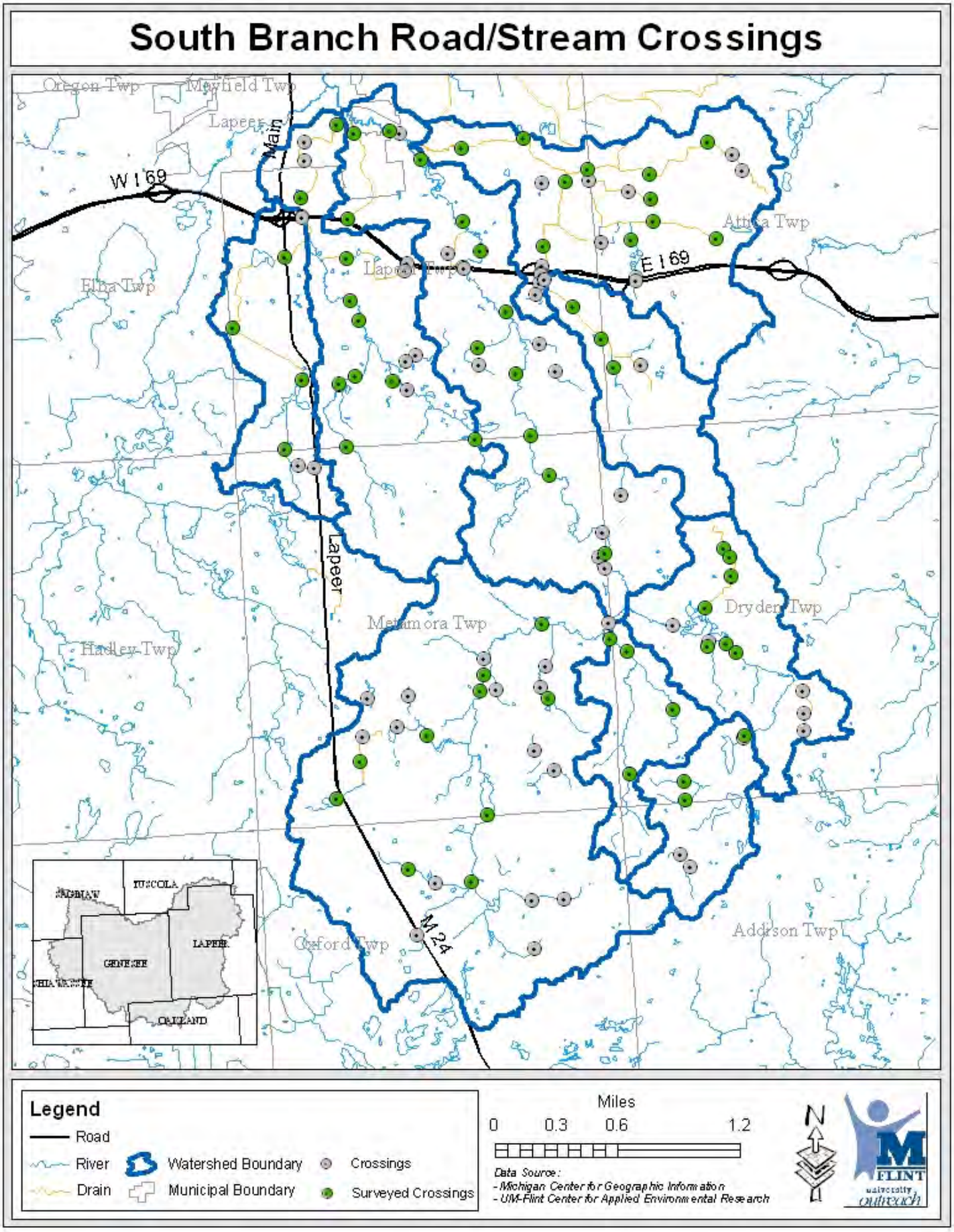
Appendix 5:
Water Quality Research

Road/Stream Crossing Surveys

The condition of water quality in the Flint River South Branch watershed would best be determined through data collection based on quantifiable metrics such as pH, Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Nitrogen, Phosphorous, etc. at a large number of discrete sampling points throughout the watershed. Also, this data would be collected at regular intervals throughout a season in order to develop a complete profile of water quality indices that would show any alterations with changing climatic conditions and land uses in the watershed and act as a baseline for further monitoring. Such a program is prohibitively time consuming, however, and the automated monitoring equipment needed to minimize time commitments is prohibitively expensive. Even macroinvertebrate (MIV) monitoring would require a considerable time commitment if done over a large area multiple times during the year and would still require extensive staff training. These problems of cost and time indicate the need for another strategy for collecting water quality data for the South Branch that provides a reliable snapshot of current conditions but still be robust enough to meet a state acceptable standard. Based on experience from past WMP work, it was decided to use the Michigan Department of Environmental Quality's (DEQ) Stream Crossing Watershed Survey Procedure for data collection in the South Branch. This procedure is described by the DEQ as "a quick screening tool to identify issues and the need for more in depth investigations" and provides qualitative instead of quantitative data. The watershed survey procedure consists of a two page data sheet that is completed by visual observations at road/stream crossings in the watershed. The form can be filled out in 15 minutes or less, making it easy to conduct 10 or 12 in a day instead of one or two MIV surveys in the same time period.

Crossings in the South Branch were identified using ESRI's ArcInfo GIS software. The stream and road layer from the Michigan Geographic Data Library were intersected to identify all potential crossing points for a total of 124. The points were numbered starting at the pour point of the watershed and sequentially numbered toward the headwaters. Since the sub-watersheds had not yet been developed, the standard alpha-numeric system recommended by the DEQ to indicate sub-watersheds was not used. The site survey order was based on travel logistics for the sake of time efficiency. Stream crossing surveying was conducted in July 2006, and completed in August 2007 with a total of 64 sites monitored. The DEQ recommends a survey completion rate of 30 percent for a watershed. A 41 percent survey rate was achieved in 2006, but CAER staff decided to survey more sites in 2007 in order to provide consistency across the watershed and gather additional data for some of the sub-watersheds. 64 road/stream crossings were monitored by the end of August for a final coverage rate of 52 percent (see figure A5.1 for road/stream crossings and completed crossings).

Figure 1


South Branch Road/Stream Crossings
Oregon Twp
Mayfield Twp
Lapeer
Main
W I 69
E I 69
Attica Twp
Elba Twp
Lapeer Twp
Lapeer
Dryden Twp
Metamora Twp
Hadley Twp
Oxford Twp
M 24
Addison Twp
TUSCOLA
LAPEER
GENESEE
OAKLAND
Legend
Road
River
Drain
Watershed Boundary
Municipal Boundary
Crossings
Surveyed Crossings
Miles
0
0.3
0.6
1.2
N
Data Source:
- Michigan Center for Geographic Information
- UM-Flint Center for Applied Environmental Research
FLINT
university outreach

The nutrient Phosphorous is a limiting element to growth in aquatic ecosystems causing nuisance weed growth when even small amounts are added to a river or pond. Although it occurs naturally it is often added by humans through fertilizers, manure, and soil erosion. Floating and filamentous algae in a river indicate nutrient pollution of the water since algae quickly uses added phosphorous. Floating and filamentous algae were found at only 16 and 17 percent of the surveyed crossings (see table 1). Floating algae were abundant on both sides of two crossings and abundant on one side of three others. Filamentous algae were only abundant on both sides of one crossing and abundant on one side of two others. An oil sheen on the water indicates petroleum pollution which may have its source in oil dumped down storm drains, road runoff, or runoff from homes or businesses. Fortunately, oil sheens were found at only three percent of crossings (table 1) and were abundant only at one crossing on one side. Turbidity reduces light infiltration into a stream and buries spawning areas and MIV habitat. It can by any type of suspended particle, but it is most often made up of soil that has eroded from a construction site or other non-vegetated surface. Turbidity was observed at only three percent of surveyed crossings (table 1) and was abundant only at one side of one crossing. Trash in a river and along its banks often has its source in storm sewer runoff as well as casual littering. Trash was observed at eight percent of crossings (table 1) but did not approach the quantities observed in more developed parts of the Flint River Watershed such as the City of Flint

Table 1

Water Quality Indicator	# of Sites	% of Sites
Floating Algae	10	16
Filamentous Algae	11	17
Oil Sheen	2	3
Turbidity	2	3
Trash	5	8

Low levels of bank erosion can be found at 25 percent of upstream and 23 percent of downstream monitored crossings with little medium and no high erosion (table 2). What little light erosion was observed appears to be mostly due to sparsely vegetated stream banks and the grade from road to stream.

Table 2

	Bank Erosion			
	Upstream		Downstream	
Erosion Extent	# of Sites	Site %	# of Sites	Site %
Not Recorded	8	13	6	9
0	39	61	41	64
L	16	25	15	23
M	1	2	2	3
H	0	0	0	0

Table 3 shows the crossing survey list of potential pollution sources and the scores for those sources that were observed in the watershed. Scores were recorded for 12 of the 26 potential sources, but three of them stand out. 17 percent of surveyed sites showed potential problems with urban non-point-source pollution, largely due to the proximity of residential lawns. Most of these sites were in the developed parts of the watershed and in currently developing areas like the M24 corridor. 19 percent of the sites show potential problems with crop related pollution sources. Specific problems involved farming up to the edge of the stream, often without a buffer strip present. In some cases, the topography, soil color, and wet spots in nearby farm fields indicated that a branch of the stream or an adjacent wetland had been plowed under but that the land still drained to the stream carrying pollutants with it. The potential pollution source that was most widely recorded was road runoff at 47 percent of surveyed sites. Site problems were due to grading that allowed sediment from unpaved roads to wash into the river. Moderate cases involved some type of rill erosion starting to form a gully in the side of the road but with a sufficient buffer of vegetation for sediment capture. The worst cases had small channels directing runoff to the river without benefit of a buffer.

Table 3

Potential Pollution Sources	# of sites	% of Sites
Crop Related Sources	12	19
Grazing Related Sources	5	8
Intensive Animal Feeding Operations	2	3
Highway/Road/Bridge Maintenance and Runoff	30	47
Channelization	1	2
Dredging	0	0
Riparian Vegetation Removal	1	2
Bank and Shoreline Erosion/Modification/Destruction	4	6
Flow Regulation/Modification	1	2
Upstream Impoundment	1	2
Construction: Highway/Road/Bridge/Culvert	2	3
Construction: Land Development	0	0
Urban Runoff (Residential/Urban NPS)	11	17
Land Disposal	0	0
On-Site Wastewater Systems	0	0
Silviculture (Forestry NPS)	0	0
Resource Extraction (Mining NPS)	0	0
Recreation/Tourism Activities (General)	0	0
Golf Courses	0	0
Marinas/Recr. Boating (water releases)	0	0
Marinas/Recr. Boating (bank or shoreline erosion)	0	0
Debris in Water	0	0
Industrial Point Source	0	0
Municipal Point Source	0	0
Natural Sources	0	0
Source(s) Unknown	1	2

Pollutants affect the quality of the water in the in a river and can determine the presence of aquatic life (amphibians are very sensitive to chemical pollution, and a phosphorous induced algae bloom can use up the available oxygen in the water). The kind of in-stream and streamside habitat also determines stream quality and the types of organisms that can live there. The rivers in the headwater sub-watersheds are largely natural but 69 percent of the surveys were at crossings where the river is designated as a drain (table 4). Dredging of these drains removes streamside vegetation that shades the water and keeps it cool, increases erosion and sedimentation by increasing water velocity, and removes the structure that fish and other organisms need to hid and find food in. Not all of the rivers designated as drains have been channelized; Pine Creek is almost all designated drain, but the headwaters south of I-69 have not yet been altered. Table four also shows that 63-64 percent of the channels are in a natural state and 11-13 percent of them are recovering from disturbance. Even the more recently channelized crossings categorized as maintained have started showing signs of recovery by developing some sinuosity in their new beds.

Table 4

River Status	# of Sites	% of Sites
Designated Drain	44	69

Table 5

	Upstream			Downstream		
River Morphology	%Natural	%Recovering	%Maintained	%Natural	%Recovering	%Maintained
Channel	64	11	16	63	13	14

Riffles are places in a river where water riffles over barely covered rocks. Riffles help to oxygenate the water and provide habitat for conservative MIV species such as stoneflies and clinging mayflies that cannot survive in slow moving, low oxygenated water. Pools are areas of relatively slow water usually downstream of riffles where fish, like trout, eat the insects that are dislodged from rocks in the riffle. A well developed riffle/pool sequence is a sign of a high quality natural stream with no channelization. Only 27 percent of surveyed sites had riffles, and many of those barely met the definition of a riffle. Pools were more common at 58 percent of crossings, often located below some obstruction other than a riffle. The majority of crossings possessed neither of these features but a strait run devoid of riffle/pool habitat variation.

Table 6

River Morphology	# of Sites	% of Sites
Riffles	17	27
Pool	37	58

Removal of streamside shrubs and trees opens the canopy of branches and leaves that shade the stream. Without shading, sunlight increases the stream temperature. Warmed water can hold less oxygen and cannot support stenotypic fish species such as trout that can’t live in warm waters suitable for panfish or bass. Table 7 shows that approximately 60 percent of the surveyed crossings have 50 percent or less canopy cover. The lack of decent canopy cover was the most noticeable deficienciy noted while conducting surveys.

Table 7

	Stream Canopy Percent			
	Upstream		Downstream	
Percent Canopy	Number of Sites	% of Sites	Number of Sites	% of Sites
<25	31	48	24	38
25-50	8	13	11	17
>50	16	25	19	30

The final step in the crossing survey worksheet is a site ranking score of low, medium or high that is given by the surveyor as a summation of the collected data and her/his impression of the river at the crossing. The standard DEQ scoring was reversed for purposes of the South Branch Watershed Management Plan. This means that a score of "low" indicates a site with many problems requiring extensive work to meet designated uses. A score of "high" would indicate a high quality site with no or a few easily solved problems. Figure 2 gives the scores for the watershed: 17 low scores, 21 medium scores, 35 high scores, and one crossing unscored. The distribution of these scores is important. The low and medium scores appear in the more developed main branch sections of the sub-watersheds, along channelized drains (Pine Creek Main Branch), and along the developing M24 corridor (Mirror Creek, Hunters Creek, and the western part of the South Branch Headwaters).

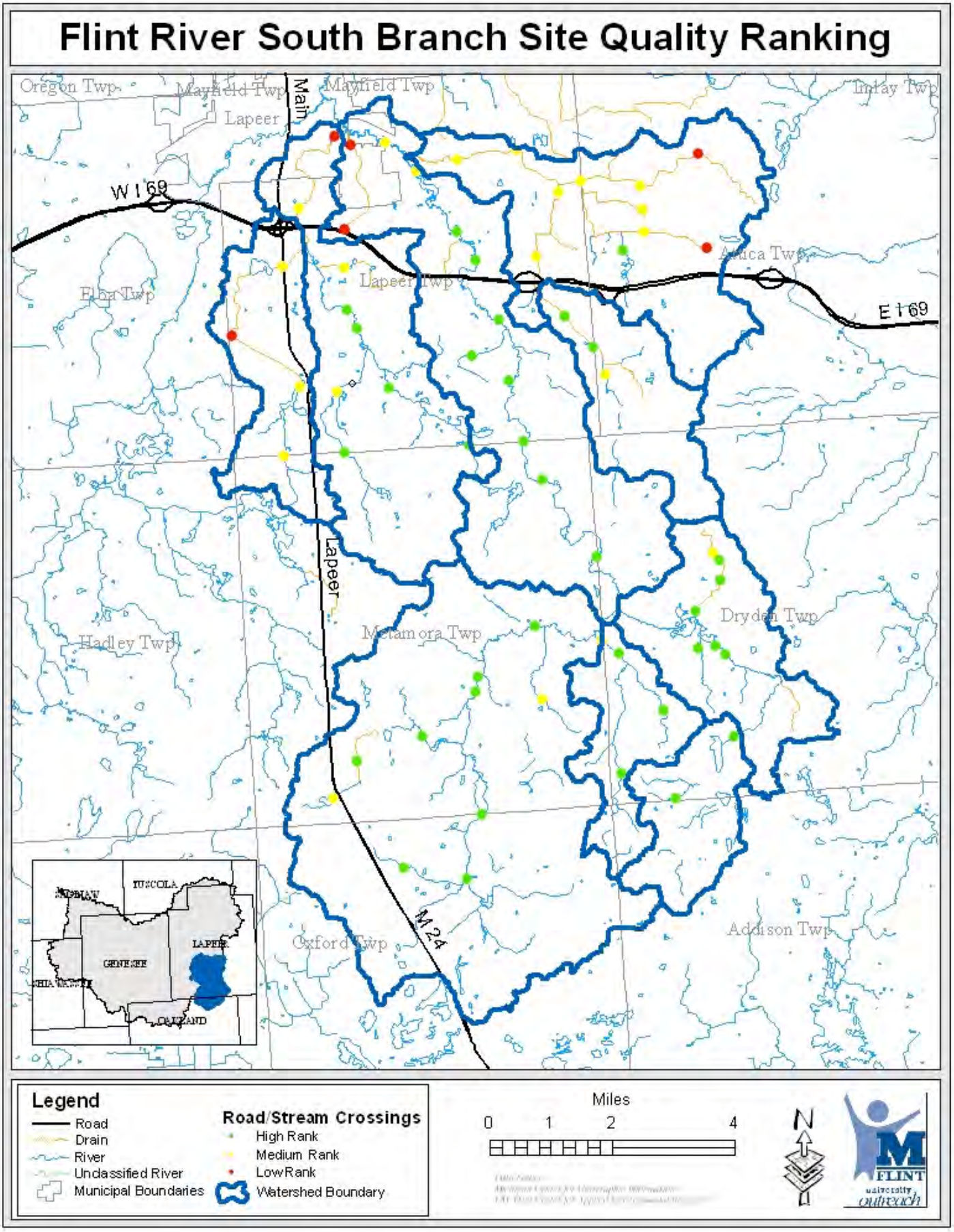


Figure A5.2 South Branch Site Quality Ranking

Macroinvertebrates

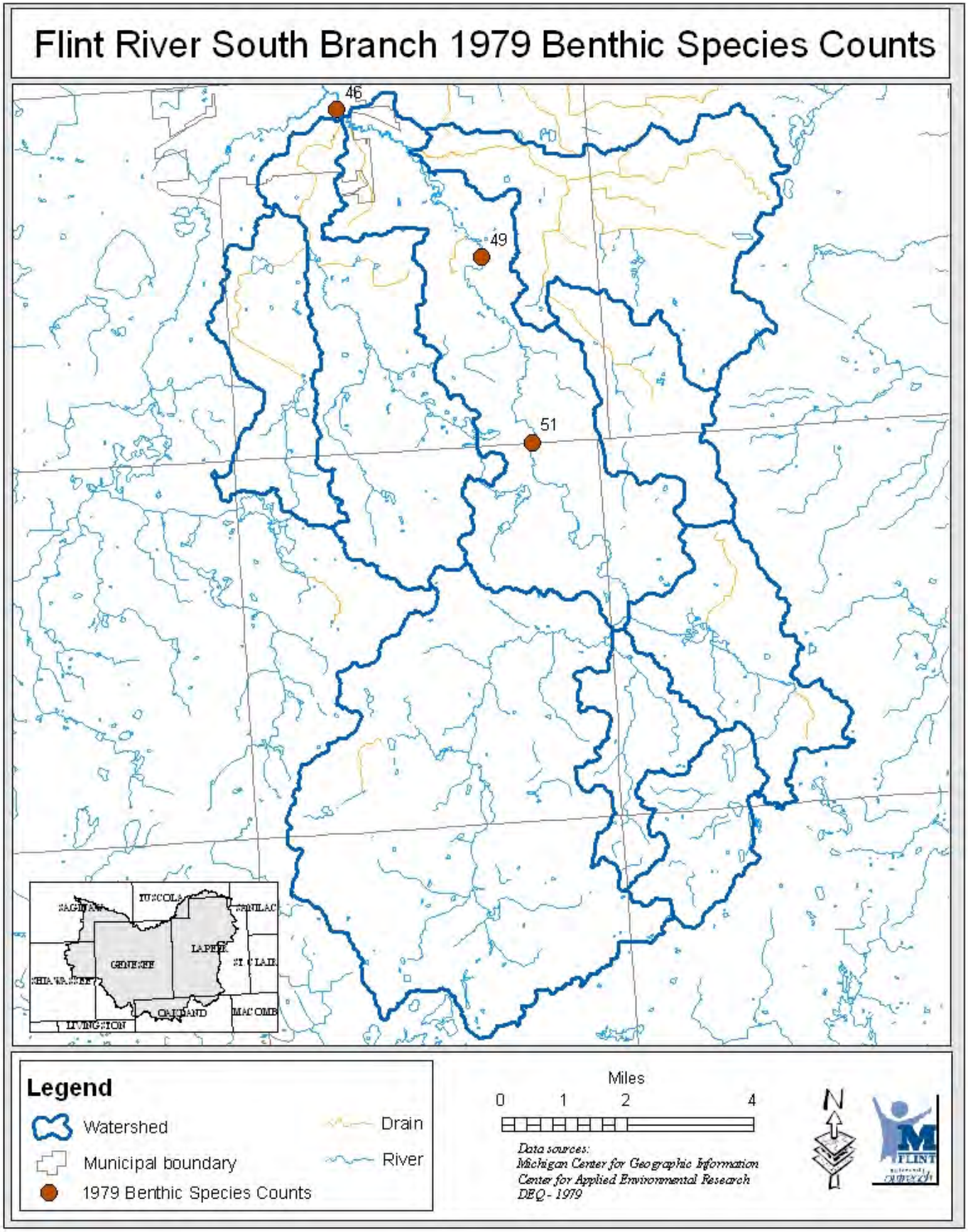
Macroinvertebrates (MIV) are valuable subjects for water quality studies because they stay put. They are not very mobile and unlike fish they cannot move to avoid pollution. Using these creatures to identify water quality conditions is based on the fact that every species has a certain range of physical and chemical conditions in which it can survive. The kinds of benthic invertebrates living in a stream indicate conditions within the stream because they cannot migrate to a different location if conditions are not conducive to survival. Some organisms can survive in a wide range of conditions and are more tolerant of pollution, and so are labeled "tolerant". Other species are very sensitive to changes in conditions and are "intolerant" of pollution. These are labeled "sensitive". The presence of tolerant organisms and few or no sensitive organisms indicates the presence of pollution, because pollution tends to reduce the number of species in a community by eliminating the organisms that are sensitive to changes in water quality.

The total numbers of species found in August of 1974 were 51, 49, and 46. A1979 survey data used artificial multiplate substrates for sampling. Three stations were sampled along the main stem of the South Branch Flint River. The mean numbers of species found at the three stations were 19.5, 28.5 and 20 respectively. The percent of mayfly-caddisfly-stonefly individuals was 66.6, 34.9, and 71.3 respectively.
To the best of CAER's knowledge, MIV sampling was not conducted again until 1993. Four stations were sampled of which all 4 were rated as "good" by the MDNR with a total of 53 species collected.

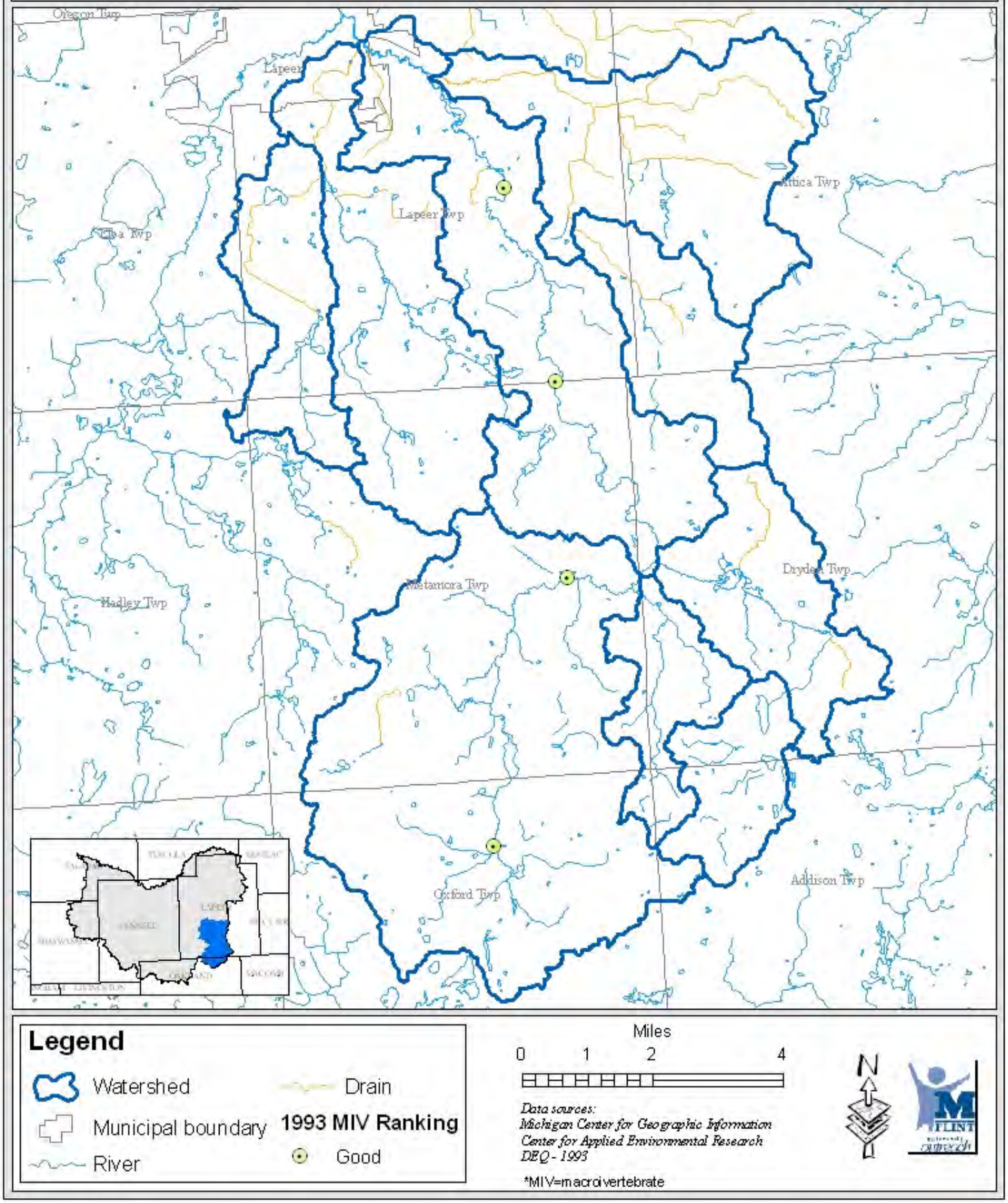
In 2001, seven stations were sampled for macroinvertebrates. The 3 stations on the South Branch were rated as excellent with 31, 38, and 23 total species found. The 2 stations on Hunters Creek were rated as acceptable (Turrill Rd) and as poor (Newark Rd) with totals of 31 and 11 species. The two Pine Creek stations were rated as acceptable and excellent with totals of 24 and 27 species collected. The South Branch was rated excellent at 4 of the 5 sites, and at one site on Pine Creek.

In the spring of 1999 the Flint River Watershed Coalition (FRWC) and the Center for Applied Environmental Research (CAER) at UM-Flint established a twice-yearly volunteer monitoring program for the Flint River watershed. The program was funded originally by a grant from MDEQ. Benthic monitoring assesses the quality of the Flint River watershed and educates the public. The volunteer monitoring program uses trained volunteers to gather information about the relative health of the areas stream and rivers. In the past five years over 100 volunteer monitors have participated in the program. The volunteers have helped to build awareness of pollution problems, been trained in pollution prevention, provided valuable data for waters that may otherwise be unassessed, and increased the amount of water quality information available to citizens and decision makers. The data collected thus far has been used to characterize various watersheds, screen for water quality problems, and measure existing conditions and trends.
The major element of the program is the collection and analyzing of benthic macroinvertebrates at 30 locations across the whole Flint River Watershed.

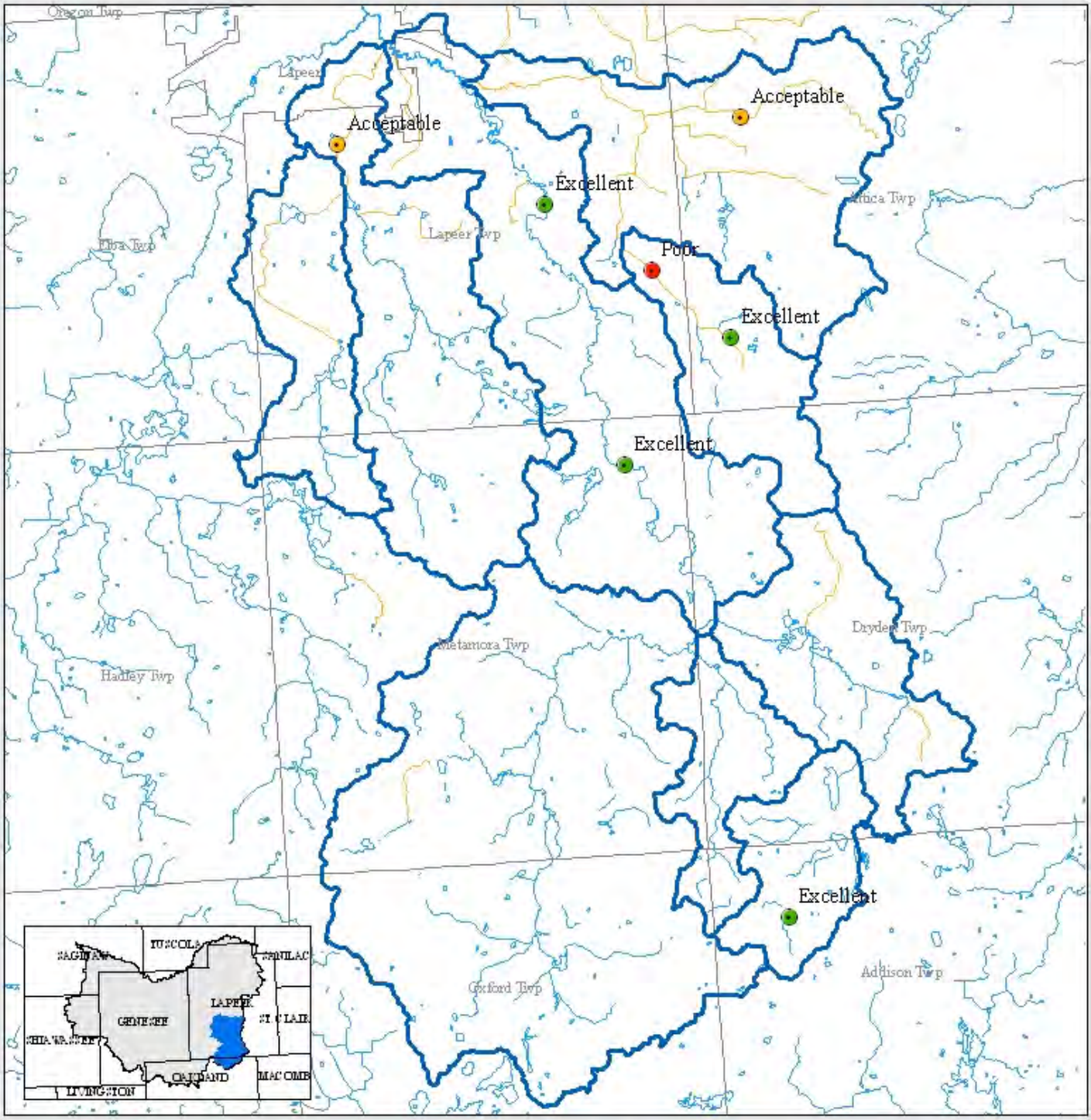
Studies done by the FRWC are performed by a group of volunteers. Volunteers are generally in groups of 2-3 that follow the Instream Survey Data Sheet available in the Stream Crossing Watershed Survey Procedure by the MDEQ. Monitoring started in June of 1999 and continues on to the present. One station on the South Branch has ranged from excellent to good. The Hunter Creek station has been surveyed from 2002-2003, and 2005. Scores for this site have ranged from poor to fair.


Flint River South Branch 1979 Benthic Species Counts
46
49
51
Legend
Watershed
Municipal boundary
1979 Benthic Species Counts
Drain
River
Miles
0
1
2
4
Data sources:
Michigan Center for Geographic Information
Center for Applied Environmental Research
DEQ - 1979
N

Flint River South Branch 1993 MIV* Ranking



Flint River South Branch 2001 MIV* Ranking



Legend

- Watershed
- Municipal boundary
- Drain
- River
- **2001 MIV Ranking**
- Excellent
- Acceptable
- Poor

Miles

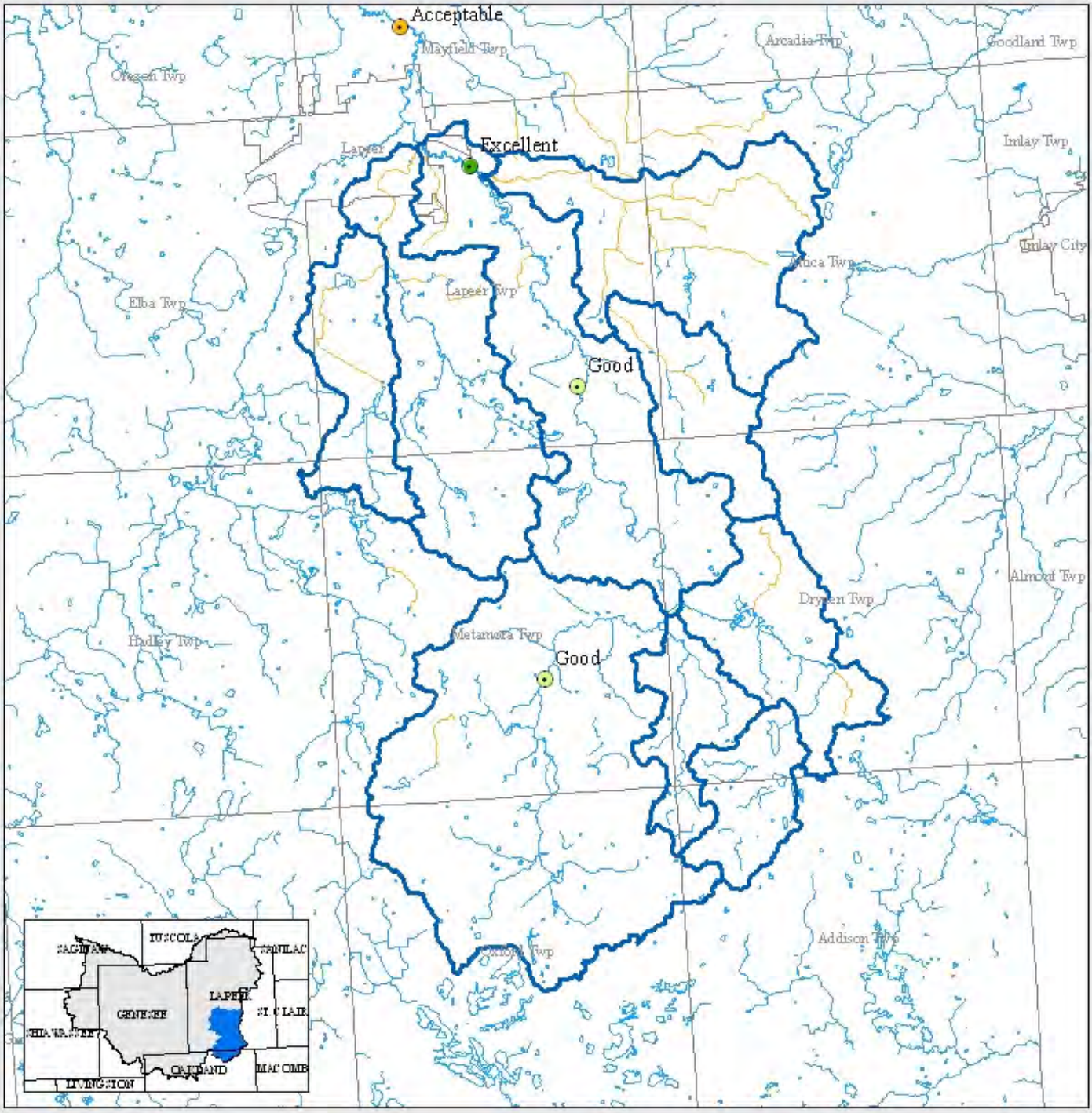
0 1 2 4

N

Data sources:
Michigan Geographic Data Library
Center for Applied Environmental Research
DEQ - 2001

*MIV = Macroinvertebrate

Flint River South Branch 2004 MIV* Rating



Legend

- River
- Watershed
- Drain
- Municipal boundary
- **2004 MIV Ranking**
- Excellent
- Good
- Acceptable

Miles

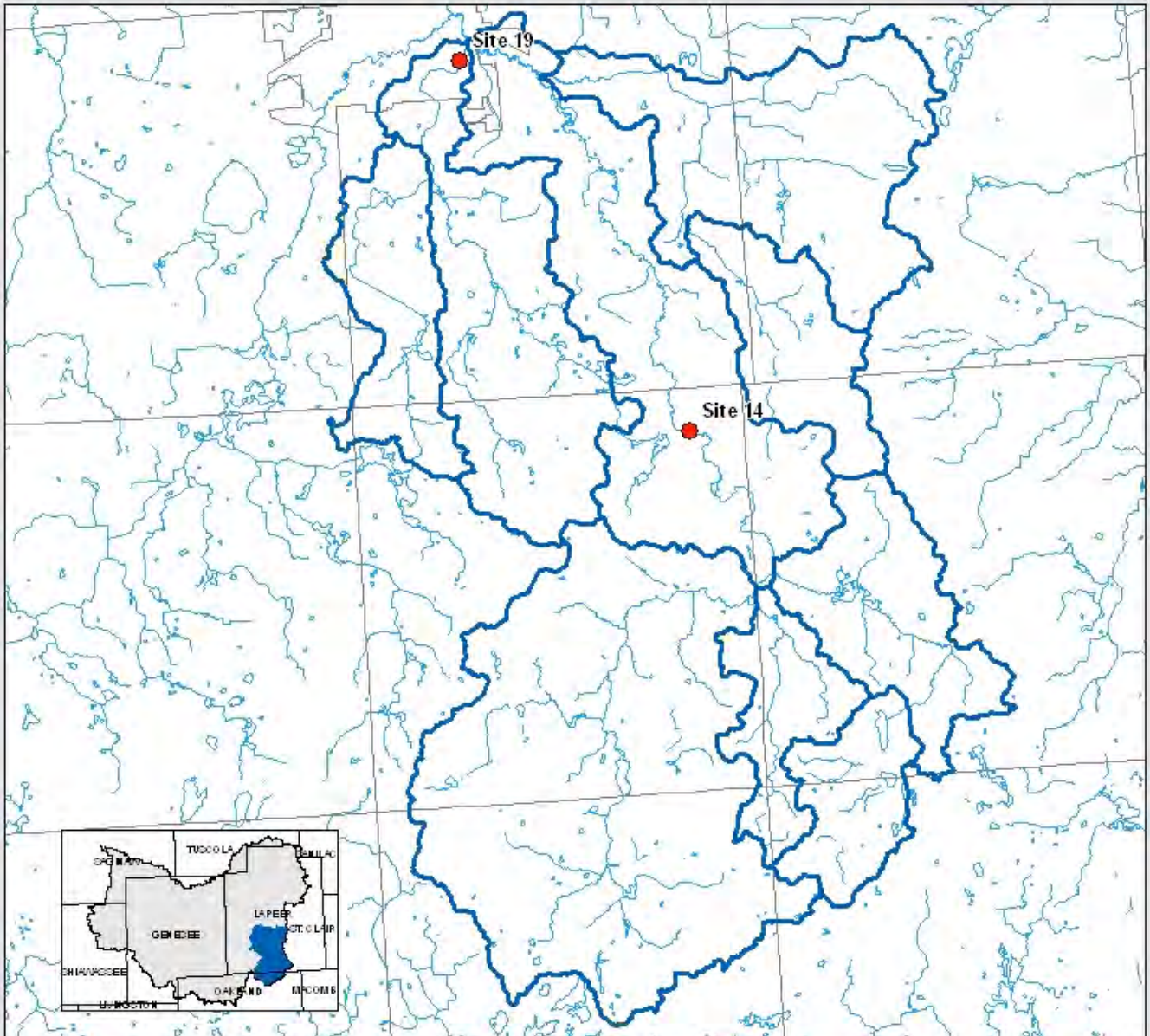
0 1.25 2.5 5

N

Data sources:
Michigan Center for Geographic Information
Center for Applied Environmental Research
DEQ - 2004

* MIV=Macroinvertebrate

Flint River Watershed Coalition MIV* Monitoring Data



Site	Jun-99	Sep-99	May-00	Oct-00	Apr-07	Aug-07	Apr-07	Oct-07	Jun-07	Oct-07	Apr-07	Oct-07	Apr-07	Oct-07	Apr-07	Oct-07	Apr-07
14	55.2 Excellent	43.7 Good	34.4 Good	54.2 Excellent	56.3 Excellent	53.2 Excellent	46.1 Good	35.7 Good	36.3 Good	48.1 Excellent	44.4 Good	37.0 Good	25.6 Fair	46.9 Good	35.3 Good	41.0 Good	42.6 Good
19	N/M	N/M	N/M	N/M	N/M	N/M	16.6 Poor	22.6 Fair	19.7 Fair	N/M	N/M	N/M	19.3 Fair	26.2 Fair	N/M	15.4 Poor	14.1 Poor

Legend

- Monitoring Sites
- Watershed
- Township Boundaries
- River

Miles

0 1.25 2.5 5

N

Data Source:
Michigan Center for Geographic Information
Flint River Watershed Coalition
*Macroinvertebrate

RIVERINE HABITAT STUDIES

Fisheries Studies in Flint River Sub-basin

The original fish communities of the Great Lakes region are of recent origin. Melt water from the Wisconsinan glacier created aquatic environments for fish. Original fish gained access through migration from connecting waterways. A description of the fish community in the Flint River Watershed at the time of European settlement (early 1800's) is not available. However anecdotal accounts of the time mention several species. Surveys on the Flint River and several tributaries in 1927 provide a reasonable account for additional indigenous fish species (MDNR, Fishery Division). Seventy-seven species are believed to be indigenous to the Flint River Watershed. The Original fish habitat of the Flint River watershed has been greatly altered by human settlement. The 1900's gave rise to the industrial era and the urbanization of the Flint River watershed. Cities and towns located near the river became more developed as their population increased. The discharge of human wastes and synthetic pollutants into the river degraded water quality to the extent that only the most tolerant fish species could survive. Dams were built for flood control, flow augmentation, ice harvesting, agriculture, and water supply to municipalities and industry. The biologic communities in the Flint River and its tributaries have improved significantly since the 1970's with water quality improvements resulting from the Clean Water Act (CWA). Continued efforts to improve water quality will most probably result in greater biological integrity. Although 77 species of fish remain present, at least 5 fish species that once used the Flint River for spawning (lake sturgeon, muskellunge, lake trout, lake herring, lake whitefish) are believed extirpated from the river. The status of 8 other fish species remains unknown. Present day biological communities must adapt to human alteration of the watershed. The geological and hydrological characteristics of the watershed and the development of an extensive drainage system result in an unstable flow and reduce habitat. The result is that highly adaptable biological communist will.

Fish communities have been altered through intentional and inadvertent introduction of exotic species. Fish stockings by the MDNR, Fisheries Division has focused on improving recreational fishing opportunities. In the early 1920's, many headwaters tributaries were stocked with brook trout. Although brook trout are indigenous to Michigan, no evidence exists to suggest they were native to the Flint River. No other non-indigenous species introduction has altered or affected the Flint River watershed fish communities like the common carp. This exotic was first introduced into Michigan waters in 1885 and spread rapidly.

Advisories to limit the consumption of certain fish species and sizes (fish contaminant advisories [FCAs]) have been published by MDEQ and the Michigan Department of Community Health for portions of the Flint River and the Thread Creek. All inland lakes, reservoirs, and impoundments within the State of Michigan are also under a fish advisory for mercury contamination. The latter is a general advisory applied to all inland lakes in Michigan since not all inland lakes, reservoirs, and impoundments have been tested or monitored.

South Branch Headwaters, Unnamed Creek, Whigville Creek, Whigville Headwaters

These segments includes the river reach from the origin, a small inlet to Horseshoe Lake, downstream to Winns Pond, a 25 acre impoundment southeast of the town of Lapeer. Whigville Creek is the principal tributary to this reach. Moderate groundwater inflow, moderate gradient, cool water temperature, and stable flow typify this segment. Habitat is available in the form of pool-riffle-run sequencing, rock substrate, and submerged woody structure. In 1997, collections from three sites found 29 fish species with hornyhead chub, common shiner, and creek chub being most common. (Leonardi 2001)

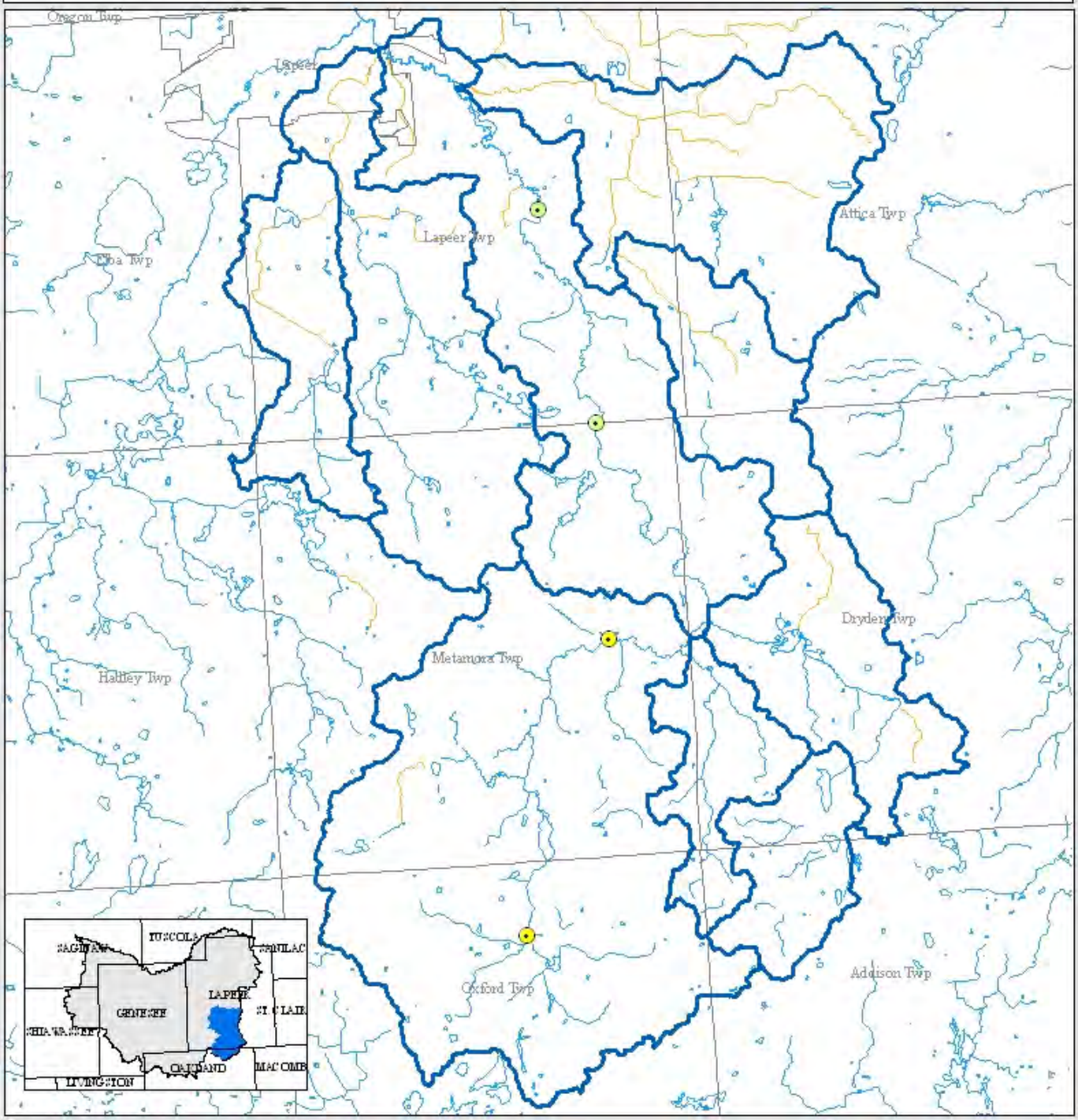
Collectively, cyprinids and catostomids accounted for 78% of the catch. The fish communities at each site were rated excellent (non-impaired) using Great Lakes and Environmental Assessment Section (GLEAS), Procedure 51 (Leonardi 1997, MDEQ 1997c). Shallow water depth and low base flow limits top predator species. Winns Pond supports a warm-water fish community of bluegill, pumpkinseed sunfish, largemouth bass, northern pike, and common carp.

Hunters Creek, Mirror Creek, Pine Creek, Pine Creek Headwaters and Main Branch

These segments differs from the upper South Branch Sub-watersheds as it has less groundwater inflow, less gradient, reduced flow stability, and warmer water temperatures. Human perturbation is also greater. All tributaries in this portion have been partially altered to accommodate land drainage, resulting in reduced fish habitat and flow stability. Pool-riffle-run sequencing is less frequent and sand, loam, and clay are the prevalent stream substrates.

A self-sustaining brook trout fishery exists in the Pine Creek Headwaters. South of Interstate 69 the creek is less perturbed, maintaining a natural flow with dense bank cover. Moderate groundwater inflow results in a cold-water temperature regime and coldwater fish community. North of Interstate 69, the creek has been dredged and channelized resulting in increased water temperature and loss of fish cover. Water temperatures taken July 7, 1997, south of Interstate 69, averaged 55 °F but, north of Interstate 69, temperature averaged 63 °F (Leonardi 1997). Four sites were sampled in 1997. Thirteen fish species were found with creek chub, blacknose dace, central mudminnow, and brook trout accounting for 76% of the combined catch. Pine Creek was the only tributary of the Flint River where longnose dace exist. No brook trout were found north of Interstate 69. (Leonardi 2001)

Flint River South Branch 1993 Habitat Conditions



Legend

- Watershed
- Municipal boundary
- Drain
- River

1993 Habitat Conditions

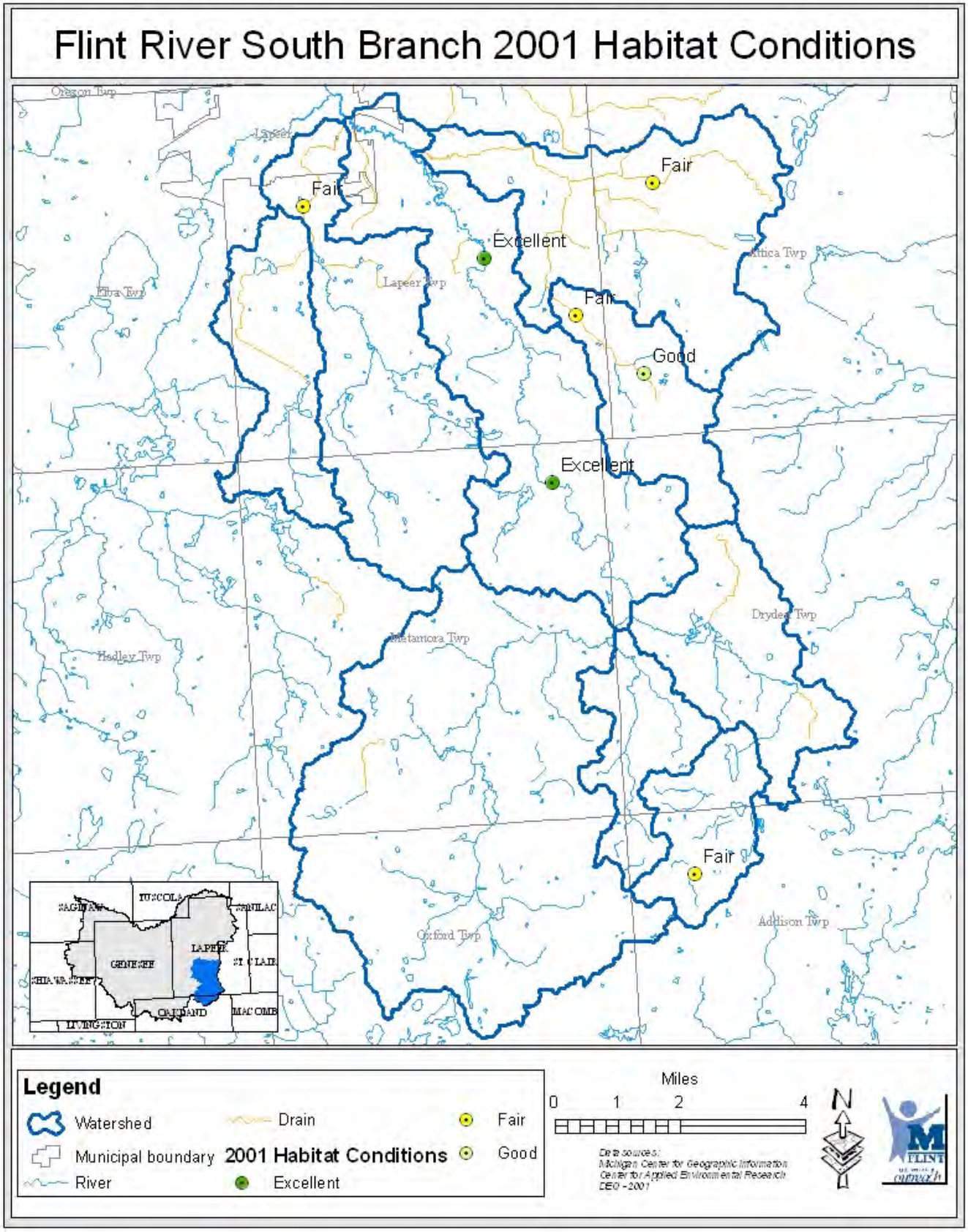
- Good
- Fair

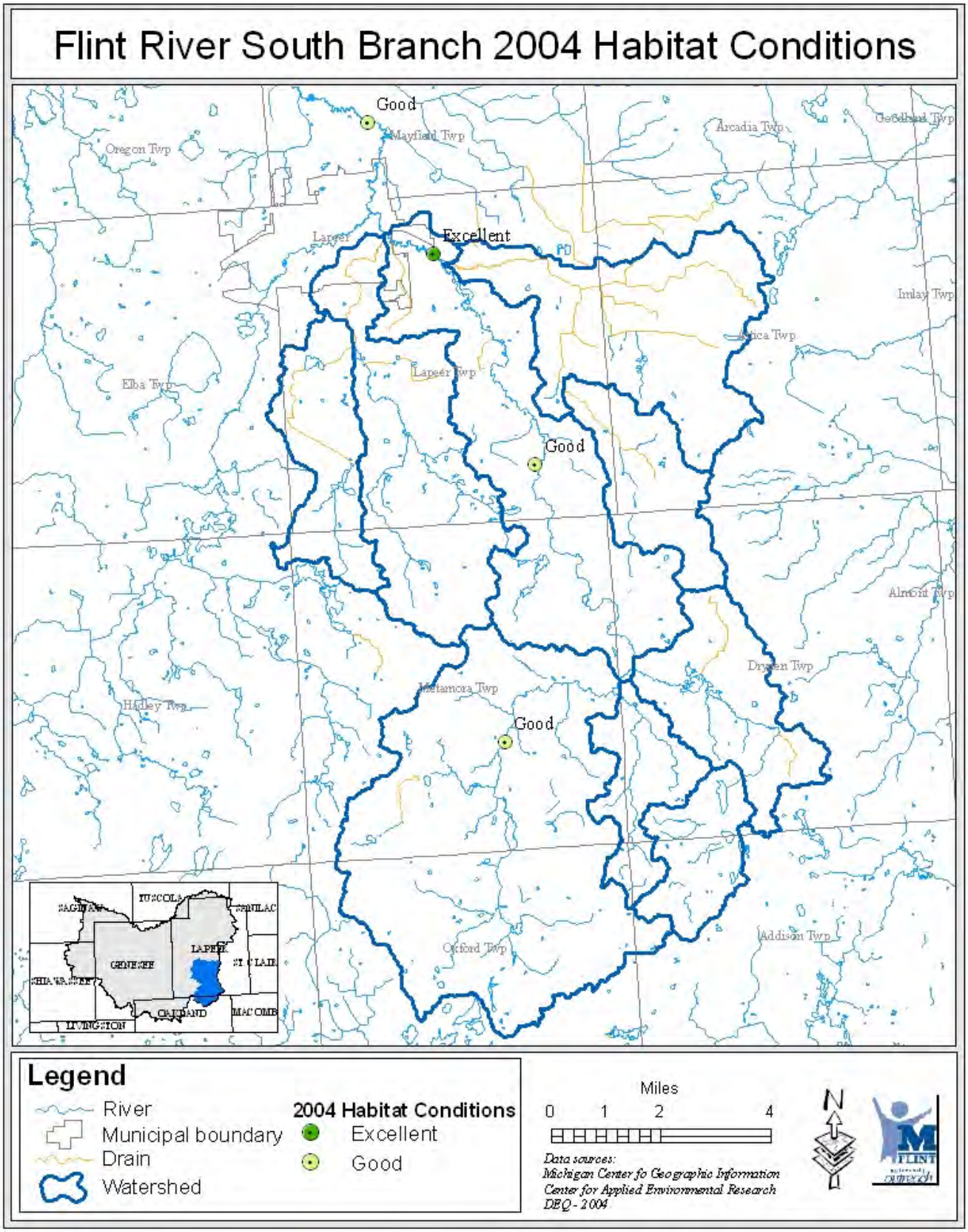
Miles

0 1 2 4

N

Data sources:
Michigan Center for Geographic Information
Center for Applied Environmental Research
DEQ - 1993

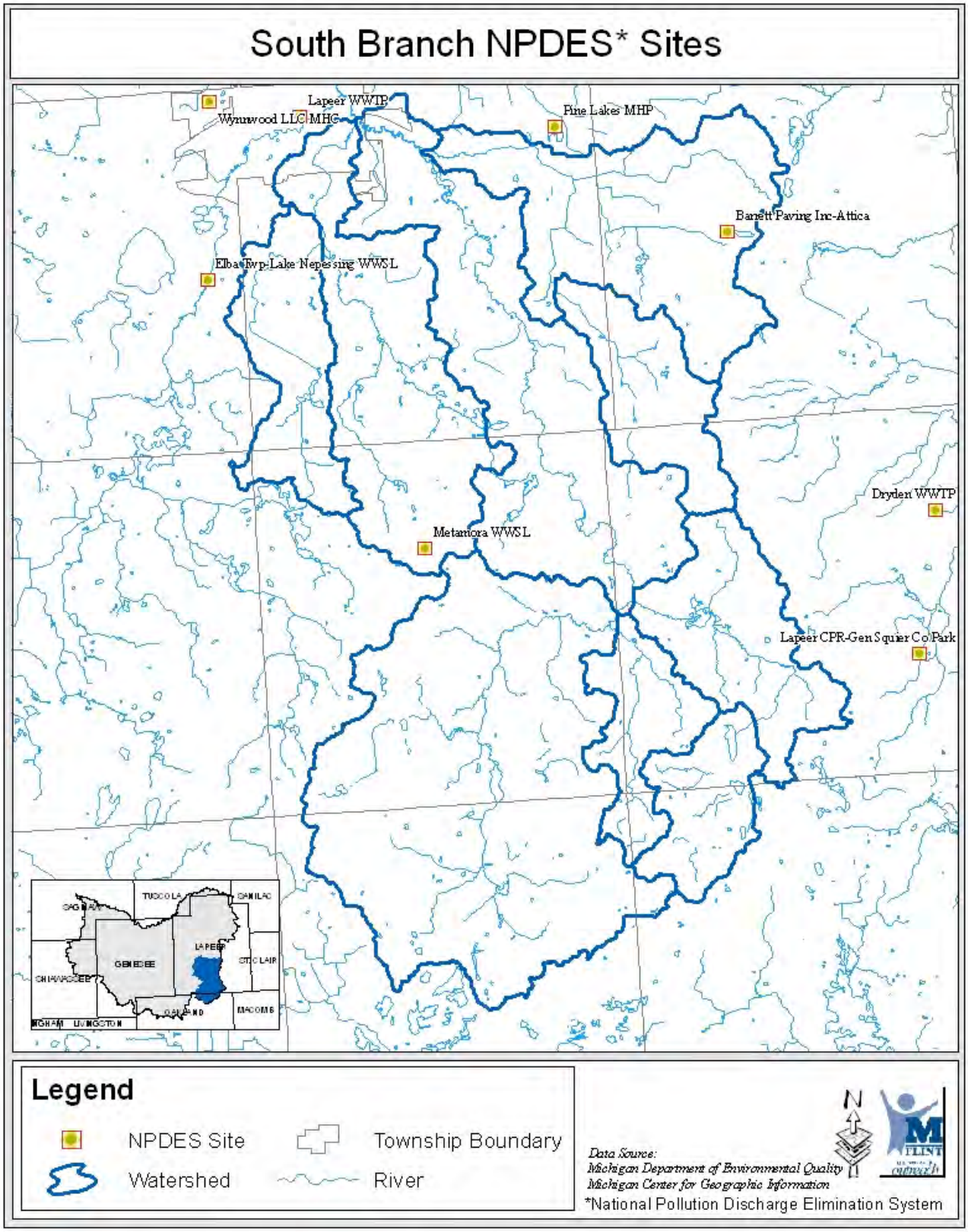

Flint River South Branch 2001 Habitat Conditions
Oregon Twp
Lapeer
Fair
Fair
Excellent
Ittica Twp
Elba Twp
Lapeer Twp
Fair
Good
Excellent
Drydeen Twp
Metamora Twp
Hadley Twp
Fair
Addison Twp
Oxford Twp
TUSCOLA
SANILAC
SAGINAW
LAPEER
GENESEE
ST CLAIR
SHIAWASSEE
OAKLAND
MACOMB
LIVINGSTON
Legend
Watershed
Municipal boundary
River
Drain
2001 Habitat Conditions
Excellent
Fair
Good
Miles
0
1
2
4
N
Data sources:
Michigan Center for Geographic Information
Center for Applied Environmental Research
DEQ - 2001
FLINT

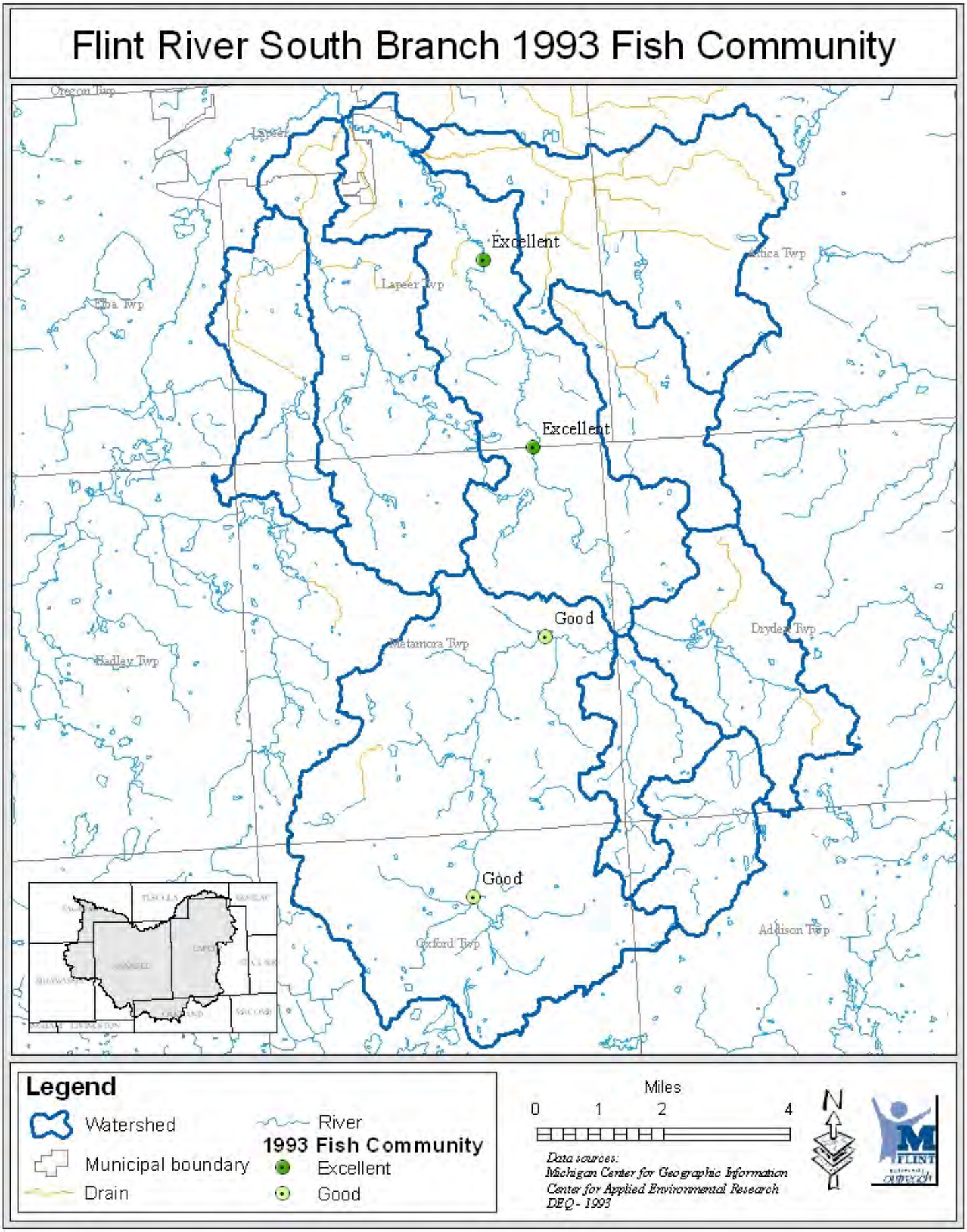

Flint River South Branch 2004 Habitat Conditions
Good
Mayfield Twp
Oregon Twp
Arcadia Twp
Goodland Twp
Lapeer
Excellent
Imlay Twp
Elba Twp
Lapeer Twp
Good
Almont Twp
Dryden Twp
Metamora Twp
Hadley Twp
Good
Oxford Twp
Addison Twp
Legend
River
Municipal boundary
Drain
Watershed
2004 Habitat Conditions
Excellent
Good
Miles
0 1 2 4
Data sources:
Michigan Center fo Geographic Information
Center for Applied Environmental Research
DEQ - 2004
N

Point sources

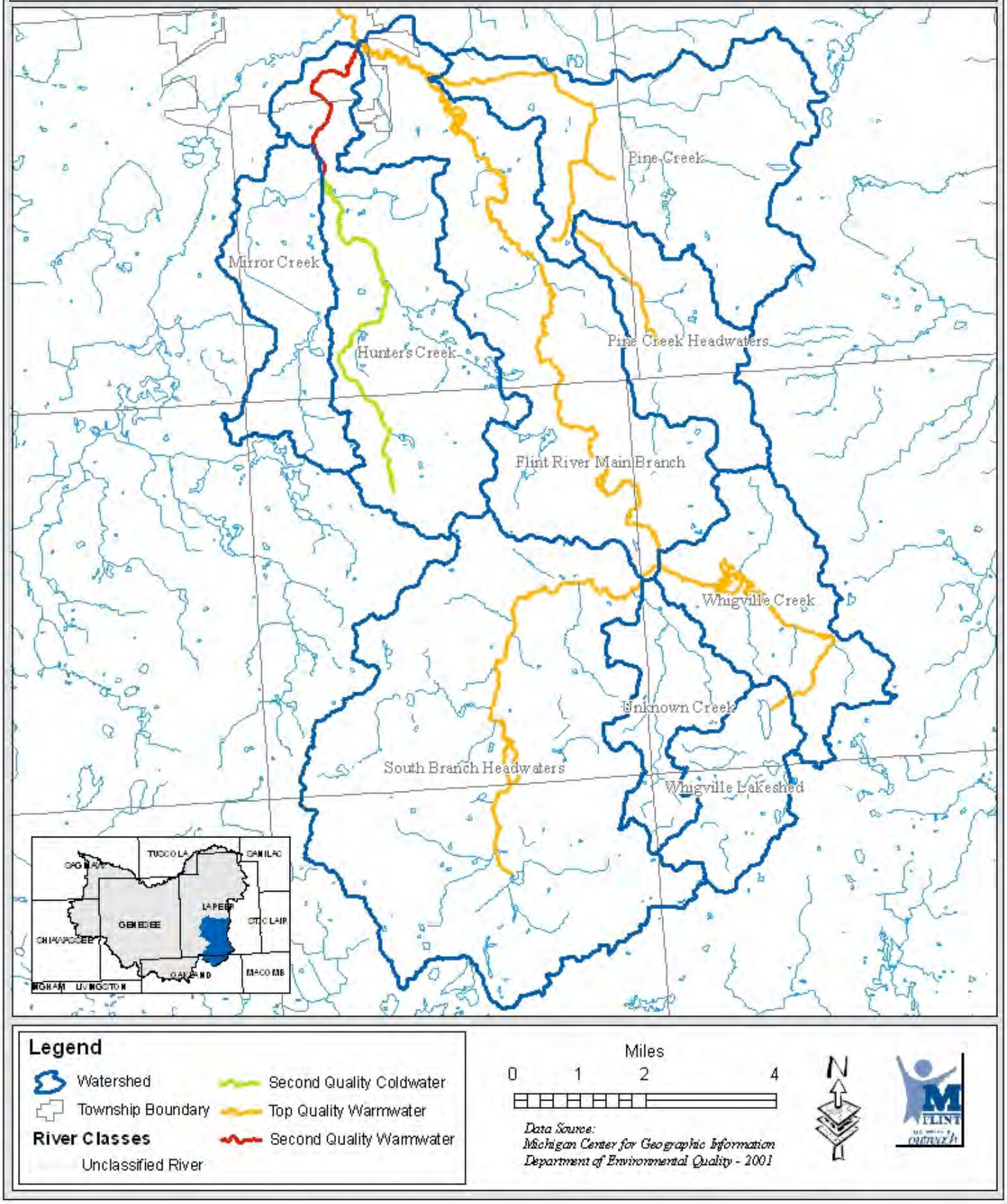
Table 7.1 – National Pollution Discharge Elimination System (NPDES) South Branch Sites

Facility Name	City	Ownership	Permit Expiration
Barrett Paving Inc-Attica	Attica	Private	4/1/2010
Metamora Waste Water Stabilization Lagoon	Metamora	Public	10/1/2009

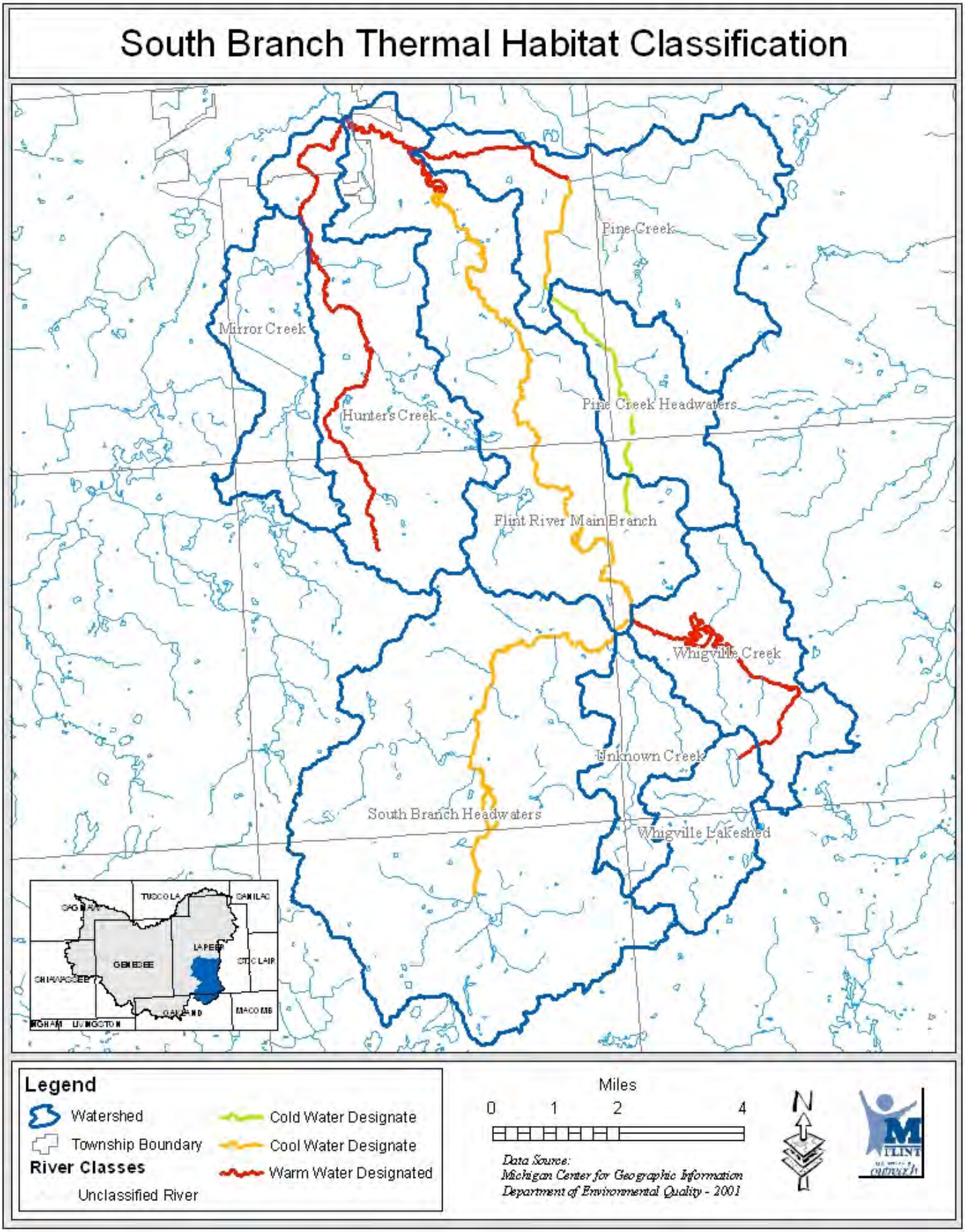

South Branch NPDES* Sites
Lapeer WWTP
Wynnwood LLC MHC
Pine Lakes MHP
Barrett Paving Inc-Attica
Elba Twp-Lake Nepessing WWSL
Dryden WWTP
Metamora WWSL
Lapeer CPR-Gen Squier Co Park
TUSCOLA
SANILAC
SAGINAW
LAPEER
GENESEE
ST CLAIR
CHIAWASSEE
OAKLAND
MACOMB
LIVINGSTON
Legend
NPDES Site
Township Boundary
Watershed
River
N
Data Source:
Michigan Department of Environmental Quality
Michigan Center for Geographic Information
*National Pollution Discharge Elimination System


Flint River South Branch 1993 Fish Community
Oregon Twp
Lapeer
Excellent
Lapeer Twp
Elba Twp
Attica Twp
Excellent
Good
Metamora Twp
Hadley Twp
Dryden Twp
Good
Oxford Twp
Addison Twp
Legend
Watershed
Municipal boundary
Drain
River
1993 Fish Community
Excellent
Good
Miles
0
1
2
4
N
Data sources:
Michigan Center for Geographic Information
Center for Applied Environmental Research
DEQ - 1993

South Branch Michigan Stream Classification



South Branch Thermal Habitat Classification



Appendix 6
Public Education Plan

GOAL 3: Promote and establish educational programs that support watershed planning goals, objectives and tasks, and increase stewardship.
Pollutants Addressed: All

There are two primary objectives for public education as a component of this watershed management plan. The first is to create broad community awareness of the word and concept "watershed." It is important that all community members understand that we live, learn and work in a watershed and that we rely on its water as a basic resource. Our watershed is an important element of "place" and efforts will be made to encourage people to identify with their own watershed just as they identify with their local municipality or school district. The second educational objective is to promote stewardship of water resources as a common-sense civic responsibility of good citizenship. What we do on land can have a direct impact on the present and future quality of surface and ground water in our watershed. Our goal is to elevate public understanding of these connections and to encourage actions that maintain the highest water quality and a healthy watershed ecosystem.

Categories:

1. General
2. Shoreline Protection and Restoration
3. Road Stream Crossings
4. Agriculture
6. Habitat, Fish and Wildlife
8. Wastewater
10. Wetlands
12. Land Protection and Management
13. Development
14. Zoning and Land Use
15. Groundwater
16. Monitoring

Target Audiences Include:
Agriculture
Builder/Developer/Realtor
Business and Industry
Education
Households
Local Governments
Partner Organizations
Riparian Landowners
General

General Education (Focus on Sub-Basin, Flint River Watershed)

Task 1: Regularly inform the public about activities, study findings, successful example projects, and opportunities for contribution in the Flint River Watershed.

Subtask A: Publish and distribute quarterly newsletter of the FRWC
Estimated Cost: $2000 each
Timeline: Ongoing
Priority: High
Potential Project Partners: FRWC
Target Audience: General

Subtask B: Publish annual *Freshwater Focus* (State of the Watershed) tabloid summarizing the overall condition of the region's water resources and highlighting current research, implementation accomplishments, monitoring programs and other topics relevant to the water quality of the bay.
Estimated Cost: $10,000/year
Timeline: Ongoing
Priority: High
Potential Project Partners: FRWC
Target Audience: General

Subtask C: Provide watershed information and news to the local and regional media on a regular basis in the form of press releases, PSAs, feature stories, story ideas, editorials, etc.
Estimated Cost: $5,000/year
Timeline: Ongoing
Priority: High
Potential Project Partners: All
Target Audience: General

Task 2: Maintain and promote South Branch web page in a comprehensive website containing information about the watershed along with activities, events, ways to get involved, plan documents, links to relevant organizations and resources, etc.
Estimated Cost: $1,500/year
Timeline: Ongoing
Priority: High
Potential Project Partners: CAER, FRWC
Target Audience: All

Task 3: Host annual, regional "Water Summit" for regional stakeholders to address priority issues impacting water quality, review implementation efforts and accomplishments, share resources, etc.
Estimated Cost: $5,000/year
Timeline: Ongoing
Priority: High
Potential Project Partners: FRWC, CAER, MSU-E, GCDC, LCDC, CD's
Target Audience: Local Government, Partners, General Public, Community Leaders (special target audience)

Task 4: Establish educational signage and kiosks throughout the watershed at parks, demonstration projects, schools. etc.
Estimated Cost: $10,000
Timeline: 10 years
Priority: Medium
Potential Project Partners: FRWC, CAER, MSU-E, GCDC, LCDC, CD's
Target Audience: General

Task 5: Develop comprehensive set of watershed maps and make available to landowners, local governments and others.
Estimated Cost: $5,000
Timeline: 3 years
Priority: Medium
Potential Project Partners: CAER, County Gov.
Target Audience: Local Governments, General Public, Partner Organizations

Task 6: Provide training to local citizens regarding environmental advocacy and the Clean Water Act.
Estimated Cost: $2,500
Timeline: 3 years
Priority: Medium
Potential Project Partners: FRWC
Target Audience: Households, Riparians

Task 7: Host annual "Get to Know Your Watershed" guided and/or self-guided tours.
Estimated Cost: $5,000
Timeline: 10 years
Priority: Low
Potential Project Partners: FRWC, CAER, MSU-E, GCDC, LCDC, CD's, Land Conservancies
Target Audience: General

Task 8: Develop a watershed-wide speaker's bureau as a resource for civic clubs and organizations, workshops, conferences, etc.
Estimated Cost: $1,500
Timeline: 10 years
Priority: Low
Potential Project Partners: FRWC
Target Audience: General

Task 9: Develop educational 10-12 minute video about priority watershed issues for use in presentations.
Estimated Cost: $15,000
Timeline: 3 years
Priority: Low
Potential Project Partners: CAER, FRWC
Target Audience: All

Shoreline Protection and Restoration

Task 1: Conduct shoreline and riparian landowner workshops to stress the benefits and importance of riparian buffers to protect water quality.
Estimated Cost: $5,000
Timeline: 3 years
Priority: High
Potential Project Partners: FRWC, CAER, MSU-E, GCDC, LCDC, CD's
Target Audience: Riparians

Task 2: Develop native landscaping education program including workshops, demonstrations, and brochures.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, CD's, Applewood Estate, Landscaping Companies
Target Audience: Households, Riparians

Task 3: Produce or distribute existing riparian and/or shoreline landowners' guidebooks.
Estimated Cost: $10,000
Timeline: 3 years
Priority: Medium
Potential Project Partners: CAER, FRWC, CD's
Target Audience: Riparians

Road Stream Crossings

Task 1: Host workshops for County Road and Drain Commissions to provide education regarding possible BMPs to establish at road crossings to reduce the harmful effects of sedimentation and stormwater runoff.
Estimated Cost: $5,000
Timeline: 10 years
Priority: Medium
Potential Project Partners: CAER, FRWC, CD's
Target Audience: Local Governments

Agriculture

Task 1: Identify existing farms with conservation practices to serve as a demonstration site. Invite the public for tours and workshops.
Estimated Cost: $10,000
Timeline: 10 years
Priority: Medium
Potential Project Partners: MSU-E, CDs, NRCS
Target Audience: Agriculture, Households

Task 2: Develop marketing strategy for federal and non-federal programs to promote conservation practice implementation
Estimated Cost: $10,000
Timeline: 2 years
Priority: Medium
Potential Project Partners: MSU-E, CDs, NRCS
Target Audience: Agriculture, Households

Habitat, Fish, and Wildlife

Task 1: Provide education to the general public on the importance of maintaining diverse wildlife habitats and developing wildlife corridors on their property.
Estimated Cost: $5,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, CDs, NRCS
Target Audience: Households, Agriculture, Local Government

Task 2: Educate the public regarding CAERs GreenLinks program through 1) conducting tours to existing lands enrolled in Conservation programs and 2) mailed packets of information to potential landowners.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, Land Conservancies
Target Audience: Households, Agriculture, Local Government

Task 3: Educate public officials through workshops, demonstration tours, and information packets regarding the impacts of increased land fragmentation on wildlife habitat and corridors.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: CDs, NRCS
Target Audience: Local Government

Waste Water

Task 1: Develop comprehensive public education program regarding septic systems including:

- Using proper septic system design for the site conditions and considering the proximity to bodies of water when sitting them,
- Properly maintain existing septic systems, and
- Providing education regarding the development of alternative onsite wastewater treatment systems.

Estimated Cost: $3,000/year
Timeline: 3 years
Priority: High
Potential Project Partners: FRWC, Health Depts.,
Target Audience: Households, Riparians

Wetlands

Task 1: Educate local governments, developers, contractors, and others through workshops and presentations, press releases, brochures, etc, regarding the ecological consequences of developing unregulated wetland areas, especially in headwater/recharge areas.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: FRWC, CAER
Target Audience: Local Governments, Builder/Developer/Realtor

Task 2: Host a series of workshops and seminars throughout the watershed to educate public officials regarding appropriate and successful methods for restoring wetlands.
Estimated Cost: $10,000
Timeline: 3 years
Priority: Medium
Potential Project Partners: CAER, FRWC, CD's
Target Audience: Local Governments

Land Protection and Management

Task 1: Provide landowner education regarding voluntary conservation easements and other available land protection measures utilizing direct mail, publications, etc. Schedule bus tours of areas already in conservation easements to provide examples of successful efforts.
Estimated Cost: $10,000
Timeline: 10 years
Priority: High
Potential Project Partners: CAER, OLC
Target Audience: Households, Riparians

Land Development

Task 2: Compile information packet and host workshops, luncheons, or small seminars for area realtors providing them with basic information regarding environmental laws (wetlands, beach maintenance, onsite wastewater treatment, etc.) that might impact new homeowners.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, Realtors Association
Target Audience: Households, Riparians, Builder/Developer/Realtor

Task 3: Develop watershed information packet for realtors, developers, and other businesses to hand out to customers, new homeowners, and others on activities the can do to improve/protect water quality on their property.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, FRWC, Chambers, Newcomers Clubs
Target Audience: Households, Riparians, Builder/Developer/Realtor

Task 4: Encourage design, construction and maintenance of new and existing development in the watershed that utilizes Best Management Practices to protect water quality.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, Home Builders Association, FRWC,
Target Audience: Builder/Developer/Realtor, Local Government

Zoning and Land Use

Task 1: Provide key elected/appointed public officials (planning commissioners, etc.) with summary version of South Branch Watershed Management Plan and basic recommendations relevant to local units of government. (See Appendix 2)
Estimated Cost: $3,500
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, FRWC, CDs
Target Audience: Local Governments

Task 2: Educate and inform local planning and zoning officials regarding up-to-date information on planning, zoning, and design innovations relating to the protection of water quality.
Estimated Cost: $10,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER
Target Audience: Local Governments

Task 3: Develop an information packet for Zoning Boards of Appeals and Planning Commissions to assist them in developing reasonable conditions to place on requests for variances (i.e., installing or providing riparian buffers and/or other BMPs on site).
Estimated Cost: $10,000 initial year; $2,500/yr after packet is completed
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, FRWC
Target Audience: Local Government

Task 4: Facilitate meetings between townships regarding the sharing of model ordinances that protect water quality and natural resources.
Estimated Cost: $5,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, FRWC, MSU-E
Target Audience: Local government

Ground Water

Task 1: Educate local governments, developers, contractors, and others regarding headwater and groundwater recharge areas (how they work, soils, vegetation, etc.) and why it is important to protect them and avoid overdeveloping them.
Estimated Cost: $25,000
Timeline: 3 years
Priority: High
Potential Project Partners: CAER, MSU-E Groundwater Stewardship, CDs
Target Audience: Local Government, Builder/Developer/Realtor

Monitoring

Task 2: Provide ongoing information to stakeholders regarding research and monitoring efforts conducted by the TWC and various partner organizations in the watershed and what it means to various target audiences (through documents such as the annual *Freshwater Focus* newspaper insert, TWC website, press releases, etc).
Estimated Cost: $5,000
Timeline: 3 years
Priority: High
Potential Project Partners: FRWC, CAER
Target Audience: All

Appendix 7
Pollution Loading Calculations

Pollutant Loading Calculations

The purpose of the pollutant loading calculation in a watershed management plan is to standardize the progress in reporting so water quality impacts and state-wide advancements can be systematically represented. Calculations were conducted using the Pollutant Controlled Calculation and Documentation for 319 Watersheds Manual (MDEQ 1999) and recommendations from the Genesee County District Conservationist. It is recognized that this system has limitations, but does provide a uniform system of estimating relative pollutant loads.

A majority of the work identified in the South Branch Watershed and implementation work plans focused on anti-degradation policies and education. The watershed planning team was unable to identify quality quantitative methods for developing pollutant load reductions based upon future education and policy implementation In the following section we have provided pollutant loading calculations for only known inputs of sediment, sediment-borne phosphorus and nitrogen. This method does not account for nutrients that are dissolved in solution, suspected bacteria and nutrients from septic systems and sedimentation from suspected gully erosion sites. However, as suspected gulley erosion and septic system failures sites are identified calculations will be conducted as part of the monitoring and evaluation process.

The mitigation of agricultural impacts within riparian corridor of the entire South Branch Watershed is identified as a critical task in the implementation work plan. Appendix 2 of the plan provides information about the percent and total area of agricultural land cover directly adjacent to the stream channel. This information is based upon the National Oceanic and Atmospheric Administrations Costal Change Analysis Program (C-CAP) land use data. Recognizing the limitations of C-CAP and the importance of agricultural land mitigation in the riparian corridors, the planning team generated a new “adjacent agriculture” data set from aerial photography provided by the communities. (Figure 1) This area was identified by overlaying the 1978 MIRIS Land Use Data set over 2005 high resolution aerial photography. CAER staff then updated agricultural polygons within a 150 foot buffer of the watershed’s rivers. This data was then clipped to the nine sub-watershed boundaries. Figure A7.2 illustrates a small portion of the data layer. This new data set provides the planning team with an accurate as possible estimation of areas critical for BMP implementation. These areas serve as the basis for implementing BMPs and loadings calculations

Figure A7.2 Adjacent Agricultural Land Areas

Loading Reduction Calculations

Due to potential variability in implementation measures by individual landowners, the planning team based its loading calculation on the assumption that all areas would be mitigated using a 50 ft filter strip. Other BMPs are available including no till practices but the implementation of filter strips was believed to be more suitable to local landowners, and where large enough, provide wildlife habitat.

Sub-watershed 50 foot adjacent ag			
Watershed	**Sub-Watershed Area (Acre)**	**Ag Buffer Area (Acre)**	**Watershed %Ag Buffer**
Hunters	8,297.3430	32.587	0.4
Main Branch	11,395.3180	50.425	0.4
Mirror	3,880.4440	19.304	0.5
Pine	8,479.7620	115.740	1.4
Pine headwaters	3,515.4370	10.395	0.3
South Branch headwaters	18,300.2840	443.822	2.4
Unknown	2,758.8260	96.490	3.5
Whigville	4,703.0280	24.243	0.5
Whigville headwaters	2,674.0720	17.307	0.6

Table A7.1 Area and percent of 50 foot agriculture buffer

Pollutant loading reduction calculations are presented in table xxx by sub-watershed. The pollution loading calculations for sediment were conducted using the Revised Universal Soil Loss Equations 2.0 computer program. The Genesee County NRCS field office conducted calculations for soil loss on the individual soil types identified in the new adjacent agricultural data layer. Based upon local knowledge of the agricultural practices and landscape the following assumptions were made:

1. Soybean 15” 20” rows
2. Spring Cultivation with Strait Point Plow and Disc
3. 150 ft slope for A-C slope soils
4. 200 ft slope for D-F slope soils
5. Soil percent slope
    a. A soils = 1%
    b. B soils = 4%
    c. C soils = 8%
    d. D soils = 15 %
    e. E Soils = 22%
    f. F Soils = 25%

Nitrogen and Phosphorus calculations were completed using the Nutrient Reduction Calculation identified in the Pollutants Controlled Calculation and Documentation of Section 319. Based upon the recommendations of the manual the following assumptions were made:

1. Phosphorus concentration = .0005 lbP/ld soil
2. 0.001 lbn/lb soil
3. Soil Textures
    a. Clay = 1.15
    b. Silt = 1.00
    c. Loam = .95 (The use of .95 for loam was on the recommendation of NRCS field staff)
    d. Sand = .85
    e. Peat = 1.50

Watershed	**Current Erosion***	**After BMP Erosion***	**Erosion Reduction***	**Phosphorus Reduction****	**Nitrogen Reduction****
Hunters Creek	43.608583	0.2208131	43.38777	40.71508807	81.43017613
Main Branch	133.77071	0.7617431	133.00896	120.0508728	240.1017456
Mirror Creek	65.865262	0.381592	65.48367	65.29647005	130.59294
Pine Creek	77.458531	0.6602098	76.7983212	67.62676486	135.2535297
Pine Creek Headwaters	4.625352	0.024368	4.600984	4.2315895	8.463179
South Branch Headwaters	305.69793	1.71249593	303.985437	276.7573705	553.5147409
Unknown Creek	217.30122	1.048335	216.25288	209.6093341	419.218668
Whigville Creek	35.684608	0.213109	35.4715	34.8118336	69.6236671
Whigville Creek Headwaters	257.57571	1.3152457	256.26046	228.4129128	456.8258256
*Tons/Year		**Total**	**1135.249982**	**1047.512236**	**2095.024472**
**Pounds/Year					

Appendix 8.
Relevant Water Quality Standards for the South Branch Watershed

Dissolved Oxygen

Dissolved oxygen (DO) refers to the volume of oxygen that is contained in water. Oxygen enters the water as rooted aquatic plants and algae undergo photosynthesis, and as oxygen is transferred across the air-water interface. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen). Gas solubility increases with decreasing salinity (freshwater holds more oxygen than does saltwater). Both the partial pressure and the degree of saturation of oxygen will change with altitude. Finally, gas solubility decreases as pressure decreases. Thus, the amount of oxygen absorbed in water decreases as altitude increases because of the decrease in relative pressure.

Once absorbed, oxygen is either incorporated throughout the water body via internal currents or is lost from the system. Flowing water is more likely to have high dissolved oxygen levels compared to stagnant water because the water movement at the air-water interface increases the surface area available to absorb the oxygen. In flowing water, oxygen-rich water at the surface is constantly being replaced by water containing less oxygen as a result of turbulence, creating a greater potential for exchange of oxygen across the air-water interface. Because stagnant water undergoes less internal mixing, the upper layer of oxygen-rich water tends to stay at the surface, resulting in lower dissolved oxygen levels throughout the water column. Oxygen losses readily occur when water temperatures rise, when plants and animals respire (breathe), and when aerobic microorganisms decompose organic matter.

Oxygen levels are also affected by the diurnal (daily) cycle. Plants, such as rooted aquatic plants and algae produce excess oxygen during the daylight hours when they are photosynthesizing. During the dark hours they must use oxygen for life processes.

Dissolved oxygen may play a large role in the survival of aquatic life in temperate lakes and reservoirs during the summer months, due to a phenomenon called stratification (the formation of layers). Seasonal stratification occurs as a result of water's temperature-dependent density. As water temperatures increase, the density decreases. Thus, the sun-warmed water will remain at the surface of the water body (forming the epilimnion), while the more dense, cooler water sinks to the bottom (hypolimnion). The layer of rapid temperature change separating the two layers is called the thermocline.

At the beginning of the summer, the hypolimnion of the lake will contain more dissolved oxygen because colder water holds more oxygen than warmer water. However, as time progresses, an increased number of dead organisms from the epilimnion sink to the bottom and are broken down by microorganisms. Continued microbial decomposition eventually results in an oxygen-deficient hypolimnion. If the lake has high concentrations of nutrients, this process may be accelerated. When the growth rate of microorganisms is not limited by a specific nutrient, such as phosphorus, the dissolved oxygen in the lake could be depleted before the summer's end.

Microbes play a key role in the loss of oxygen from surface waters. Microbes use oxygen as energy to break down long-chained organic molecules into simpler, more stable end-products such as carbon dioxide, water, phosphate and nitrate. As the organic molecules are broken down by microbes, oxygen is removed from the system and must be replaced by exchange at the airwater interface.

Each step above results in consumption of dissolved oxygen. If high levels of organic matter are present in water, microbes may use all available oxygen. This does not mean, however, that the removal of microbes from the ecosystem would solve this problem. Although microbes are responsible for decreasing levels of dissolved oxygen, they play a very important role in the aquatic ecosystem. If dead matter is not broken down it will "pile up," much as leaves would if they were not broken down each year.

The introduction of excess organic matter may result in a depletion of oxygen from an aquatic system. Prolonged exposure to low dissolved oxygen levels (less than 5 to 6 mg/l oxygen) may not directly kill an organism, but will increase its susceptibility to other environmental stresses. Exposure to less than 30% saturation (less than 2 mg/l oxygen) for one to four days may kill most of the aquatic life in a system.

If all oxygen is depleted, aerobic (oxygen-consuming) decomposition ceases and further organic breakdown is accomplished anaerobically. Anaerobic microorganisms obtain energy from oxygen bound to other molecules such as nitrates and sulfates. The oxygen-free conditions result in the mobilization of many otherwise insoluble compounds. As sulfate compounds break down, the water may smell like rotten eggs.

Low dissolved oxygen levels may occur during warm, stagnant conditions that prevent mixing. In addition, high natural organic levels will often cause a depletion of dissolved oxygen.

Water Quality Standards for Dissolved Oxygen

Rule 64 of the Michigan Water Quality Standards (Part 4 of Act 451) includes minimum concentrations of dissolved oxygen which must be met in surface waters of the state. This rule states that surface waters designated as coldwater fisheries must meet a minimum dissolved oxygen standard of 7 mg/l, while surface waters protected for warm water fish and aquatic life must meet a minimum dissolved oxygen standard of 5 mg/l.

Phosphorus

Phosphorus (P) is an essential nutrient for all life forms, and is the eleventh-most abundant mineral in the earth's crust. In surface waters, phosphorus is usually present as phosphate (PO4- P). Phosphorus is needed for plant growth and is required for many metabolic reactions in plants and animals. Organic phosphorus is a part of living plants and animals, their by-products, and their remains. Generally, phosphorus is the limiting nutrient in freshwater aquatic systems. That is, if all phosphorus is used, plant growth will cease, no matter how much nitrogen is available.

Phosphorus typically functions as the "growth-limiting" factor because it is usually present in very low concentrations. The natural scarcity of phosphorus can be explained by its attraction to organic matter and soil particles. Any unattached or "free" phosphorus is quickly removed from the aquatic system by algae and larger aquatic plants. Excessive concentrations of phosphorus can quickly cause extensive growth of aquatic plants and algal blooms. Several detrimental consequences may result.

Excessive algae and plant growth can lead to depletion of the oxygen that is dissolved in the water. Water can hold only a limited supply of dissolved oxygen (DO) and it comes from only two sources- diffusion from the atmosphere and as a byproduct of photosynthesis. Excessive growth leads to depletion of DO because of nighttime respiration by living algae and plants and because of the bacterial decomposition of dead algae/plant material. Depletion of DO adversely affects many animal populations and can cause fish kills.

In addition to low DO problems, excessive plant growth can increase the pH of the water because plants and algae remove dissolved carbon dioxide from the water during photosynthesis, thus altering the carbonic acid-carbonate balance. Because plants and algae provide food and habitat to animals, the relative abundance of species affects the composition of the animal community. Drinking water supplies may experience taste and odor problems, and the costs of treating drinking water can increase.

Finally, high nutrient concentrations interfere with recreation and aesthetic enjoyment of water resources by causing reduced water clarity, unpleasant swimming conditions, objectionable odors, blooms of toxic and nontoxic organisms, interference with boating, and "polluted appearances." The economic implications are significant for many communities.

Phosphorus may accumulate in bottom sediment, both in deposited clays and silts and deposited organic matter. In such cases, phosphorus and other nutrients may be released from the sediment in the future. This results in an internal phosphorus loading. Because of this phenomenon, a reduction in phosphorus inputs may not be effective in reducing algal blooms for a number of years.

Phosphorus enters surface waters from both point and nonpoint sources. The primary point source of phosphorus is sewage treatment plants. A normal adult excretes 1.3 - 1.5 g of phosphorus per day. Additional phosphorus originates from the use of industrial products, such as toothpaste, detergents, pharmaceuticals, and food-treating compounds. Primary treatment removes only 10% of the phosphorus in the waste stream; secondary treatment removes only 30%. Tertiary treatment is required to remove additional phosphorus from the water. The amount of additional phosphorus that can be removed varies with the success of the treatment technologies used. Available technologies include biological removal and chemical precipitation.

Nonpoint sources of phosphorus include both natural and human sources. Natural sources include 1) phosphate deposits and phosphate-rich rocks which release phosphorus during

weathering, erosion, and leaching, and 2) sediments in lakes and reservoirs which release phosphorus during seasonal overturns. The primary human nonpoint sources of phosphorus include runoff from 1) land areas being mined for phosphate deposits, 2) agricultural areas, and 3) urban/residential areas.

Because phosphorus has a strong affinity for soil, little dissolved phosphorus will be transported in runoff. Instead, the eroded sediments from mining and agricultural areas carry the adsorbed phosphorus to the water body. An additional source is the overboard discharge of phosphorus containing sewage by boats.

Phosphate itself does not have adverse health effects. However, phosphate levels greater than 1.0 may interfere with coagulation in water treatment plants. As a result, organic particles that harbor microorganisms may not be completely removed.

Water Quality Standards for Phosphorus

Rule 60 of the Michigan Water Quality Standards (Part 4 of Act 451) limits phosphorus Concentrations in point source discharges to 1 mg/l of total phosphorus as a monthly average. The rule states that other limits may be placed in permits when deemed necessary. The rule also requires that nutrients be limited as necessary to prevent excessive growth of aquatic plants, fungi or bacteria, which could impair designated uses of the surface water.

Bacteria

Bacteria are among the simplest, smallest, and most abundant organisms on earth. Bacteria are "procaryotic" organisms- a term which indicates a cellular structure lacking an organized nucleus and nuclear membrane. Instead of containing genetic information stored on several chromosomes, bacteria contain a single strand of DNA. These organisms reproduce by binary fission, which occurs when a single cell divides to form two new cells called daughter cells. Each daughter cell contains an exact copy of the genetic information contained in the parent cell. The process continues with each daughter cell giving rise to a generation of two new cells. The generation time is the time required for a given population to double in size. This time can be as short as 20 minutes for some bacteria species (e.g., *Escherichia coli*).

While the vast majority of bacteria are not harmful, certain types of bacteria cause disease in humans and animals. Examples of waterborne diseases caused by bacteria are: cholera, dysentery, shigellosis and typhoid fever. During the London cholera epidemics of 1853-1854, Dr. John Snow observed that nearly everyone who became ill obtained their drinking water from a specific well into which a cesspool was leaking. Those who became ill either drank water from the well or came into contact with fecally contaminated material while tending those already sick.

Concerns about bacterial contamination of surface waters led to the development of analytical methods to measure the presence of waterborne bacteria. Since 1880, coliform bacteria have been used to assess the quality of water and the likelihood of pathogens

being present. Although several of the coliform bacteria are not usually pathogenic themselves, they serve as an indicator of potential bacterial pathogen contamination. It is generally much simpler, quicker, and safer to analyze for these organisms than for the individual pathogens that may be present. Fecal coliforms are the coliform bacteria that originate specifically from the intestinal tract of warmblooded animals (e.g, humans beavers, racoons, etc.). They are cultured in a special growth media and incubated at 44.5o C.

The first U.S. standards for drinking water, established by the Public Health Service in 1914, were based on coliform evaluations. It was reasoned that the greatest source of human pathogens in water was from human waste. Each day, the average human excretes billions of coliform bacteria. These bacteria are present whether people are ill or healthy. Monitoring for coliform bacteria was designed to prevent outbreaks of enteric diseases, rather than to detect the presence of specific pathogens. Today, coliform bacteria concentrations are determined using methods specified by the Environmental Protection Agency (EPA) and *Standard Methods for theExamination of Water and Wastewater* (AWWA, APHA, and WEF, 20th ed., 1998).

Bacteria sources

Human sources of bacteria can enter water via either point or nonpoint sources of contamination. Point sources are those that are readily identifiable and typically discharge water through a system of pipes. Sewered communities may not have enough capacity to treat the extremely large volume of water sometimes experienced after heavy rainfalls. At such times, treatment facilities may need to bypass some of the wastewater. During bypass or other overflow events, bacteria-laden water is discharged directly into the surface water as either sanitary sewer overflow (SSO) or as combined sewer overflow (CSO). Power outages and flooding can also contribute to the discharge of untreated wastewater.

Illicit connections to storm sewers are a source of bacteria in surface waters, even during dry periods. A connection to a storm sewer is "illicit" when the wastewater requires treatment prior to discharge and should be routed to the sanitary sewer. Only storm water and certain permitted discharges (e.g. clear noncontact cooling water) should be discharged to a storm sewer.

Nonpoint sources are those that originate over a more widespread area and can be more difficult to trace back to a definite starting point. Failed on-site wastewater disposal systems (septic systems) in residential or rural areas can contribute large numbers of coliforms and other bacteria to surface water and groundwater.

Animal sources of bacteria are often from nonpoint sources of contamination. Concentrated animal feeding operations, however, are often point source dischargers. Agricultural sources of bacteria include livestock excrement from barnyards, pastures, rangelands, feedlots, and uncontrolled manure storage areas. Storm water runoff from residential, rural, and urban areas

can transport waste material from domestic pets and wildlife into surface waters. Land application of manure and sewage sludge can also result in water contamination, which is why states require permits, waste utilization plans, or other forms of regulatory compliance. Bacteria from both human and animal sources can cause disease in humans.

Bacteria-laden water can either leach into groundwater and seep, via subsurface flow, into surface waters or rise to the surface and be transported by overland flow. Bacteria in overland flow can be transported freely or within organic particles. Overland flow is the most direct route for bacteria transport to surface waters. Underground transport is less direct, because the movement of water and bacteria is impeded by soil porosity and permeability constraints.

Water Quality Standards for Bacteria

Rule 62 of the Michigan Water Quality Standards (Part 4 of Act 451) limits the concentration of microorganisms in surface waters of the state and surface water discharges. Waters of the state which are protected for total body contact recreation must meet limits of 130 *Escherichia coli* (*E.coli*) per 100 milliliters (ml) water as a 30-day average and 300 *E. coli* per 100 ml water at any time. The limit for waters of the state which are protected for partial body contact recreation is 1000 *E. coli* per 100 ml water. Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 ml water as a monthly average and 400 fecal coliform bacteria per 100 ml water as a 7-day average. For infectious organisms which are not addressed by Rule 62, The Department of Environmental Quality has the authority to set limits on a case-by-case basis to assure that designated uses are protected.

Temperature

Thermal pollution occurs when humans change the temperature of a body of water. The most common point source of thermal pollution is cooling water, which is used to cool machinery. Thermal pollution may also be caused by stormwater runoff from warm surfaces such as streets and parking lots. Soil erosion is another cause, since it can cause cloudy conditions in a water body. Cloudy water absorbs the sun's rays, resulting in a rise in water temperature. Thermal pollution may even be caused by the removal of trees and vegetation which normally shade the water body.

Thermal pollution can result in significant changes to the aquatic environment. Most aquatic organisms are adapted to survive within a specific temperature range. As temperatures increase, cold water species, such as trout and stonefly nymphs, may be replaced by warmwater species, like carp and dragonfly nymphs. Thermal pollution may also increase the extent to which fish are vulnerable to toxic compounds, parasites, and disease. If temperatures reach extremes of heat or cold, few organisms will survive.

In addition to thermal pollutions' direct effects on aquatic life, there are numerous indirect effects. Thermal pollution results in lowered levels of dissolved oxygen, since cooler water can hold more oxygen than warmer water. Low dissolved oxygen levels will cause oxygen-sensitive species to die.

Photosynthesis and plant growth increase with higher water temperatures, resulting in more plants. When these plants die, they are decomposed by bacteria that consume oxygen. This can result in a further drop in dissolved oxygen levels.

The metabolic rate of fish and aquatic organisms also increases with increasing water temperatures, and additional oxygen is required for respiration. Life cycles of aquatic insects may speed up in response to higher water temperatures. Animals that feed on these insects may be harmed, especially birds that depend on aquatic insects emerging at specific times during their migratory flights.

Water Quality Standards for Temperature

Rules 69 through 75 of the Michigan Water Quality Standards (Part 4 of Act 451) specify temperature standards which must be met in the Great Lakes and connecting waters, inland lakes, and rivers, streams and impoundments. The rules state that the Great Lakes and connecting waters and inland lakes shall not receive a heat load which increases the temperature of the receiving water more than 3 degrees Fahrenheit above the existing natural water temperature (after mixing with the receiving water). Rivers, streams and impoundments shall not receive a heat load which increases the temperature of the receiving water more than 2 degrees Fahrenheit for coldwater fisheries, and 5 degrees Fahrenheit for warmwater fisheries.

These waters shall not receive a heat load which increases the temperature of the receiving water above monthly maximum temperatures (after mixing). Monthly maximum temperatures for each water body or grouping of water bodies are listed in the rules.

The rules state that inland lakes shall not receive a heat load which would increase the temperature of the hypolimnion (the dense, cooler layer of water at the bottom of a lake) or decrease its volume. Further provisions protect migrating salmon populations, stating that warm water rivers and inland lakes serving as principal migratory routes shall not receive a heat load which may adversely affect salmonid migration.