that are adjacent to rivers or streams, and are located within the floodplain, store water during flooding events and then release water slowly into the stream or river, maintaining flow. Ponds and lakes that have a stream or river flowing through them are also important in supplying and regulating streamflow as well. Other wetlands that discharge groundwater at varying degrees also provide streamflow but at a more moderate rate.

Streamflow Maintenance	***High***	• All headwater wetlands (hw) ▪ 1st order perennial streams and above ▪ 2nd order perennial streams
	Moderate	• Lotic floodplain wetlands • Lotic stream fringe wetlands • Throughflow & outflow ponds & lakes • Terrene outflow wetlands associated with a pond • Terrene outflow wetlands outflowing to streams

Figure 10: Examples of NWI Wetlands Rated High and Moderate for Streamflow Maintenance



Nutrient Transformation

All wetlands recycle nutrients in some capacity, but wetlands that have a fluctuating water table are best able to capture and recycle nutrients. Natural wetlands performing this function help improve local water quality of streams and other watercourses by capturing and filtering these nutrients. Heavily vegetated wetlands are uniquely suited to slow water flows causing soils, minerals, and other materials to precipitate out of the water column and be deposited in the wetland. Wetland types that are vegetated and fall on the wetter end of the water regime scale perform this function significantly, where as vegetated wetlands on the dryer end of that scale perform this function at a slightly less significant level. From the water quality standpoint wetlands that are associated with a stream or river are in the correct landscape position to provide this function at a significant level. Generally speaking, when evaluating this particular function, vegetative class and water regime are the most important considerations.

Nutrient Transformation	***High***	• Vegetated Wetlands from NWI P_ (AB, EM, SS, FO, and mixes) with water regime C, E, F, H, G. No Open Water types.
	Moderate	• Seasonally Saturated and Temporarily Flooded Vegetated Wetlands from NWI P_ (AB, EM, SS, FO, and mixes) with A, B water regime. • Lacustrine vegetated wetlands (no open water)

Figure 11: Examples of NWI Wetlands Rated High and Moderate for Nutrient Transformation

Sediment and Other Particulate Retention

This function supports water quality maintenance by capturing sediments with bonded nutrients or heavy metals. Vegetated wetlands will perform this function at higher levels than those of non-vegetated wetland types (Tiner, 2003b). Specifically wetlands that are considered lentic, or wetlands along streams, and rivers that have natural watercourses (not agricultural ditches) are likely to trap and retain sediments and particulates at more significant levels. In-stream ponds are also important for this function and are rated high. These ponds slow the waterflow and allow the sediments to precipitate out and settle to the pond floor. Basin wetlands surrounded by upland also tend to perform this function highly, trapping sediments entering in runoff from adjacent upland. Other ponds are also significant in retaining such materials and are rated moderate. Basin wetlands that outflow also perform sediment and other particulate retention at a moderate rate.

Sediment and Other Particulate Retention	***High***	• Basin wetlands associated with lakes • Fringe and island wetlands associated with lakes • Floodplain wetlands • Lotic stream basin, flat, and fringe wetlands that are throughflow or throughflow intermittent • Lotic river floodplain or fringe throughflow wetlands • Throughflow or throughflow intermittent ponds • Island wetlands • Terrene basin wetlands that are isolated
	Moderate	• Terrene basin wetlands that are outflow, outflow intermittent or outflow artificially • Natural ponds not already “high” • All wetlands associated with a pond

Figure 12: Examples of NWI Wetlands Rated High and Moderate for Sediment Retention

Shoreline Stabilization

Vegetated wetlands along all water bodies (e.g. estuaries, lakes, rivers, and streams) provide this function. Vegetation stabilizes the soil or substrate and diminishes wave action, thereby reducing shoreline erosion potential (Tiner, 2002*)*. Vegetated wetlands along lakes, streams, or rivers provide a buffer to shorelines that would otherwise be more vulnerable to erosion. Wetlands that are along rivers, streams, and lakes that are vegetated perform this function at highly significant level. Wetlands in a headwater position within a watershed, that are outflowing to other surface water, perform this function at a more moderate rate.

Shoreline Stabilization	***High***	• Vegetated (except island types) along water bodies ▪ Rivers, lakes, streams
	Moderate	• Terrene vegetated wetlands along ponds • Terrene outflow, outflow intermittent, outflow Artificial Wetlands that are headwater

Figure 13: Examples of NWI Wetlands Rated High and Moderate for Shoreline Stabilization

Fish Habitat

The fish habitat function looks at wetlands that are considered essential to one or more parts of fish life cycles. Wetlands designated as important for fish are generally those used for reproduction, or feeding. These wetland types include; lentic wetlands, throughflow wetlands adjacent to streams and rivers, ponds (excluding isolated, artificial ponds) and adjacent wetlands, aquatic bed wetlands that are outflowing to other surface water, and all headwater wetlands that have not been artificially modified. Wetlands that provide habitat at a moderate level include; aquatic bed wetlands not otherwise rated as high for this function, artificially created lakes and ponds, and wetlands that are intermittently connected to other surface water.

Fish Habitat	***High***	• Lentic wetlands • Stream and river wetlands that are only throughflow • Wetlands associated with a pond • Ponds that are associated with a wetland • Palustrine aquatic bed outflowing • Natural ponds that are isolated • Natural lakes • Lakes that are throughflow, throughflow intermittent, or artificial, outflow, outflow intermittent or artificial • Headwater wetlands except artificial types

Fish Habitat	***Moderate***	• Palustrine aquatic bed that are outflowing artificially, or intermittently, isolated and are not coded High • Diked impounded ponds not H • Throughflow ponds • Palustrine aquatic bed throughflows • Lotic stream wetlands that are intermittent throughflow • Terrene that outflow intermittently or artificially • Excavated isolated lakes

Figure 14: Examples of NWI Wetlands Rated High and Moderate for Fish Habitat

Stream Shading

Wetlands providing this ecological service regulate water temperature due to the proximity to streams and waterways. These wetlands generally are palustrine forested or scrub-shrub. Wetlands performing this function at a high level are adjacent to a headwater stream, and are forested or shrub-scrub wetlands performing this function at a moderate level are non-headwater, lotic wetlands that are forested and shrub-scrub. This function is particularly important for aquatic life in and around coldwater streams and the wetlands adjacent to them.

Stream Shading	***High***	• Stream Wetlands that are palustrine forested and palustrine scrub-shrub and headwater
	Moderate	• Stream Wetlands that are palustrine forested and palustrine scrub-shrub and not headwater

Figure 15: Examples of NWI Wetlands Rated High and Moderate for Stream Shading

Waterfowl and Waterbird Habitat

Wetlands designated as important for waterfowl and waterbirds are generally those used for nesting, reproduction, or feeding. The emphasis is on the wetter wetlands and ones that are frequently flooded for long periods (Tiner, 2003b). For this function, the analysis prioritizes projected habitat for these species. Vegetation types include; aquatic bed, emergent, and shrub-scrub wetlands with associated water regimes including; seasonally flooded, semi-permanently flooded, and permanently flooded. Wetlands performing the above function at a moderate rate tend to be the deciduous forested wetland types that are seasonally flooded to permanently flooded. These could include floodplains or forested basins.

Waterfowl and Waterbird Habitat	***High***	• Palustrine aquatic bed emergent and scrub-shrub wetlands that are seasonally flooded, seasonally flooded/saturated, Semi permanently flooded, intermittently exposed, and permanently flooded. No coniferous.
	Moderate	• Palustrine forested wetlands that are seasonally flooded, seasonally flooded/saturated, semi permanently flooded, intermittently exposed, and permanently flooded. No coniferous.

Figure 16: Examples of NWI Wetlands Rated High and Moderate for Waterfowl/Waterbird Habitat

Shore Bird Habitat

Shorebirds generally inhabit open areas of beaches, grasslands, wetlands, and tundra and undertake some of the longest migrations known. Along their migration pathway, many shorebirds feed in coastal and inland wetlands where they accumulate fat reserves needed to continue their flight. Common species include; plovers, oystercatchers, avocets, stilts, and sandpipers. This function attempts to capture wetland types most likely to provide habitat for these species. Wetland types that provide this function at a high rate include aquatic bed wetlands that are permanently flooded to intermittently exposed, wetlands with non-persistent vegetation, and lacustrine unconsolidated shore. Wetlands performing this function at a moderate rate of significance are the more common wetland types such as emergent, shrub-scrub, and forested areas that are not permanently flooded.

Shorebird Habitat	***High***	• Palustrine aquatic bed wetlands that is not intermittently exposed or permanently flooded. • Non-persistent wetlands (PEM2) • Lacustrine unconsolidated shore that is parentally flooded.
	Moderate	• Palustrine emergent, scrub-shrub, and forested wetlands including mixed types that are not intermittently exposed or permanently flooded.

Figure 17: Examples of NWI Wetlands Rated High and Moderate for Shorebird Habitat

Interior Forest Bird Habitat

Interior forest birds require large forested areas to breed successfully and maintain viable populations. This diverse group includes colorful songbirds such as; tanagers, warblers, vireos that breed in North America and winter in the Caribbean, Central and South America, as well as residents and short-distance migrants such as; woodpeckers, hawks, and owls. They depend on large forested tracts, including streamside and floodplain forests. It is important to note that adjacent upland forests to these riparian areas are critical habitat for these species as well. This function attempts to capture wetland types most likely to provide habitat for these species. Habitat that rates highly significant for interior forest birds includes forested floodplains and shrub-scrub wetlands. Moderately significant wetlands are all other forested wetlands that have not already been ranked as high. This function is evaluated in more general terms to include the multiple forest bird species.

Interior Forest Bird Habitat	***High***	• Palustrine Forested wetlands that are along Rivers • Palustrine scrub-shrub wetlands and those mixed with other wetlands types
	Moderate	• Palustrine Forested wetlands that are not already High

Figure 18: Examples of NWI Wetlands Rated High and Moderate for Interior Forest Bird Habitat

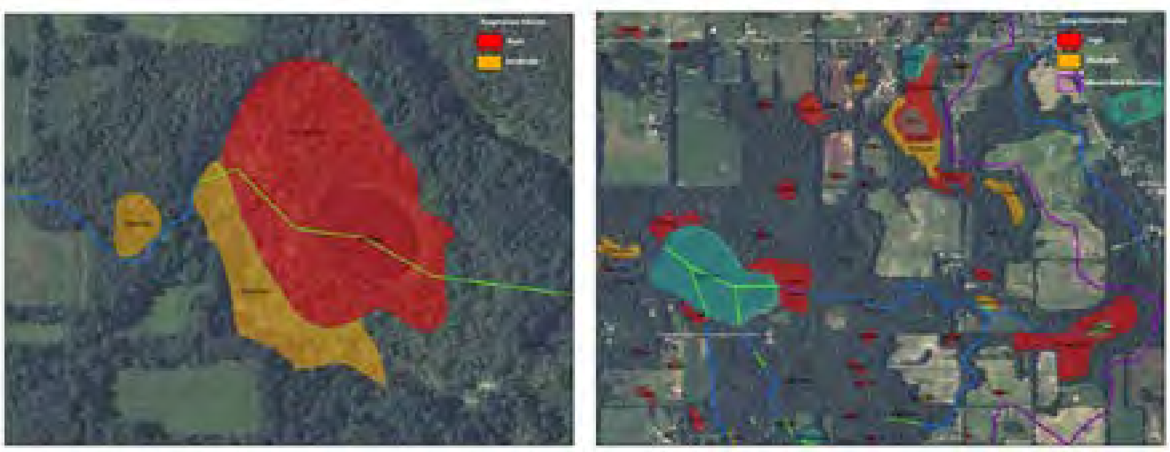
Amphibian Habitat

Amphibians share several characteristics in common including wet skin that functions in respiration and gelatinous eggs that require water or moist soil for development. Most amphibians have an aquatic stage and a terrestrial stage and thus live in both aquatic and terrestrial habitats. Aquatic stages of these organisms are often eaten by fish and so for certain species, successful reproduction may occur only in fish-free ponds. Common sub-groups of amphibians are salamanders, frogs, and toads. This function attempts to capture wetland types most likely to provide habitat for these species. For this function, wetland size is actually taken into consideration. Wetlands that are less than five acres in size, vegetated, and isolated are ranked high for amphibian habitat. Naturally outflowing wetlands are also ranked high for this function. Floodplain wetlands and lentic wetlands are significant wetland types for amphibian habitat as are natural ponds and isolated aquatic beds. Vegetated wetlands that are less than 5 acres in size that are either throughflow, or outflowing artificially or intermittently fall into the moderate range for this function. Other wetland types that are significant but don't fall into the high category include rivers, forested and shrub-scrub wetlands smaller than five acres and isolated vegetated wetlands that have not already been ranked highly.

Amphibian Habitat	***High***	• Palustrine emergent, scrub-shrub, and forested wetlands along with those mixed types that are less than 5 acres and Isolated and only seasonally flooded, seasonally flooded/saturated, or semi-permanently flooded. • Outflowing wetlands • Palustrine Aquatic beds that is isolated and not intermittently exposed or permanently flooded. • Wetlands adjacent to rivers • Lakeside wetlands • Natural ponds and any wetlands that are associated with those ponds

Amphibian Habitat	***Moderate***	• Palustrine emergent, scrub-shrub, and forested wetlands with those mixed types that are less than 5 acres and adjacent to a stream (throughflow) and only seasonally flooded, seasonally flooded/saturated, or semi-permanently flooded. • Palustrine emergent, scrub-shrub, and forested wetlands along with those mixed types that are less than 5 acres and outflowing artificially or intermittently and only seasonally flooded, seasonally flooded/saturated, or semi-permanently flooded. • Palustrine emergent, scrub-shrub, and forested wetlands along with those mixed types that are isolated and only seasonally flooded, seasonally flooded/saturated, or semi-permanently flooded. • Palustrine aquatic bed isolated wetlands that are permanently flooded. • Scrub-shrub and forested wetlands less than 5 acres (must be PFO1) • Rivers • Ponds and the wetlands associated with them unless already High

Figure 19: Examples of NWI Wetlands Rated High and Moderate for Amphibian Habitat

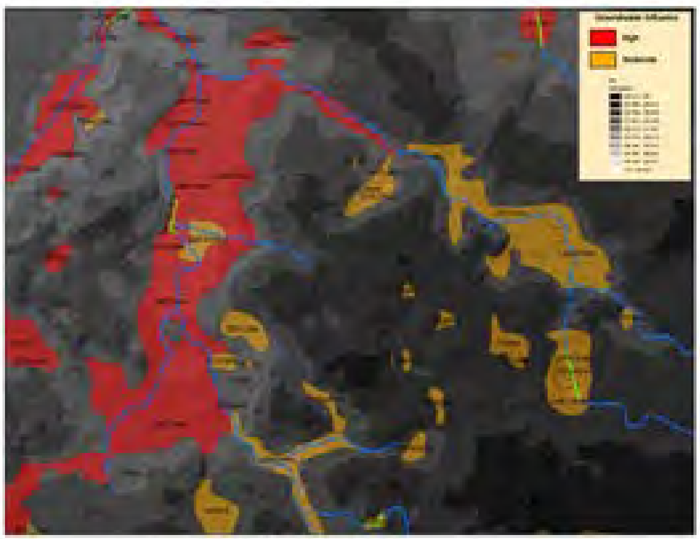


Groundwater Influence

Wetlands categorized as high or moderate for groundwater influence are areas that receive some or all of their hydrologic input from groundwater reflected at the surface. The Darcy's Law (DARCY) model was the data source utilized to determine this wetland/groundwater connection, which is based upon soil transmissivity and topography. Groundwater movement is tracked as meters/day – 1 by cell. The ranges that were used in this analysis to differentiate between high and moderate groundwater influence are listed in the 'GIS Users Version of the Functional Correlations' document included with Appendix 4. Wetlands rated for this function are important for maintaining streamflows and temperature control in water bodies. The DARCYoutput was then intersected with wetlands on the ground to identify areas of potential wetland/groundwater connection. Using the models output data wetlands were ranked either highly likely or moderately likely to provide this function.

Ground Water Influence	***High and Moderate***	• Uses DARCY to determine areas of ground water influence

Figure 20: Examples of NWI Wetlands Rated High and Moderate for Groundwater Influence



Conservation of Rare and Imperiled Wetlands and Species

Wetlands that are considered rare either globally or at the state level are identified for this function. They are likely to contain a wide variety of flora and fauna, or contain threatened or endangered species. This function is derived from the MNFI Datasetof known sightings of threatened, endangered, or special concern species and high quality natural communities. The model values are reported on a 40 acre polygon grid for the state of Michigan, or a subset of Michigan. Due to this, the dataset should not be used as a comprehensive inventory of Rare and Imperiled wetlands. This data set is intersected with the current wetlands layer only to identify wetlands currently on the landscape that have potential to either be habitat for a threatened or endangered species or be a wetland that is of rare nature.

Conservation of Rare and Imperiled Wetlands	***High***	• Intersection with MNFI's Biological Rarity Index and Probability value layer to identify wetlands and species of rarity.

Figure 21: Examples of NWI Wetlands Rated High and Moderate for Conservation of Rare and Imperiled Wetlands and Species

Michigan LLWFA Advisory Council

It was apparent to MDEQ, WRD staff upon completion of the first LLWFA in Michigan in the Paw Paw River, that changes would need to be made to help the LLWFA better reflect the wetland resources of Michigan. To address this need, an advisory council of Michigan wetland biologists, specialists, and individuals familiar with Michigan's wetland resources was convened and tasked with reviewing the functional correlations created by Mr. Ralph Tiner of USFWS and modifying them to apply to Midwestern conditions. The council analyzed each correlation and either made adjustments or agreed with the correlation as USFWS originally devised it. The LLWFA Advisory council was pivotal in helping MDEQ staff compile and create the functional correlations as well as the various documents needed to continue work on the Landscape Level Assessment in Michigan. To help educate the advisory council MDEQ staff created training materials and detailed presentations to help explain the LLWW descriptors as well as the LLWFA. These documents are included on a DVD available upon request (Appendix 4). A full listing of advisory group members and their respective organizations is included at the end of this report.

RESULTS

The wetland spatial data produced as a result of this effort can be used for a multitude of purposes. The addition of the LLWW information to the original NWI database facilitates a greater ability to subset the data. This gives the end user the ability to craft the data to the specific needs of the organization, and produce maps that highlight wetlands of significance for one specific function or multiple. Because of the scalability of the final datasets, watershed-scale maps can be produced as quickly and easily as maps showing sub-watersheds or local communities.

Several watersheds across the state have found innovative ways to utilize the landscape level assessment information. An example of this would be the Black River Watershed in Allegan and Van Buren Counties, a link to the approved watershed plan can be found here: (http://www.michigan.gov/deq/0,1607,7-135-3313_3682_3714_31581-120463--,00.html). The watershed planners performed interesting analyses on the connections between inland lakes and wetland resources, in addition to creating a prioritization process (utilizing the LLWFA data) meant to inform decision making on the siting of wetland restoration projects.

The Gun River Watershed is another strong example of how this type of landscape level assessment information can be incorporated into watershed planning efforts. A link to the approved watershed management plan can be found here: (http://www.michigan.gov/deq/0,1607,7-135-3313_3682_3714_31581-104278--,00.html). The watershed coordinator for this project utilized the LLWFA in combination with his local knowledge of landowners to prioritize wetland restoration efforts down to actual properties using parcel data. The watershed coordinator then met with local landowners to gauge their interest in completing a wetland restoration project on their property, assisting interested landowners with the procedural aspects of working through the various requirements of state/federal restoration programs, (Wetland Restoration Program, Partners for Fish and Wildlife, etc.) to help address the needs of the overall watershed.

The most essential piece of any successful LLWFA project is a strong, stable watershed coordinator, with local knowledge. A local champion has the ability and connections to utilize these tools where they are most likely to be implemented. Unfortunately, many watershed planning organizations, conservation districts and municipalities just don't have the resources to provide a lasting position to work on watershed related issues. In these instances, the department attempts to put more effort into working with the permanent fixtures at the local level; city/township planners, municipal employees, and planning commissions are all appropriate audiences for this type of assessment.

GENERAL LIMITATIONS OF THE STUDY

Historical wetland data produced from existing soils surveys, are obvious approximations of wetland extent and condition. NWI Coding for Pre-European Settlement wetland polygons was derived from soil characteristics, and checked against Pre-European Settlement vegetation maps produced by interpreting GLO Surveys from the early 1800s. This required an approximation of flooding and ponding frequency (water regime), as well as vegetative cover. Given that landform information in this analysis was derived from NWI water regime, certain types of landform (fringe, slope, etc) may be underrepresented in the Pre-European Settlement coverage. Pre-European Settlement hydrology was approximated using current surface water data, and checked with GLO Surveys. Streams that appeared to have a natural channel, were major courses, or were denoted as undisturbed in the attribution were included in the Pre-European Settlement analysis.

The 2005 NWI data should be an accurate reflection of wetland extent and condition within the State of Michigan. However, given the inherent limitations of using a data source that is mainly derived from aerial photo interpretation, care should be exercised when using the results of this analysis. Issues with photo quality, scale, and variable environmental conditions should be taken into consideration when interpreting this information (Tiner, 2002). Also, errors of omission and commission are possible. Drier-end wetlands tend to be difficult to interpret on aerial photos, as are forested wetlands where canopy can obscure hydrology below. Because water regime information was interpreted from one snapshot in time, it may not always be reliable in determining seasonal saturation. Many times, the seasonal saturation of wetlands can vary widely over long time periods which can be difficult to account for in this type of mapping effort.

This analysis produces a planning tool that can assist in identifying potential wetlands of significance for certain functions. However, no effort was made to compare the relative significance of two wetlands predicted to perform the same function. The W-PAWF also does not consider the condition of adjacent upland or the relative water quality of adjacent waterbodies, which may be considered important factors in determining the overall health and condition of a wetland (Tiner, 2005).

No assessment technique on wetland function is likely to be robust enough to first evaluate the level of a particular function and then further distinguish whether the function is part of a human-based value system (Brinson, 1993). Also, it should be noted, that this type of analysis is not intended for a user to take it to the field for the purpose of matching indicators with functions. Rather, this type of analysis is intended to show how some fundamental knowledge about water flows and sources and geomorphic setting can be interpreted to illustrate ecological functioning (Brinson, 1993).

APPROPRIATE USE OF THIS TYPE OF ANALYSIS

At the watershed or regional level, an understanding of the status and trends of wetland ecosystems is essential for the establishment of policies, strategies, and priorities for action (Ramsar Convention on Wetlands, 2005).

The United States Environmental Protection Agency (U.S. EPA) considers the development of a State comprehensive wetland monitoring and assessment program as a top priority to determine the causes, effects and extent of pollution to wetland resources, and to improve pollution prevention, reduction and elimination strategies (Fennessy et. al., 2004). This is used to enhance wetland inventory and assessment techniques at a watershed scale and should assist local planners in a monitoring strategy if that goal is identified at a local level. Also, wetland assessment is the identification of the status of, and threats to, wetlands as a basis for the collection of more specific monitoring activities (Apfelbeck, 2006).

Wetland inventories can be carried out at different levels of detail and a sequential inventory, starting simple and subsequently undertaking more detailed work, should be undertaken (Ramsar Convention on Wetlands, 2005). With the development of the Michigan Rapid Assessment Method (MiRAM), a field-based assessment method, opportunities exist to enhance landscape level wetland inventory and assessment. Really, this type of rapid assessment method should be paired with landscape level assessment to ensure proper management decisions. For example, degrees of landscape-level stress and wetland functions are best determined by also considering landscape-level information (Apfelbeck, 2006). Field-based assessments are necessary to accurately assess wetland functions. However, remote assessments are important when evaluating wetland functions at the watershed scale since it is often necessary to have some way to screen wetlands to target for further assessment (Apfelbeck, 2006).

This type of analysis is meant to be an initial screening of the overall status and trends of the wetland resource base within a watershed. When paired with Pre-European Settlement information, cumulative impacts of wetland functional degradation can be evaluated. Given limited public understanding of the functions and values of wetlands, this analysis can serve as an effective illustration of the role of wetlands within the larger landscape and the role that wetland destruction and degradation has played in reduced surface-water quality, habitat, and flood control over time.

The overall results of this effort provide many possibilities and unlimited potential for future use of these datasets within Michigan's 404 Program, and 319 Program. MDEQ, WRD staff involved in this project envision myriad applications of this assessment within not only the non-regulatory arena, but also regulatory applications. Given the use of best professional judgment as a basis for permitting and enforcement/compliance decisions, data that can speak to wetland functions and values within a watershed will be extremely useful to regulatory staff. In a non-regulatory sense, this analysis can help to pinpoint potential restoration, enhancement, and protection activities to appropriate areas of the watershed that are most in need of a particular wetland function. From a regulatory perspective, wetlands should be inventoried, assessed, monitored, and managed in the context of the entire watershed to supplement the site-by-site regulatory-based assessments which are often necessary for addressing direct impacts such as dredging, filling, and draining. A watershed approach can also integrate indirect wetland impacts that are caused by land use practices that require a broader understanding of how wetlands function on the landscape and the benefits that they provide. For this reason, watershed planning allows communities to make better choices on preserving the highest quality wetlands by protecting the most vulnerable wetlands and for prioritizing sites for restoration (Cappiella et al. 2006). Given the recent push to incorporate and understand the 'watershed context' of a wetland resource in Clean Water Act guidance involving mitigation efforts, landscape level assessment of this type will continue to play an increasingly large role in wetland regulatory actions.

The usefulness of this data will also depend on the goals of the partnering watershed management authority. For example; in a watershed undergoing problems with excessive sedimentation in waterways, this data could be used to pinpoint wetlands which are currently performing that function at a significant rate. In a highly urbanized watershed, this analysis can be used to pinpoint wetlands of significance for flood control and sediment retention. The high level of scalability of this analysis is what makes it so versatile for use in a wetland management program. Watershed groups and local governments should consider using landscape assessments to identify priority areas, probable stressors, and wetland restoration and conservation opportunities (Apfelbeck, 2006).

When taken a step further, a set of profiles and reference wetlands could be developed based on this approach. By studying in detail the functioning of various reference wetland types, one should be able to extrapolate to other similar wetlands on the assumption that wetlands with similar landscape position and landform, similar location with respect to water sources, and similar slope and catchment area will also have similar functions (Brinson, 1993). The array of key wetland types that emerge as reference wetlands can be used not only for the purposes of characterizing and quantifying various aspects of wetland function, but also as standards to evaluate wetland construction and restoration projects. In this sense they become the standards of success in contrast to relying on endless lists of design criteria and performance standards. One of the most valuable uses may be in the training of wetland scientists who will be involved in work on permit review, assessment of functions, construction of new wetlands, and restoration of degraded ones (Brinson, 1993).

In Michigan, wetlands are just beginning to be considered in the context of watershed management planning and the creation of municipal master plans. Wetland restoration and enhancement are increasingly becoming popular tools, in lieu of traditional best management practices, to enhance the overall ecological health and surface water quality of a watershed. Understanding the overall historic impact of wetland loss and degradation can assist local planners and resource managers in sighting future development as it lends new importance to the wetlands that remain.

CONCLUSIONS

The findings of this analysis provide an estimate of the extent of wetland area and associated functionality since Pre-European Settlement times. Given that any landscape level analysis is a ‘first-cut’ approach to understanding wetland loss and its impacts, this type of assessment should be used as one piece to a larger wetland restoration/management plan and field work should be done to verify specific wetland functions predicted as part of this effort. However, understanding at a small scale the changes in wetland extent and functionality that have occurred throughout various watersheds over time should be a valuable tool to resource managers on the ground.

With the recent release of the FGDC Draft Wetland Mapping Standard, it is expected that all Federal efforts to map wetlands in the future will include the LLWW attribution explained in this report. This development ensures that information collected on wetlands at a landscape level will include the data necessary to produce a functional assessment for large geographic areas. The methodology employed in this study provides a consistent approach to assessing wetland function, which as a concept is being incorporated more and more into resource management of all kinds in Michigan. In the future, perhaps this information can be obtained at a statewide level, and give the first glimpse into the status and trends of Michigan’s wetlands from a functional qualitative perspective.

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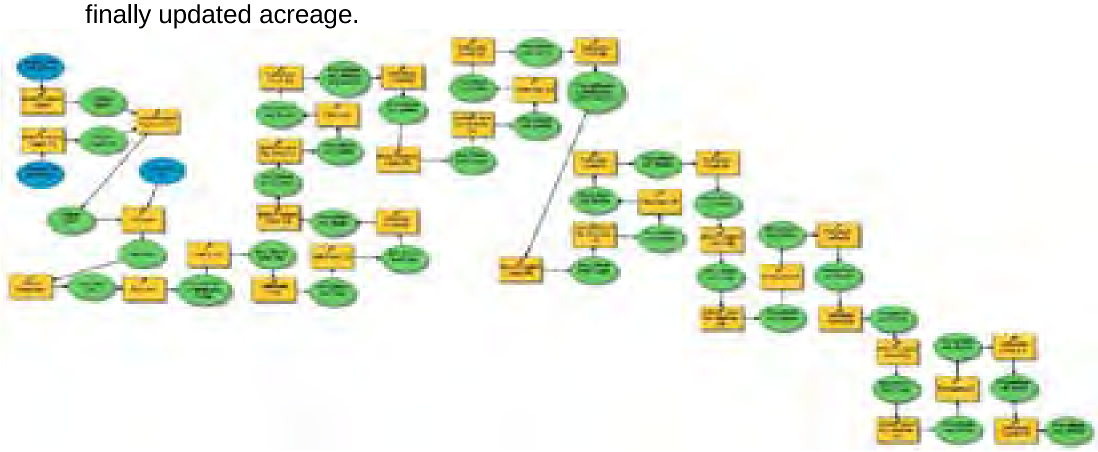
Appendix 1: Automation for Pre-European Settlement Spatial Data Creation

Pre-European Settlement Wetland Coverage Creation

In order to create the Pre-European Settlement Wetland layer some well thought out GIS processes had to be conducted.

1. Layers: Statewide Hydric Soils data, Watershed boundary. These two layers are used to select all hydric soils polygons that intersected the watershed boundary.
2. The result of process one is then intersected with the land cover 1800 dataset in order to create polygons that contained hydric soils data along with the land cover type that they fell onto from the land 1800 data layer. These areas are then "Dissolved" based on landcover type so that any adjacent areas with the same covertype and MUSYM code are merged together.
3. With the resulting polygons the goal now is to limit as many "smaller/or sliver" polygons as possible. The acreage is calculated for each of the polygons within the layer and then a selection done to select all wetlands >= 1 acre. These selected polygons are then "Eliminated" into neighboring polygons to remove the entire sliver or smaller polygons created during the intersect/dissolve process.
4. The "Eliminate Process is done a total of 5 times. After each time the acreage is recalculated and then the attributes reselected for 1 acre, 2 acre, 3 acre, 4 acre, 5 acre polygons. This allows for many small sliver, or inconsistent polygons to be incorporated into the neighboring polygon.
5. The final Dissolve leaves you with a polygon shapfile containing hydric soils codes, cover type, and finally updated acreage.



6. The next step is to cross walk the cover type and covert that into the NWI coding system (See Pre-European Settlement NWI coding document). This step simply selects out cover types that are the same and then classes them to an NWI code based on this cover type. The water regime will come from the hydric soils data in the next step.
7. The polygons should contain a MUSYM soil code which will allow for the NWI water regime to be assigned to the correct wetland.
   a. See the Hydric soils excel spreadsheet to locate the county in which the watershed falls.
   b. Select out and convert the chosen county to a dbf file.
   c. Add the table to your ArcMap mxd and Join that table with the table for your wetlands based on the MUSYM code.
   d. Export out your joined shapefile.
8. You should now have a Pre-European Settlement wetland shapefile that contains NWI cover type polygons with a NWI attribute and a separate field for the water Regime. You then need to add the water regime to the end of the NWI attribute to complete your final NWI code.
9. Keep in mind that some watersheds cross multiple counties. When this happens you must break the Pre-European Settlement polygons up by county in order to get the correct MUSYM codes for each county.
10. Fill in the remaining water regimes that do not have a match by searching the hydric soils table to find the MUSYM code and a location similar to the one you are working in and assign it that water regime.

Appendix 2: 1800 Land Cover Codes to Cowardin Class Conversion

Pre-EuropeanSettlement Land Cover Classes
Conversion Table to
Cowardin NWI Vegetative Classes

Uplands

CoverType: Beach-Sugar Maple Forest
Beach-Sugar Maple-Hemlock Forest
PFO1

CoverType: Black Oak Barren
Aspen Birch Forest
PFO1

CoverType: Mixed Oak Forest
Mixed Oak Savanna
Oak-Hickory Forest
Oak-Pine Barrens
PFO1

CoverType: Sand Dune
Grassland
PEM1

Cover Type: White Pine-Mixed Hardwood Forest
White Pine-White Oak Forest
White Pine-Red Pine Forest
Hemlock White Pine Forest
Pine Barrens
Spruce-Fir-Cedar Forest
PFO4

Wetlands

CoverType: Black Ash Swamp
PFO1

CoverType: Lake/River
River (Use Riverpoly) R2UB
Lakes (Use Lakepoly) L1UB

CoverType: Mixed Conifer Swamp
PFO4

CoverType: Mixed Hardwood Swamp
Cedar Swamp
PFO1

CoverType: Shrub Swamp/Emergent Marsh
PSS/EM

CoverType: Wet Prairie
Muskeg/Bog
PEM1

Appendix 3: NRCS Water Regime Definitions

Correlation Legend Scheme
Of the
NWI Water Regime - NRCS Hydric Soils Map Unit List

[A] Temporarily Flooded – **"Non-hydric," Moderately Well, Moderately Wet and Somewhat Poorly Drained Soils on Floodplain Terraces**
Surface water is present for brief periods during the growing season, but the water table usually lies well below the soil surface for most of the season. Plants that grow both in uplands and wetlands are characteristic of the temporarily flooded regime.

[B] Saturated – **All Non-flooding, Poorly Drained Mineral Soils**
The substrate is saturated to the surface for extended periods during the growing season, but surface water is seldom present. (**Note:** *Farmed areas of these soils are not saturated to the surface. In some counties five to ten percent of the NRCS map units are on flood plains and in drainageways*.)

[C] Seasonally Flooded – **Flooding, Poorly Drained, Coarse Soils with Fluctuating Water Tables**
Surface water is present for extended periods especially early in the growing season, but is absent by the end of the season in most years. The water table after flooding ceases is variable, extending from saturated to the surface to a water table well below the ground surface.

[E] Seasonally Flooded/Saturated – **Flooding, Very Poorly Drained, Mineral Soils**
Surface water is present for extended periods especially early in the growing season and when surface water is absent, substrate remains saturated near the surface for most of the growing season.

[F] Semi-permanently Flooded – **Flooding Marshes, Mucks, Mucky Soils and Very Poorly Drained Mineral Soils**
Surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land surface. (**Note:** *In some counties from 10 to 35 percent of these map units are in non-flooding, upland areas*.)

[G] Intermittently Exposed – Non Flooding Marshes, Mucks, Mucky Soils and Very Poorly Drained Mineral Soils
Surface water is present throughout the year except in years of extreme drought. **(Note:** *In some counties from 5 to 30 percent of the NRCS map units are on floodplains and in drainageways.*)

[H] Permanently Flooded – Subaqueous Soils along the Great Lakes, Bays and Major Rivers
Water covers the land surface throughout the year in all years.

by: William Bowman, NRCS, State Soil Scientist
9-26-08

Appendix 4: DVD and list of contents (available upon request)

- All LLWFA Final Watershed Reports
- LLWFA Advisory Group Powerpoint Presentation
- Functional Correlations Advisory Group Powerpoint Presentation
- GIS Users Version of Functional Correlations
- NRCS Crosswalk Document: MI Hydric Soils List to NWI Water Regime
- NWI Cowardin Wetland and Deepwater Habitats Classification

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Appendix G: Letters of Plan Approval

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
CADILLAC DISTRICT OFFICE

RICK SNYDER
GOVERNOR

KEITH CREAGH
DIRECTOR

July 19, 2016

Mr. Scott Gest
Networks Northwest
PO Box 506
Traverse City, Michigan 49685-0506

Mr. Gest:

Thank you for submitting the May 2016, Betsie River/Crystal Lake Watershed Management Plan to the Department of Environmental Quality (DEQ) for review with respect to meeting criteria for:

(1) The State Clean Michigan Initiative (CMI) Nonpoint Source Pollution Control program.
(2) The United States Environmental Protection Agency (USEPA) Section 319 program of the Federal Clean Water Act.

The effort of Networks Northwest and your partners to preserve and protect Michigan's surface water resources are appreciated.

As you may know, the CMI program criteria were promulgated pursuant to Part 88 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, effective October 27, 1999. Beginning in 2004, the USEPA required that all implementation projects funded under Section 319 be supplemented by a watershed management plan that meets nine required elements as described in the USEPA's document titled, "Nonpoint Source Program and Grants Guidelines for States and Territories (October 23, 2003)."

Our review of the Betsie River/Crystal Lake Watershed Management Plan, which we received electronically on May 10, 2016, and by mail on May 20, 2016, indicates the plan meets the state CMI criteria. Accordingly, **Water Resources Division (WRD) staff is pleased to hereby approve the Betsie River/Crystal Lake plan** for the purposes of the CMI Nonpoint Source Pollution Control program. The document is very well-written and includes an appropriate mix of both broad and focused actions needed to protect a rural watershed where water quality protection is the focus.

Given the plan is CMI approved, the DEQ will forward the plan to the USEPA Region 5 Office in Chicago for their review and comment on whether the plan meets the criteria for approval under the USEPA Section 319 program. Once the USEPA has provided comments to the DEQ, we will send you a copy of their comments along with a letter either granting federal 319 approval of the plan or identifying modifications needed in the plan to achieve federal approval.

120 WEST CHAPIN STREET • CADILLAC, MICHIGAN 49601-2158
www.michigan.gov/deq • (231) 775-3960

Mr. Scott Gest -2- July 19, 2016

The enclosed document, titled "Federal 9 Minimum Elements of Watershed Planning," identifies that the DEQ believes the plan sufficiently addresses each of the nine USEPA criteria. That document, along with the enclosed DEQ general review comments, will be forwarded to USEPA along with our request for USEPA review of the Betsie River/Crystal Lake plan. We suggest that Networks Northwest refrain from printing a final version of the plan until you receive our letter conveying the USEPA comments to you.

If you have questions about CMI approval or the USEPA review process, please feel free to contact Mr. Greg Goudy by phone at 231-876-4472; by email at goudyg@michigan.gov; or you may contact me by phone at 231-429-0982 or by email at jankowskib@michigan.gov.

Sincerely,

Brian W. Jankowski, P.E.
Cadillac District Supervisor
Water Resources Division

Enclosures

cc: Mr. Bob Day, DEQ
Mr. Greg Goudy, DEQ

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
CADILLAC DISTRICT OFFICE

RICK SNYDER
GOVERNOR

DEQ

C. HEIDI GRETHER
DIRECTOR

August 31, 2016

CERTIFIED MAIL

Mr. Scott Gest
Networks Northwest
P.O. Box 506
Traverse City, Michigan 49685

Mr. Gest:

The United States Environmental Protection Agency (USEPA) has completed their review of the May 2016, Betsie River/Crystal Lake Watershed Management Plan and deemed it approvable under Section 319 of the federal Clean Water Act. Accordingly, Department of Environmental Quality (DEQ) staff is pleased to hereby approve the Betsie River/Crystal Lake plan for the purposes of the Section 319 Nonpoint Source Pollution Control Program.

The USEPA did not have any review comments. However, if you choose to make any changes to the plan based on the minor DEQ review comments provided with our July 19, 2016, letter to you, please provide Mr. Greg Goudy with both an electronic copy and printed copy of the revised plan. Please note that as stated in the July letter, none of those DEQ review comments are required to be addressed; the plan is approved as written.

Congratulations on preparing a well-written document that provides an appropriate mix of both broad and focused actions needed to protect the watershed's environmental quality. The efforts of Networks Northwest, the Crystal Lake & Watershed Association, and your other local partners, to preserve and protect Michigan's surface water resources are appreciated.

If you have questions about the Section 319 plan approval, feel free to contact Mr. Greg Goudy by phone at 231-876-4472; by email at goudyg@michigan.gov, or you may contact me directly by phone at 231-429-0982; or by email at jankowskib@michigan.gov.

Sincerely,

Brian W. Jankowski
Cadillac District Supervisor
Water Resources Division

BWJ:sh

cc: Mr. Bob Day, DEQ, e-mail
Mr. Greg Goudy, DEQ, e-mail

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