2-2003

White River Watershed Preliminary Habitat Assessment

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PRELIMINARY HABITAT ASSESSMENT

MR-2003-18

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The Community Foundation *for* Muskegon County

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February 2003

Acknowledgements

The authors would like to thank The Community Foundation *for* Muskegon County for developing and managing this project with funding assistance from the Alcoa Foundation. This project would not have been possible without the support of Mr. Dennis Albrechtsen, Vice President – Special Projects, Howmet Castings, an Alcoa Company and other key executive staff at Howmet Castings and the Alcoa Corporation, Inc.

I also would like to thank Dr. Alan Steinman for his review and comments on this report. In addition, we would like to recognize student research assistants Mike Buth, Eric Andrews, Scott Mueller, John Genet, Rochelle Heyboer, Shawn Wessell, Kelly Martin, and Beau Braymer for the work on data collection and analysis. Finally, we would like to acknowledge the important contributions of the US Department of Agriculture, Michigan Department of Natural Resources, the Lake Michigan Federation, and the Muskegon County Soil Conservation District for their steadfast stewardship efforts to improve the quality of this important resource.

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Executive Summary

The White River watershed is the product of the interaction of its unique geologic, hydrologic, and ecologic systems. Glacial geology formed the moraine ridges in the headwaters and produced the outwash plains, soil associations, tributary systems, and pitted areas where kettle lakes and depressional wetlands are found. The coupling with Lake Michigan and the influence of its water level fluctuations carved the deep river valleys and formed the extensive drowned rivermouth complex of White Lake and its wetlands. The hydrologic system in the watershed focuses local groundwater into the stream channel, maintains cold temperature environments that support a significant trout fishery, sustains the regional lakes and wetlands, and provides the vehicle that transports and deposits carbon and nutrients throughout the watershed. Using these geologic and hydrologic resources, a diverse array of biological communities function and interact in the upland forests and prairies of the catchment, the transitional wetland areas, and the aquatic systems present in lakes and streams. In its current state, the White River watershed contains approximately 200,000 acres of forest, 43,000 acres of wetlands, 6,300 acres of open water (lakes and streams), and 38,000 acres of open field. Lands under agricultural production and urban land use cover only 30% of the watershed area. These anthropomorphic systems interact with the geologic, hydrologic, and ecologic framework of the watershed to define the structure and function of the entire basin.

In this project, a preliminary assessment of habitats in the White River watershed was conducted. Land cover and land use were evaluated using available remote sensing data to provide an assessment of current conditions and an analysis of significant change over a 20 year period (1978 to 1992/1997/1998). Investigations of water and habitat quality were also conducted in White Lake, the drowned rivermouth wetland, and selected streams and wetlands in the tributaries and branches of the White River. Significant findings of these assessments include:

- Land cover/use on a watershed basis appeared to be stable with forested and wetland areas showing slight increases in total acreage. With respect to agriculture, row crop usage declined with a corresponding increase in orchards and open fields.
- Areas of significant change were noted on a subwatershed basis. The areas of greatest urban growth were concentrated in the US 31 corridor, the villages, and around larger lakes.
- Mid and lower stream sections and wetlands were located in forested areas with riparian vegetative cover and buffers. Wetlands and streams in several of the headwater areas have poor riparian zones.
- The watershed contains a number of rare and endangered habitats including coastal marshes, bogs, dry sand prairies, barrens, wet

meadows, and mesic prairies. The acreage of Pine/Oak Barrens have decreased by almost 50% over the last 20 years.

- White Lake has remained eutrophic and will require a detailed investigation of nutrient loading and hydrologic modeling to develop a plan to improve water quality.
- The drowned rivermouth was found to be impacted by a combination of agricultural and urban sources.
- Cushman Creek and Heald Creek were found to be impacted by anthropogenic pollution.
- Several wetlands in the upper watershed were impacted by adjacent land use practices (agriculture and road/stream crossings).

Based on the above findings, the following recommendations were made:

- Establish a watershed assembly to promote, prioritize, and coordinate water quality and habitat management/restoration activities throughout the basin.
- Initiate programs involving public education, best management practices, and land acquisition to promote stewardship, improve environmental quality, and preserve rare habitats, respectively.
- Conduct the necessary hydrologic modeling to evaluate nutrient loading to White Lake and identify critical areas to target source control programs in the upper watershed.
- Develop and implement a plan to restore the drowned rivermouth wetland

This project was an important beginning for future planning and educational activities in the watershed. Preliminary data on the geological, hydrological, and ecological systems were assembled and several areas of concern were identified. In consideration of the size and complexity of the watershed, it is clear that more information will be required to develop effective management plans. Without this information, it is impossible to prioritize issues, formulate mitigation strategies, and initiate changes that are truly beneficial to the system. We must also communicate this information through a public educational process that fosters resource preservation and stewardship. Education will help foster lasting change. The data from this project also illustrate the importance of a holistic approach to watershed management. It will be impossible to maintain water and habitat quality on a watershed basis if problems in headwater streams and development pressure are not addressed. The future of the White River watershed depends on a detailed assessment of the resource, the development of a holistic preservation plan, and a strong public education component to promote active stewardship. The watershed is a unique and diverse resource with important ecologic and economic value that will require a coordinated and holistic approach for preservation and restoration.

1.0 Introduction

The White River is an important part of the Great Lakes ecosystem. Through its riparian forests, wetlands, and flowing waters, the 344,166 acre (139,279 ha) White River watershed provides the necessary habitat diversity to support fisheries and wildlife resources of regional and national significance. With headwaters in northeastern Newaygo County, the river flows for approximately 83 miles (134 km) before discharging to Lake Michigan. A map of the watershed is presented in Figure 1. Approximately 12,000 years ago, the glacial activity that formed the Great Lakes also created the White River. In its natural state, the White River was a system of dense riparian forests, sprawling wetlands and marshes, inland lakes, and riffle areas. The system was drastically changed in the 1800s when lumber barons harvested the region's timber resources and left behind a legacy of barren riparian zones and severe erosion. Today, the White River is a somewhat divergent system of scenic and biologically productive areas contrasted with locations that are subject to the adverse impacts of nonpoint source pollution, agriculture, and development. The continued loss of the riparian zone by development and the uncontrolled input of sediment by erosion will ultimately result in significant degradation of this valuable resource.

The White River watershed is located in Muskegon, Newaygo, and Oceana Counties of Michigan (Figure 1.1) and contains an extensive marsh/wetland environment that provides critical transitional habitats for fisheries and wildlife. The river gradient flattens in Muskegon County and forms a freshwater estuary consisting of wooded wetlands, emergent beds, and open water marshes. This estuary is coupled with White Lake, a 2,571 acre drowned-rivermouth system that is connected to Lake Michigan. Approximately 23% of the watershed (76,853 acres) is included in the Manistee National Forest (MDNR 2001) and is managed for the protection of woodland and wildlife habitat (Figure 1.2). The Manistee National Forest acts as a buffer zone around the river and protects it from urban development and local runoff. The White River is divided into two branches, the North Branch and the South Branch. The North Branch has headwaters in central Oceana County while the South Branch originates in eastern Newaygo County. The two branches converge within the Manistee National Forest (southeastern Otto Township) and form the main channel of the river. Many tributaries are also part of this watershed and function as important waterways that support coldwater fisheries and provide a transitional environment from the larger river to first and second order streams. While the wetlands and tributaries of the White River watershed are recognized as natural features that are significant to the region and to the Great Lakes, very little is known about their ecology and overall function in the system. It is therefore important to conduct an initial survey of the White River watershed that documents current

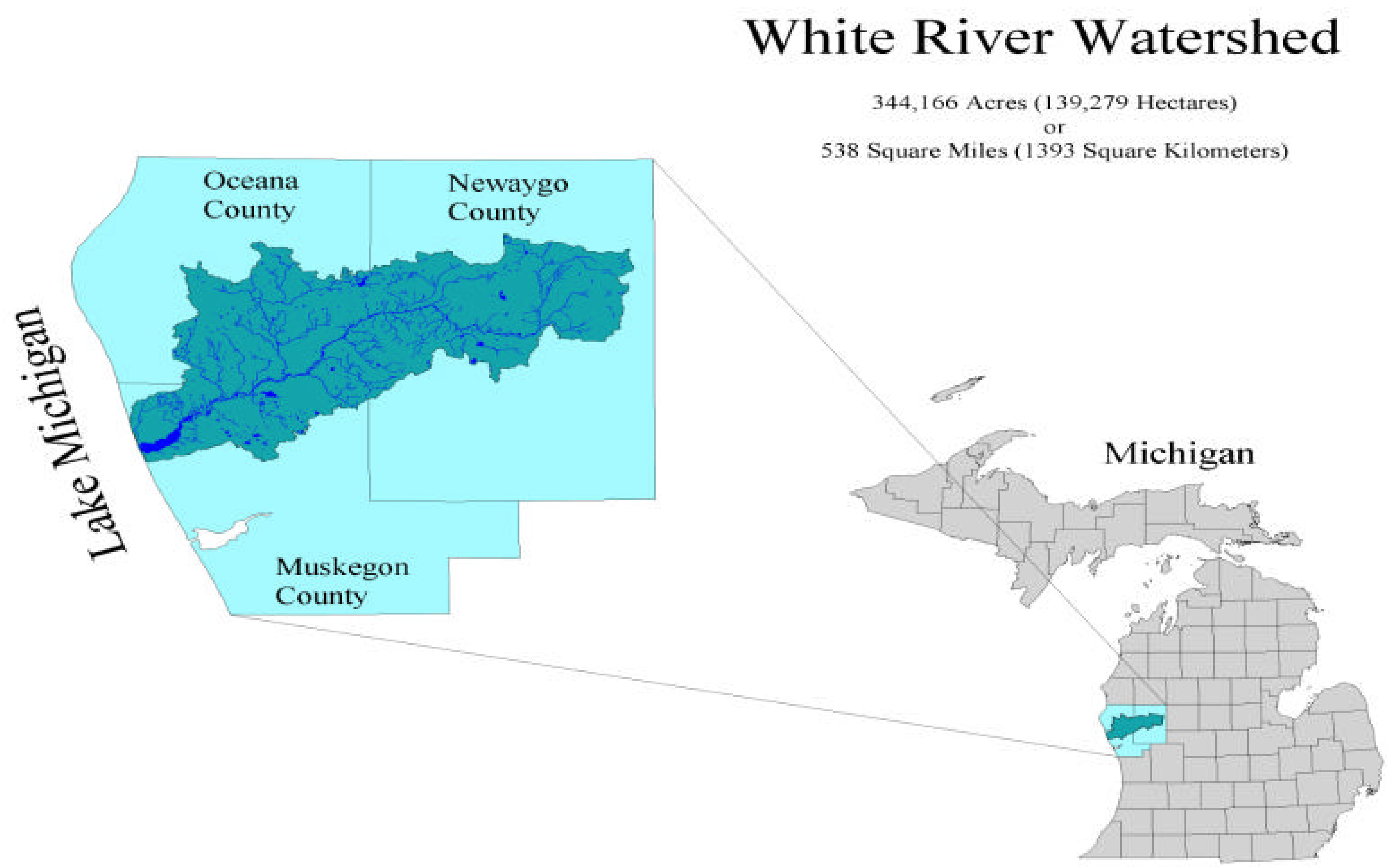


FIGURE 1.1 THE WHITE RIVER WATERSHED.

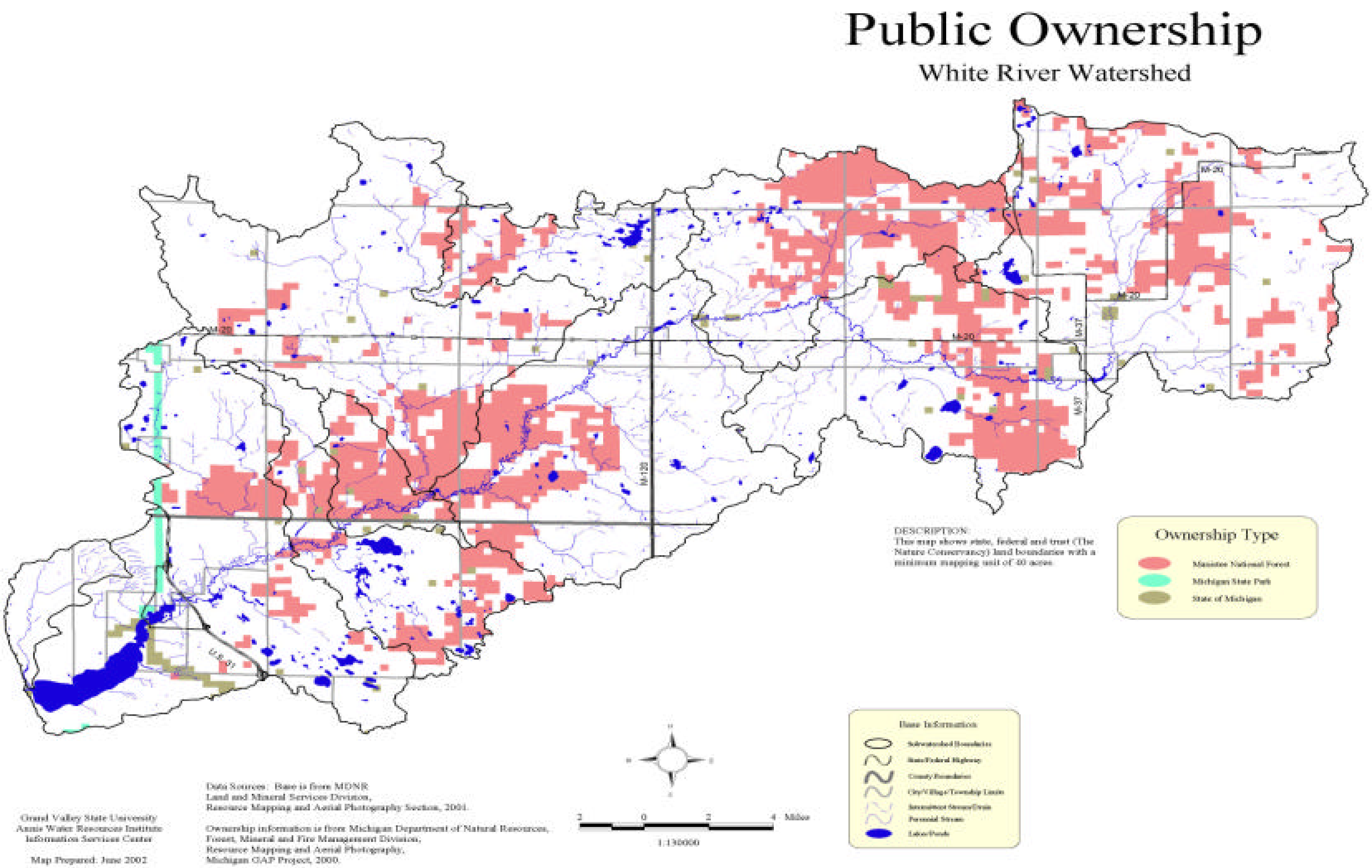


FIGURE 1.2 FEDERAL AND STATE LAND IN THE WHITE RIVER WATERSHED.

environmental conditions and identifies areas of significant change. These data will serve as the basis for future assessments of problem areas, educational outreach programs, and the development of management and restoration plans.

1.1 PROJECT OBJECTIVES AND TASK ELEMENTS

The objectives of this project were to conduct a preliminary assessment of the aquatic and terrestrial habitats present in the lower White River watershed and to identify areas of significant change. In addition, a series of benthic macroinvertebrate and water chemistry samples were collected in wetland environments to further assess the status of the important aquatic habitats and their water quality. Because of the size of the watershed, the aerial data and interpretations from the Michigan Resource Information System (MIRIS) were used (MDNR 1978 and 1992/1997/1998). Specific objectives and task elements are summarized below:

?? review existing soils, hydrology, and ecology data and identify significant data gaps;
?? inventory current environmental conditions and develop an assessment of baseline status;
- analyze and summarize MIRIS data for 1992/1997/1998
- conduct a preliminary field survey on major tributaries
- conduct assessments of the biological integrity of important wetland systems

?? review 1978 MIRIS data and determine areas that have undergone significant land cover changes from 1978 – 1992/1997/1998
?? identify significant areas of concern for the lower White River watershed.

This project will provide a set of baseline data that is important in the identification of areas of concern in the watershed and to the development of environmental management plans. It contains information useful to scientists who are involved in conducting detailed assessments of fisheries and wildlife habitats. In addition, the project serves as an important tool for public education about the ecological importance of the White River watershed and the significance of problem areas.

2.0 Background

The traditional view of a river is a place with certain recreational and aesthetic qualities associated with the water and stream bank. There is however an alternate perspective that is more attuned to the hydrology and ecology of river systems. Like the fish that lives in it, the river itself is an entity with a unique structure and function, with a specific history, and capable of self-generated dynamic behavior (Wiley and Seelbach 1997). There are four fundamental characteristics, which are essential to understanding the nature of river systems: A river is:

- A landscape-scale system because of its connection with its valley, soils, and aquifers.
- A hydrologic system because it participates in regional water cycling.
- A geomorphic system because it shapes the landscape it occurs on and its own channel.
- An ecological system because it supports a diverse and highly adapted biota.

The landscape of the White River watershed extends beyond the water and stream banks to the entire drainage basin (catchment). It is broadly influenced by regional climate and rainfall in addition to local scale events that affect smaller sections. In addition, the landscape scale of a watershed guarantees that every river presents a complex mosaic of interactions and relationships involving the many smaller elements in its catchment. These can include terrestrial ecosystems as well as various human political and economic units. In conjunction with what we see in the current landscape, the historical context of regional and local events also shape the watershed. The history of the White River began with the glacial events that formed the Lake Michigan Basin. Glacial events in the upper part of the Great Lakes caused a drop in Lake Michigan water levels that in turn, affected the landscape of the White River watershed. Anthropogenic events such as logging, agricultural development, and urbanization also have influenced the landscape. Today, the White River watershed reflects a summation of historical landscape changes that will be modified by future events.

A river's hydrologic properties are an inseparable component from its geomorphic, chemical, and biological characteristics. The amount and timing of water transport through a river channel network is the end result of a complex interaction between landscape elements and the climate (Wiley and Seelbach 1997). In order to examine the hydrologic characteristics of a river, we have to understand the key processes that generate stream flow and control its distribution in time and space. These hydrologic processes include: precipitation, evaporation, transpiration, storage, infiltration, overland flow, and groundwater flow. The summation of these processes link the river to its landscape. The watershed is the basic unit in river hydrology. Every site on a river has a catchment area, that is the source of its water flow. For every watershed there is a balance between inputs, outputs, and storage of water in the landscape. As a result the flow characteristics of a river depend on the nature of its hydrologic source. Rivers supplied primarily by runoff respond dramatically to rain, rapidly generate high peak discharges and then quickly pass water downstream. In between rain events these rivers experience rapid and severe declines in discharge since most excess water in the basin has already been transported away. In contrast, rivers supplied primarily by groundwater respond slowly to precipitation events. Small increases in discharge increases are noted because most precipitation is captured by infiltration. This water slowly makes its way to the channel, and the resultant lag time ensures a continuous supply of groundwater to the river between rain events. Groundwater driven rivers are hydrologically stable systems, with lower peak flows and higher base flows than in runoff-driven rivers of comparable size. The White River watershed contains streams influenced by groundwater and runoff to varying extents. Groundwater influenced streams provide a stable habitat for benthic organisms and support trout based fisheries. Groundwater quality also plays an important role with respect to habitat and fisheries. Runoff driven streams tend to be unstable and more subject to sedimentation and erosion. These streams tend to support warm water fisheries and contain benthic fauna that are more tolerant of sedimentation.

With respect to geomorphology, Davis (1899) described landscapes to be the result of cycles of geologic uplift and erosion. Rivers can be viewed as an agent of continental erosion, and between episodic uplift events, they continually reduce landform elevations towards a base level established by the river mouth. As rivers carry water across the landscape, they also transport sediment and dissolved materials. In this manner, they transform the landscape by erosion, dissolution, and deposition. A simplified but useful model of the overall geomorphic structure of a river (Figure 2.0) divides the system into three types of reaches (Montgomery and Buffington 1993). Each reach is distinctive in terms of material processing. Source reaches are generally small tributaries or headwater streams. Sediment in source reaches is moved intermittently during peak flow or disturbance events. Transport reaches are high gradient areas where channel building occurs. These reaches will rapidly convey increased sediment inputs. In the White River watershed, source reaches are located in the headwaters of the North and South Branches. The transport reach is located in the mid section of the river.

Response reaches are low-gradient transport-limited channels in which significant morphologic adjustment occurs in response to increased sediment supply. Low gradient stream reaches lack the capacity to transport all the sediment that is delivered from the surrounding watershed. Sediment delivered to these reaches is deposited in the reach rather than transported further downstream. Although response reaches tend to have the greatest stream flow in a watershed, they have the lowest velocity. Transport of

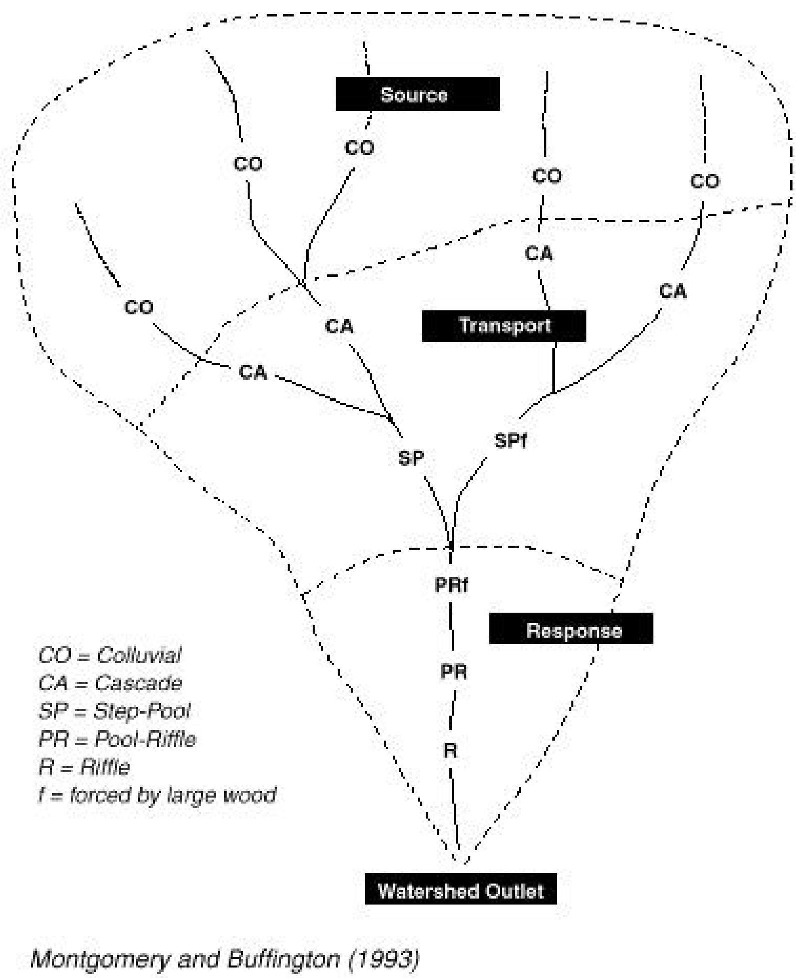


FIGURE 2.0 DIAGRAM OF RIVER ZONES (MONTGOMERY AND BUFFINGTON 1993).

sediments deposited in response reaches usually occur during peak flows events (runoff from snowmelt or seasonal thunderstorms). Sediment deposition in response reaches is a natural process. The sediment may form bars or be stored in stream banks, allowing the reach to retain its function. In the White River watershed, the response reach is located in the lower section where the drowned rivermouth estuary is located. The flattening of the stream gradient plus the reduction in velocity from the discharge into White Lake results in sediment deposition. The highly braided channels in this segment illustrates the historical effects of sediment deposition.

In addition to the physical characteristics of landscape, hydrology, and geomorphology, rivers contain highly diverse ecosystems. Rivers are structurally unique from most other ecosystems because of the following reasons (Wiley and Seelbach 1997):

- rivers have a large-scale directional organization (upstream-downstream).
- rivers are dominated by advective rather than diffusive material transport.
- rivers have high rates of energy and material throughput
- rivers always contain many other embedded ecosystems (both terrestrial and aquatic).

Biologists have long recognized that communities in rivers change progressively in a downstream direction. Longitudinal zonation was an early organizing principal in stream ecology that gave rise to the River Continuum Concept (Vannote et al. 1980), which suggested that longitudinal changes in community structure reflect longitudinal changes in the availability of various forms of organic carbon during its transport through the channel system. For example, headwater streams in forested areas are likely to transport large amount of leaf material and have a fauna (shredders) adapted to feeding on this material. In large downstream segments of rivers, fine particulate matter are deposited and the fauna is dominated by animals that feed by collecting these particles (collectors and gatherers).

The physical flow of a river leads to an ecosystem that is based on advective (active) transport. This is true for the transport of sediment, particulate organic matter, nutrients, dissolved gases, pollutants, and even organisms themselves. Advective transport also leads to rapid turnover rates for biological materials. The high turnover rate leads on the one hand to an enhanced sensitivity to changes in inputs. Changes in flow, sediment, nutrients, and organic matter are quickly manifested in the biological community. At the same time, the high turnover rates of water in rivers give them an extraordinary resilience to recover when inputs are returned to normal. The fact that the White River is a high quality stream, despite its legacy of abuse from lumbering, is a testimony to the ecological resilience of river systems.

Ecosystems along the course of a river serve both as regulators of water quantity and water quality. Several types of ecosystems, notably forests and wetlands, are known to act as hydrological buffers, retaining water when it rains and releasing it gradually over several weeks and months. This helps to protect downstream communities from flooding and ensures that water continues to flow during the drier periods of the year. Ecosystems also regulate water quality. On sloping ground, for example, vegetation anchors soil and prevents it from being washed into the watercourse where it would cause sedimentation and reduce light penetration. This would reduce water quality, the health of aquatic ecosystems, and the suitability of the water for aquaculture and other uses. The physical structure of watercourses and the organisms that inhabit it also regulate water quality. For example, waterfalls, rapids, and aquatic vegetation oxygenate the water, and riverbanks, riverbeds, and vegetation trap sediment. These hydrological and biological processes enable the watercourse to function as a water purification unit providing fresh water. Riverine wetlands also play an important role in regulating water quality. They remove sediments and excessive nutrients from the water by processes of entrainment, decomposition, and uptake by vegetation. As wetlands hold water for long periods of time, decomposition and uptake processes are given enough time to remove nutrients from the water.

The ecosystems in the White River watershed also play a central role in shaping the character of the landscape. The forests, wetlands, lakes, and streams function in synergy to sustain the diverse flora and fauna found in the region. While the system has a large capacity for resiliency, the White River can still be adversely impacted by localized development, erosion, riparian zone modification, and nutrient enrichment. If left uncontrolled, anthropogenic alterations can affect the watershed on a larger scale.

In summary, the White River watershed that we see today is a summation of its glacial history, landscape, hydrology, geomorphic functions, and ecology. On a simple level, it can be enjoyed as a place for observing nature and outdoor recreation. Using a broader perspective, the complexities and interrelationships inherent in the watershed provide the opportunity for study and reflection. The following sections describe the physical and ecological characteristics of the watershed. Section 3 provides a description of the watershed with respect to:

- Glacial History
- Geology
- Soils
- Topography
- Hydrology and Stream Characteristics
- Terrestrial and Aquatic Habitats

Section 4 presents the results of the land use change analyses for the entire watershed and the subwatersheds. The results of the assessments conducted for White Lake and wetlands are provided in Sections 5 and 6, respectively. A discussion of the project data is provided in Section 7. Key issues for the watershed are presented along with recommendations in this section. This document is designed to provide a preliminary assessment of the White River watershed. It is structured as an information source for future research and a tool for public education.

3.0 Watershed Description

3.1 GLACIAL HISTORY

The White River watershed lies between two glacial moraines in western Michigan (Figure 3.1.1). Approximately 12,000 years ago, melt water from the receding glaciers began to carve out the channel of the White River and fill the Lake Michigan Basin (Hough 1958). As a coupled system, water elevations in Lake Michigan have a significant influence on the hydrology of the White River. A summary of Lake Michigan's geologic history and water elevations are presented in Figure 3.1.2 (Larson and Randall 2001). The White River was formed during the stage known as Lake Calumet with a water elevation of 620 ft. A brief period of lower water elevation (Kirkfield Low Water Stage) followed, as a drainage channel from Lake Huron to Lake Ontario was cut. Around 11,500 bp (before present), the climate became colder and the final glacial field advanced across Michigan. The

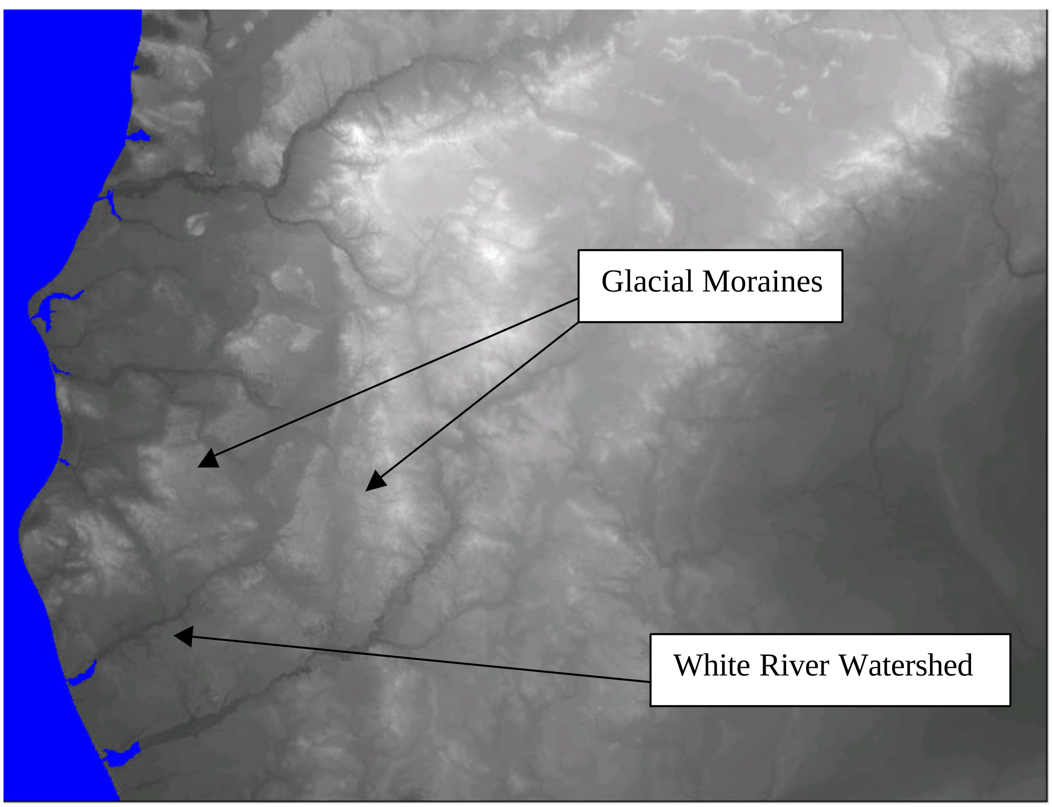
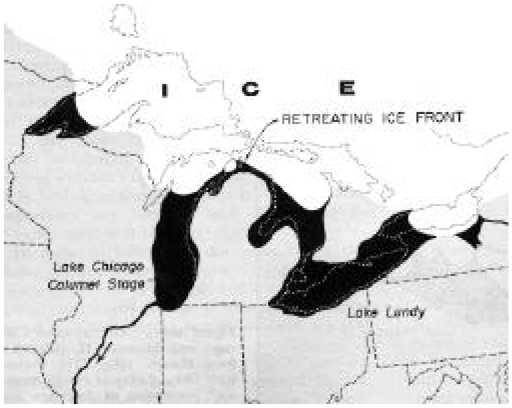
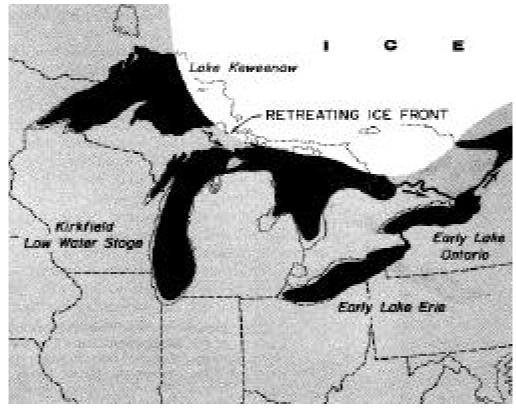


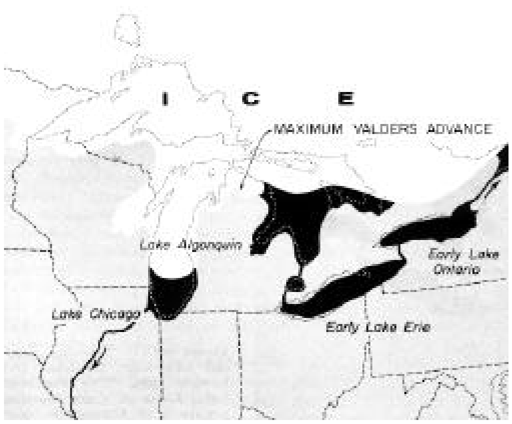
FIGURE 3.1.1. SATELLITE IMAGE OF THE WHITE RIVER WATERSHED.



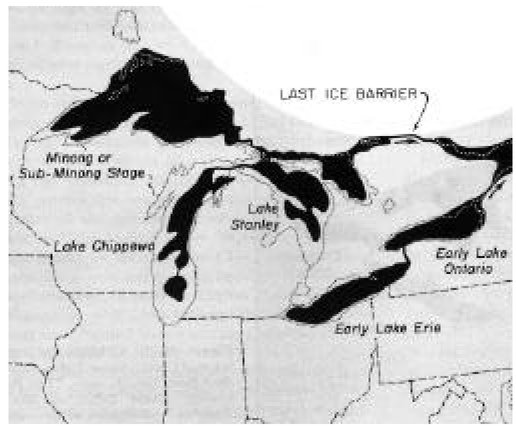
12000 bp Elevation 620 ft.



11,850 bp Elevation 565 ft.



11,500 bp Elevation 605 ft.



9,500 bp Elevation 230 ft.

4,000 bp Elevation 605 ft.

2,500 bp Elevation 580 ft.

FIGURE 3.1.2. GLACIAL HISTORY AND WATER ELEVATIONS OF LAKE MICHIGAN (LARSON AND RANDALL 2001).

channel to Lake Ontario was frozen and the water level rose back to 605 ft. This stage was called Lake Algonquin and approximately 75% of Lake Michigan was frozen. As the final ice field receded, a large channel was cut across Canada and Lake Michigan levels fell by 373 ft to an elevation of 230 ft. This stage was called Lake Chippewa and low water levels persisted for almost 5,000 years. The dramatic drop in the Lake Michigan's elevation caused the gradient of the White River to correspondingly increase and cut deeply into the landscape. Steep valley segments were formed in the main channel and many of the tributaries. When Lake Michigan levels rose during the Lake Nippising Stage (4000 bp), the valleys in the White River basin began to fill with water and stabilize at 605 ft. A depiction of the White River during this stage is shown in Figure 3.1.3 (M. Wiley personal communication). The river was considerably wider and the rising water table resulted in the formation of many wetlands. A larger version of White Lake was also formed that extended inland to the confluence of the North and South Branches.

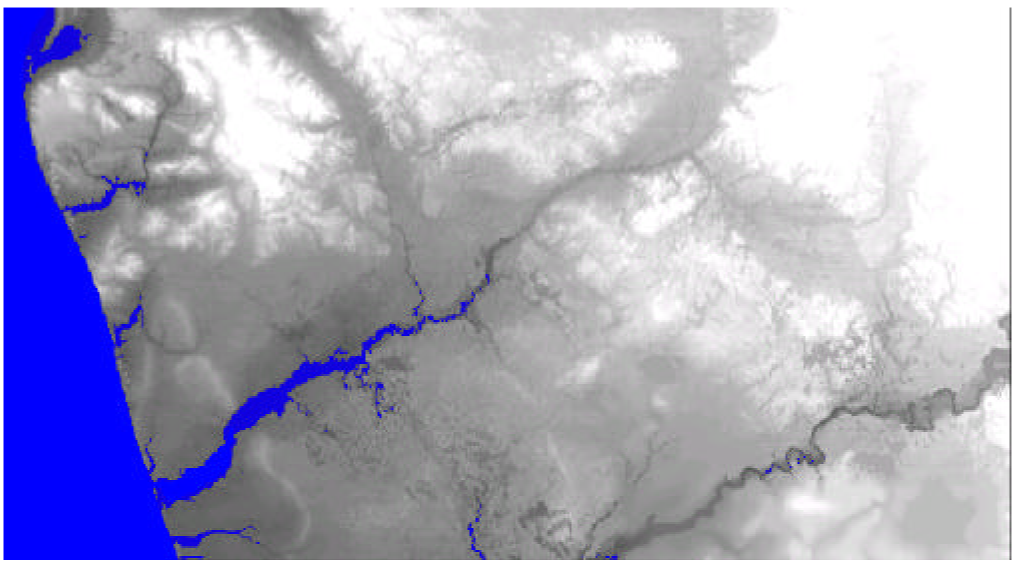


FIGURE 3.1.3. WATER ELEVATION IN THE WHITE RIVER WITH LAKE MICHIGAN AT 605 FT.

Lake Michigan's water elevation began to stabilize near current levels during the Algoma Stage approximately 3,000 years ago. Sediment loads that were formerly deposited in Lake Michigan began to fill in the inland river valley. The large wetland complex near White Lake was gradually formed by this sedimentation process. While sediments were accumulating in the lower White River watershed, the shifting sand dunes along the Lake Michigan shore began to restrict the rivermouth to a narrow channel. The resulting system is called a drowned rivermouth and contains the transitional environments shown below:

Large lake ? intermediate lake ? estuary ? river ? headwaters

These environments provide a variety of niches that support a diverse flora and fauna. The ecological diversity is enhanced further by the sloping valleys that were cut during the period of low water in Lake Michigan. These valleys focus groundwater into the floodplain and create a full transition of wetland environments from aquatic beds to wooded wetlands. Glacial features such as kettle lakes and depressional lowlands provide the same transitional environments in upland areas. Figure 3.1.4 shows the variety of inland and riverine wetlands associated White River watershed (M. Wiley personal communication). The drowned rivermouth system and estuary, inland lakes, and topography are all the result of regional glacial history and the coupling of the White River watershed to Lake Michigan. These important features define the hydrology, land cover, and ecology of the watershed.

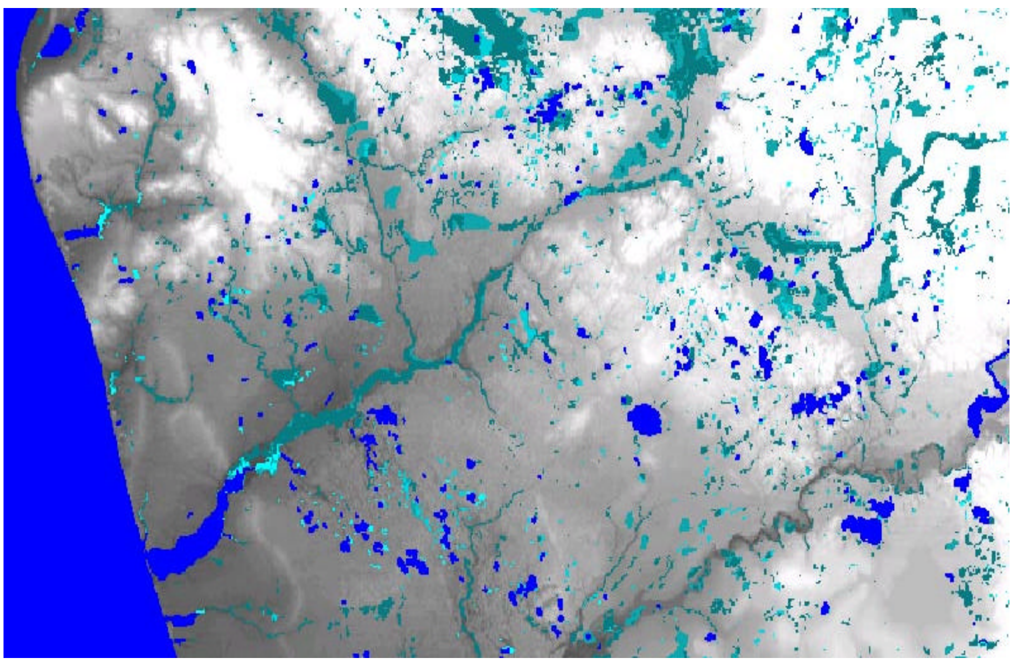


FIGURE 3.1.4 LAKES AND WETLANDS ASSOCIATED WITH THE WHITE RIVER WATERSHED.

3.2 GEOLOGY

The major geologic associations found in the White River watershed are displayed in Figure 3.2.1 (MNFI 1999). Moraine ridges dominate the northern and eastern portions of the watershed. The North Branch begins in a narrow outwash channel between a moraine ridge in Oceana County. The South Branch originates on a broad outwash plain between moraine segments. The river then passes through a pitted outwash plain that contains many kettle lakes and depressional lowlands. South of Hesperia, a broad glacial till plain can be found that also contains a number of small lakes. The area west of Hesperia contains a large and relatively flat outwash plain that forms the upland area for the channel of the White River and its two main branches. The till soils in the outwash plains are of high quality and are extensively used for agriculture (USDA 1995). Poorly drained tills predominate the channel area west of Hesperia and grade into muck and peat associations. The deposits of rich organic materials form the freshwater estuary located near US 31. A second pitted outwash plain borders the south channel of the White River in northern Muskegon County. This area contains many small kettle lakes. This pitted outwash plain also contains many kettle lakes and depressional lowlands. In the area bordering Lake Michigan, sand dunes dominate the landscape. A bisected moraine is located north of Montague. Bisected moraines have flow channels cut on either side of a central ridge. They are visible on Figure 3.2.1 in the region where numerous, parallel stream channels are located.

3.3 SOILS

The soil types found in the watershed can be classified as associations of coarse and fine tills, alluvial materials, and highly organic mucks. The distribution of soil textures is shown in Figure 3.3.1. The distribution of hydric soils is show in Figure 3.3.2. The White River watershed is composed of the following major textures (USDA 1968, 1995, 1996):

- Sands (Plainfield-Grattan-Brems-Benona associations in Oceana and Newaygo Counties)
- Sand (Rubicon-Au Gres-Roscommon associations in Muskegon County)
- Sandy loam (Marlette-Metea-Spinks associations)
- Mucky sands and peat (Houghton-Kerston-Carlisle-Adrian-Tawas and Pipestone-Covert-Kingsville

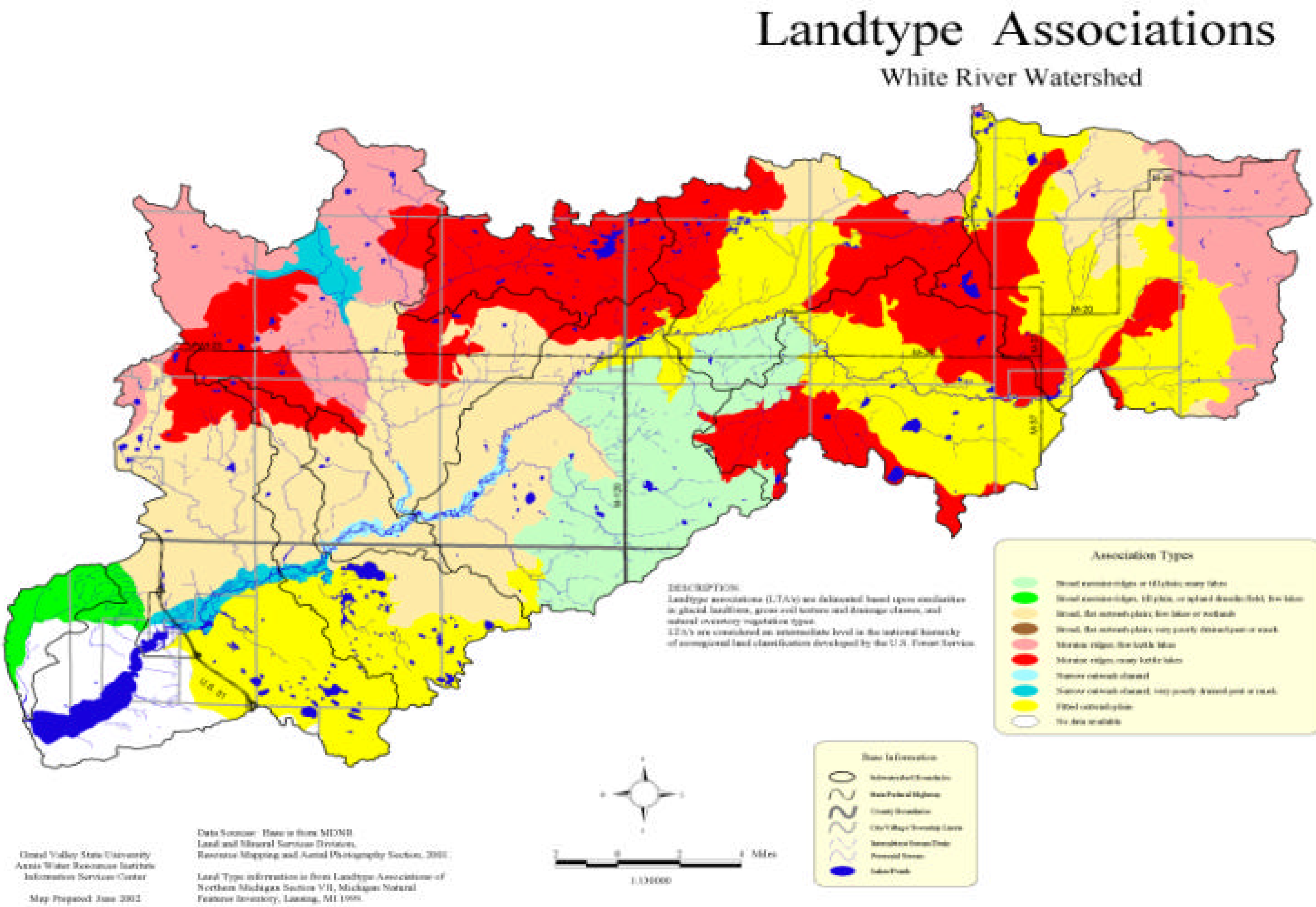


FIGURE 3.2.1 GEOLOGIC ASSOCIATIONS IN THE WHITE RIVER WATERSHED.

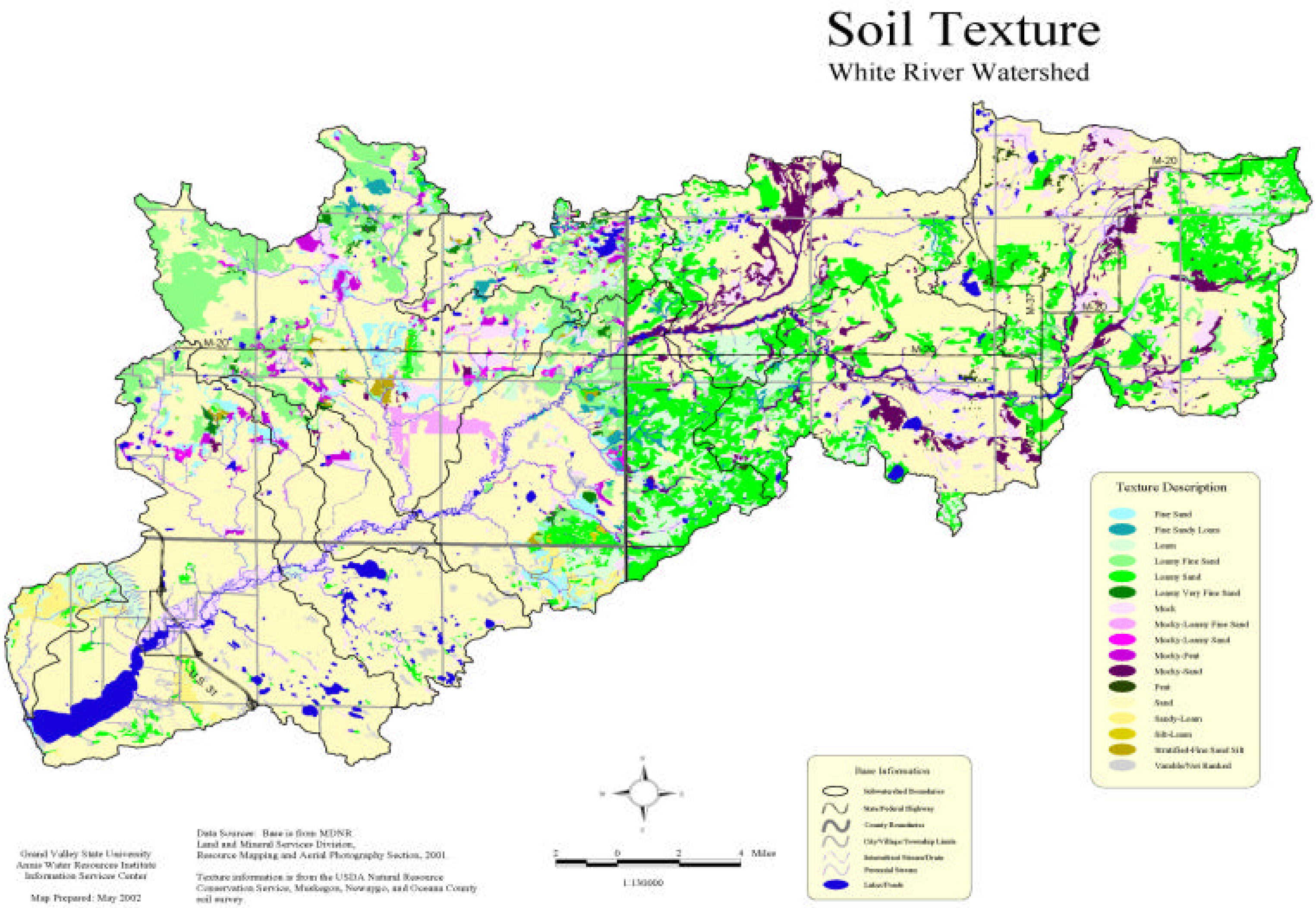


FIGURE 3.3.1 SOIL TEXTURES FOUND IN THE WHITE RIVER WATERSHED.

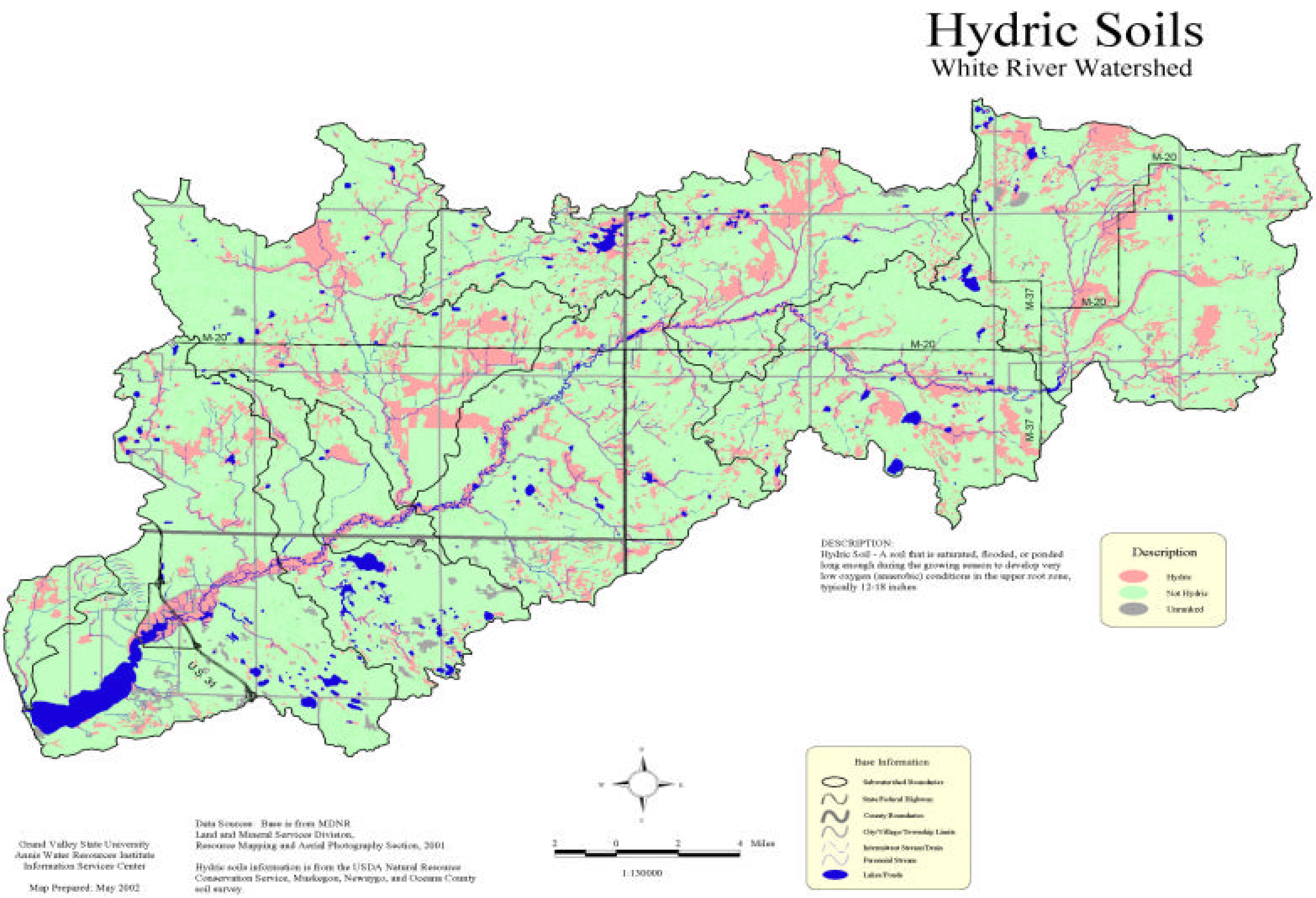


FIGURE 3.3.2 DISTRIBUTION OF HYDRIC SOILS IN THE WHITE RIVER WATERSHED.

Changes in soil type and texture appear to follow county lines rather than geologic features. This is true along the Oceana/Newaygo county line west of Hesperia and the Oceana/Muskegon county line below the confluence of the two branches of the White River. Consequently, the diversity in soil associations within a specific texture reflects more on the individual interpretation of the strata than actual variability. In general, sandy soils have poor water holding capacities, are well drained, and not useful for agriculture. These soils have a very thin organic layer (approximately 1-2 inches) followed by a coarse, sandy textured soil. The coarse texture results in a soil that has a high permeability and very low water holding capacity. In addition, the low organic content makes this type of soil a poor medium for plant growth and one that is easily eroded by wind and water action. It is therefore critical that the integrity of the ground cover in areas that contain sandy soils be retained to prevent losses due to runoff and wind erosion.

The sandy loam soil associations found in the moraine areas of the central, eastern, and northwest of the watershed are conducive to agricultural production and have good drainage and water holding capacity characteristics. Upland locations with these soils in Oceana County are used for orchards due to their proximity to Lake Michigan. Sandy loam soils in Newaygo County are generally used for row crops and truck farming. Even though these associations have a lesser potential for wind and water erosion due to increased water holding capacity and improved ability to support ground cover, row cropping can circumvent these characteristics and facilitate soil loss.

The distribution of hydric soils shown in Figure 3.3.2 is associated with the glacial outwash plains (Figure 3.2.1) and stream valley segments. The term hydric refers to soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation typically adapted for life in saturated soil conditions. In most cases, these soils have a high organic content due to the slower breakdown of organic material in the absence of oxygen. They support wetland vegetation and are highly influenced by both groundwater quality and quantity.

3.4 TOPOGRAPHY

The Digital Elevation Model for the White River Watershed is shown in Figure 3.4.1. Geological features are also identified. Topographic slopes are provided in Figure 3.4.2. The glacial moraines and outwash plains are clearly visible in the headwater areas of the North and South Branches on Figure 3.4.1. The elevation at the headwaters in Newaygo County is 298 meters and grades down to 178 meters at White Lake. There are several distinct changes

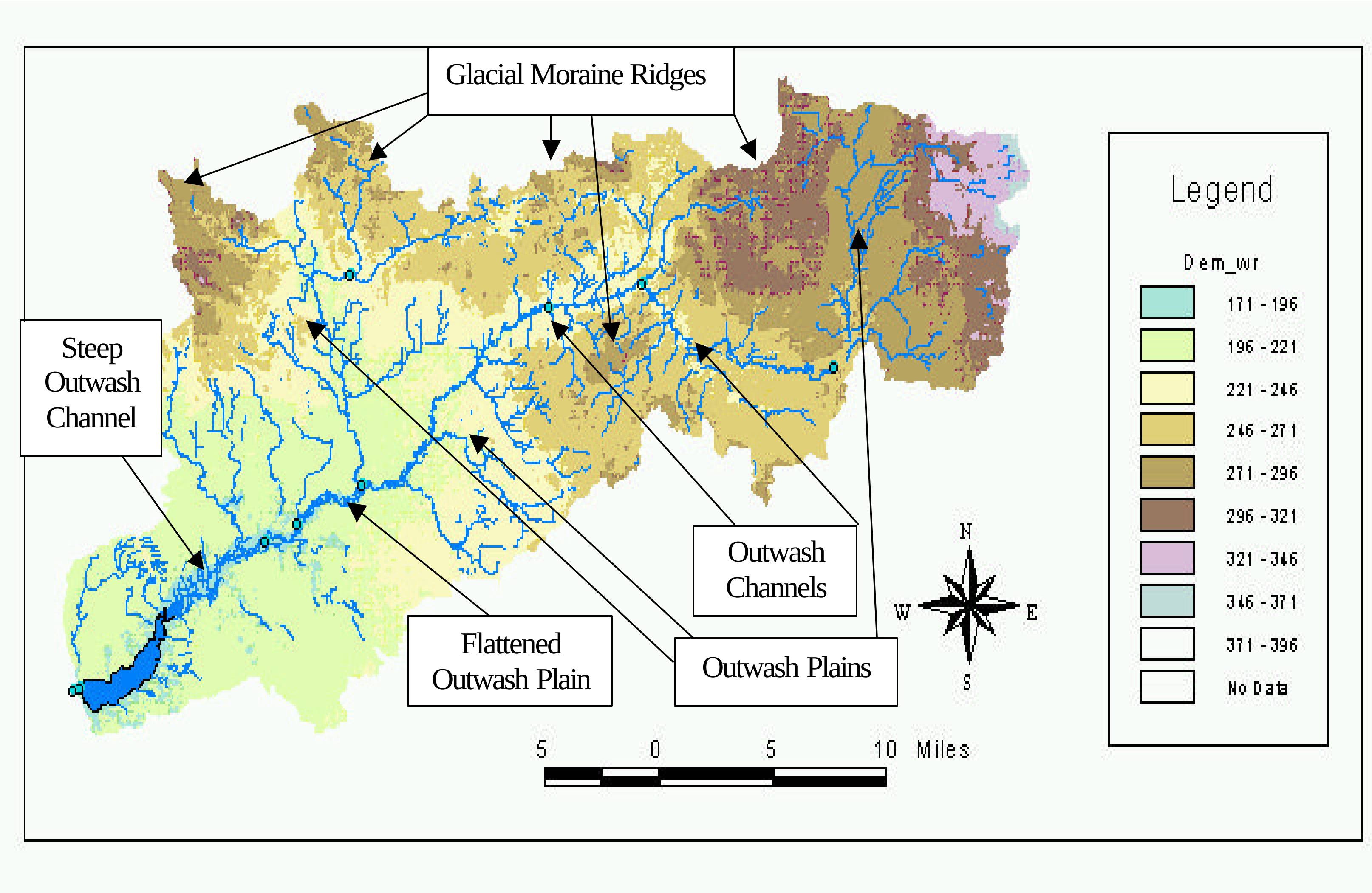


FIGURE 3.4.1 DIGITAL ELEVATION MODEL OF THE WHITE RIVER WATERSHED. ELEVATION IN METERS.

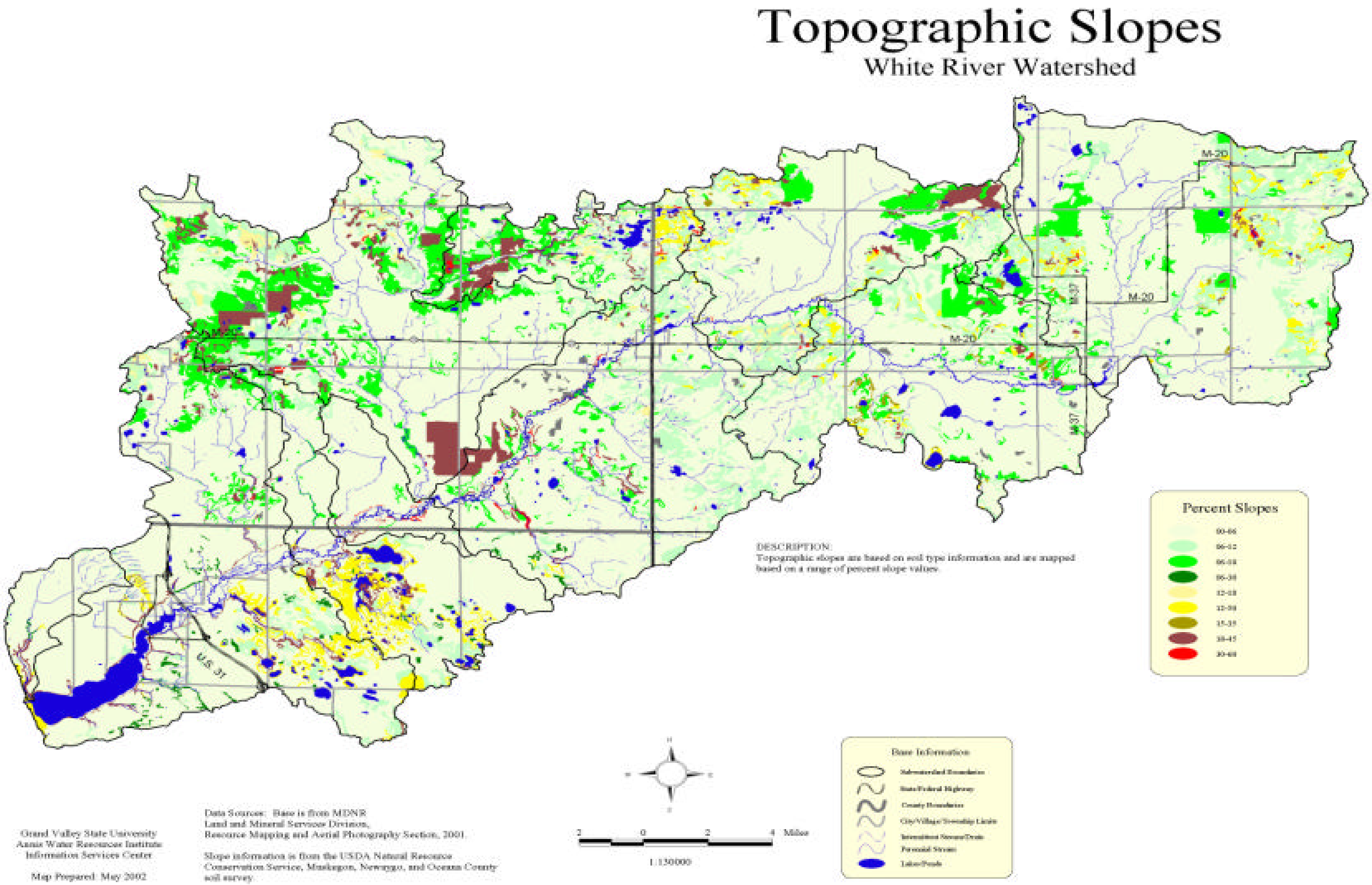


FIGURE 3.4.2 TOPOGRAPHIC SLOPES IN THE WHITE RIVER WATERSHED.

in topography throughout the watershed. The flood plain surrounding the lower White River is relatively flat alluvial lowland with 0-6% slopes (Figure 3.4.2). Land with 6-18% slopes is found in the glacial moraine valleys and outwash plains that have features related to pitting (kettle lakes and depressions). The steepest slopes (30-60%) are almost exclusively found in river valleys of the White River and selected tributaries located west of Hesperia. These valleys were carved out during the low water periods the Great Lakes (Section 3.1). The remaining lands with steep slopes are related to moraine remnants in the upper Oceana and Newaygo sections of the watershed.

3.5 HYDROLOGY AND STREAM CHARACTERISTICS

Geomorphic features discussed in the previous sections (geology, soils, and topography) play an integral role in structuring the hydromorphic characteristics (lakes, groundwater, and streams) of the watershed. The White River watershed contains over 253 linear miles of streams and 20 major lakes (MDNR 1975). Figure 3.5.1 shows the major perennial streams, subwatershed boundaries, and lakes found in the drainage basin (MDEQ 1998). Subwatersheds are established based on the catchments of individual tributaries and branches that make up the entire White River watershed. Because they represent distinct drainage basins, subwatersheds are logical units to evaluate water quality and land use issues on a smaller scale. Figures 3.5.2 and 3.5.3 and 3.5.4 provide information on stream gradient, hydrologic status, and temperature respectively (MDNR 1997). The information from these figures is summarized in Table 3.5.1. The watershed contains a mixture of groundwater and

Table 3.5.1. Summary of Stream Characteristics in the White River Watershed by Subwatershed (MDNR 1997).

Stream	Gradient	Hydrologic Status	Temperature
White Lake and Carlton/Mud Creeks			
Carlton Creek	> 10 ft/mi	Runoff Driven Moderate Base Flow	Cool Low Variation
Silver Creek	< 4 ft/mi	Runoff Driven Moderate Base Flow	Cold Low Variation
SAND CREEK/WOLVERINE LAKE			
Sand Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cold Low Variation
Cleveland Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cold Low Variation
White River	< 4 ft/mi	Groundwater Driven High Base Flow	Cool Moderate Variation
Middle White River			
White River	< 4 ft/mi	Groundwater Driven High Base Flow	Cool Moderate Variation
North Branch			
North Branch	4-10 ft/mi	Groundwater Driven High Base Flow	Cold Moderate Variation
Bear Creek	4-10 ft/mi	Groundwater Driven High Base Flow	Cold Low Variation

Table 3.5.1 (continued). Summary of Stream Characteristics in the White River Watershed

Stream	Gradient	Hydrologic Status	Temperature
North Branch			
Knutson Creek	4-10 ft/mi	Groundwater Driven High Base Flow	Cold Low Variation
Swinson Creek	4-10 ft/mi	Groundwater Driven High Base Flow	Cold Low Variation
Upper North Branch			
North Branch	< 4 ft/mi	Runoff Driven Moderate Base Flow	Cool Moderate Variation
Skeel/Cushman/Braton Creeks			
Skeel Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cool Low Variation
Cushman Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cool Moderate Variation
Braton Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cool Moderate Variation
South Branch	> 10 ft/mi	Groundwater Driven High Base Flow	Cold Moderate Variation
Martin/Mena/Held Creeks			
Martin Creek	> 10 ft/mi	Groundwater Driven High Base Flow	Cold Low Variation
Mena Creek	> 10 ft/mi	Groundwater Driven High Base Flow	Cold Low Variation
Held Creek	> 10 ft/mi	Groundwater Driven High Base Flow	Cold Low Variation
South Branch	> 10 ft/mi	Groundwater Driven High Base Flow	Cold Moderate Variation
South Branch/Robinson Lake			
South Branch North of M-20	> 10 ft/mi	Groundwater Driven High Base Flow	Cold Moderate Variation
South Branch South of M-20	< 4 ft/mi	Groundwater Driven High Base Flow	Cold Moderate Variation
Robinson Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cool High Variation
Upper South Branch			
South Branch North of M-20	< 4 ft/mi	Groundwater Driven High Base Flow	Cool Moderate Variation
South Branch South of M-20	< 4 ft/mi	Runoff Driven Fair Base Flow	Cold Moderate Variation
Flinton Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cool High Variation
Five Mile Creek	4-10 ft/mi	Runoff Driven Fair Base Flow	Cool High Variation
Mullin Creek	< 4 ft/mi	Runoff Driven Fair Base Flow	Cool Moderate Variation

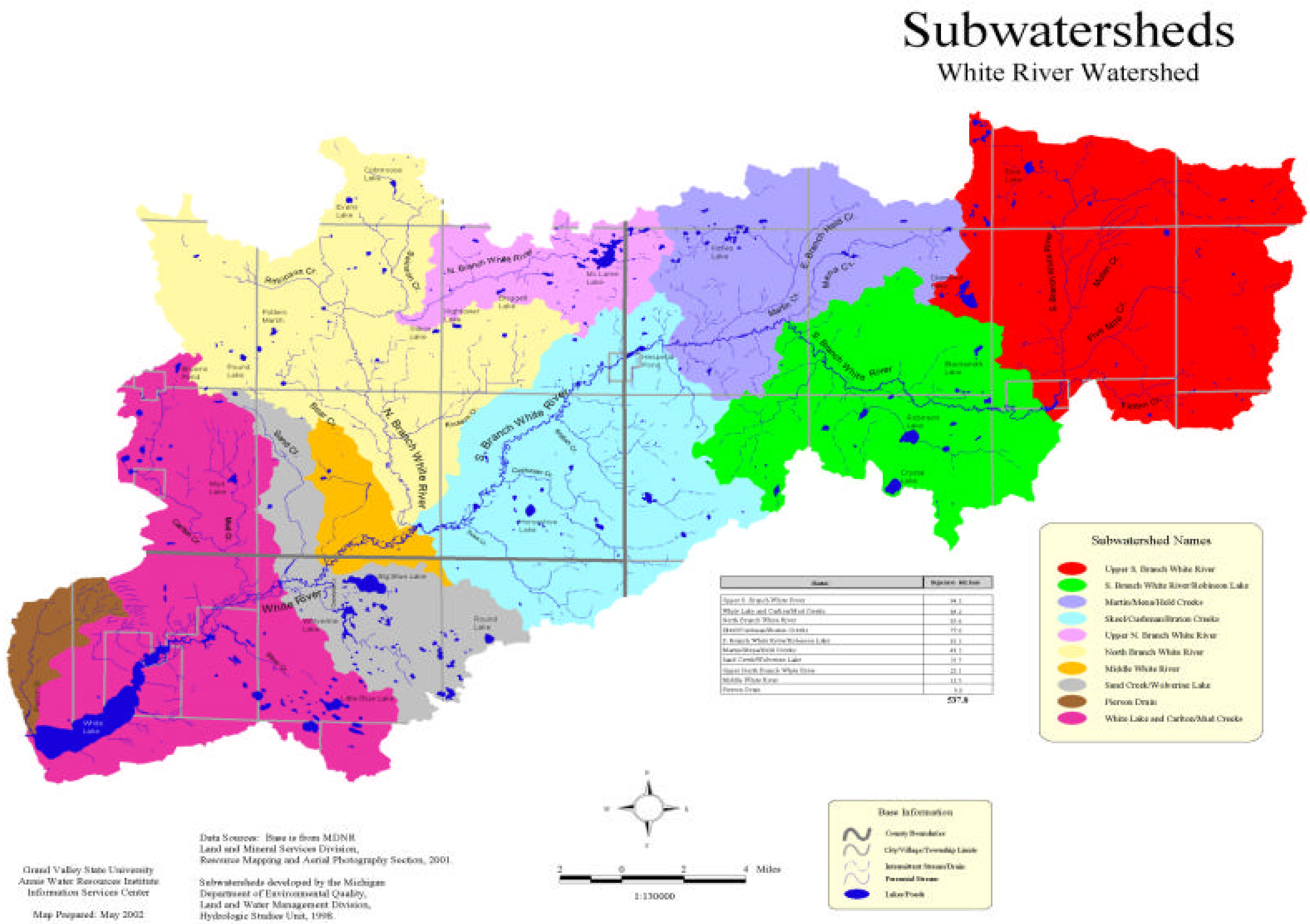


FIGURE 3.5.1 SUBWATERSHEDS IN THE WHITE RIVER WATERSHED.

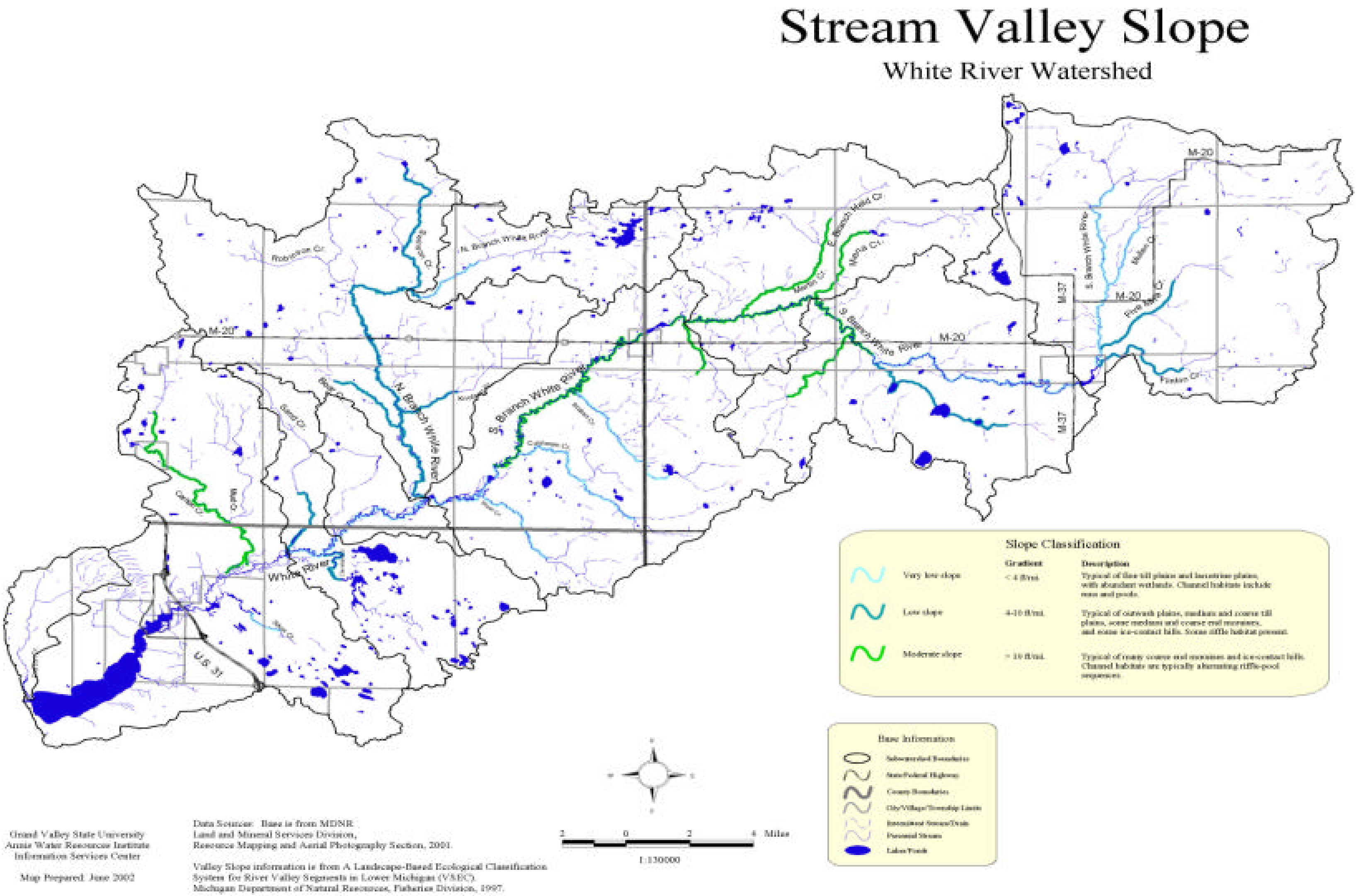


FIGURE 3.5.2 STREAM VALLEY SLOPE IN THE WHITE RIVER WATERSHED.

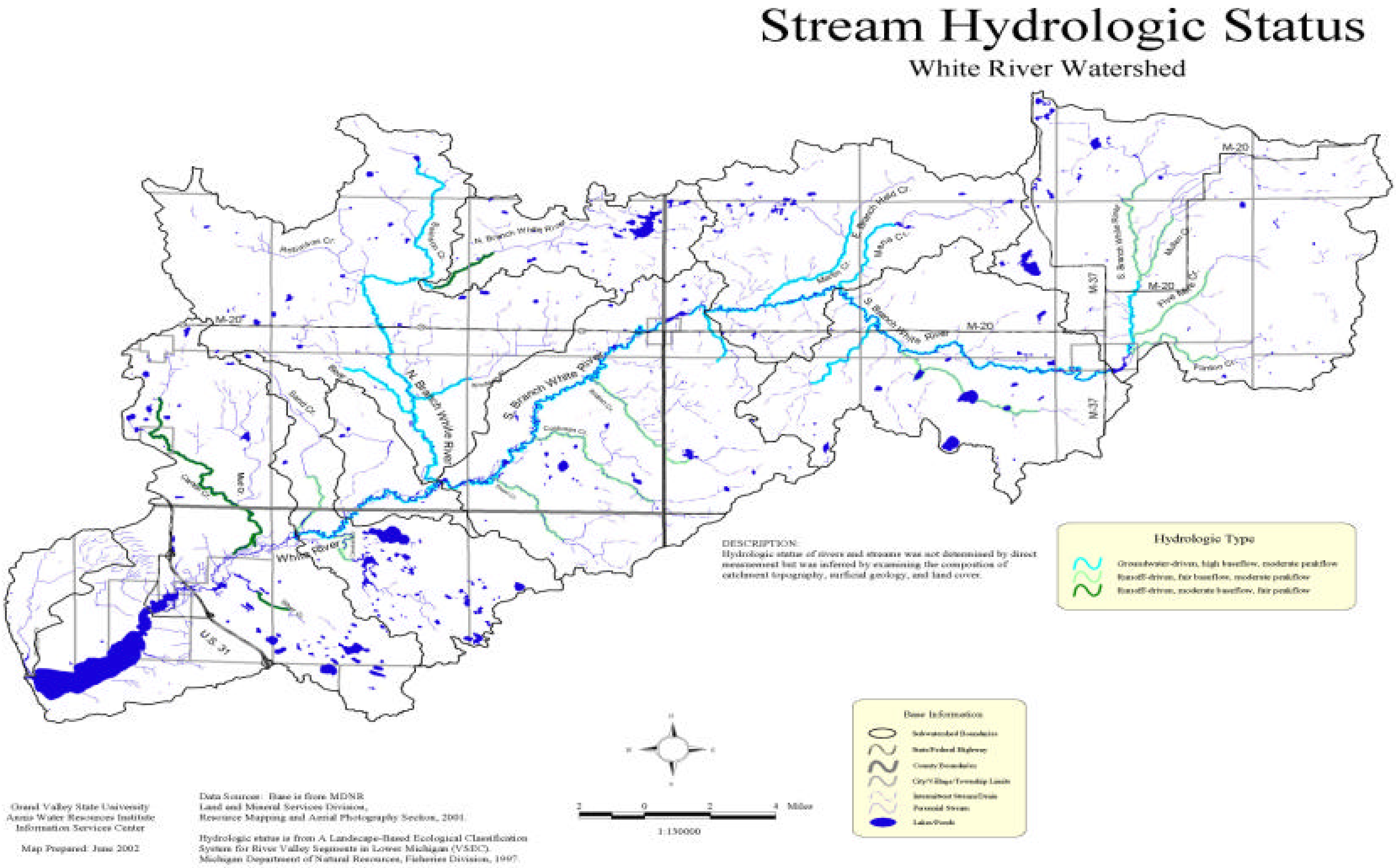


FIGURE 3.5.3 HYDROLOGIC STATUS OF STREAMS IN THE WHITE RIVER WATERSHED.

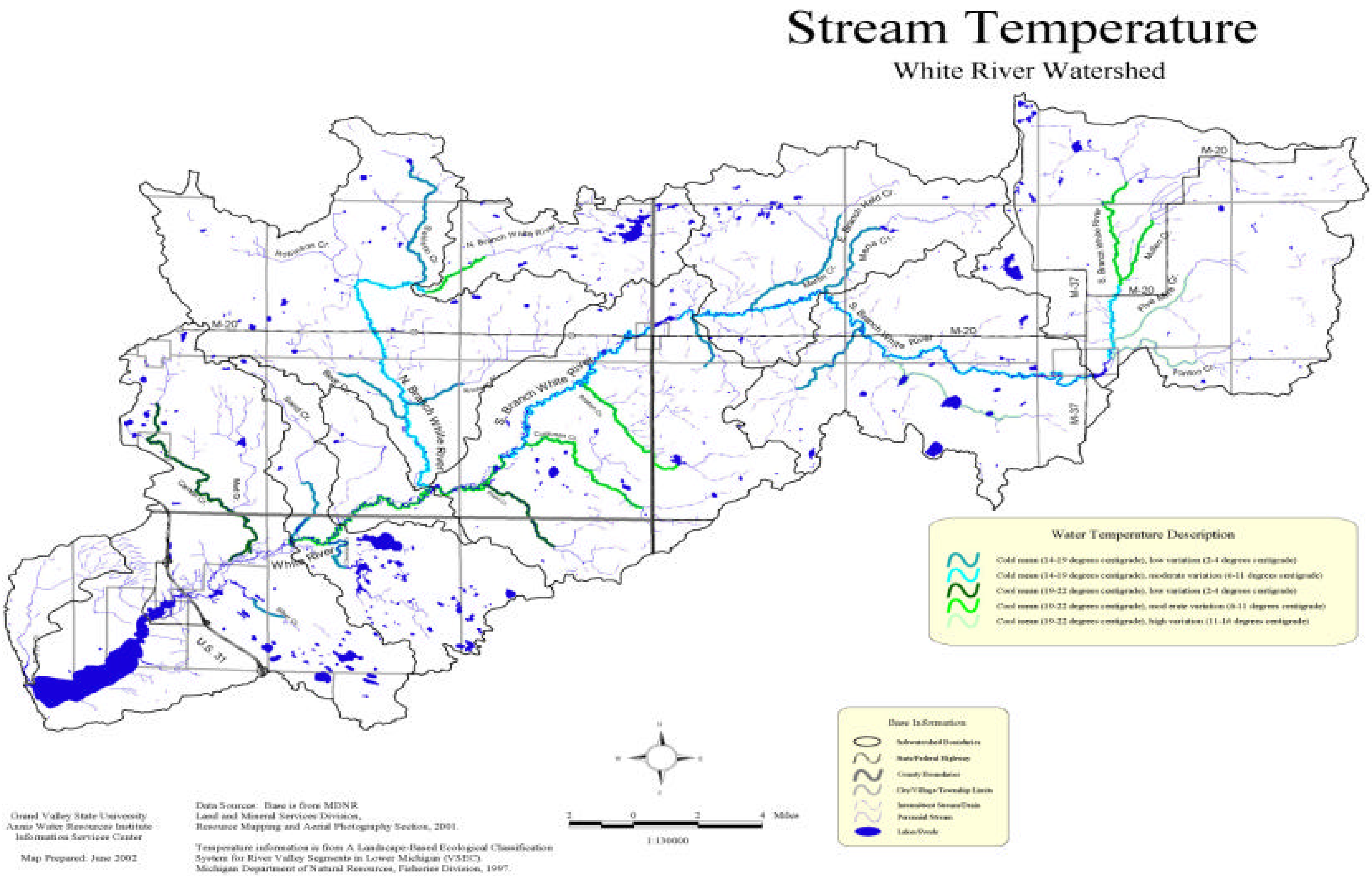


FIGURE 3.5.4 STREAM TEMPERATURE IN THE WHITE RIVER WATERSHED.

runoff driven streams that are ranked as cold and cool with respect to temperature. Groundwater-fed rivers have deeper channels and faster flows during the summer. Substrates are generally coarse. Stable groundwater temperatures keep the streams cool in the summer and also help warm these rivers during winter. Fishes of stable, groundwater rivers (e.g. trout and sculpin) are habitat specialists, adapted to a rather narrowly defined constant, cold, swift-water environment. Runoff driven rivers are wide and shallow during summer months with temperatures that are influenced by ambient conditions. During summer months, these streams generally have low velocities that allow the accumulation of fine silt and sand substrates. During storm events, discharge increases and transports bedload sediments and the nutrients and soil associated with runoff downstream. Fishes found in flashy, runoff driven rivers are diverse and adapted to warm, slow water, with variable conditions (e.g. many sunfishes, minnows, catfishes, and suckers).

Approximately 20 large lakes ranging in size from ten acres up to several hundred acres, drain into the White River. In addition to the two impoundments on the mainstream at White Cloud (60 acres) and Hesperia (100 acres), five smaller impoundments (3-35 acres) on tributaries, drain into the White River. As part of this project, a field survey of the watershed was conducted of major road/stream crossings and by canoes during August and September 2002. Most of the tributaries in the headwaters of Newaygo County (Flinton, Five Mile, and Mullen Creeks) and the mainstream above White Cloud had a mixture of bottom types composed of sand, silt, and gravel. Some channelization was evident; however, pool and run sequences were common. Between White Cloud and Hesperia, the South Branch passed first through a broad elm swamp where the bottom was mostly sand and contained many deep holes from historical logjams. North of Robinson Lake (Lutes Bridge), the river flowed through glacial moraines and for several miles downstream, the current was moderate and the bottom contained an abundance of gravel with some larger boulders (Figure 3.5.5). The river then slowed and the bottom type changed to sand as the river entered the impoundment at Hesperia. Below Hesperia for eight to ten miles, the river was fairly swift and flowed over a sand and gravel bottom. Below the Pine Point Campground in the Manistee National Forest and extending to White Lake, the river had a moderate current and sandy bottom with many meanders and oxbows. The North Branch begins in McLaren Lake and flows west to Ferry and then south to its junction with the mainstream. Due to the influence of its headwater lakes, the North Branch had warm water temperatures (30 ^{0}C), for the first four or five miles. Below this area, sufficient groundwater entered the stream to reduce the temperatures to a cool water designation. The steam bottom was generally sandy with fair amounts of gravel scattered throughout its length. Sand bar deposition and stream bank erosion sites were more

FIGURE 3.5.5 THE WHITE RIVER WEST OF HESPERIA.

common on the North Branch than the upper South Branch. The USGS operates a gauging station on the White River near Whitehall. Data from 1953-present is available on their web site (www.usgs.org/michigan). Robertson (1997) conducted a hydrological analysis of the White River watershed in order to estimate sediment and total phosphorus loadings to Lake Michigan. His estimates did not include the effects of White Lake and the wetland to the east and west of US-31 on sediment deposition. The estimates reported for suspended sediment and total phosphorus therefore overstate actual loadings to Lake Michigan. They do, however, reflect potential loadings to White Lake. A summary of Robinson's analyses and USGS data are presented below:

Watershed area	406 mi^2
Long-term daily average flow	450 f^3/sec
Long-term daily minimum flow	220 f^3/sec
Long-term daily maximum flow	602 f^3/sec
Peak flow	1834 f^3/sec
Flashiness	4
Suspended Solids Load to Lake Michigan	0.62% (34,000 kg/d)
Total Phosphorus Load to Lake Michigan	0.54% (45 kg/d)
Stream gradient	1.15 m/km

A loading study of nutrients entering White Lake from the White River was conducted in 1972-1975 (Freedman et al. 1979). The average load of total phosphorus to White Lake during this period was 68 kg/day. White Lake was found to retain approximately 75% of the phosphorus load leaving an average of 20 kg/d discharged to White Lake. These results show the potential for error in the calculations made by Robinson (1977) when the function of White Lake as a nutrient sink is not factored into the estimate. Freedman et al. (1979) also concluded that 94% of the nitrogen and phosphorus loading to White Lake came from the White River. Their study calculated the average phosphorus load upstream of the drowned rivermouth wetland to be 47 kg/d during the same time period. These results suggest that the wetland may be a significant source of the phosphorus load. The drowned rivermouth wetlands have been modified by agricultural producers as shown in Figure 3.5.6. Many of the muck fields have dikes and dewatering systems that discharge into the wetlands. In addition, bridges and elevated roadways have restricted the flow at the rivermouth from the typical wide delta to a narrow channel under the bridge. The extensive physical modifications plus the addition of drainage water may be responsible for turning the wetlands into more of a nutrient source rather than a system of storage and processing. Storm events and seasonal peak flows also may release nutrients from the wetlands by flushing and scouring.

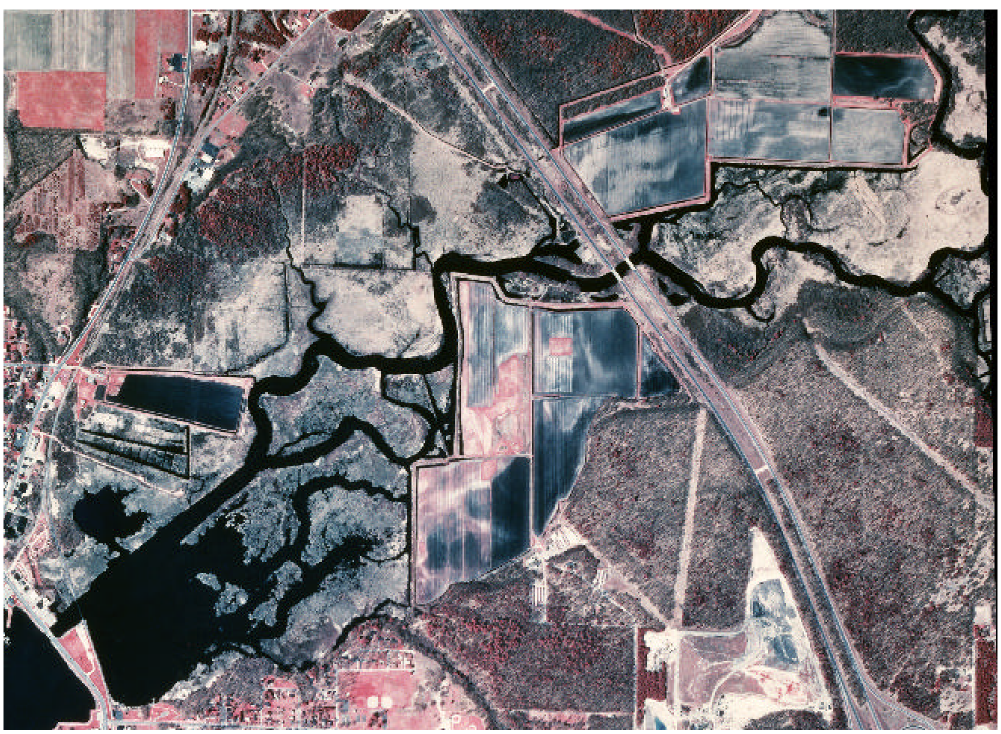


FIGURE 3.5.6 AERIAL VIEW OF THE WHITE RIVER DROWNED RIVERMOUTH WETLANDS.

White Lake is a significant hydromorphic feature of the watershed. It has an area of 10.2 km^2 and a mean depth of 7.3 m. The lake has an estimated volume of $7.6x10^7$ m^3 and a residence time of 56 days. White Lake has a long history of environmental issues related to water quality and the discharge of toxic materials. The lake was impacted in the mid 1800s when saw mills were constructed on the shoreline during the lumbering era. A large portion of the littoral zone was filled with sawdust, wood chips, timber wastes, and bark during this period. Large deposits of lumbering waste can still be found today in the nearshore zone of White Lake. The lumbering era was followed in the 1900s by an era of industrial expansion related to the construction of specialty chemical production facilities and a leather tanning operation. Tannery waste from Whitehall Leather was discharged directly into White Lake from 1890-1973 while effluents from Hooker Chemical's chloralkali and pesticide production were discharged from the 1950s-1986 (Evans 1992 and GLC 2000). One tributary in the local watershed was also used for the discharge of industrial waste effluent from another specialty chemical production facility. As a result, degraded conditions were observed in much of the lake, as well as high sediment concentrations of heavy metals and pesticide related chemicals. Evans (1992) presented a review of studies that described extensive areas of oxygen depletion, high quantities of chromium in the sediments, thermal pollution, the discharge of waste with a high oxygen demand from the tannery (sulfide and organic matter), tainted fish, frequent algal blooms, and high nutrient concentrations. Generally, oligochaetes were the dominant benthic taxa and macroinvertebrate species richness and diversity were low across the lake, indicating eutrophic conditions were prevalent in 1972, especially, the southeastern portion of the lake (Evans 1976). The International Joint Commission designated White Lake as an Area of Concern (AOC) because of severe environmental impairments related to these discharges. The AOC boundary includes the lake and several small subwatersheds. One of these systems, Mill Pond Creek, was used for the discharge of a variety of chlorinated solvent and ether compounds from the Muskegon/Koch Chemical facility. In 1973, a state of the art wastewater treatment facility was constructed and the direct discharge of waste effluents and partially treated municipal sewage to White Lake was eliminated. The new facility was constructed near Silver Creek and utilized aeration, lagoon impoundment, spray irrigation and land treatment to remove nutrients, heavy metals, and organic chemicals. While the system was very effective in reducing the point source load of nutrients to White Lake, nonpoint contributions from upstream sources increased after construction and a net reduction in loading was not observed during 1974 and 1975 (Freedman et al 1979). The same authors used the Vollenweider model (Vollenweider 1975) to examine the amount phosphorus reduction necessary to limit the rate of eutrophication in White Lake. The results of the modeling predicted that external phosphorus loading would have to be reduced by almost 70% before a change in trophic status would be seen.

Considerable progress has been made related to the issue of contaminated sediments in White Lake. Areas of contaminated sediment were delineated (Rediske et al. 1998) and remedial action plans were developed for the sites posing the greatest risk to White Lake. Remediation of the contaminated sediments near the tannery began in the fall of 2002 and will be completed by mid 2003. The area of contaminated sediments near the former Hooker Chemical facility is scheduled for remediation during the latter part of 2003. These remedial actions will address a majority of the issues related to contaminated sediments in White Lake. In contrast, issues of eutrophication and nutrient loading have not been examined in sufficient detail because current hydrologic and water chemistry data are lacking. The hydrology of the White River watershed is complex due to the topography, meander patterns, and the strong influences of the wetlands, Lake Michigan, and White Lake. It will be necessary to develop a detailed hydrologic model for the watershed in order to evaluate solutions for the eutrophication issues in White Lake. Through hydrologic modeling, it will be possible to determine the nutrient contributions of the tributaries and wetlands and to develop an understanding of the transport, storage, and processing dynamics in the watershed.

3.6 TERRESTRIAL AND AQUATIC HABITATS

A diverse assemblage of flora and fauna is found in the White River watershed. A complete inventory of species has not been performed and consequently, the information included in this report is based on field observations and reviews of species inventories conducted in other areas of western Michigan. The fauna species range from migratory and transient species to native animals (MNFI 1998, TNC 2002) and are summarized in Appendix A (Tables A-1 through A-5). Species common to upland forests and wetland environments are present.

A map of presettlement vegetation is shown in Figure 3.6.1. The map was developed from historical surveys that were conducted during the late 1700s. The western section of the watershed was dominated by pine and mixed hardwood forests. Beach, sugar maple, and hemlock forests covered much of the mid section. The eastern part of the watershed contained a mixture of hard and softwood species in addition to large conifer swamps in the headwater regions. Dominant forms of land cover are summarized in Table 3.6.1. Approximately 43,500 acres of wetland environments were present in the late 1700s. The current vegetative cover based on aerial photography is shown in

Table 3.6.1 Summary of Presettlement Vegetation in the White River Watershed.

PRESETTLEMENT VEGETATION	ACRES	%
BEACH/RIVERBANK	116	< 0.1
BEECH-SUGAR MAPLE-HEMLOCK FOREST	116,962	34.6
BLACK ASH SWAMP	1,663	0.5
BLACK OAK BARREN	4,824	1.4
CEDAR SWAMP	7,169	2.1
GRASSLAND	83	< 0.1
HEMLOCK-WHITE PINE FOREST	9,802	2.9
JACK PINE-RED PINE FOREST	748	0.2
LAKE/RIVER	7,385	2.2
MIXED CONIFER SWAMP	20,431	6.0
MIXED HARDWOOD SWAMP	9,834	2.9
MUSKEG/BOG	6	< 0.1
OAK/PINE BARRENS	5,684	1.7
SHRUB SWAMP/EMERGENT MARSH	4,435	1.3
WHITE PINE-MIXED HARDWOOD FOREST	79,349	23.4
WHITE PINE-RED PINE FOREST	1,215	0.4
WHITE PINE-WHITE OAK FOREST	68,812	20.3
TOTAL WETLANDS	43,538	12.9

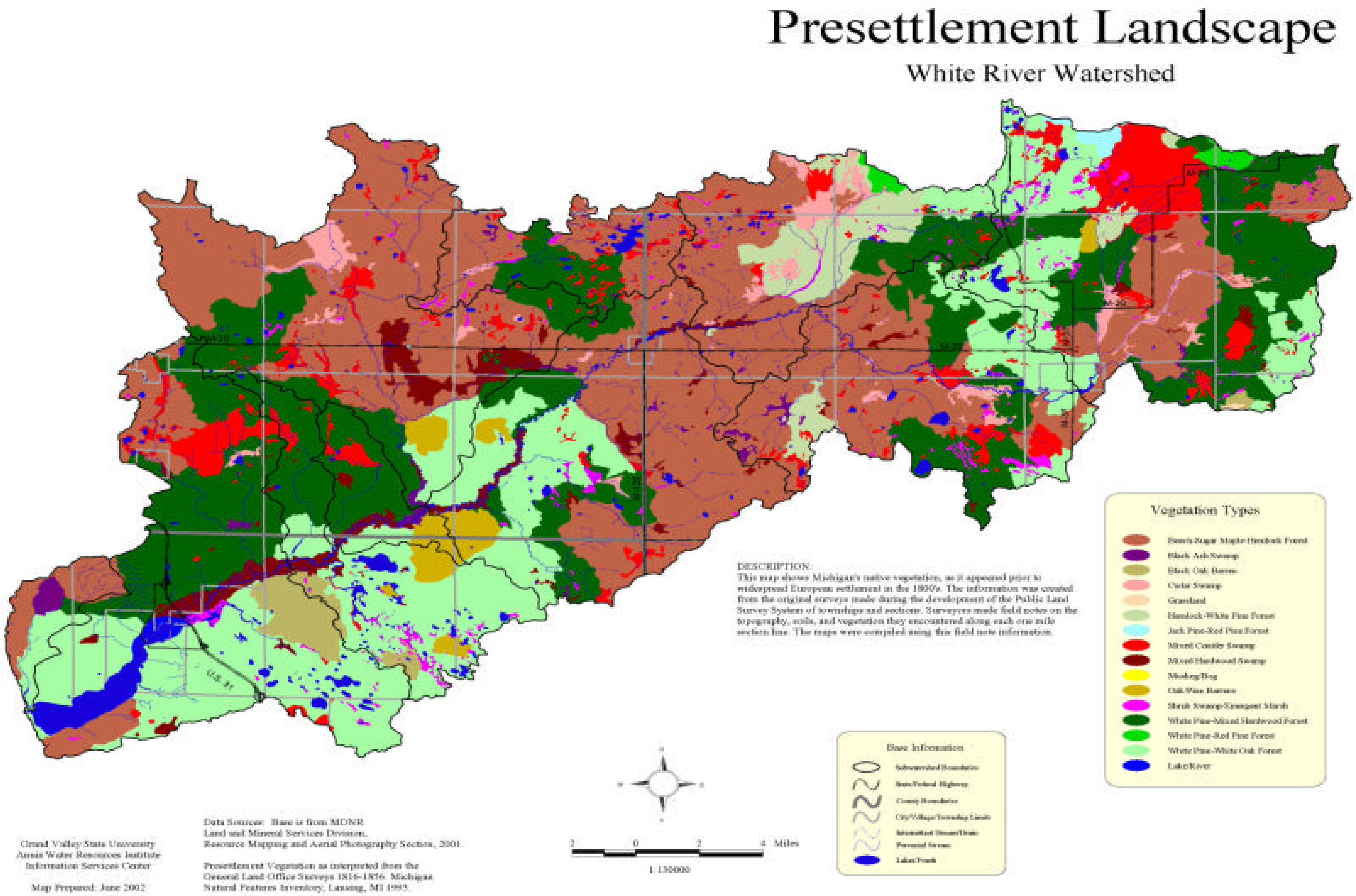


FIGURE 3.6.1 PRESETTLEMENT VEGETATION IN THE WHITE RIVER WATERSHED.

Figure 3.6.2. Land cover and land use types are summarized in Table 3.6.2. An index to these classifications is included in Table 3.6.3. A majority of the watershed is classified as forested (58%) and open field (11%). Approximately 20% of the land use is agricultural while residential and commercial/industrial developments account for 3.25% and 0.5% respectively. While lumbering, agriculture, and urban development have dramatically altered the watershed, the most noteworthy change has been observed in the reduction of wetland acreage. Presettlement wetlands covered 43,500 acres while the current coverage amounts to about 38,825 acres. A comparison of the two maps reveals that the conversion of wetlands to agricultural production accounts for most of this change. The presettlement wetlands designated as Mixed Conifer Swamps (red color) all contain networks of channelized streams that indicate the wetlands were artificially drained. Areas designated as cedar and hardwood swamps also appear to have been drained for agricultural production. Some of the differences between current and historical wetland acreage also may be due to changes in classification criteria and survey methods.

Table 3.6.2 Summary of Current Land Use and Cover in the White River Watershed (1992, 1997, and 1998).

White River Watershed Land Use/Cover	Acres	%
Barren/Sand Dune	170	0.049
Commercial/Institutional	1,031	0.295
Confined Feeding	710	0.203
Cropland	65,839	18.837
Northern Hardwoods	48,215	13.795
Central Hardwoods/Oak	84,047	24.046
Aspen-Birch	15,913	4.553
Lowland Hardwoods	26,612	7.614
Pine	23,889	6.835
Other Upland Conifer	12	0.003
Lowland Conifers	2,161	0.618
Managed Christmas Trees	2,621	0.750
Mixed Conifer/Broadleaf	147	0.042
Wooded Wetland	98	0.028
Industrial	713	0.204
Open Field	37,678	10.780
Orchards or Other Specialty Crops	8,009	2.291
Other Agricultural Lands	342	0.098
Other Developed Areas	3,668	1.050
Residential	11,385	3.257
Water	6,300	1.802
Wetland	9,954	2.848
Transitional Land	11	0.003
Total Wetlands	38,825	11.1
Total Forest	203,715	58.2

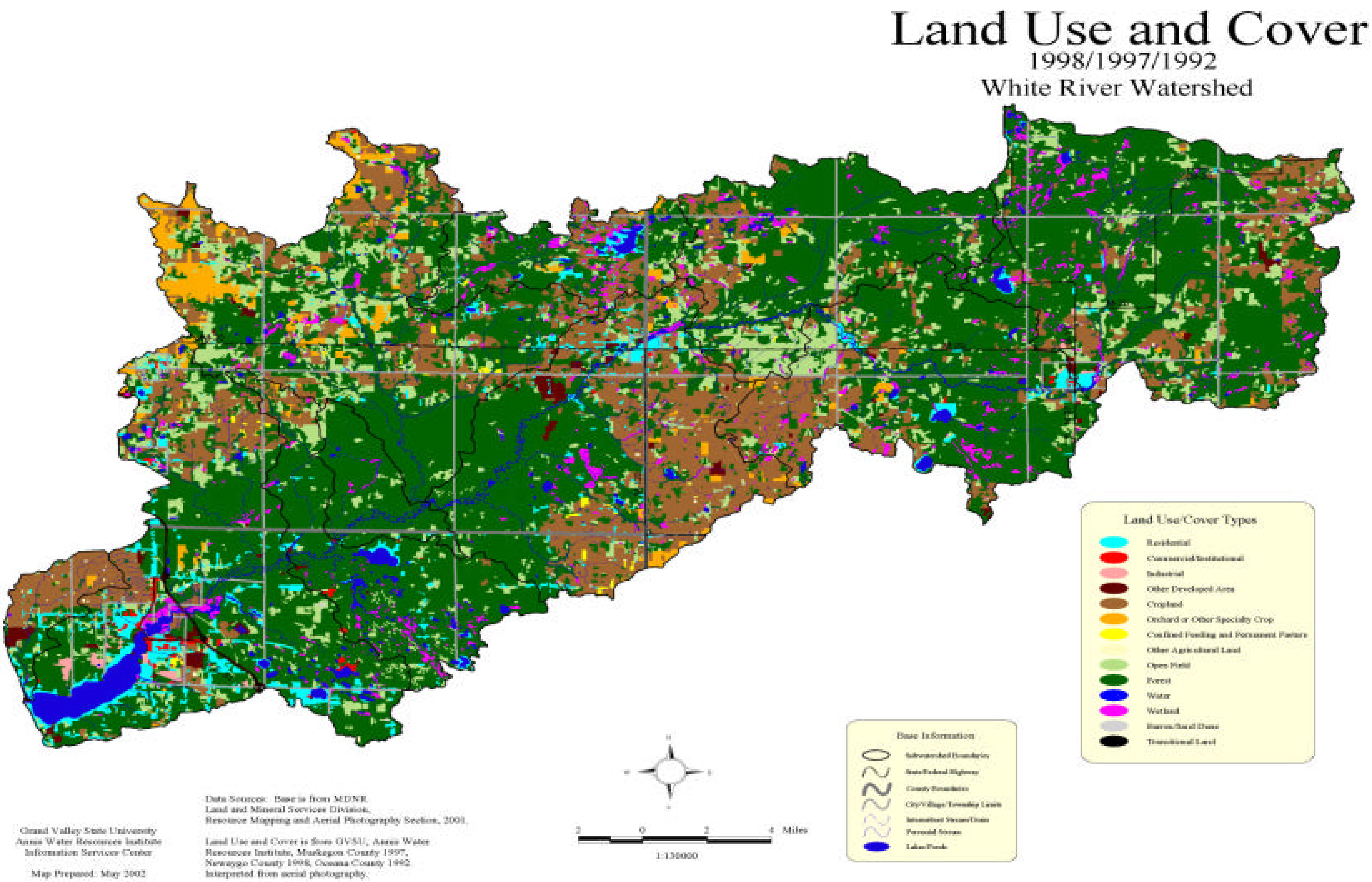


FIGURE 3.6.2 CURRENT LAND COVER IN THE WHITE RIVER WATERSHED (1992/1997/1998).

Table 3.6.3. MIRIS Classification Definitions For Land Cover Maps

Land Use Descriptions	
Classification	Description
Residential	Characterized by land that is covered by multiple and single family structures. Density is greater than one unit per acre.
Crop Land	Land used primarily for production of row crops and vegetables.
Water	Areas of land that are persistently water covered including lakes, rivers, stream, and creeks.
Orchard and Specialty Crops	Land used primarily for fruit trees, vineyards, nurseries, seed/sod, and floricultural production.
Barren/Dune	Land that has a limited ability to support life and little or on vegetation.
Commercial Institutional	Areas that are primarily used for the sale of products and services.
Transitional	Disturbed land that is transitional to developed areas.
Confined Feeding	Areas of land that are used for large livestock and poultry farms.
Other Agricultural	Areas of land that are used for greenhouses, out buildings and storage.
Other Developed Areas	Land that is used for mining (extractive), utilities, infrastructure, and recreational areas.
Forest	Areas that contain at least 10% deciduous and/or conifer species.
Open Field	Land used for recreational purposes that does not contain heavy structures or native vegetation, including zoo's, cemeteries, ski areas, and botanical gardens.
Wetland	Wetlands are areas where the water table is at, near, or above the land surface for a significant part of the year. The hydrologic regime supports aquatic and/or hydrophytic vegetation.
Industrial	Areas that contain manufacturing facilities that include light and heavy industries, which produce various commercial goods.
Wetland Shrub	Wetlands dominated by shrubs where the soil surface is seasonally or permanently flooded with up to 1 foot of water. Meadow or marsh emergents occupy open areas.
Central Hardwoods	Areas dominated by white, black, and red oak, hickories, and black locust.
Lowland Hardwoods	Areas dominated by ash, elm, sycamore, and maple species
Aquatic Bed	Includes wetlands dominated by plant that grow principally on or below the surface of the water for most of the growing season, during most years.
Lowland Conifer	Areas dominated by cedar, spruce, and fir species.
Wooded Wetland	Wetlands dominated by trees. The soil surface is seasonally flooded with up to 1 foot of water. Several levels of vegetation are usually present, including trees, shrubs, and herbaceous plants.
Emergent	Wetlands dominated by robust or marsh emergents, with an average water depth less than 6 inches during the growing season. Surface water may be present throughout the year or absent during the late summer and abnormally dry periods. Floating leafed plants and submergent plants are usually present in open areas.

A map of the current wetlands in the White River watershed is shown in Figure 3.6.3. Four types of wetlands classifications are present (Satterlund et al. 1992):

- Aquatic Beds - rooted aquatic plants and water lilies. 6" - 36" water depth
- Emergent Bed - cattails, sedge grass, pickerel weed, and reeds. 0" - 6" water depth
- Shrub – willow, alder, dogwood, and elderberry. 0" - 12" water depth
- Forested - ash, elm, sycamore, cottonwood, oak, and maple. Area prone to seasonal flooding.

Aquatic beds in the drowned rivermouth area serve as environments that support regional and Great Lakes fisheries (Jude and Pappas 1992). Emergent beds, wetland shrubs, and lowland hardwoods provide valuable habitats for wildlife and are an important source of organic materials for the aquatic food web.

Wetlands develop from a combination of factors including glaciation, climate, agriculture, and hydrologic processes. Each type of wetland is a unique ecosystem with its own inherent values and functions. These ecosystems are among the most productive and threatened ecosystems in the world. Wetlands are classified based upon plant and soil types and the frequency of flooding (Cowardin et al. 1979). Inland wetlands that incorporate a river or stream are called **riverine** wetlands. Wetlands that include a permanently flooded lake or reservoir are called **lacustrine**. Wetlands that are dominated by trees, shrubs, and emergent vegetation are called **palustrine**. Palustrine wetland systems often border riverine and lacustrine systems. The drowned rivermouth wetland at the river mouth near White Lake is a unique system that has both riverine and lacustrine characteristics. While it is similar to a coastal marine estuary in appearance, it does not have the salt gradient that is present in these systems. Each type of wetland is distinguished by its physical and chemical characteristics and by the types of plants and animals that live there. However, many plants and animals may be found in more than one wetland type.

In addition to wetlands, a number of other unique natural communities are present in the White River watershed. The locations and classifications of these communities are presented in Figure 3.6.4 (USFS 2001). The drowned rivermouth wetland near White Lake is classified as a Great Lakes Coastal Marsh (Albert 2001). These systems are influenced by Great Lakes water levels with respect to short-term fluctuations (seiches), seasonal fluctuations from the annual hydrological cycle, and interannual fluctuations from precipitation and evaporation within the basin. They are also characterized by deep accumulations of organic sediment, shallow stream channels, nutrient rich water, and a linear floodplain. The accumulation of organic matter in the

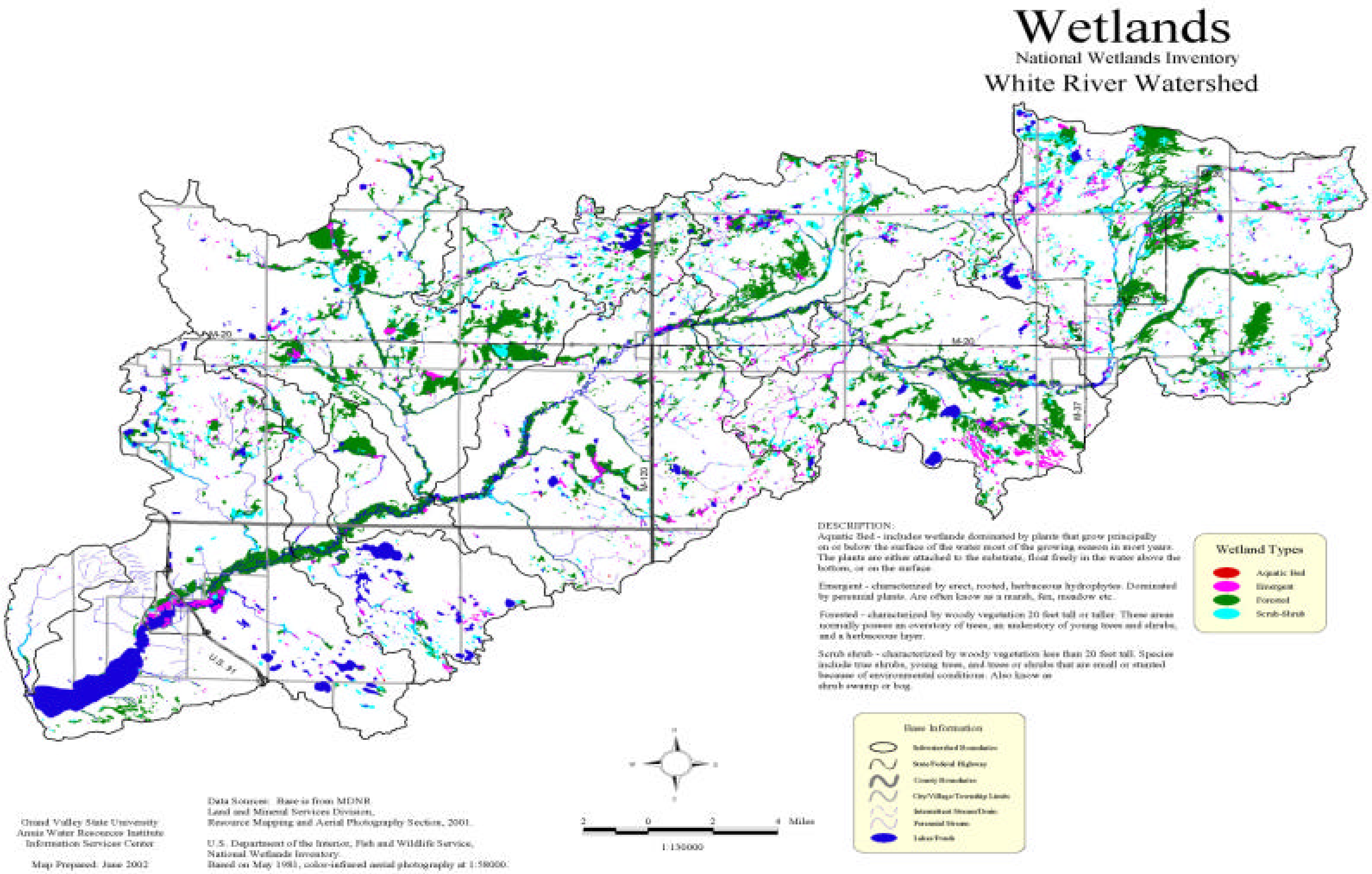


FIGURE 3.6.3 WETLAND CLASSIFICATIONS IN THE WHITE RIVER WATERSHED.

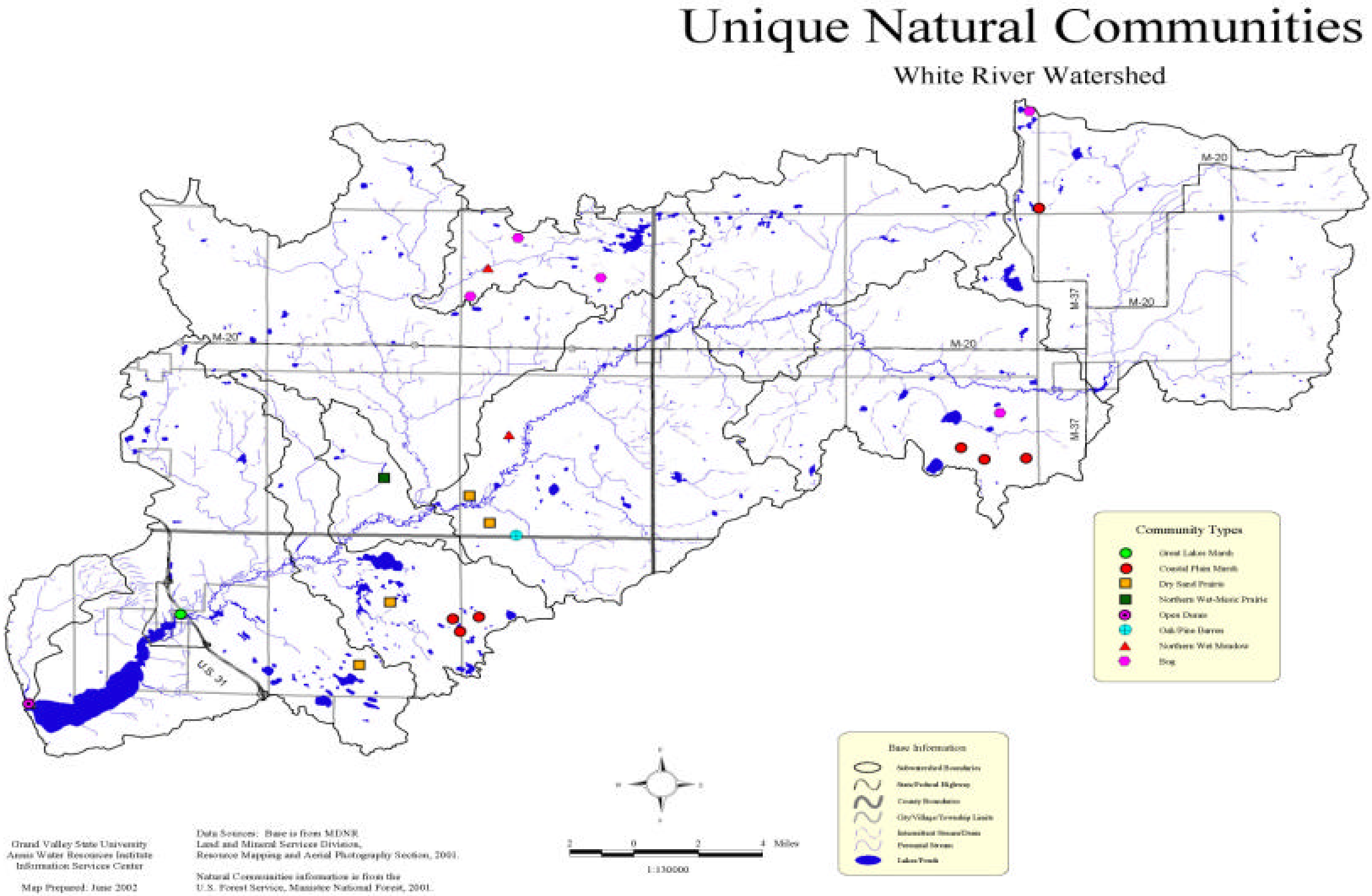


FIGURE 3.6.4 UNIQUE NATURAL COMMUNITIES IN THE WHITE RIVER WATERSHED.

wetland influences the plant communities found in the emergent and herbaceous zone.

Coastal Plain Marshes are found in eastern Muskegon County, central Newaygo County near Robinson Lake, and northern Newaygo County in the headwaters of the South Branch. These systems are formed in depressions of pitted outwash plains (Chapman 1990) and have concentric bands of vegetation around a center area of open water. A broad range of wetland communities are present in these bands including aquatic beds, emergents, wet prairies, and hardwood swamps (Kost 2000). Given the diversity of plant communities and zonation present, these systems are very sensitive to hydrologic disturbances from draining and shoreline development. With only forty of these systems identified in Michigan, the presence of eight Coastal Marsh Plains in the White River watershed represents a unique concentration of these rare wetlands.

FIGURE 3.6.5 COASTAL PLAIN MARSH IN NEWAYGO COUNTY.

Another rare wetland community, the Northern Wet –Mesic Prairie, is found in Oceana County near the confluence of the North and South Branches. Only 37 of these systems are found in Michigan and they have extreme hydrological regimes ranging from spring flooding to drought conditions in the summer (Albert and Kost 1998). These conditions are due to soil structure (1-3 meters of permeable sand overlaying clay) and the variability in moisture limits the establishment of woody plant species. Northern Wet–Mesic Prairies have very diverse plant communities and are subject to wildfires during the dry season. Wildflower communities are especially diverse in this type of habitat due to seasonal variations in soil moisture. The Northern Wet –Mesic Prairie in Oceana County is shown in Figure 3.6.6.

FIGURE 3.6.6 NORTHERN WET –MESIC PRAIRIE IN OCEANA COUNTY.

Two Northern Wet Meadows are found in central section of the watershed. These wetlands have acidic soils and are dominated by sedges (*Carex*) and forbs (Kost 2001). Northern Wet Meadow systems are formed in depressional, glacial, lowlands and are covered with *Carex* tussocks. The drying of tussocks during drought conditions renders these wetlands very susceptible to fire. Figure 3.6.7 shows a Northern Wet Meadow in Oceana County.

FIGURE 3.6.7 NORTHERN WET MEADOW IN OCEANA COUNTY.

In contrast to wetlands, Dry Sand Prairies are characterized by arid, sandy soils that are very susceptible to fire and wind erosion (Hauser 1953). Figure 3.6.8 shows a Dry Sand Prairie located in Muskegon County. Wildflowers such as Lupine and a variety of grasses and forbs dominate the landscape. The Karner Blue Butterfly is often associated with the lupine species common to these environments. In addition, prickly pear cactus can also be found (Figure 3.6.9). Dry Sand Prairies are very fragile environments and must be isolated from adverse anthropogenic impacts. If natural events such as fire or extreme drought destroys the vegetative cover, the area can often be rehabilitated by seeding with native grasses and wildflowers.

Oak/Pine Barrens are also very dry environments and are characterized by small jack pines (*Pinus banksiana*) mixed with scrubby Hill's oaks and bur oaks interspersed with openings in which shrubs dominate (Cohen 1999). Level topography and soils that are sandy and well drained are characteristic of these environments. Oak/Pine Barrens are maintained by periodic fires and drought conditions. These systems are also rare and only a few hundred acres remain in Michigan. A photograph of the only Oak/Pine Barren in the watershed is shown in Figure 3.6.10.

FIGURE 3.6.8 DRY SAND PRAIRIE IN MUSKEGON COUNTY.

FIGURE 3.6.9 PRICKLY PEAR CACTUS IN A DRY SAND PRAIRIE LOCATED IN MUSKEGON COUNTY.

FIGURE 3.6.10 OAK/PINE BARRENS IN OCEANA COUNTY.

Several bogs are present in Oceana and Newaygo Counties. These wetlands have acidic waters (Bridgham and Richardson. 1993) and are dominated by various combinations of sedges, sphagnum mosses, and insectivorous herbs. Sphagnum moss forms a dense mat that is often floating on the water. This species of moss releases H^+ into the water and creates the acidic environment. Under these conditions, organic matter decays very slowly and large deposits of peat accumulate. A typical bog environment is shown in Figure 3.6.11. While plant diversity is low in bogs, a number of rare and endangered species are usually present. These include the pitcher plant and the marsh five finger (Figure 3.6.12).

The unique wetland and upland environments discussed above add to the ecological diversity found in the White River watershed. They are natural features that are products of the unique set of hydromorphic and geomorphic features present in the watershed and the linkage to the Great Lakes.

FIGURE 3.6.11 BOG SYSTEM IN OCEANA COUNTY.

FIGURE 3.6.12 PITCHER PLANT AND MARSH FIVE FINGER FROM A BOG IN OCEANA COUNTY.

3.7 FISHERIES

The White River watershed has a diverse aquatic habitat that supports a variety of cold water and warm water fish species. This area provides multiple environments for these fish, including spawning grounds, migratory corridors, nursery habitats, and feeding areas. Currently, 70 fish species are found in the river, with 7 introduced to the region (MDNR 1989). A list of fish species found in the lower White River watershed is presented in Appendix B Table B-4 (MDNR 1989). The MDNR (1975) described the habitats and fisheries found in the White River and its tributaries. Stratton, Flinton, Five Mile and Mullen Creeks were classified as excellent streams for fishing with good populations of brook, brown and rainbow trout. Near White Cloud, the impoundment changed the temperature enough to favor rough fish and suckers. The trout population between White Cloud and Hesperia wasclassified as fair with brown trout in greatest abundance. Several tributaries in the middle section of the White River also contained excellent trout populations. Martin Creek was listed as an excellent brook-brown stream while Mena Creek was listed as good. The lower White was classified as a transitional fishery with strong spring and fall runs of steelhead plus populations of brown trout, smallmouth bass and northern pike. Some of the smaller tributaries in the middle section including Braton, Skeel and Cushman Creeks were listed as having good populations of brooks, browns and rainbows.

Due to the influence of McLaren Lake, a majority of the upper North Branch is a transitional fishery that supports warm water fish. As the stream passes through forested areas and accumulates groundwater, the temperature decreases and reaches a point that will support trout. From the mid point of Newfield Township until it joins with the lower White River, the North Branch was ranked as a good brown trout stream that also supported seasonal runs of steelhead. Several excellent coldwater tributaries enter the North Branch including Robinson Creek, Cobmosa Creek, Newman Creek and Knudsen Creek. All of these streams were reported to contain brooks and browns of respectable size. Downstream from the mouth of the North Branch, several tributaries of the White River were listed as viable brook trout streams. Carlton Creek was ranked as the best of the group, with Silver Creek and Sand Creek ranked above Cleveland Creek. Small impoundments on Sand Creek, Silver Creek and Cleveland Creek alter the temperature regime inundate sufficiently to support suckers and other rough fish. On a watershed basis, the White River supports a variety of coldwater species in addition to providing transitional environments for more tolerant species. The fishery is therefore an ecologically significant feature as well as a factor that adds to the recreational and economic value to the watershed.

4.0 White River Watershed Land Cover Analysis

Land cover analyses were conducted in each of the subwatersheds using MIRIS data from 1978 and 1992/1997/1998. The most recent data sets were used for each county (Oceana 1992, Newaygo 1997, and Muskegon 1998) and were compared to the 1978 information to determine areas where significant change occurred. The results of the GIS land cover analyses and field surveys are presented in Sections 4.1-4.10 for the individual subwatersheds. Summaries of the current land cover and significant changes from 1978 to 1992/1997/1998 are also presented.

4.1 UPPER SOUTH BRANCH

The Upper South Branch subwatershed covers 60,473 acres and includes sections of eight townships and the City of White Cloud. The land cover data for this area are summarized in Table 4.1.1 and displayed in map format on Figure 4.1.1. The Upper South Branch subwatershed consists primarily of mature forests (68.4%), cropland (13.6%), open fields (11.2%), wetlands (4.25%), open water (0.57%), and developed (0.99% residential, 0.04% commercial/institutional, 0.56% other development). Most of the cropland and open fields are concentrated in the southern and eastern portions of the subwatershed, and the wetlands are mainly found in the northwest portions in Monroe and Merrill Townships. This subwatershed contains nearly 26% of all the wetlands found in the White River watershed, totaling 2,571.2 acres (Table 4.1.1). The majority of these wetlands are located in close proximity to the smaller headwater tributaries and lakes of the Upper South Branch. A large wetland complex is also located in the upper northwest portion of the watershed (Oxford Swamp). The western headwaters of the South Branch and part of Mullen Creek near Van Buren Street, pass through a section of agricultural land where the stream channel lacks a significant riparian zone. This is reflected by a change in water temperature as the streams pass through this area. Diamond Lake is the largest water body in the subwatershed. Approximately 60% of the shoreline is residential and agricultural lands border the home sites in the eastern shore. Since 1978, very little change in land usage has occurred (Table 4.1.1). The most significant change was a shift from cropland and open fields to forested areas. The increase in other developed areas was related to the expansion of an oil and gas field near Four Mile Road and the addition of lands dedicated to utilities and infrastructure in the White Cloud area. The continued stability of the wetlands and forests in this subwatershed is essential to the local trout fishery and protection of the headwater streams.

Table 4.1.1 Land Cover Analysis of the Upper South Branch Subwatershed.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	576	596	1.0	20	3.5
Commercial/Institutional	19	23	< 0.1	4	23
Industrial	54	75	0.1	20	37
Other Developed Area	125	341	0.6	216	173
Cropland	8,771	8,196	14	-575	-6.6
Confined Feeding and Permanent Pasture	232	8	< 0.1	-223	-96
Orchard or Other Specialty Crop	8	154	0.3	146	1,781
Other Agricultural Land	23	25	< 0.1	2	8.5
Open Field	7,191	6,753	11	-438	-6.1
Forest	40,661	41,372	68	711	1.7
Water	350	347	0.6	-4	-1.1
Wetland	2,464	2,571	4.3	108	4.4
Transitional Land	0	3	< 0.1	3	NA
Total Acres		60,464			

4.2 SOUTH BRANCH WHITE RIVER/ROBINSON LAKE

The South Branch White River/Robinson Lake subwatershed covers 39,372 acres and includes sections of six townships and the City of White Cloud. GIS land cover data are presented in Table 4.2.1 and displayed in map format on Figure 4.2.1. Approximately 60% of the subwatershed is undeveloped forest, 20% is cropland and 11% is open fields. The forested areas are found in the eastern half of the subwatershed, and the majority of the cropland and open fields are concentrated in the western portion. Riparian corridors have been removed from most of the wetlands and stream channels in the agricultural area. This subwatershed contains 12% of all the wetlands found in the White River watershed, which are concentrated mainly in Dayton and Sherman Townships south of Baseline Road. Developed areas include approximately

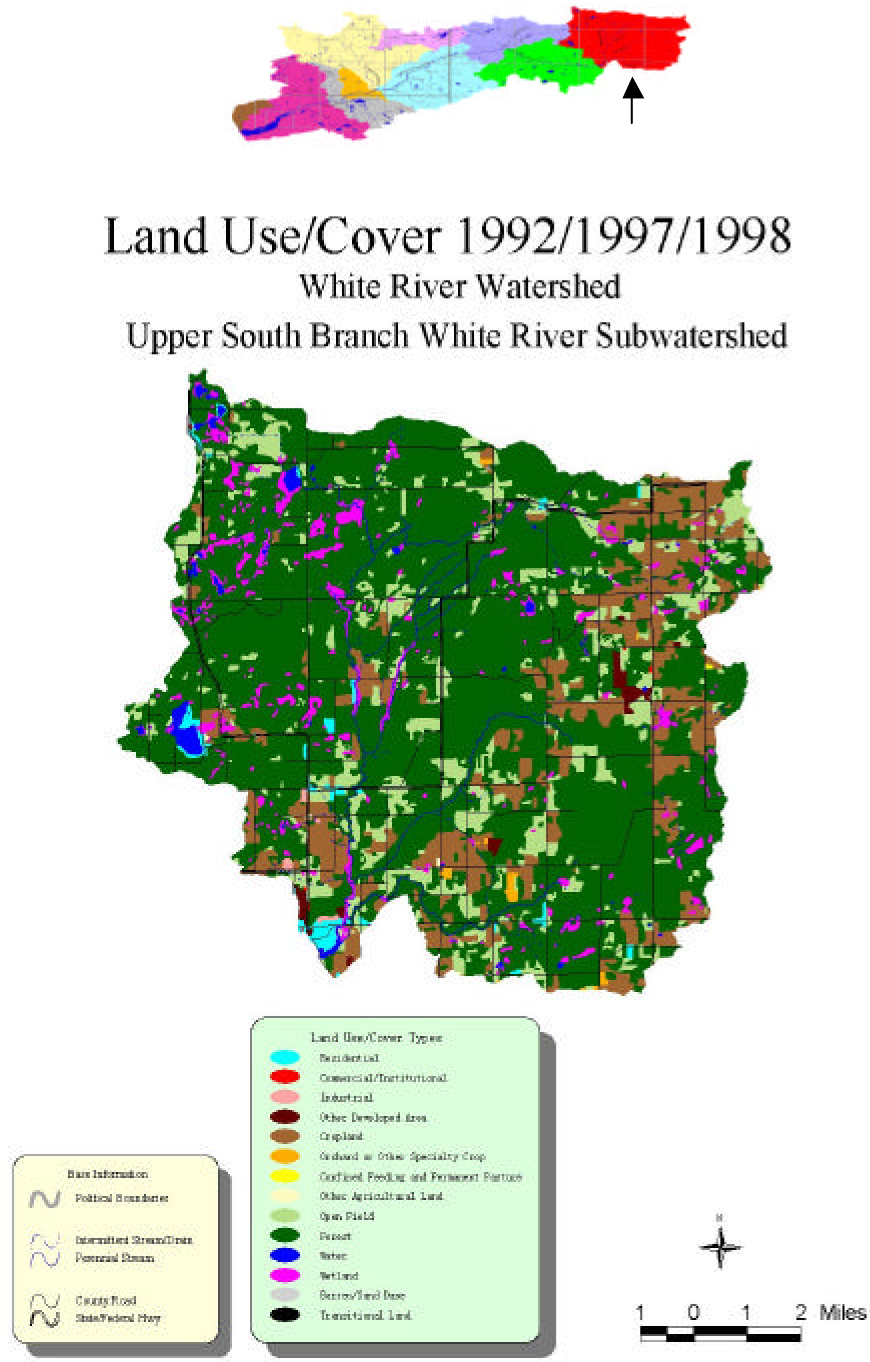


FIGURE 4.1.1 LAND COVER MAP OF UPPER SOUTH BRANCH SUBWATERSHED.

2% residential land use, with less than 1% being commercial, institutional or industrial development. Development is concentrated around Robinson Lake (including the resort area of Jugville), on the western side of White Cloud, and in section of the riparian zone near Aetna. Land use changes since 1978 (Table 4.2.1) are similar to the general trend visible throughout the watershed, with a shift in a small amount of cropland to open field, orchard, and forest.

Table 4.2.1 Land Cover Analysis of the South Branch White River / Robinson Lake Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	835	900	1.5	65	7.8
Commercial/Institutional	50	67	0.1	17	34
Industrial	56	59	0.1	4	6
Other Developed Area	112	222	0.4	110	99
Cropland	10,040	7,876	13	-2,164	-21.6
Orchard or Other Specialty Crop	146	382	0.6	236	161
Confined Feeding and Permanent Pasture	7	9	< 0.1	2	27
Other Agricultural Land	24	46	0.1	21	88.6
Open Field	2,995	4,368	7	1,372	45.8
Forest	23,446	23,699	39	253	1.1
Water	503	505	0.8	2	0.4
Wetland	1,159	1,233	2.0	74	6.3
Transitional Land	0	7	0.0	7	NA
Total Acres		39,372			

A majority of these land use changes occurred in Denver Township. An important feature of this subwatershed is the wetland / lake system present in Sherman Township, which includes Coonskin Creek, Robinson Lake and Robinson Creek, as well as several other smaller lakes and associated wetlands. Robinson Lake is reported to be eutrophic due to runoff and septic tank leachate from residential and commercial development. Robinson Lake and the developed section of Robinson Creek represent a source of nutrient loading to the South Branch. Crystal Lake is classified as a trout lake and supports a cold water fishery. This lake is unique with respect to this designation in the White River watershed. A majority of the cropland present

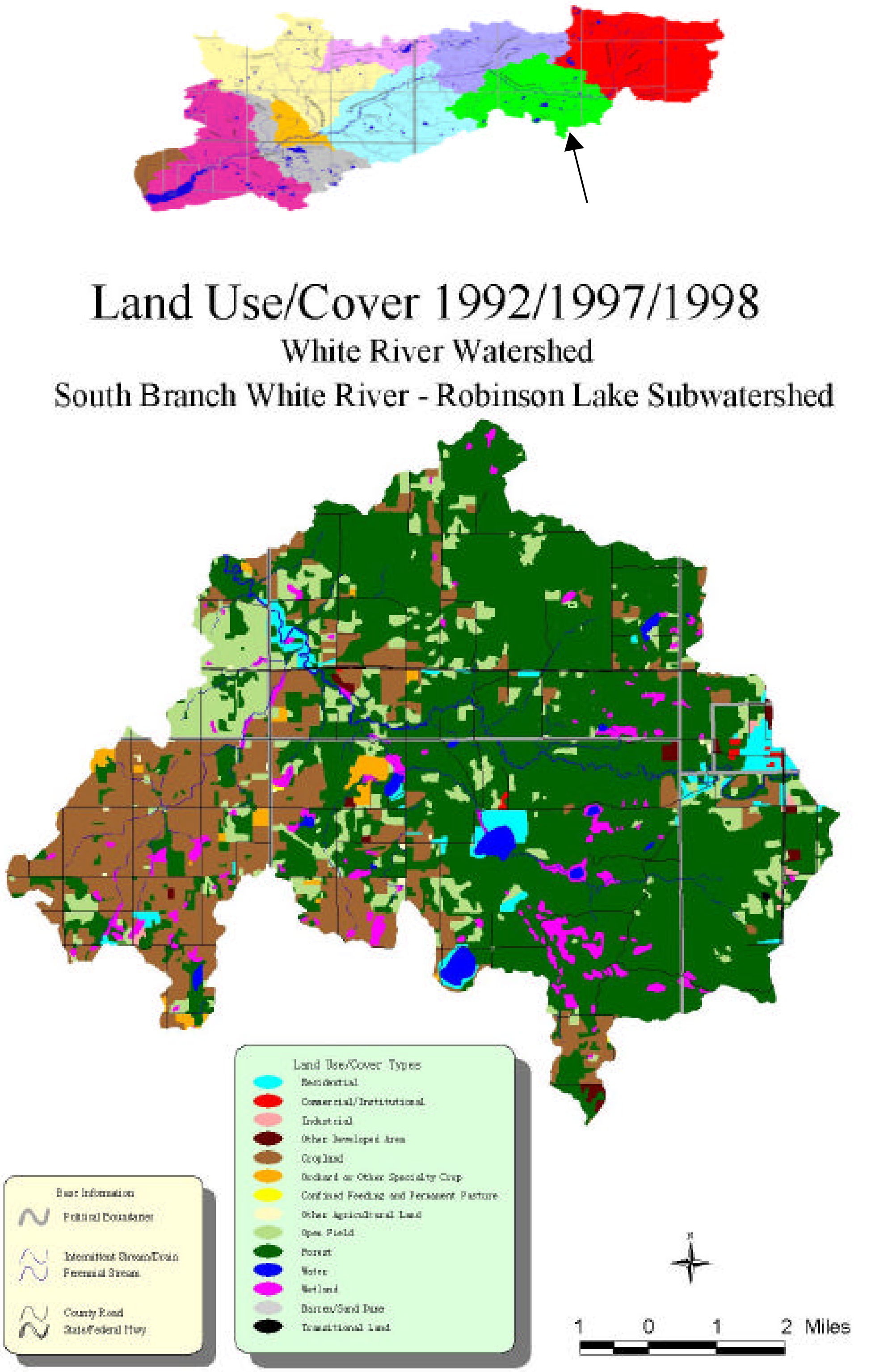


FIGURE 4.2.1 LAND COVER MAP OF SOUTH BRANCH WHITE RIVER / ROBINSON LAKE SUBWATERSHED.

Figure 4.2.2 Cattle near Back Creek in the South Branch Subwatershed of the White River.

in this subwatershed is drained by Black Creek in Dayton Township. Figure 4.2.2 shows an area along Black Creek where cattle have access to the water. A bloom of *Cladophora* was observed, which indicates nutrient enrichment. Nutrient loading from these creeks may be significant because of the effects of the impoundment located downstream at Hesperia.

4.3 MARTIN/MENA/HELD CREEKS SUBWATERSHED

The Martin/Mena/Held Creeks subwatershed covers 31,669.8 acres (9.4% of the total watershed area). Land cover data are shown in Table 4.3.1.and displayed in map format on Figure 4.3.1. Undeveloped forested areas account for 68.5% of the subwatershed, followed by open fields (14.7%) and cropland (11.5%). Approximately 10% of all the wetlands present in the White River watershed are located in this subwatershed (965 acres). Less than 1% of the subwatershed land is classified as residential or industrial. Most of the forested areas are found in the eastern portion of the subwatershed north of the main channel of the White River. The western section of the subwatershed contains most of the cropland and open fields. Many of the wetlands and streams in the agricultural area lack riparian zones, which is significant with respect to runoff. A large group of wetlands are located near the headwaters of Martin, Held, and Mena Creeks. These creeks and wetlands are located in forested areas of the subwatershed. There has been significant change in land use within this subwatershed since 1978. Over 3300 acres of cropland

Table 4.3.1 Land Cover Analysis of the Martin/Mena/Held Creeks Subwatershed 1978 - 1992/1997/1998

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	31	36	0.1	5	15.0
Industrial	0	5	0.0	5	NA
Other Developed Area	0	49	0.2	49	NA
Cropland	6,988	3,654	12	-3,334	-48
Orchard or Other Specialty Crop	161	395	1.2	234	146
Confined Feeding and Permanent Pasture	31	31	0.1	0	-0.6
Other Agricultural Land	10	27	0.1	17	163
Open Field	2,358	4,644	15	2,285	97
Forest	20,945	21,692	68	747	3.6
Water	172	173	0.5	0	0.2
Wetland	976	965	3.0	-11	-1.1
Total Acres		31,670			

changed to open fields, and a large portion of this change was concentrated south of the main channel of the White River's south branch near M-20 and Green Avenue in Dayton Township. Martin, Mena, and Held Creeks are classified as quality trout streams with high gradients and considerable woody debris. It is imperative that the riparian zone and surrounding forests be maintained in their current condition to maintain habitat quality.

4.4 SKEEL/CUSHMAN/BRATON CREEKS SUBWATERSHED

The Skeel/Cushman/Braton Creek subwatershed covers 49,644 acres or 14.8% of the White River watershed. Land cover data are shown in Table 4.4.1.and displayed in map format on Figure 4.4.1. The subwatershed includes seven townships in addition to the City of Hesperia. With respect to land cover, cropland and forested area percentages are nearly equal (38.4% and 44.8%, respectively), followed by open fields (5.9%). Developed areas account for slightly more than 5% of the land area. The undeveloped forested areas are located primarily in the southwestern portions of the subwatershed in the areas surrounding the White River channel. A majority of the residential land use is located in the city of Hesperia and in the surrounding areas, extending

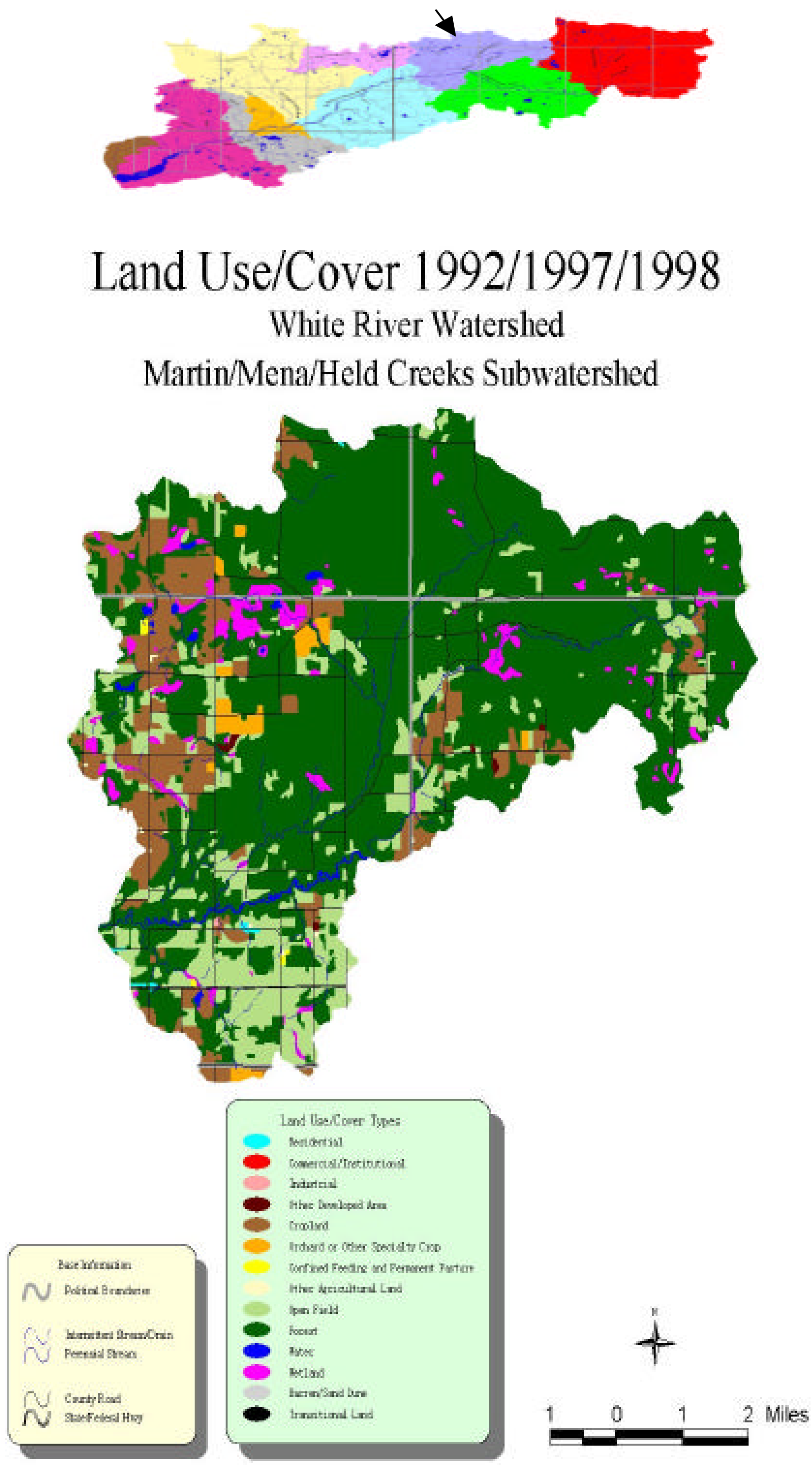


FIGURE 4.3.1 LAND COVER MAP OF THE MARTIN/MENA/HELD CREEKS SUBWATERSHED.

Table 4.4.1 Land Cover Analysis of the Skeel/Cushman/Braton Creeks Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	752	1,682	3.4	929	124
Commercial/Institutional	63	77	0.2	14	23
Industrial	9	9	< 0.1	0	0.1
Other Developed Area	552	920	1.9	368	67
Cropland	21,651	19,068	38	-2582	-12
Orchard or Other Specialty Crop	957	952	1.9	-5	-0.5
Confined Feeding and Permanent Pasture	318	251	0.5	-67	-21
Other Agricultural Land	9	99	0.2	91	1059
Open Field	2,493	2,938	5.9	445	18
Forest	21,457	22,228	45	771	3.6
Water	203	250	0.5	46	23
Wetland	1,167	1,154	2.3	-14	-1.2
Barren/Sand Dune	32	16	< 0.1	-16	-49
Total Acres		49,644			

southward along the Oceana / Newaygo County line. Since 1978 there has been an marked increase in residential land use (124% increase, 929 new acres). Cropland decreased by 2,582 acres with a corresponding increase in developed areas (1,297 acres), forest (771 acres) and open field (368 acres). A majority of the land taken out of agricultural production is located north of Hesperia. A loss of 16 acres of Oak/Pine Barrens was noted in the transition zone of agricultural and forest lands near Braton Creek. Barrens are unique habitats (Section 3.6) and should be preserved to promote diversity. The increase in the other developed area category was related to the expansion of extractive sites. A number of gravel mining sites are located in the subwatershed and constructed in close proximity to streams. Hesperia Dam is also located in this subwatershed. The impoundment was very shallow and was subject to excessive siltation. This impoundment may be a source of nutrients and temperature related problems to the downstream section of the South Branch. As discussed in Section 3.7, Skeel, Cushman, and Braton Creeks were classified as trout streams that support natural reproduction. The headwaters of the three creeks are located in agricultural lands with limited riparian cover. Soil textures and slopes in the headwater areas have the potential for erosion and consequently, these creeks may be subject to

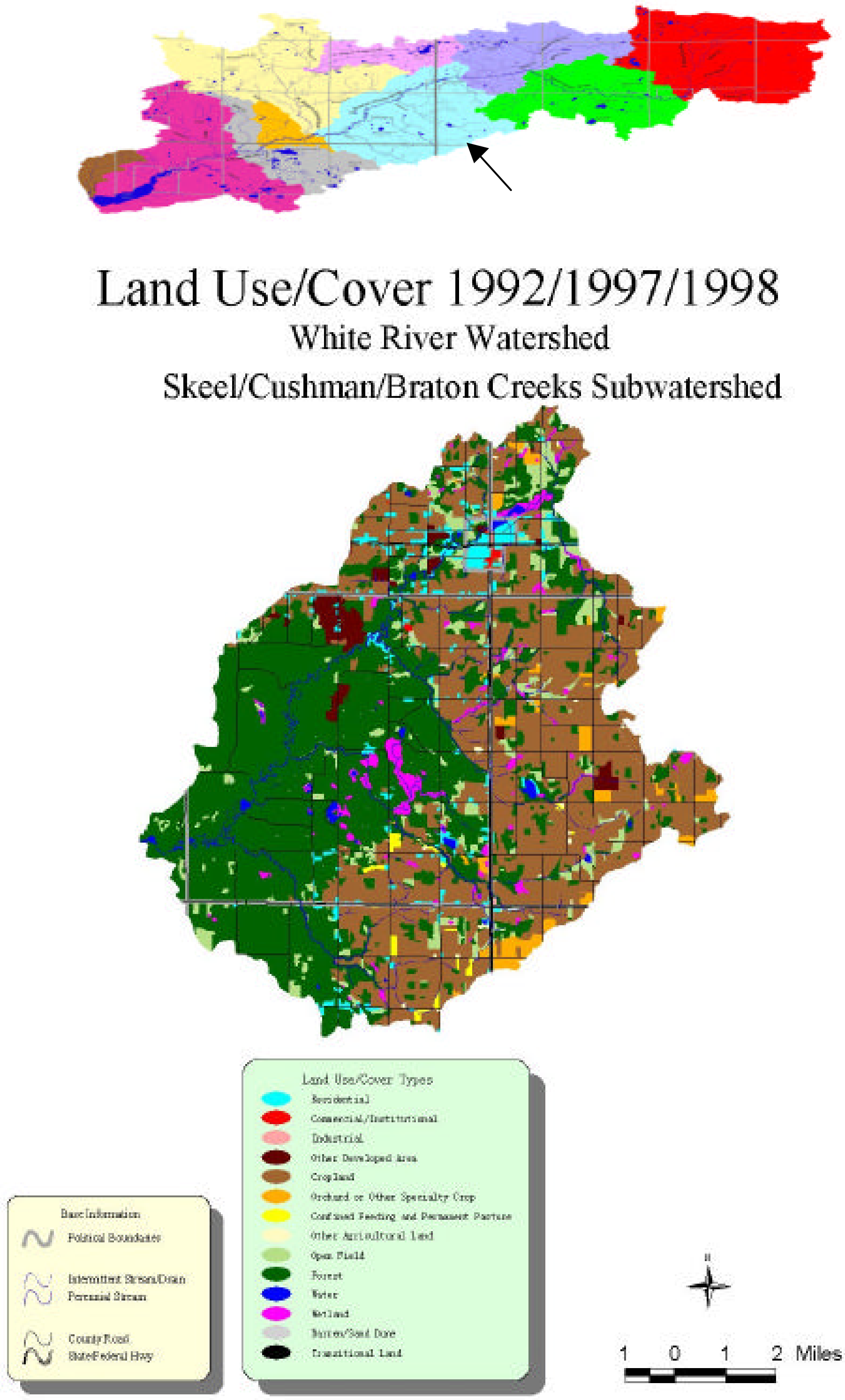


FIGURE 4.4.1 LAND COVER MAP OF THE SKEEL/CUSHMAN/BRATON CREEKS SUBWATERSHED.

sedimentation and nutrient addition. Many of the headwater streams are straight, indicating channelization was performed to enhance drainage. Programs for riparian zone enhancement and best management practices should be initiated in this subwatershed.

4.5 UPPER NORTH BRANCH SUBWATERSHED

The Upper North Branch White River contains 14,800 acres and includes McLaren Lake. Land cover data are shown in Table 4.5.1.and displayed in map format on Figure 4.5.1. The subwatershed is dominated by forested areas

Table 4.5.1 Land Cover Analysis of the Upper North Branch Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	285	621	4.2	335	118
Commercial/Institutional	0	4	0.0	4.0	NA
Other Developed Area	2	39	0.3	36	1500
Cropland	3231	2692	18.2	-540	-17
Orchard or Other Specialty Crop	146	299	2.0	153	104
Confined Feeding and Permanent Pasture	15	15	0.1	0.0	< 0.1
Other Agricultural Land	0	4	< 0.1	4.2	NA
Open Field	1556	1287	8.7	-269	-17
Forest	8141	8385	57	244	3
Water	457	462	3.1	5.7	1
Wetland	936	961	6.5	25	3
Barren/Sand Dune	21	33	0.2	11	53
Total Acres		14801			

(8,384.5 acres or 56.7%), followed by cropland (18.2%) and open fields (8.7%). Wetlands (6.5%) and residential land usage (4.2%) also contribute to land cover. A Northern Wet Meadow and bog ecosystems are located within the Upper North Branch White River subwatershed (Figure 3.6.5).

The eastern portion of this subwatershed contains a mixture of croplands, forests, and wetlands. More than half of the wetlands present within the subwatershed are located in agricultural areas with no apparent riparian zone.

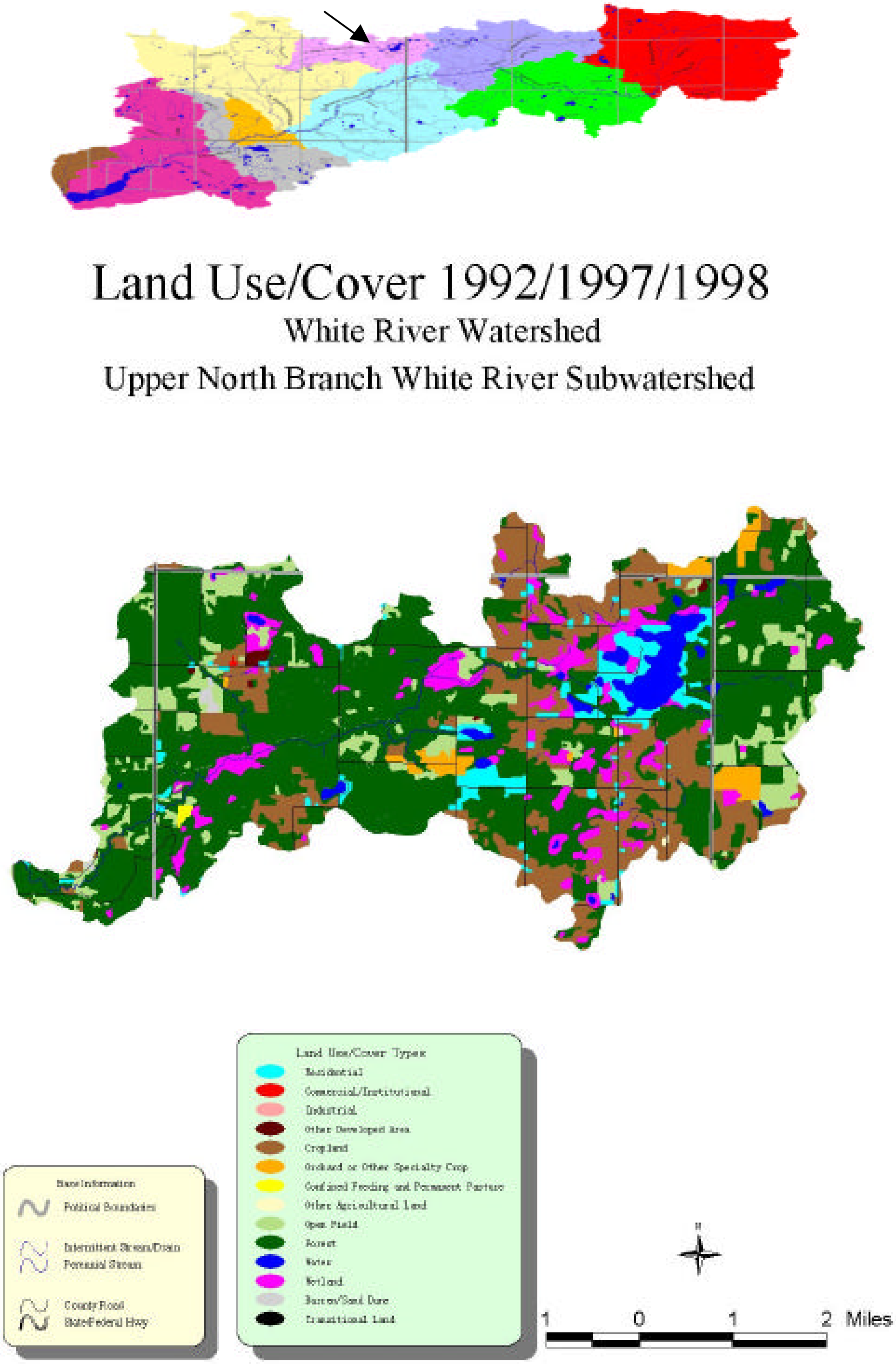


FIGURE 4.5.1 LAND COVER MAP OF THE UPPER NORTH BRANCH SUBWATERSHED.

Much of the residential development present in this subwatershed is located around McLaren Lake, with some areas extending to the southwest. The western half is much less developed and contains large tracts of undeveloped forested areas. A few areas of cropland are present, although the majority of cropland is found to the east in the areas surrounding McLaren Lake. Land use changes since 1978 are slightly different than the pattern found throughout the White River watershed. There was a shift from both cropland and open fields to residential and orchard land use types. Forested areas expanded by 244 acres. As discussed in Section 3.7, this subwatershed is the only one that supports a warm water fishery. Drainage from McLaren Lake and several open wetlands form the headwaters of the Upper North Branch and influence the temperature. After passing through the riparian forests and reaches with additional groundwater flows, the temperature decreases to a cold water fishery. Continued residential development in the area surrounding McLaren Lake may be problematic in the future due to increased eutrophication and nutrient loading in the headwaters.

4.6 NORTH BRANCH SUBWATERSHED

The North Branch subwatershed, includes portions of 7 townships and has a area of 53,804 acres (16% of the entire watershed). Land cover data are shown in Table 4.6.1 and displayed in map format on Figure 4.6.1. The subwatershed has a very diverse array of land usage with significant amounts of agricultural, residential, forested and wetland areas. Undeveloped forested areas represent the predominant land cover (27,182 acres or 50.0%) followed by croplands (11,358 or 20.7%). Other significant land covers include 16.3% open fields, 8.9% orchards, 1.5% wetland and 1.4% residential. Agricultural land use is primarily concentrated in Shelby Township, and in Elbridge Township in the northern portions of the subwatershed. On a percentage basis, the North Branch has low amount of wetlands compared to the remainder of the subwatersheds. This is due to the higher elevation and permeable soils found in the moraine ridge that makes up a majority of the area. A notable feature of this catchment area is the high percentage of land cover designated as orchards or specialty crop land. Orchards are found primarily in Shelby Township, however smaller plots are scattered throughout the subwatershed. Land use changes since 1978 involved more acreage in the North Branch than the other subwatersheds. The largest change was the conversion of 3,655 acres of cropland into orchard/specialty crops and open fields. This conversion should enhance water quality by lowering the potential for erosion and reducing the amount of land that is extensively fertilized. Residential growth for the watershed was also high as development increased by 82% (340 acres).

Table 4.6.1 Land Cover Analysis of the North Branch Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	416	756	1.4	340	82
Commercial/Institutional	30	27	0.0	-3.2	-10
Industrial	0.0	6.7	0.0	6.6	NA
Other Developed Area	179	259	0.5	80	45
Cropland	15,013	11,358	21	-3,655	-24
Orchard or Other Specialty Crop	2,519	4,903	8.9	2,385	95
Confined Feeding and Permanent Pasture	343	193	0.4	-150	-44
Other Agricultural Land	0.0	25.2	< 0.1	25	NA
Open Field	7,887	8,955	16	1,068	14
Forest	27,362	27,182	50	-180	-0.7
Water	245	252	0.5	6.9	2.8
Wetland	719	842	1.5	123	17
Barren/Sand Dune	44.5	44.9	0.1	0.4	1.0
Total Acres		54,804			

4.7 MIDDLE BRANCH SUBWATERSHED

The Middle Branch is a small subwatershed that is located almost exclusively in the Manistee National Forest. Land cover data are shown in Table 4.7.1 and displayed in map format on Figure 4.7.1. The subwatershed covers 8030 acres with forested and agricultural lands covering 90% and 7.6% of the landscape, respectively. Land cover changes from 1978 were minimal due to the high percentage of federal land. This subwatershed contains the only Northern Wet-Mesic Prairie found in the White River basin.

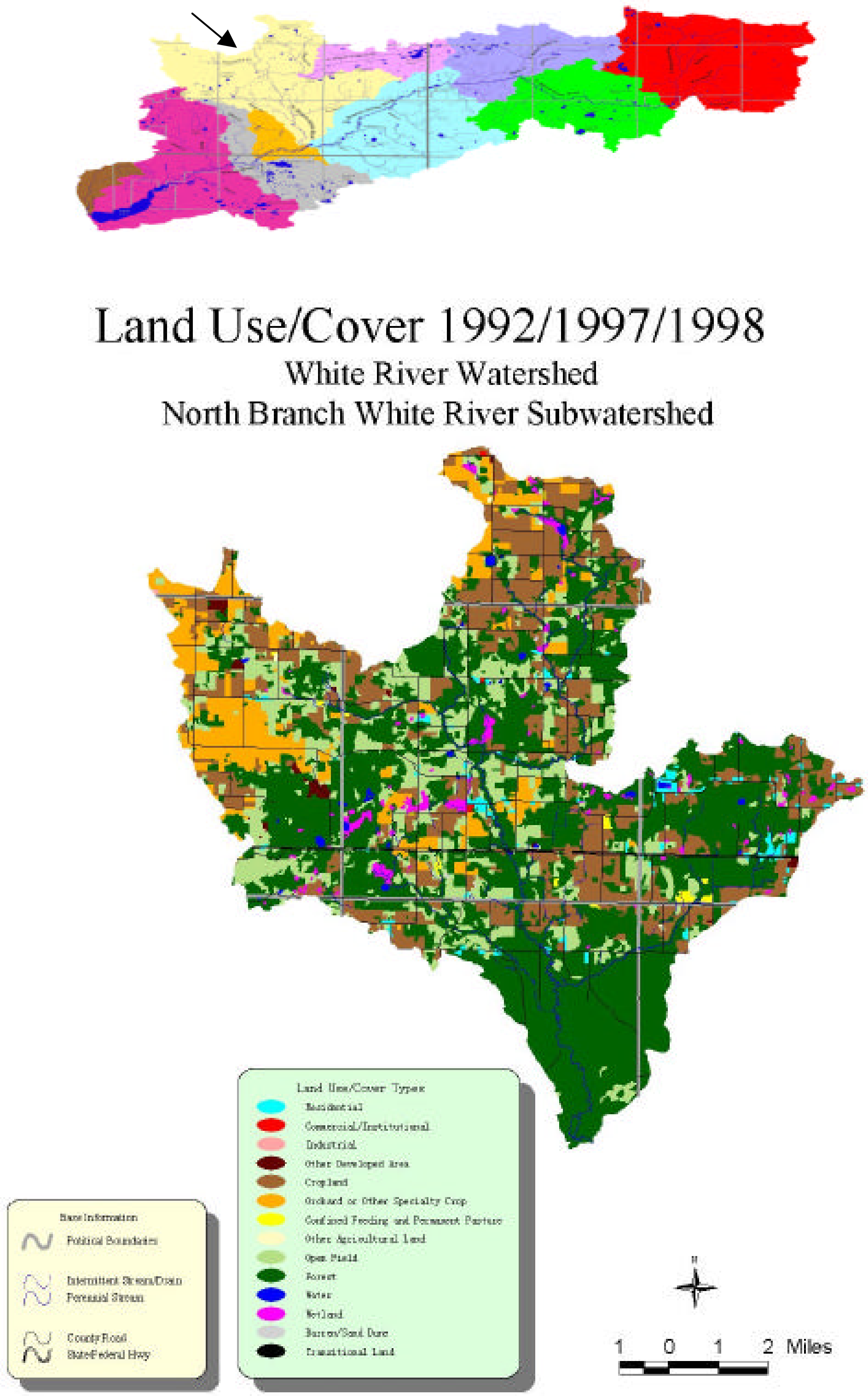


FIGURE 4.6.1 LAND COVER MAP OF THE NORTH BRANCH SUBWATERSHED.

Table 4.7.1 Land Cover Analysis of the Middle Branch Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	26	74	0.9	49	188
Commercial/Institutional	17	18	0.2	0.5	3
Cropland	48	20	0.2	-29	-60
Open Field	568	610	7.6	42	7
Forest	7.269	7.215	90	-54	-1
Water	16	17	0.2	0.0	0.0
Wetland	77	77	1.0	0.0	0.0
Total Acres		8.030			

4.8 WHITE LAKE CARLTON/MUD CREEK SUBWATERSHED

The Carlton/Mud Creek subwatershed includes portions of 7 townships and has an area of 53,804 acres. Land cover data are shown in Table 4.8.1 and displayed in map format on Figure 4.8.1. This subwatershed contains the villages of Whitehall, Montague, New Era, and Rothbury. It also contains White Lake and the drowned rivermouth wetland. Land to the east of US 31 is mostly forested below Rothbury. North of the village, land cover changes to agricultural and open field. Forested lands comprise 54% of the area with cropland, open field and residential covering 12%, 10%, and 9.4%, respectively. Significant tributaries of the White River include Silver Creek to the south of the main channel and Carlton and Mud Creeks to the north. The latter two creeks originate in agricultural areas with little riparian cover.

Land cover changes from 1978 included the addition of 1,370 acres of residential development and the conversion of 905 acres of cropland and confined animal feeding operations to open field and other non agricultural uses. This subwatershed was the only one to have a significant amount of forest acreage (564 acres) change to industrial and residential developments. A loss of 46 acres of Pine/Oak Barrens was also recorded. This subwatershed will continue to experience development pressure because of the number of urban centers, good highway access, and the large number of small lakes present. It will be critical to implement the proper zoning measures that encourage the preservation of water quality and greenspace in order to prevent the loss and degradation of important natural resources.

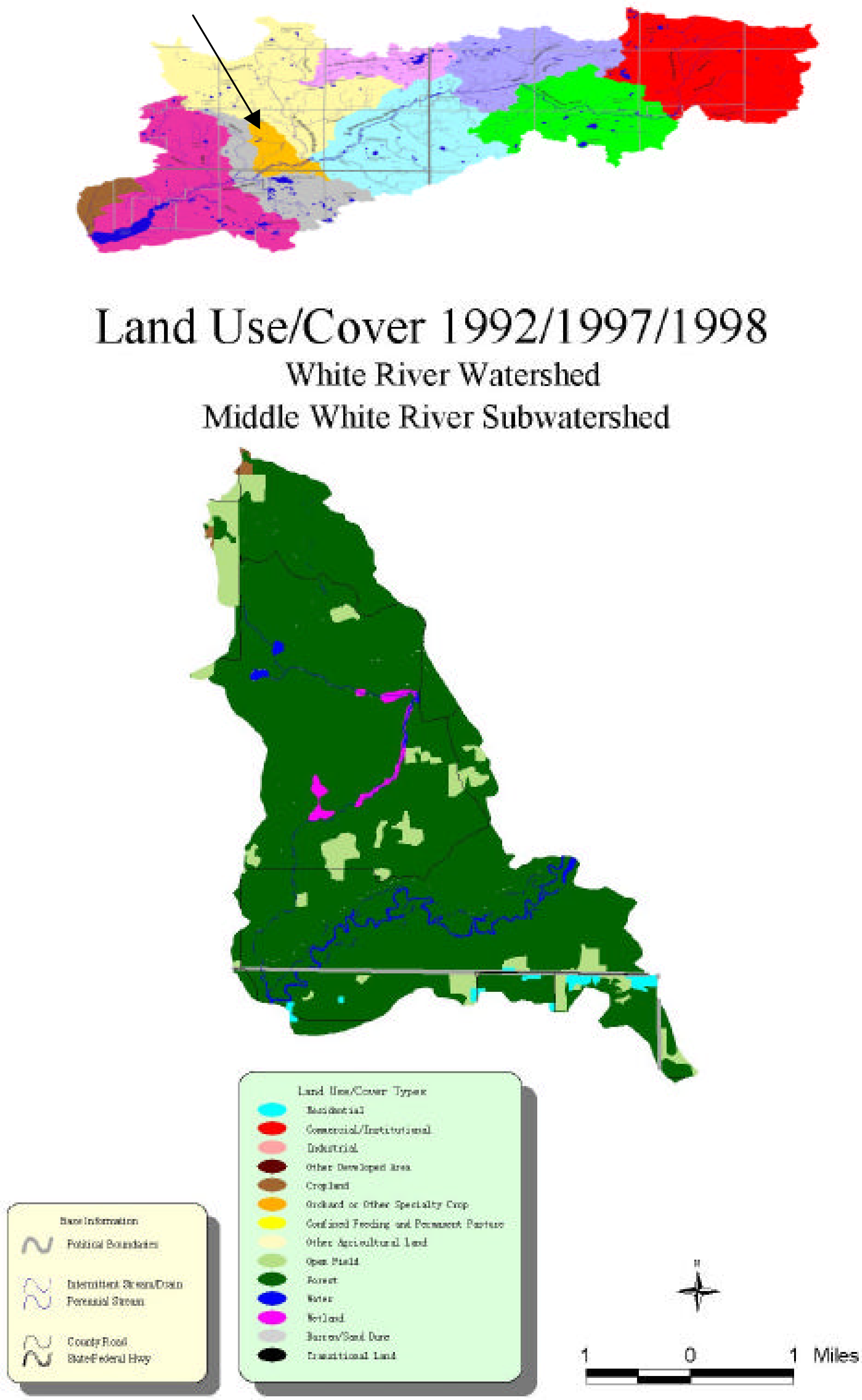


FIGURE 4.7.1 LAND COVER MAP OF THE MIDDLE BRANCH SUBWATERSHED.

Table 4.8.1 Land Cover Analysis of the White Lake/Carlton/Mud Creek Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	4004	5375	9.4	1370	34
Commercial/Institutional	505	759	1.3	254	50
Industrial	515	558	1.0	43	8.4
Other Developed Area	1132	1190	2.1	58	5.1
Cropland	7876	6971	12	-905	-11
Orchard or Other Specialty Crop	633	710	1.2	77	12
Confined Feeding and Permanent Pasture	720	178	0.3	-542	-75
Other Agricultural Land	6	53	0.1	47	763
Open Field	5704	5902	10	198	3
Forest	31095	30531	54	-564	-1.8
Water	3400	3413	6.0	12	0.4
Wetland	1374	1364	2.4	-10	-0.7
Barren/Sand Dune	107	61	0.1	-46	-43
Total Acres		57064			

4.9 SAND CREEK/WOLVERINE LAKE SUBWATERSHED

The Sand Creek/Wolverine Lake subwatershed includes portions of 4 townships and has an area of 22,694 acres. Land cover data are shown in Table 4.9.1 and displayed in map format on Figure 4.9.1. This subwatershed includes a large pitted outwash plain that contains a number of small to middle sized lakes, and a variety of wetlands, three Costal Plain Marshes, and two Dry Sand Prairies. Two tributaries of the White River are located within the drainage basin. Sand Creek originates in an agricultural area with a moderate riparian buffer zone. Cleveland Creek originates on Wolverine Lake and passes through forested land before discharging into the White River. Forested lands comprise 78% of the area with cropland, open field and residential covering 3.9%, 3.7%, and 2.6%, respectively. Residential development is concentrated in areas around major lakes and the village of Holton.

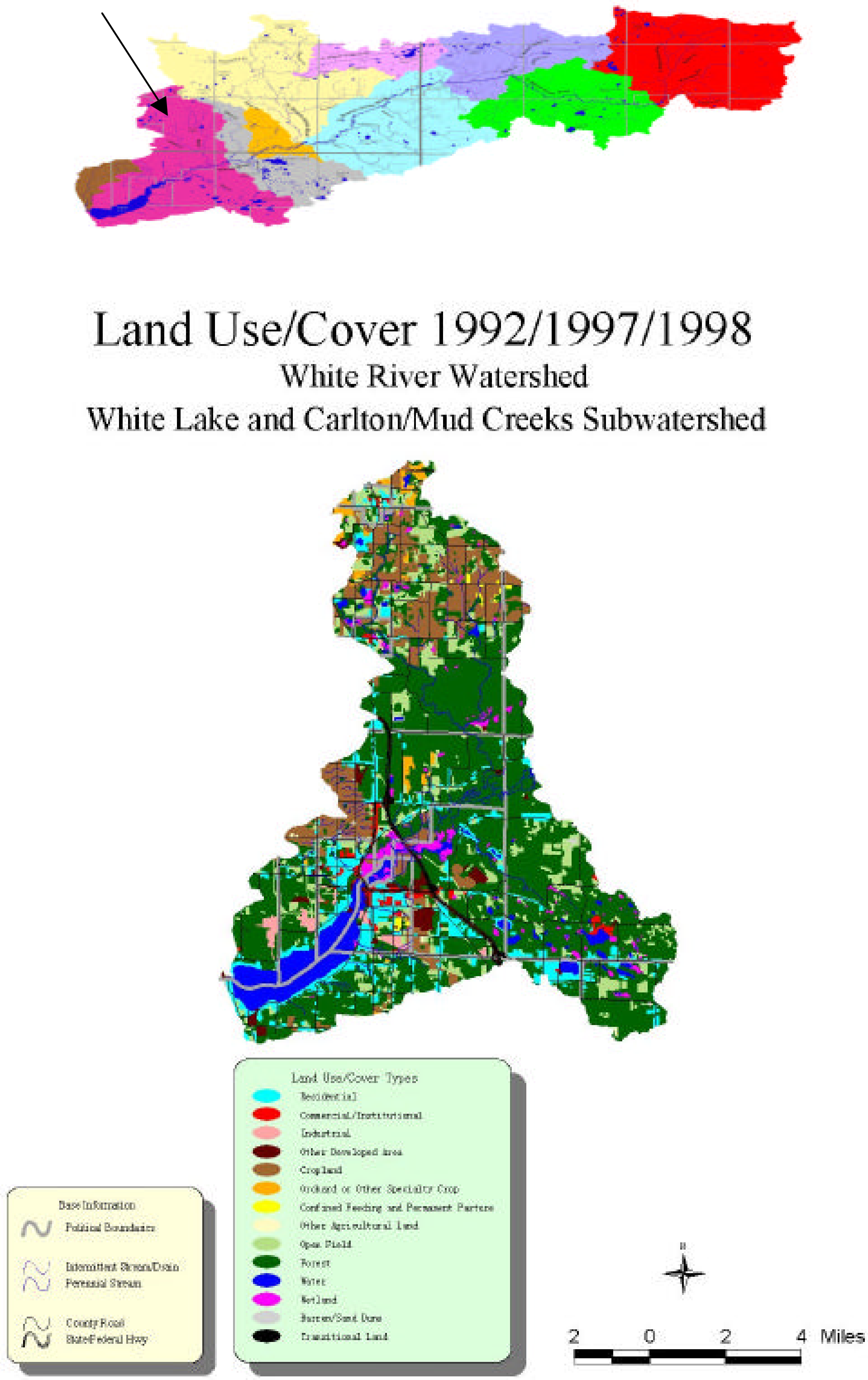


FIGURE 4.8.1 LAND COVER MAP OF THE WHITE LAKE CARLTON/MUD CREEK SUBWATERSHED.

Table 4.9.1 Land Cover Analysis of the Sand Creek/Wolverine Lake Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	378	597	2.6	219	58
Commercial/Institutional	68	73	0.3	5.1	7.5
Other Developed Area	50	63	0.3	13	25
Cropland	827	882	3.9	55	6.7
Orchard or Other Specialty Crop	100	76	0.3	-25	-25
Confined Feeding and Permanent Pasture	37	0	< 0.1	-37	-100
Other Agricultural Land	0	6	< 0.1	5.9	NA
Open Field	1933	1695	7.5	-237	-12
Forest	17,747	17,702	78	-44	-0.3
Water	842	840	3.7	-1.7	-0.2
Wetland	714	759	3.3	45	6
Total Acres		22,693			

Land cover changes in the Sand Creek/Wolverine Lake subwatershed included the conversion of 237 acres of open field and 44 acres of forest to residential development (219 acres) and cropland (51 acres). This area may also be subject to development pressure due its proximity to US 31 and Whitehall in addition to the large number of small lakes present. It also will be critical to implement zoning measures that encourage the preservation of water quality and greenspace in this subwatershed.

4.10 PIERSON DRAIN SUBWATERSHED

Pierson Drain is the smallest of all the subwatersheds and includes only 5,650 acres. Land cover data are shown in Table 4.10.1 and displayed in map format on Figure 4.10.1. The drain originates in an agricultural area in Montague and White River Townships. The headwaters have very limited riparian buffer zones while the downstream areas are mostly forested. Cropland comprise 59% of the area with forested, open field and residential covering 22%, 4.5%, and 6.6% respectively.

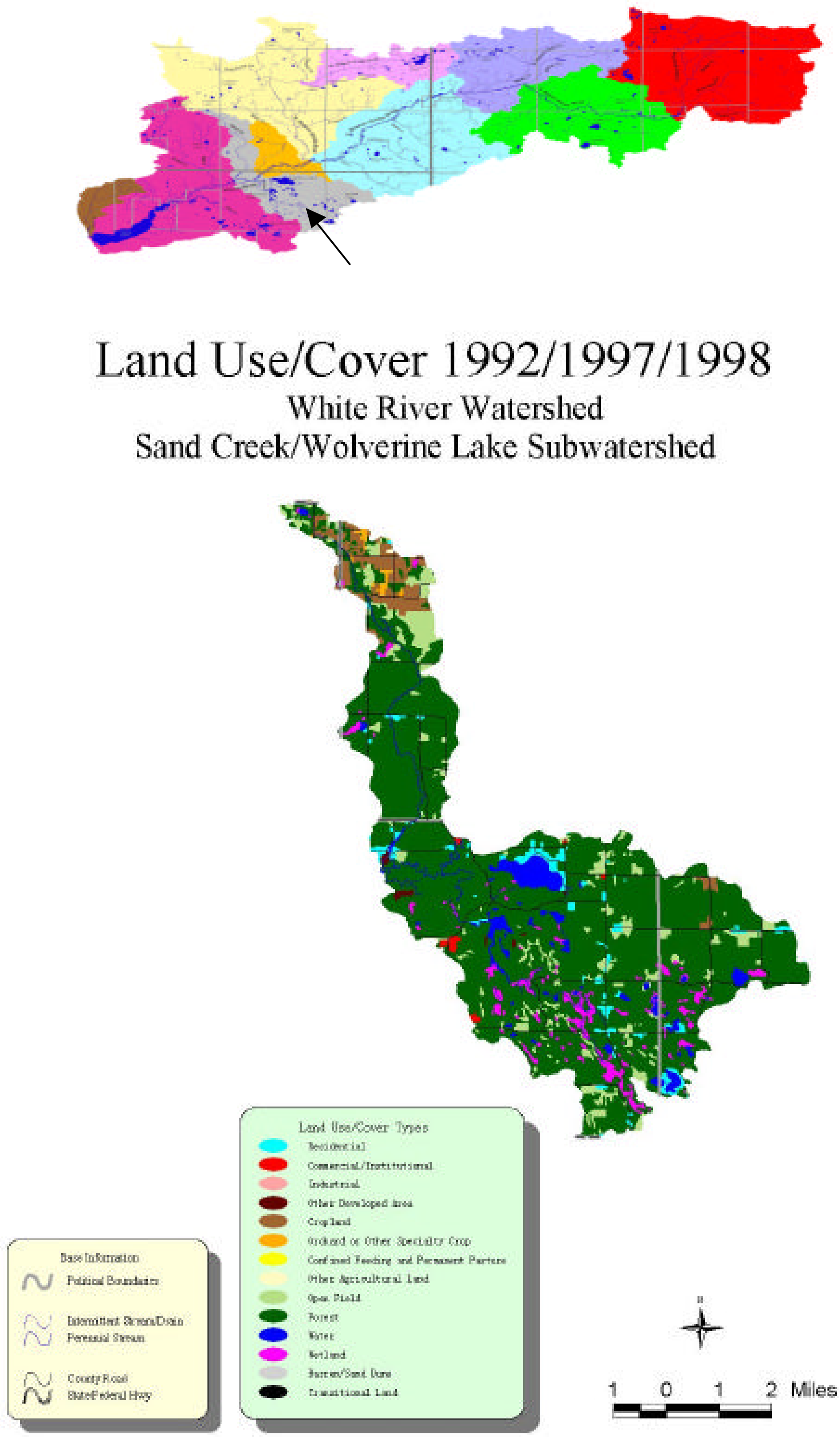


FIGURE 4.9.1 LAND COVER MAP OF THE WHITE LAKE SAND CREEK/WOLVERINE LAKE SUBWATERSHED.

Table 4.10.1 Land Cover Analysis of the Pierson Drain Subwatershed 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Residential	395	374	6.6	-21	-5.3
Other Developed Areas	0	293	5.2	293	NA
Cropland	3749	3334	59	-415	-11
Orchards and Other Specialty Crops	0	69	1.2	69	NA
Confined Feeding or Permanent Pasture	0	13	0.2	13	NA
Other Agricultural Lands	0	28	0.5	28	NA
Open Field	201	256	4.5	55	28
Forest	1260	1240	22	-20	-1.6
Water	21	21	0.4	0.1	0.2
Wetland	14	14	0.2	0.0	-0.1
Barren/Sand Dune	10	7.2	0.1	-2.3	-24
Total Acres		5650			

Land cover changes in the Pierson Drain subwatershed included the conversion of 415 acres of cropland to a golf course (other developed areas, 219 acres) and open field (55 acres) in addition some minor categories. This area may also be subject to development pressure due its proximity to Whitehall and the availability of large parcels of land. The recent conversion of agricultural and residential land to a golf course is indicative of development pressure. It will be critical to implement zoning measures that encourage the preservation of water quality and greenspace in this subwatershed.

4.11 SUMMARY AND CONCLUSIONS

Land cover change data for the entire White River watershed are shown in Table 4.11.1 and displayed on Figure 4.11.1. The data show that land cover and land use have remained stable over the last 20 years in watershed. Forests and wetlands actually show an increase in total acreage over the evaluation period (4,363 acres and 345 acres, respectively). Stewardship, wetland protection laws, and reforestation efforts by the Manistee National Forest have

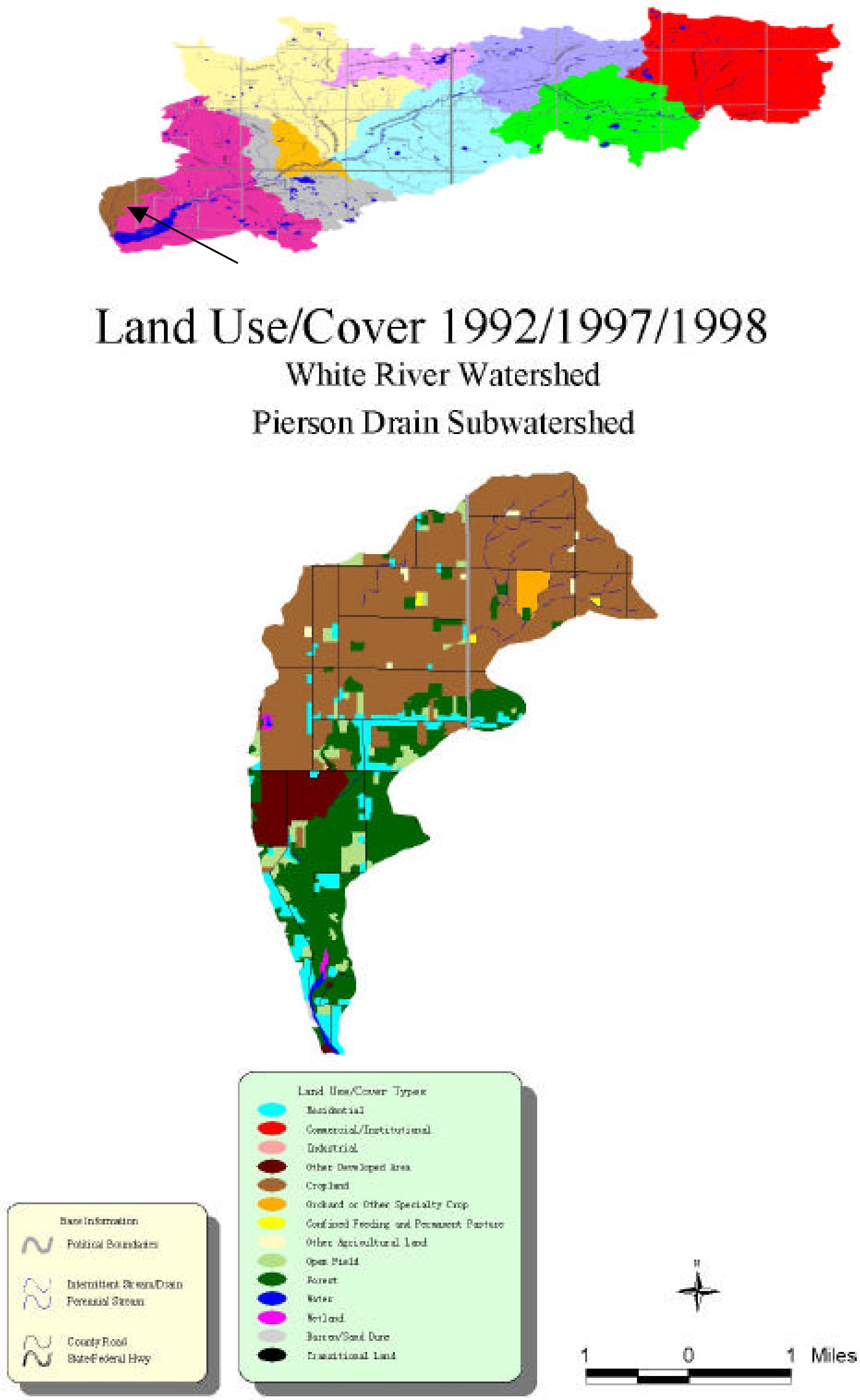


FIGURE 4.10.1 LAND COVER MAP OF THE PIEARSON DRAIN SUBWATERSHED.

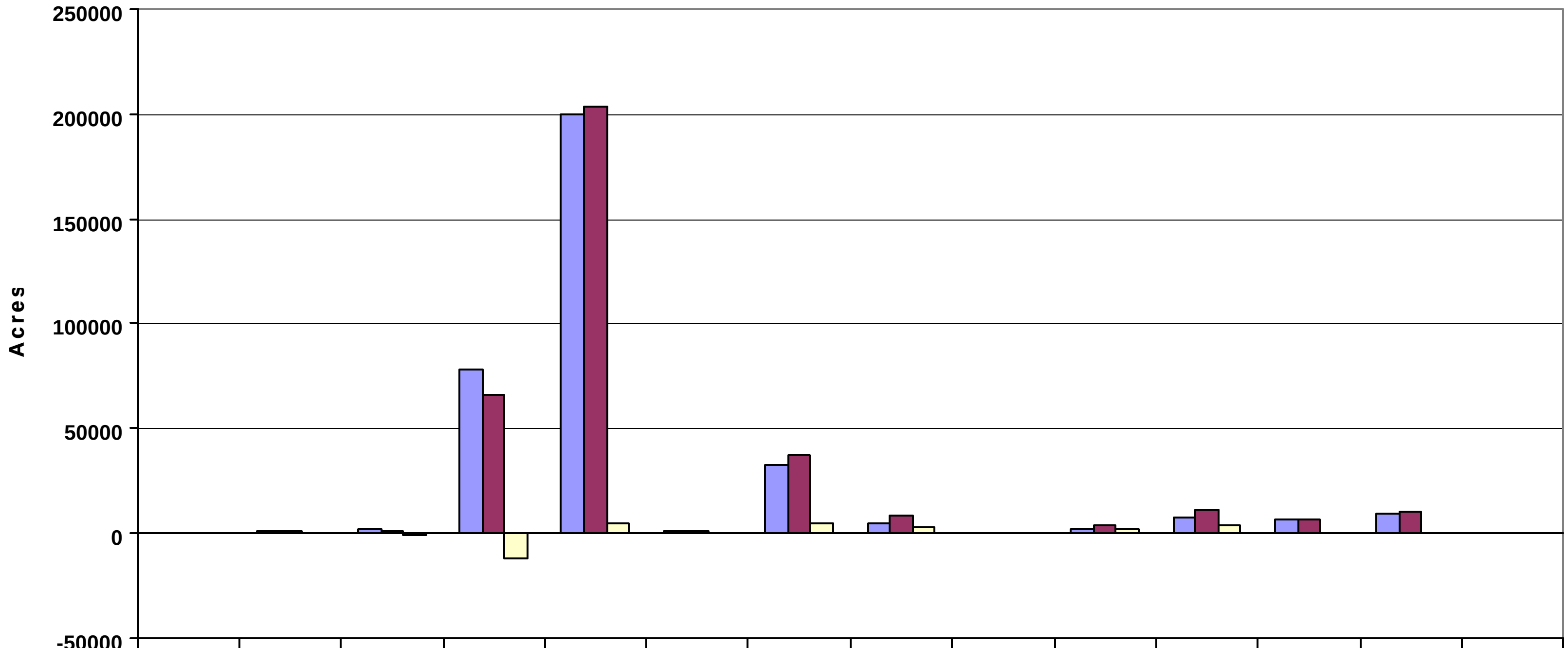
TABLE 4.10.1 LAND COVER ANALYSIS OF THE WHITE RIVER SUBWATERSHED 1978 - 1992/1997/1998.

Land Use/Cover Classification	1978 Acreage	1992/1997/1998			
		Acreage	Percent of Total	Net Change Acreage	Percent Change
Barren/Sand Dune	214	170	< 1	-44	-21
Commercial/Institutional	753	1031	< 1	278	37
Confined Feeding or Permanent	1478	710	< 1	-768	-52
Cropland	78193	65839	19	-12354	-16
Forest	199382	204017	58	4636	2
Industrial	634	713	< 1	78	12
Open Field	32885	37678	11	4793	15
Orchards or Other Specialty Crops	4893	8009	2	3116	64
Other Agricultural Lands	72	342	< 1	269	373
Other Developed Areas	2152	3668	1	1516	70
Residential	7699	11385	3	3686	48
Water	6210	6300	2	89	1
Wetland	9600	9954	3	354	4
Transitional Land	0	11	< 1	11	NA

all contributed the preservation of these natural resources. The only significant change to the natural land cover was the loss of 44 acres of Pine/Oak Barrens. While this represents a small change in total acreage, the loss of this rare habitat is significant to the ecological diversity in the watershed. In consideration of the fragile nature of these systems, future preservation will depend on the acquisition and management of these rare habitats to prevent impacts from surrounding land use.

Agricultural production and development declined in over the last 20 years, following regional trends in western Michigan. Sixteen percent of the cropland (12,354 acres) was allowed to go fallow for open fields (4,793 acres) or be converted to orchard (3,116 acres). The remainder was reforested or converted to residential/commercial use. Urban development was concentrated in the areas of Whitehall, White Cloud, Hesperia, and Rothbury. The land around the US 31 corridor experienced the most growth. Residential development was also noted around many of the areas lakes including McLaren Lake, Robinson Lake, Diamond Lake, and Blue Lake. These lakes are all in remote areas and are all serviced by private wells and septic systems.

FIGURE 4.11.1 LAND USE/COVER CHANGES FROM 1978-1992/98 IN THE WHITE RIVER WATERSHED



	Barren Sand Dune	Comm.	CFO	Cropland	Forest	Industrial	Open Field	Orchards	Other Ag Lands	Other Areas	Res	Water	Wetland	Transitional Land
1978	214	753	1478	78193	199382	634	32885	4893	72	2152	7699	6210	9600	0
1998	170	1031	710	65839	204017	713	37678	8009	342	3668	11385	6300	9954	11
Net	-44	278	-768	-12354	4636	78	4793	3116	269	1516	3686	89	354	11

In consideration of the sandy soils and high water tables in the land surrounding these lakes, increased residential development can have a negative affect on surface and groundwater quality. The same consideration applies to urban growth in the watershed's villages. These villages have limited infrastructure and increased population density and commercial growth can result in local stormwater and wastewater problems.

A trend that was evident in most of the subwatersheds was that riparian zones in many of the headwater streams contained limited vegetative cover. This was true also for wetlands with respect to the absence of buffer zones separating adjacent agricultural uses. In streams, high quality water that is buffered from excessive sedimentation and peak flows is critical to the integrity of the headwaters and the downstream reaches. These same considerations are true for wetlands as the unstable hydrology and sedimentation will adversely impact their structure and function. A number of state and federal programs are available through the Michigan Department of Agriculture and the USDA.'s Natural Resources Conservation Service that provide technical and financial assistance to install vegetative buffer strips and restore riparian zones along stream corridors. The implementation of these programs will benefit aquatic ecosystems by lowering nutrient and sediment influx, improving flow and temperature stability, and increasing particulate organic carbon inputs to the stream.

5.0 White Lake Survey

5.1 INTRODUCTION

A survey of White Lake was conducted on July 27, 2002. The lake has a long history of environmental problems related to the discharge of hazardous materials and excessive nutrient loading. The purpose of the survey was to collect and analyze a series of representative samples from White Lake and prepare a preliminary assessment of current status. Five locations were sampled and the stations are shown on Figure 5.1.1. Station 1 was located in the eastern basin near the mouth of the White River and had a depth of 2.5 m. The remainder of the stations were located in the central and western sections of the lake with depths ranging from 16 m – 20 m. Samples for dissolved oxygen, temperature, and chlorophyll were collected at one meter intervals at Stations 2-5. Discrete samples for nutrients were collected at 1 m below the

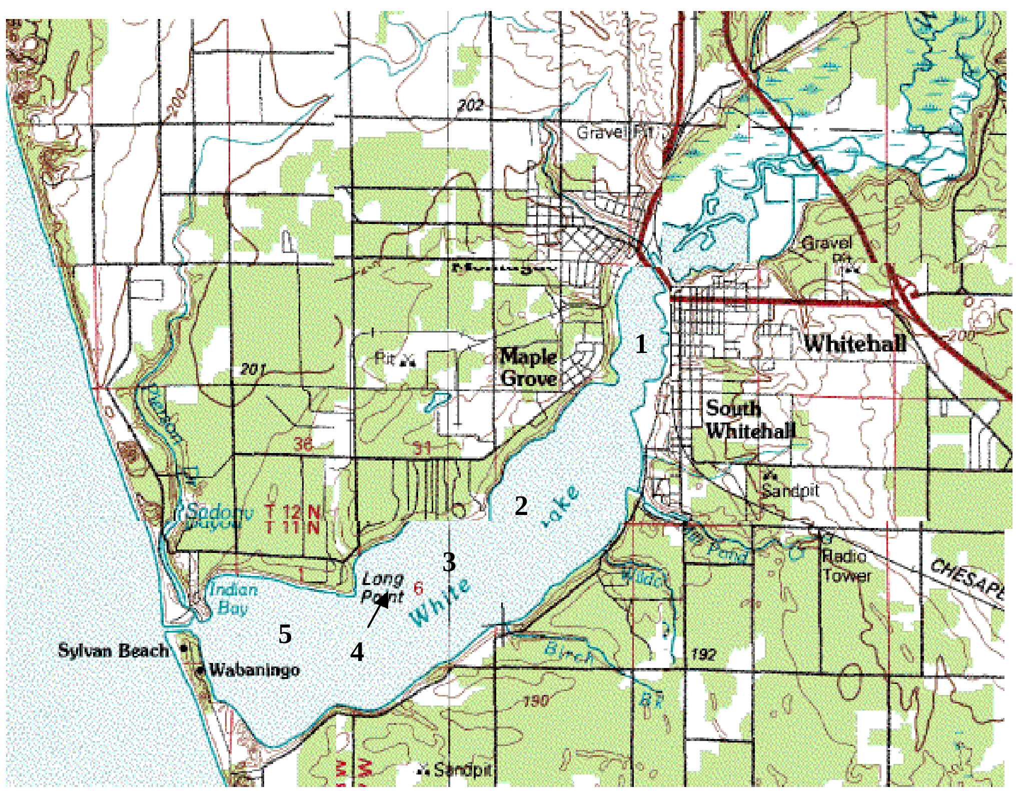


FIGURE 5.1.1 WHITE LAKE SAMPLING LOCATIONS. JULY 27, 2002.

surface, the middle of the thermocline, and 1 m from the lake bottom. The data was analyzed using the Carlson Trophic Status Index (Carlson 1977) and compared to previous data.

5.2 METHODS

All samples for nutrients and water chemistry were collected in pre-cleaned, plastic 1-liter bottles. Chlorophyll a and dissolved oxygen were measured *in situ* using a Hydrolab Data Sonde 4A. Water samples for nutrient analysis were collected with a VanDoren Bottle and maintained at 4^0C until delivery to the laboratory. Analytical methods for nutrient analysis are summarized below

PARAMETER	METHOD
NITRATE	4110*
AMMONIA	4500N-F*
CHLORIDE	4110*
SULFATE	4110*
DISSOLVED PHOSPHORUS	365.3**
TOTAL PHOSPHORUS	365.3**

* AWWA 1989.
**USEPA 1983.

5.3 RESULTS AND DISCUSSION

The dissolved oxygen and temperature results are shown in Figures 5.3.1 – 5.3.4. Thermal and oxygen stratification were observed at all of the deeper stations with anoxic conditions present in the hypolimnion (below 9 m). Isothermal conditions were present in the eplimnion (0 – 6 m) with an area of rapid temperature change noted from 6 – 8 m (thermocline). The results are shown in Table 5.3.1. Chlorophyll a results are also included and the 1 m sample reflects the maximum concentration observed. The results show the effects of anoxic conditions in the hypolimnion as increased concentrations of ammonia and phosphorus are noted as well as decreased concentrations of nitrate and sulfate. In the absence of oxygen, reductive reactions take place

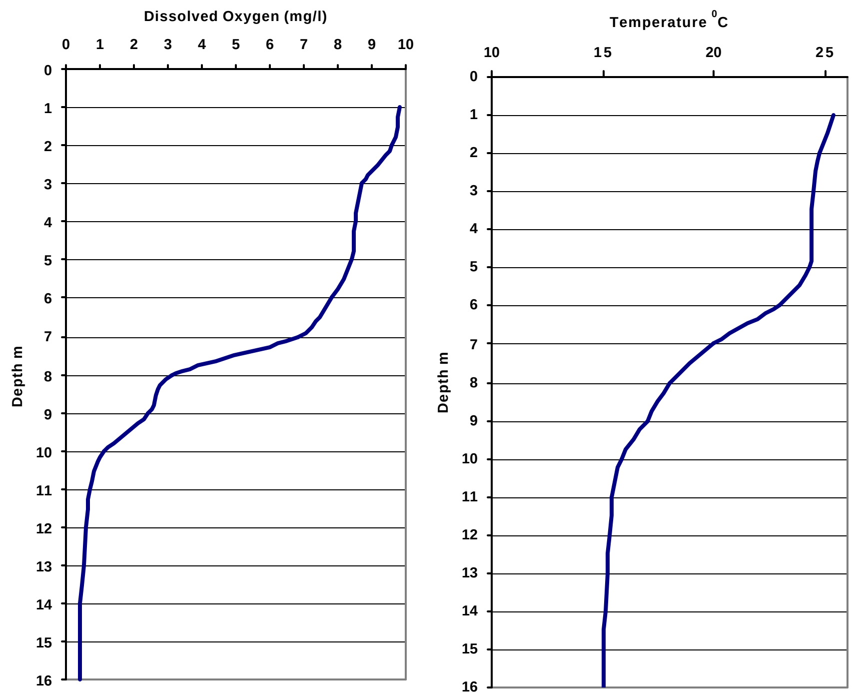


FIGURE 5.3.1 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 2 IN WHITE LAKE. JULY 27, 2002.

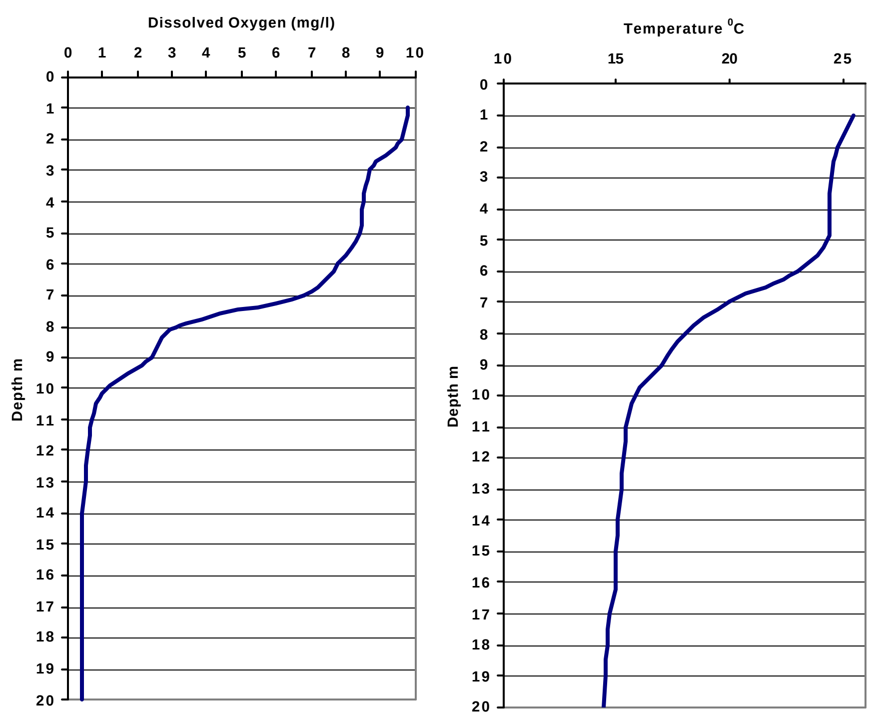


FIGURE 5.3.2 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 3 IN WHITE LAKE. JULY 27, 2002.

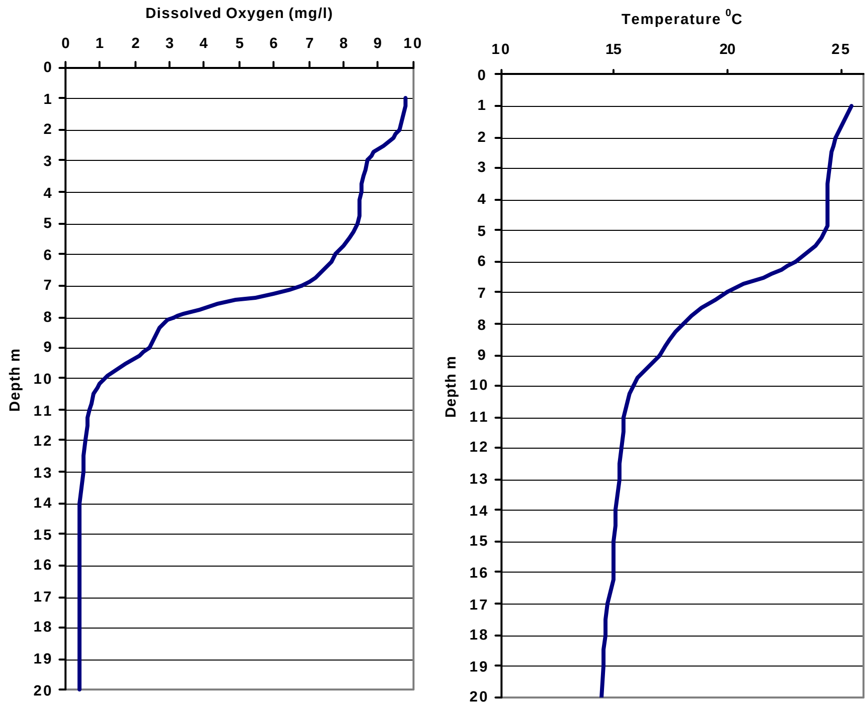


FIGURE 5.3.3 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 4 IN WHITE LAKE. JULY 27, 2002.

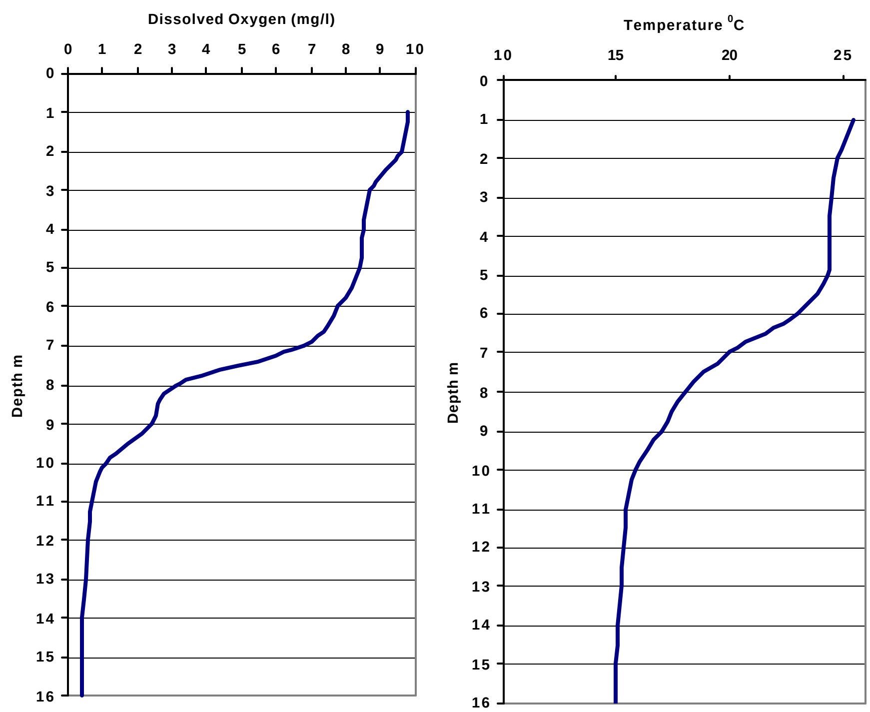


FIGURE 5.3.4 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 5 IN WHITE LAKE. JULY 27, 2002.

Table 5.3.1 Results of Nutrient and Chlorophyll Analyses conducted in White Lake. July 27, 2002.

Station	Depth meters	Secchi Depth* meters	Chloride mg/l	Sulfate mg/l	Nitrate - N mg/l	Ammonia - N mg/l	Chlorophyll a ug/l	Dissolved Phosphorous - P mg/l	Total Phosphorus - P mg/l
1 Top	1	0.54	19	18	0.22	0.08	13.7	0.03	0.05
2 Top	1	0.65	18	17	0.07	0.05	18.0	<0.01	0.06
2 Mid	7	-	19	16	0.22	0.07	6.7	0.03	0.04
2 Bot	15	-	18	12	< 0.01	0.32	2.0	0.16	0.24
3 Top	1	0.78	19	17	0.08	0.03	14.4	<0.01	0.05
3 Mid	8	-	18	15	0.19	0.10	8.7	0.05	0.07
3 Bot	18	-	18	14	0.26	0.33	2.1	0.04	0.16
4 Top	1	0.67	19	18	< 0.01	0.05	17.8	<0.01	0.05
4 Mid	6	-	17	15	0.25	0.05	11.0	0.04	0.06
4 Bot	19	-	30	11	< 0.01	0.53	2.2	0.05	0.15
5 Top	1	0.63	21	19	0.24	0.03	8.9	<0.01	0.04
5 Mid	7	-	20	19	0.24	0.05	3.3	<0.01	0.03
5 Bot	15	-	16	14	< 0.01	0.87	1.5	0.05	0.16

transforming nitrate to ammonia and sulfate to hydrogen sulfide. In addition, ferric iron undergoes reduction to the ferrous form and phosphorus becomes more soluble.

Carlson (1977) developed a simplified index that relates chlorophyll a, total phosphorus, and Secchi depth to the trophic status of lakes. The Trophic Status Index (TSI) is calculated as follows:

A. TSI (Phosphorus) = 14.42 * ln [Total Phosphorus ug/l] + 4.15
B. TSI (Chlorophyll a) = 30.6 +9.81 * ln [Chlorophyll a ug/l]
C. TSI (Secchi depth) = 60 +14.41 * ln [Secchi depth m]
D. Average TSI=(A+B+C)/3

Using the average data for chlorophyll a and total phosphorus at 1 m and the Secchi depth, TSIs for each parameter are 57, 60, and 67 respectively. The average TSI for the three parameters is 62. Carlson (1977) ranked lakes with TSIs between 50 and 70 as eutrophic. White Lake is in the middle of the eutrophic range.

The results from 2002 were similar to data reported from 1974-1977 (Freedman et al. 1979). The results of current and historical data for the months of July and August are show below:

Parameter	July/August 1974-77	July 27, 2002
Ammonia (hypolimnion)	500 – 100 ug/l	320 – 870 ug/l
Total Phosphorus (hypolimnion)	100 – 300 ug/l	150 – 240 ug/l
Chlorophyll a (1 m)	20 – 40 ug/l	8.9 – 18 ug/l
Total Phosphorus (1 m)	40 – 60 ug/l	40 – 60 ug/l

The results were similar except for chlorophyll a, which was lower in the current sampling. While it can difficult to draw conclusions from a single sample, the consistency of the results plus the TSI values suggest that current conditions in White Lake are comparable to those observed in the mid 70s. White Lake remains a eutrophic lake in the middle of the TSI classification. Based on the assessment by Freedman et al. (1979), it will be necessary to reduce nutrient loading from the White River by 70% to show an improvement in water quality. Modeling techniques for In consideration of the importance of White Lake to biological integrity of the lower watershed, a nutrient budget should be prepared that examines external loadings from the tributaries and internal loading for sediment release.

6.0 White River Watershed Wetlands Assessment

6.1 INTRODUCTION

Great Lakes coastal wetlands serve as important interfaces between upland and pelagic habitats. They have been shown to be important habitat for waterfowl (Prince *et al.* 1992; Prince & Flegel 1995; Whitt 1996), passerine birds (Harris *et al.* 1983; Whitt 1996; Riffell 2000; Weeber & Vallianatos 2000), fish (Goodyear *et al.* 1982; Liston & Chubb 1985; Jude & Pappas 1992; Brazner 1992/1997/1998) and invertebrates (Krieger 1992; Cardinale *et al.* 1992/1997/1998, 1998; Gathman *et al.* 1999; Gathman 2000). Despite their importance, Great Lakes coastal marshes have suffered extensive degradation and continue to receive developmental pressures. Understanding invertebrate community composition within these systems is vital to our understanding of their structure and function and subsequent role as an interface or buffer to the Great Lakes.

Invertebrates form important links between trophic levels and play key roles in nutrient cycling. They respond predictably to anthropogenic disturbance and are valuable indicators of ecosystem health (Kashian and Burton 2000, Burton et al. 1999, Flint 1979, Reynoldson and Zarull 1989, Uzarski et al. 2003). Benthic macroinvertebrates are continually exposed to conditions of natural and anthropogenic origin. Thus, macroinvertebrate community structure can be used to integrate time and space, and therefore, detect both episodic and cumulative impacts to water quality. Currently, invertebrate-based indices of biotic integrity (IBIs) have been developed and are being tested for use in monitoring Great Lakes coastal wetlands (Kashian and Burton 2000, Burton et al. 1999, Uzarski et al. 2003).

Discerning between natural ecosystem stressors, such as water level fluctuation, and anthropogenic stressors has likely been the greatest hurdle encountered during IBI development and partitioning this variability is key. Within-wetland variability is then superimposed on this, posing an additional challenge to developing effective wetland IBIs. The focus of this study was to determine variability in macroinvertebrate assemblages within a single coastal wetland and to determine whether assemblages could be best predicted by water quality, surrounding land-use/cover, dominant plant type, or a combination of these. Understanding the extent to which anthropogenic disturbance affects community composition within the overlying variability in community composition due to natural conditions will be valuable in future attempts to utilize macroinvertebrates in determining Great Lakes wetland health.

6.2 METHODS

6.2.1 2001 Drowned River Mouth Study Sites

The White is a fourth order river that lies on the western shore of the lower peninsula of Michigan. It drains a 1,370 km^2 watershed and forms a freshwater estuary where it empties into Lake Michigan via White Lake (Muskegon County, N43.41? W86.35?). The confluence of the White River and White Lake forms a drowned river mouth wetland of approximately 350 ha. The wetland has three diked and drained agricultural areas adjacent to it that are currently used for row crop production (Fig. 6.2.1). Runoff from these fields either drains or is pumped into the river at a number of locations. U.S. 31, a four-lane highway built on an earthen levee with a bridged opening over the main river channel, bisects the middle of the wetland. Business route U.S. 31, a two-lane road also built on an earthen levee with a bridged opening, crosses the lower wetland and links the cities of Whitehall (pop. 3,403) and Montague (pop. 2,422) (1998 U.S. Census) (Fig 6.2.1). The White River watershed is 59% forested and 24% agricultural. White Lake is a 1040 ha eutrophic drowned river mouth lake that has considerably degraded water quality from many residential, industrial, and municipal pollutants (EPA 1979) and is considered an area of concern (AOC) by the International Joint Commission (IJC 1989).

Sampling of the drowned river mouth wetland sites was conducted from 13 August through 15 August 2001. Sample sites were selected across a gradient of anthropogenic disturbance, determined a priori from adjacent land-use and preliminary limnological parameters, from the relatively pristine upper wetland to the relatively impacted lower wetland. Specific sampling locations were chosen based on inundation of vegetation and access by boat. Specific sampling locations within a site were randomly selected within each inundated monodominant vegetation type. Five plant community types were identified in the drowned river mouth and sites were classified as either *Typha*- (mostly *Typha latifolia* L.: Cattail), *Sparganium*- (Bur-reed), *Scirpus*- (mostly *Scirpus acutus* Muhl.: Hardstem-Bulrush), *Pontederia*- (mostly *Pontederia cordata* L.: Pickerel-weed), or *Nuphar* and *Nymphaea* (water lily) dominated. All sites had relatively dense vegetation and little if any detectable current. Depths rarely exceeded one meter and were as shallow as 10 cm. To facilitate comparisons of the more pristine habitats of the upper wetland to the more impacted habitats of the lower wetland, we classified sites as either ‘upper,’ ‘middle’ or ‘lower’ wetland (Fig. 16.2.1). This classification was based on upstream/downstream location of sites within the drowned river mouth which could also be interpreted as relative distance from headwaters of the White River. Henceforth, sites will be referred to by name based on their classification (upper, middle or lower), dominant vegetation type, and site location number. For instance, site Upper-Lily-3 was located in the upper wetland, was dominated by lily and was at location #3. Figure 6.2.1 shows these locations.

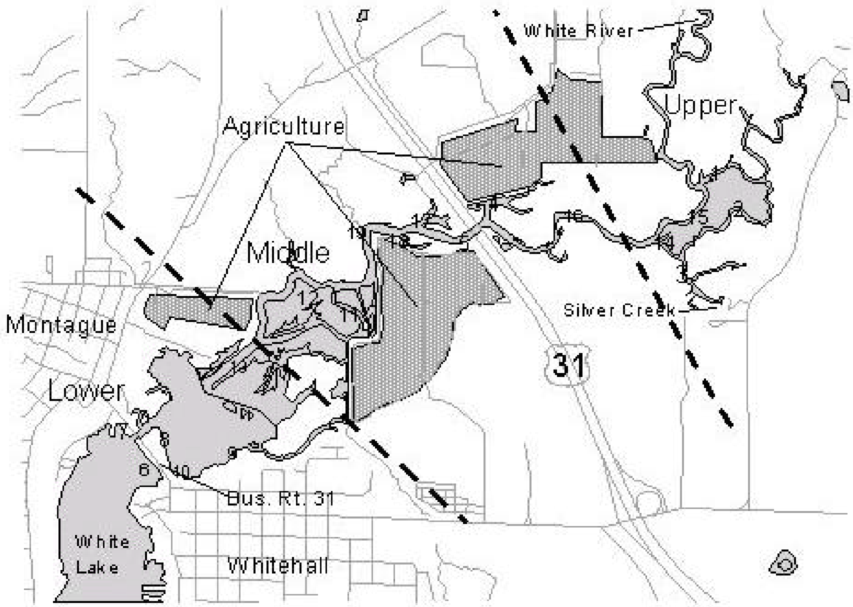


FIGURE 6.2.1 WHITE RIVER DROWNED RIVERMOUTH SAMPLING LOCATIONS, 2001.

6.2.2 2002 Watershed Paired Wetland/Stream Sites

Ten sites were sampled from the White River watershed above the drowned river mouth from 7 May through 20 May 2002. These sites contained a wetland area adjacent to either the White River or a tributary of the White River. Wetlands were either in or immediately adjacent to the riparian zone of the stream channel and in most cases were connected to the main channel by surface hydrology. Sites were chosen throughout the watershed in an effort to include both degraded and relatively pristine sites. Site locations 1, 3, 4 and 13 from the 2001drowned river mouth sampling were also sampled in May 2002 and are included in the watershed paired wetland/stream portion of this study.

Watershed wetland/stream sites were located in seven subwatersheds of the White River. The Carlton Creek site was located in the White Lake/Carlton Creek subwatershed. The wetland was adjacent to the stream and had dense *Typha* and *Carex* stands at the time of sampling. The Sand Creek site was in the Sand Creek/Wolverine Lake subwatershed. The wetland/stream site at Sand Creek was immediately downstream of an artificial impoundment and Skeels Rd. This riparian wetland was dominated by *Sparganium* and *Myosotis* at the time of sampling. We assumed that both the artificial impoundment and Skeels Rd. would have impacted this site. The Skeels Creek site was located in the Skeel/Cushman/Braton Creeks subwatershed. The wetland at the Skeels Creek site was in the flood plain of Skeels Creek at the bottom of a large ravine near the end of Eweing Rd. This site appeared to be relatively pristine and was surrounded by forest and wetland. Dominant vegetation at the Skeels Creek site included *Carex* and deciduous trees. The Cushman Creek site was also within the Skeel/Cushman/Braton Creeks subwatershed. The stream at the Cushman Creek site contained a concrete riprap riffle near where the stream passed under 192nd Ave. The wetland at this site was a large lowland marsh dominated by grasses and *Typha* stands with few inundated areas. The Robinson Creek at Johnson Rd. site was in the North Branch subwatershed. The wetland at this site was in a small depression adjacent to Robinson Creek, but was not connected to the main channel by surface hydrology. The site appeared to be relatively pristine and was surrounded by forest. Wetland vegetation at the Robinson Creek at Johnson Rd. site was mainly sedges including *Carex*. The 148th and Garfield Rd. site was also in the North Branch subwatershed. This site appeared to be one of the most degraded sites that we sampled. The wetland at the 148th and Garfield Rd. site was adjacent to, but not connect to, the stream by surface hydrology. The Fitzgerald Rd. site was in the Martin/Mena/Heald Creeks Subwatershed. This site contained a wetland in the stream flood plain and the site appeared to be relatively pristine. Deciduous trees shaded the wetland. The Alger Rd. wetland and Heald Creek sites were also in the Martin/Mena/Heald Creeks Subwatershed. The Alger Rd. wetland contained very thick organic sediments and was immediately adjacent to Alger Rd. We assumed that the road would have an impact on the biota at this site. The Heald Creek site was the stream companion site to the Alger Rd. wetland and appeared to be relatively pristine. The South Branch at Monroe Rd. site was in the Upper South Branch subwatershed and contained a forested wetland approximately 200 meters from the stream channel. This wetland contained both woody vegetation and *Typha*. The stream at this site contained both a pool and a man-made riffle near where Monroe Rd. crosses the south branch of the White River. We assumed that the biota of the wetland were being impacted by Monroe Rd. The Robinson Creek at Baldwin Rd site was in the South Branch White River/Robinson Lake subwatershed. We assumed this site would be one of our most impacted sites due to its location immediately downstream of Robinson Lake and the village of Jugville. The wetland at the Robinson Creek at Baldwin Rd site was in the riparian of Robinson Creek and contained woody shrubs including *Cornus* (Dogwood).

6.2.3 Macroinvertebrate Sampling

Macroinvertebrate samples were collected with standard 0.5 mm mesh, D-frame dip nets. Sampling consisted of sweeps at the surface, mid depth and just above the sediments in the wetland sites, and used as a kick-net in the stream sites. Nets were emptied into white pans and 150 invertebrates were collected by picking all specimens from one area of the pan before moving on to the next area. Special efforts were made to ensure that representative numbers of smaller organisms were picked to minimize any bias towards picking larger, more mobile individuals. Invertebrates were picked from plant detritus for a few minutes after 150 specimens were collected to ensure that sessile species were included. In an attempt to semi-quantify samples, individual replicates were timed. Picking proceeded for one-half-person-hour, organisms were tallied, and if 150 organisms were not acquired, picking continued to the next multiple of 50 instead of the 150-organism target. Therefore, each replicate sample contained either 50, 100, or 150 organisms. Three replicate dip net samples were collected at each plant zone at each site.

Specimens were sorted to lowest operational taxonomic unit in the laboratory; this was usually family or genus for most insects, crustaceans, and gastropods. Difficult-to-identify insect taxa such as Chironomidae were identified to tribe or family, and some other invertebrate groups including Oligochaetae, Hirudinea and Turbellaria, were identified to order level or, in a few cases, to class. Taxonomic keys such as Thorp and Covich (1991), Merritt and Cummins (1996), and mainstream literature were used for identification. As a quality control measure, random samples were exchanged between our GVSU and MSU labs and re-identified to confirm the original designation. After invertebrate identification was completed, data from replicates were averaged to obtain macroinvertebrate abundances per site. Shannon diversity and evenness, however, were calculated for each replicate sample then averaged to get mean values and standard error for each site. Macroinvertebrate data from all drowned river mouth sites (sampled in 2001) and from five watershed sites (sampled in 2002) were included in this study.

6.2.4. Chemical/Physical Parameters

Basic chemical/physical parameters were collected in conjunction with each macroinvertebrate sample. Analytical procedures followed those recommended by Standard Methods for the Examination of Water and Wastewater (APHA 1998). These measurements included soluble reactive phosphorus (SRP), nitrate-N, ammonium-N, turbidity, alkalinity, temperature, DO, chlorophyll *a*, oxidation-reduction (redox) potential, and specific conductance. Quality assurance/quality control procedures followed protocols recommended by U.S. EPA. Chemical/Physical data from all drowned river mouth sites (sampled in 2001) and from the ten watershed sites (sampled in 2002) were included in this study.

6.2.5 Land-Use/Cover Parameters

Land-use/cover parameters were calculated for a 1km buffer around each study site. Land-use/cover data were obtained from the Michigan Resource

Information System (MIRIS) with updates and ground-truthing conducted by the Information Services Center of the Annis Water Resources Institute. Seven land-use/cover parameters were calculated for each site including %agriculture, %barren field, %developed land, %forest, %wetland, %lake and total road density. Arcview version 3.3 was used to calculate all land-use/cover parameters. Land-use/cover data from all of the drowned river mouth sites were included in this study.

6.2.6 Statistical Analysis

Principal Components Analysis (PCA) was conducted on thirteen chemical/physical parameters and seven land-use/cover parameters. Correspondence Analysis (CA) was conducted on the 47 most-abundant invertebrate taxa (taxa represented by 7 or more organisms or 0.05% total abundance). Multivariate analyses were conducted using SAS version 8.0 (Cary, North Carolina).

Kruskal-Wallis and Mann-Whitney U-tests were used to determine significant differences in invertebrate data. Student's t-tests were used to determine significant differences in chemical/physical, land-use/cover data as well as site scores from the multivariate analyses. Pearson correlation was used to determine significant relationships between multivariate site scores and individual physical/chemical and land-use/cover parameters. Differences and correlations were deemed significant at $p < 0.05$. Kruskal-Wallis, Mann-Whitney U-tests, t-tests and Pearson correlation analysis were all conducted using SYSTAT version 5.0 (Evanston, Illinois).

6.3 2001 DROWNED RIVER MOUTH WETLAND RESULTS

6.3.1 Macroinvertebrates

Three of the 72 invertebrate samples were limited to less than 150 specimens by sampling time (sampling time exceeded one-half-person-hour). Ninety-nine invertebrate taxa representing 4 phyla and 8 classes were found. 78 of the 99 taxa were insects representing 9 orders. In total, 12,438 specimens were identified. Taxa richness ranged from 17 to 48 taxa per site with a mean of 29.33?1.27 (mean ± one standard error) taxa per site (Table 6.3.1.1). Shannon diversity indices ranged from 0.332±0.108 at Upper-Lily-15 to 1.175±0.010 at Middle-Sparganium-19. Evenness values ranged from 0.350±0.091 at Upper-Lily-15 to 0.828±0.007 at Middle-Sparganium-19 (Table 6.3.1.1). No significant differences (p>0.05) were found between the upper, middle and lower sites for Shannon diversity, evenness or taxa richness.

Table 6.3.1.1 Taxa richness, shannon diversity (H'), evenness (J'), most abundant macroinvertebrate taxon (T1), and second most abundant taxon (T2) for 24 wetland sites. Values in parentheses are one standard error of the mean for three replicate samples at each site.

Site	Richness	H'	J'	T1	T2
Upper-Lily-1	30	0.896(0.075)	0.757(0.055)	Coenagrionidae	*Hyallela*
Upper-Pontederia-1	29	0.747(0.039)	0.632(0.006)	Coenagrionidae	*Hyallela*
Upper-Scirpus-1	25	0.664(0.029)	0.609(0.035)	*Hyallela*	Caenidae
Upper-Sparganium-1	24	0.799(0.030)	0.711(0.009)	*Gammarus*	*Hyallela*
Upper-Lily-2	29	0.905(0.051)	0.746(0.031)	*Gammarus*	Caenidae
Upper-Lily-3	34	0.900(0.130)	0.752(0.079)	Aphididae	Mesoveliidae
Upper-Pontederia-14	31	0.722(0.055)	0.605(0.040)	*Gammarus*	Caenidae
Upper-Lily-15	17	0.332(0.108)	0.350(0.091)	Aphididae	*Gammarus*
Middle-Lily-4	32	0.906(0.028)	0.693(0.016)	*Hyallela*	Coenagrionidae
Middle-Sparganium-4	36	0.911(0.098)	0.700(0.045)	*Hyallela*	Caenidae
Middle-Lily-5	31	0.971(0.040)	0.755(0.027)	Chironomidae	Aphididae
Middle-Typha-11	30	0.622(0.076)	0.584(0.035)	*Gammarus*	Corixidae
Middle-Scirpus-12	32	0.556(0.050)	0.500(0.009)	*Gammarus*	Corixidae
Middle-Sparganium-16	24	0.573(0.096)	0.544(0.052)	*Gammarus*	Corixidae
Middle-Lily-17	34	0.910(0.070)	0.707(0.053)	*Neoplea*	*Hyallela*
Middle-Lily-18	30	0.833(0.024)	0.695(0.008)	*Gammarus*	Caenidae
Middle-Sparganium-19	48	1.175(0.010)	0.828(0.007)	Aphididae	*Gammarus*
Lower-Lily-6	24	0.876(0.044)	0.719(0.045)	*Gammarus*	Corixidae
Lower-Lily-7	28	0.845(0.017)	0.711(0.054)	Corixidae	Aphididae
Lower-Typha-8	27	0.540(0.085)	0.471(0.055)	Corixidae	*Gammarus*
Lower-Lily-9	37	0.763(0.177)	0.609(0.122)	Corixidae	*Gammarus*
Lower-Lily-10	23	0.805(0.141)	0.696(0.074)	Corixidae	Aphididae
Lower-Typha-10	28	0.836(0.139)	0.677(0.090)	Corixidae	*Gammarus*
Lower-Typha-13	21	0.442(0.054)	0.426(0.030)	Corixidae	*Gammarus*

Dimension 1 of the CA explained 23.7% of the variability in the invertebrate data (Figure 6.3.1). A summary of the abbreviations for the invertebrate taxa used in the correspondence analysis are presented in Table 6.3.1.2. In dimension 1, upper and lower wetland sites were completely separated while middle sites were plotted throughout the area occupied by the upper and lower sites. The second dimension of the CA explained 15.1% of the variability in the invertebrate data. The range of dimension two scores for middle wetland sites was again, greater than the range of scores for upper and lower wetland sites. A significant difference ($p<0.05$) was found between dimension 1 scores of upper and lower wetland sites and between lower and middle wetland sites. No significant differences ($p>0.05$) were found between dimension 2 site scores of the upper, middle and lower wetland sites.

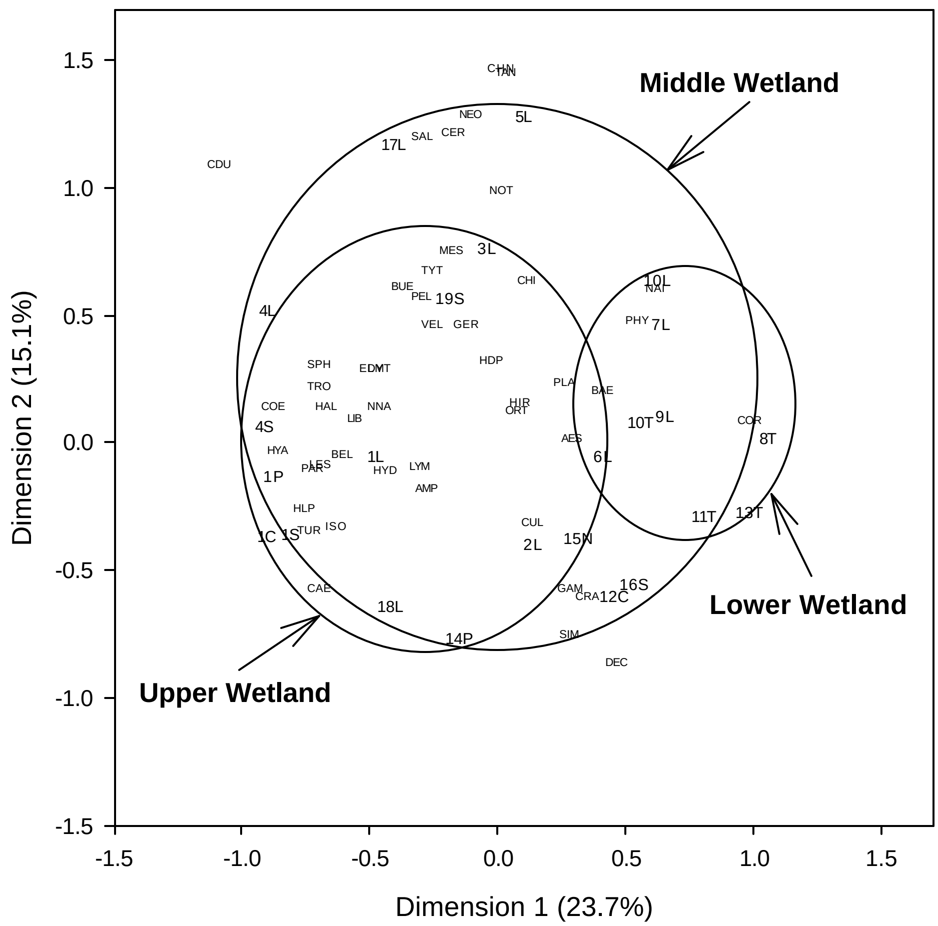


Fig. 6.3.1. Correspondence analysis of 47 invertebrate taxa grouped by wetland region. Labels indicate site location number and vegetation type (L, lily; C, Scirpus; T, Typha; P, Pontederia; S, Sparganium). Overlap of sites indicates similarity between sites.

The CA also revealed taxa that were important to each region and to particular sites. Corixidae (Hemiptera: Insecta) plotted among the lower wetland sites and representative abundances of Corixidae were significantly ($p<0.05$) greater in the lower wetland than in the upper wetland (lower=200.3±31.6 per site, upper=16.5±6.9 per site). Corixidae abundances were highest at site Lower-Typha-8 (representative abundance=327) and site Lower-Typha-13 (representative abundance=270). Corixidae was among the two most abundant taxa at all of the lower wetland sites, 3 of the 9 middle wetland sites and at none of the upper wetland sites (Table 6.3.1). Corixids were also the second most abundant taxa in the entire drowned river mouth. In total, 2,010 Corixids, representing 16.2% of the total macroinvertebrate abundance, were identified.

Table 6.3.1.2 Abbreviations used in the Correspondence Analysis of 47 Invertebrate Taxa.

Class	Order	Family	Genus/Species/ Tribe	Abbreviation
Turbellaria				TUR
Hirudinea				HIR
Oligochaeta		Naididae		NAI
Bivalvia		Sphaeriidae		SPH
Gastropoda		Hydrobiidae		HYD
		Lymnaeidae		LYM
		Physidae	Physa gyrina	PHY
		Planorbidae		PLA
Crustacea	Amphipoda	Crangonyctidae	Crangonyx sp.	CRA
		Gammaridae	Gammarus sp.	GAM
		Talitridae	Hyalella azteca	HYA
		Unknown		AMP
	Decapoda			DEC
	Isopoda			ISO
		Asellidae	Caecidotea sp.	CAE
Insecta	Ephemeroptera	Baetidae		BAE
	Odonata	Aeshnidae		AES
		Coenagrionidae		COE
		Corduliidae		CDU
		Lestidae	Lestes	LES
		Libellulidae		LIB
	Hemiptera	Belostomatidae	Belostoma sp.	BEL
		Corixidae		COR
		Gerridae		GER
		Mesoveliidae	Mesovelia	MES
		Notonectidae		NOT
			Buenoa	BUE
			Notonecta	NNA
		Pleidae	Neoplea	NEO
			Paraplea	PAR
		Saldidae		SAL
		Veliidae		VEL
	Coleoptera	Dytiscidae		DYT
		Elmidae		ELM
		Haliplidae		HAL
			Halipus	HLP
			Peltodytes	PEL
		Hydrophilidae		HDP
			Tropisternus	TRO
	Diptera	Ceratopogonidae		CER
		Chironomidae		CHI
			Chironomini	CHN
			Tanytarsini	TYT
			Orthocladiinae	ORT
			Tanypodinae	TAN
		Culicidae		CUL
		Simuliidae		SIM

Physidae (Pulmonata: Gastropoda) was also shown to be important in the lower wetland by dimension 1 of the CA. A significant difference ($p<0.05$) in Physidae abundances was found between the upper and lower wetland sites. Physidae was not the dominant taxa at any site, and the mean relative abundance of Physids was 0.018?0.005 for all sites in the drowned river mouth.

Upper wetland sites had significantly higher ($p<0.05$) *Hyallela azteca* (Talitridae: Amphipoda) abundances than lower wetland sites. The location of *Hyallela azteca* on the CA reflected the importance of this species in the upper wetland. Upper-Scirpus-1 had the most *Hyallela azteca* (representative abundance=266). *Hyallela azteca* was among the two most abundant taxa at 4 of the 8 upper wetland sites, 3 of the 9 middle wetland sites and none of the lower wetland sites (Table c). Site Middle-Lily-18 also had a notably high *Hyallela azteca* abundance (representative abundance=66). *Hyallela azteca* was not found in large numbers at any lower wetland sites (representative abundances<35).

Gammarus (Gammaridae: Amphipoda) was among the two most abundant taxa at 5 of the 7 lower wetland sites, 5 of the 9 middle wetland sites and at 5 of the 8 upper wetland sites (Table 6.3.1). *Gammarus* was also the most abundant taxa in the drowned river mouth. In total 2,460 *Gammarus* were identified which represented 19.8% of the total invertebrate representative abundance for the wetland. No significant differences were found between *Gammarus* abundances of the upper, middle and lower wetland. In dimension 1 of the CA *Gammarus* plotted in the range where upper and lower wetland sites converge (Figure 6.2.1). Coenagrionidae (Odonata: Insecta) was also shown to be important in the upper wetland by its location in dimension 1. However, Coenagrionidae abundances were not significantly different ($p>0.05$) between the upper, middle and lower wetland sites. Mean relative abundance of Coenagrionidae for all sites in the drowned river mouth was 0.059?0.016. Coenagrionidae were among the two most abundant taxa at 2 of the 8 upper sites, 1 of the 9 middle wetland sites, and was not found in large numbers at any of the lower wetland sites (Table 6.3.1).

Naididae (Oligochaeta) was relatively important at Lower-Lily-7 where it was the third most abundant taxa, representing 16.1% of the site's macroinvertebrate abundance. The CA plotted Naididae near Lower-Lily-7 in the area occupied by the lower wetland sites for this reason. Naididae was not found in large numbers at any other sites in the drowned river mouth (relative abundances ?0.035). *Neoplea* (Pleidae: Hemiptera) was especially important at Middle-Lily-17 where it represents 26.4% of the macroinvertebrate abundance and was the most abundant taxa. Relatively high abundances of *Neoplea* were also found at Lower-Lily-10 where it was the third most abundant taxa and represented 9.3% of the macroinvertebrate abundance. No significant differences ($p>0.05$) were found in *Neoplea* abundances between the upper, middle and lower wetland sites.

Since sampling was conducted within distinct vegetation zones, the CA was also used to search for patterns in macroinvertebrate assemblages based on plant community type. *Typha*-dominated zones were found only in the lower and middle wetland and three of our seven lower sites were *Typha*-dominated. The remaining lower wetland sites were lily-dominated (mostly *Nuphar*). In addition, *Pontederia*, *Scirpus* and *Sparganium*-dominated sites could only be found in the middle and upper wetland. Therefore, our interpretation of the CA based on vegetation type is tenuous. The four *Typha*-dominated sites did, however, group fairly close to one another. Lily-dominated zones formed the largest group and had the greatest range in dimension 2. *Pontederia*, *Scirpus and Sparganium*-dominated sites formed groups that overlapped nearly entirely. Further interpretation of the CA in terms of vegetation types suffers from a lack of comparable sites throughout the drowned river mouth.

Percent non-insect taxa richness was greatest at Lower-Lily-7 (46.42%) and least at site Middle-Lily-4 (21.9%). Mean %non-insect taxa richness was 34.4?1.4% for all sites. A significant difference ($p<0.05$) in %non-insect taxa was found between lower wetland and middle wetland sites and between upper and lower wetland sites. Lower wetland sites %non-insect taxa richness was 40.4?2.3% while middle and upper wetland sites %non-insect taxa richness were 31.8?1.9% and 32.0?2.0% respectively.

6.3.2. Chemical/Physical

PCA of 13 chemical/physical variables separated sites of the upper wetland from sites of the lower wetland (Figure 6.3.2). In the first two principal components (explaining 52% of the variation) seven of the eight upper wetland sites were pulled away from lower wetland sites. Sites of the middle wetland plotted throughout the area occupied by sites of the upper and lower wetland. The PCA pulled upper wetland sites out in the same direction as dissolved oxygen and pH and away from total dissolved solids, ammonium, chloride, soluble reactive phosphorus, turbidity, sulfate, and nitrate.

Six of the seven lower wetland sites and five of the nine middle wetland sites were pulled away from upper sites in either principal component 1 (PC 1) or principal component 2 (PC 2). Lower-Lily-7 was pulled out in PC 1 because of its relatively high SRP concentration (0.04 mg/L) and its low dissolved oxygen (23.1% saturation) (Table 6.3.2.1). Lower-Lily-7 and Middle-Lily-18 were the only sites with dissolved oxygen below 5 mg/L. Lower-Lily-10 is also being pulled out in PC 1, presumably because of its high ammonium (0.27 mg/L) and low specific conductance (182.7 *u*S/cm). Middle-Lily-18 had the highest score in PC 1 due to a chloride concentration that was over twice that of any other site in the drowned river mouth (95 mg/L). SRP at site Middle-Lily-18 was four-times higher than any other site (0.16 mg/L). Middle-Typha-11, Middle-Scirpus-12 and Lower-Typha-13 scored highest in PC 2 because of their high nitrate concentrations, all being greater than 0.34 mg/L.

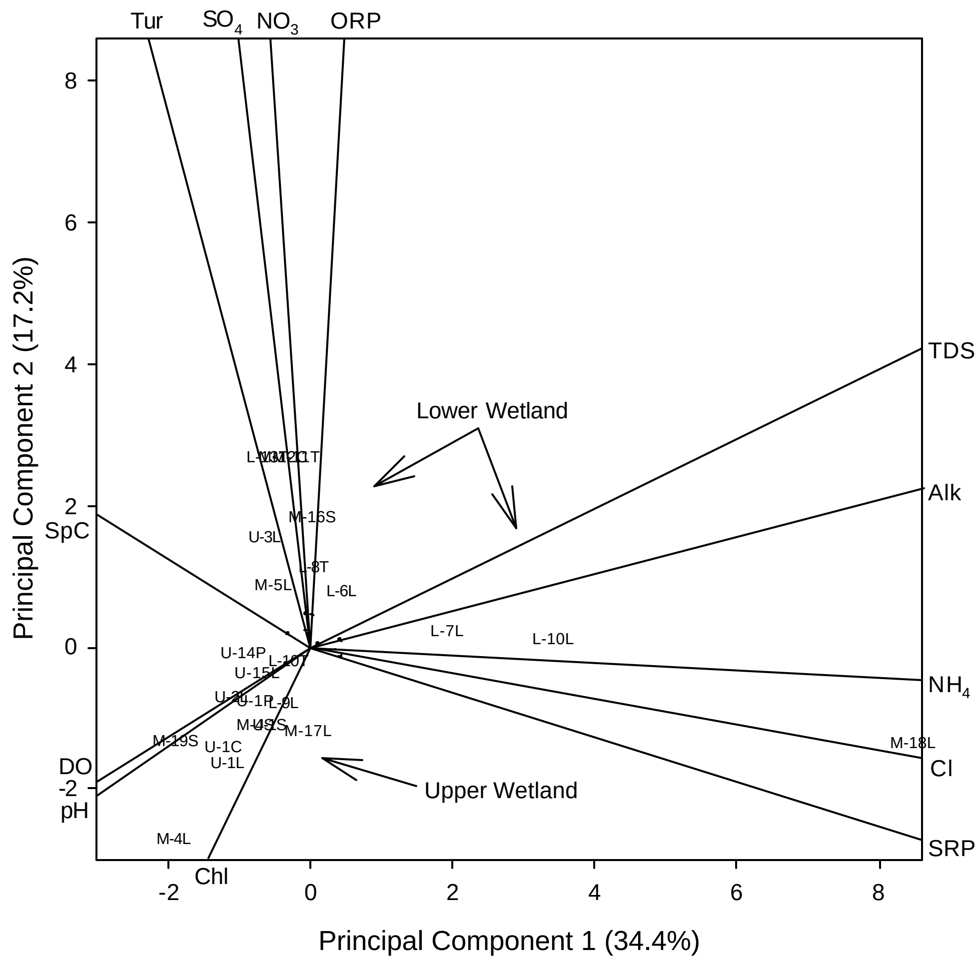


Fig. 6.3.2. Principal components analysis of 13 chemical/physical parameters. Labels indicate wetland region (upper, U-; middle, M-; lower, L-), site location number and vegetation type (L, lily; P, Pontederia; S, Sparganium; C, Scirpus; T, Typha). Overlap of sites indicates similarity between sites.

Middle-Sparganium-16 also scored relatively high in PC 2, because of the site's high nitrate concentration (0.30 mg/L) and high turbidity (34.0 NTU). Most upper wetland sites scored low in both PC 1 and PC 2. Upper-Lily-3 is the exception and was pulled out of the group of upper sites in PC 1. Nitrate concentrations and turbidity at Upper-Lily-3 were well above those of any other upper wetland site (0.16 mg/L nitrate and 38.1 NTU turbidity). Based on their smaller range of PC 1 and PC 2 scores as well as their smaller coefficients of variation for individual physical/chemical parameters (Table 6.3.2.2), sites in the upper wetland had the least physical/chemical variability

Table 6.3.2.1 Water Chemistry Results for the Drowned Rivermouth Wetlands

Site	NO_3	NH_4	SRP	Cl	SO_4	Alk	Temp	DO	%DO	SpC	TDS	Tur	ORP	Chl	pH
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	^{O}C	mg/L	% Sat	uS/cm	g/L	NTU	mV	mg/L	
Upper-Lily-1	0.01	0.038	<0.01	20	18	124	24.1	11.48	136.7	328.1	0.210	4.7	345	4.0	8.74
Upper-Pontederia-1	0.04	<0.025	<0.01	20	19	130	24.6	9.57	115.7	340.1	0.217	5.3	351	3.0	8.53
Upper-Scirpus-1	0.03	<0.025	<0.01	19	17	124	22.7	11.69	135.6	285.0	0.193	8.4	359	3.8	8.85
Upper-Sparganium-1	0.04	<0.025	<0.01	19	18	132	25.9	8.45	105.2	316.1	0.202	5.2	344	2.8	8.56
Upper-Lily-2	0.12	<0.025	<0.01	19	18	132	22.6	10.46	121.5	338.9	0.217	2.3	355	2.1	8.85
Upper-Lily-3	0.16	0.070	<0.01	25	20	133	29.8	8.62	114.7	384.7	0.246	38.1	377	0.0	8.55
Upper-Pontederia-14	0.03	<0.025	<0.01	18	18	126	22.0	8.94	102.1	340.0	0.218	31.7	362	7.4	8.54
Upper-Lily-15	0.09	<0.025	<0.01	18	17	125	22.1	8.84	101.2	340.2	0.218	11.1	364	12.1	8.39
Middle-Lily-4	<0.01	<0.025	<0.01	19	17	111	27.5	10.75	137.8	296.8	0.190	1.9	332	6.5	9.18
Middle-Sparganium-4	0.02	<0.025	0.03	24	16	135	22.6	8.68	101.8	371.4	0.237	18.5	370	25.7	8.95
Middle-Lily-5	0.09	0.037	<0.01	24	24	138	25.4	8.25	100.5	391.8	0.251	14.4	354	6.3	8.48
Middle-Typha-11	0.34	0.030	<0.01	24	22	141	22.0	7.56	87.5	372.8	0.238	11.8	387	4.2	8.43
Middle-Scirpus-12	0.35	<0.025	<0.01	25	23	140	19.6	8.67	94.7	390.4	0.250	2.7	386	2.8	8.40
Middle-Sparganium-16	0.30	<0.025	<0.01	25	23	143	21.4	8.31	93.2	231.0	0.147	34.0	359	9.7	8.46
Middle-Lily-17	0.03	<0.025	<0.01	38	13	125	22.9	7.51	87.7	393.6	0.252	15.5	353	4.1	8.30
Middle-Lily-18	0.03	0.170	0.16	95	17	204	17.5	4.67	48.7	124.8	0.067	5.0	351	4.3	7.65
Middle-Sparganium-19	0.05	<0.025	<0.01	26	22	124	24.6	12.40	149.6	355.2	0.226	10.7	331	5.7	9.11
Lower-Lily-6	0.07	0.034	0.01	25	20	135	13.4	7.96	75.4	358.4	0.226	3.1	377	4.8	8.11
Lower-Lily-7	<0.01	<0.025	0.04	27	18	142	16.2	2.34	23.1	398.7	0.255	3.1	350	5.8	7.48
Lower-Typha-8	0.32	0.026	<0.01	25	22	139	18.0	7.41	78.6	392.8	0.251	4.4	329	4.7	8.08
Lower-Lily-9	0.03	0.051	0.01	28	21	154	18.5	11.45	122.2	404.8	0.259	4.7	342	7.1	8.84
Lower-Lily-10	0.02	0.270	<0.01	36	20	145	21.2	7.23	81.7	182.7	1.358	9.8	368	4.5	8.16
Lower-Typha-10	0.01	0.029	<0.01	29	21	144	21.1	8.55	96.0	412.2	0.264	4.7	360	19.6	8.51
Lower-Typha-13	0.35	<0.025	<0.01	24	22	141	20.9	9.01	100.4	392.9	0.251	15.9	385	4.5	8.49

Table 6.3.2.2 Coefficients of Variation of 15 Chemical/Physical Parameters for the Upper, Middle, and Lower Drowned Rivermouth Wetland.

wetland region	NO_3	NH_4	SRP	Cl	SO_4	Alk	Temp	pH
upper	0.825	0.919	0.000*	0.114	0.055	0.030	0.109	0.019
middle	1.103	1.488	2.069	0.710	0.200	0.186	0.133	0.055
lower	1.316	1.490	1.069	0.147	0.068	0.041	0.157	0.052

wetland region	DO	%DO	SpC	TDS	Tur	ORP	Chl
upper	0.133	0.120	0.084	0.072	1.024	0.031	0.850
middle	0.252	0.293	0.284	0.304	0.776	0.056	0.914
lower	0.358	0.373	0.224	0.187	0.722	0.055	0.756

* No upper wetland sites had SRP above our dection limit of 0.01 mg/L.

of the three groups. Turbidity and chlorophyll *a* concentration were the only physical/chemical parameters for which sites of the lower wetland had a smaller coefficient of variation than upper wetland sites (Table 6.3.2.2).

The PCA was also used to search for patterns in water quality based on plant community type. Like the CA, our interpretation of the PCA based on vegetation type suffers from a lack of comparable sites throughout the drowned river mouth. The four *Typha*-dominated sites of the lower wetland did, however, spread out exclusively in PC 2 suggesting that one or more of the parameters contributing strongly to PC 2 may be important for *Typha* communities. Lily-dominated communities formed a group that spread out in both dimensions and was the only plant community type to be strong in PC 1. PC 1 scores of the upper and lower wetland sites were significantly different ($p<0.05$). No significant differences ($p>0.05$) were found between PC 1 scores of the upper and middle wetland sites, middle and lower wetland sites or between any vegetation types. Significant differences ($p<0.05$) in PC 2 scores were found between sites of the upper and lower wetland and between *Typha*-dominated and lily-dominated sites.

Water temperatures ranged from 13.4?C at Lower-Lily-6 to 29.8?C at Upper-Lily-3. Mean water temperature for the drowned river mouth was 21.9? 0.7?C. Cooler temperatures were generally found at sites that fringed White Lake. Temperatures at the lower wetland sites were found to be significantly different (p<0.05) from temperatures of the upper and middle wetland (Table 6.3.2.1). Turbidity was highly variable throughout the drowned river mouth with a mean of 11.1?2.1 NTU. High turbidity (>30 NTU) was found at Upper-Lily-3, Upper-Pontederia-14 and Middle-Sparganium-16. Chlorophyll *a* concentrations did not correlate with the high turbidity of these three sites, suggesting that phytoplankton did not contribute appreciably to the high turbidity. Lower-Lily-3 had the highest turbidity (38.1 NTU). Middle-Lily4 had the lowest turbidity (1.9 NTU). No significant differences (p<0.05) in turbidity were found between upper, middle and lower wetland sites.

Specific conductance values were also highly variable throughout the drowned river mouth with a mean of 339.3?14.7 *u*S/cm. Highest specific conductance levels were found in the lower wetland at Lower-Typha-9 and Lower-Typha-10. Specific conductance and chloride concentrations appeared to be negatively correlated based on their eigenvectors in the PCA. However, an insignificant correlation was found between their respective values (p>0.05). The opposing orientation of the eigenvectors of chloride and specific conductance is probably the result of sites Middle-Lily-18 and Lower-Lily-10 having high chloride concentrations and low specific conductance. No significant differences (p<0.05) were found in specific conductance of the upper, middle and lower wetland sites (Table 6.3.2.2).

6.3.3 Land-Use/Cover:

Principal components analysis of 7 land-use/land-cover parameters separated sites of the upper, middle and lower wetland (Figure 6.3.3). PC1 explained 70.9% of the variability in the land-use/land-cover data and PC2 explained 18.4%. Upper wetland sites were pulled out in the same direction as the forest and barren field eigenvectors. Middle wetland sites were pulled out in the same direction as the eigenvectors for agriculture and wetland. Sites of the lower wetland were pulled out in the same direction as the eigenvectors for lake/stream, road density and developed land. Lower-13 scored the lowest of any other lower wetland site in PC1. This site was also further upstream than any other lower wetland site. Lower and middle wetland sites were not significantly different (p>0.05) in PC 1. Thirteen significant correlations were found between individual land-use/land-cover parameters (Table 6.3.3).

No individual land-use/land-cover parameter had an overwhelming power of separation in PC1 or PC2. Significant differences (p<0.05) were found between upper, middle and lower wetland sites for most land-use/land-cover parameters. Upper and lower wetland sites were not significantly different in the amount of wetland area and the middle and upper wetland sites were not significantly different in the amount of developed land within one kilometer of their respective sites.

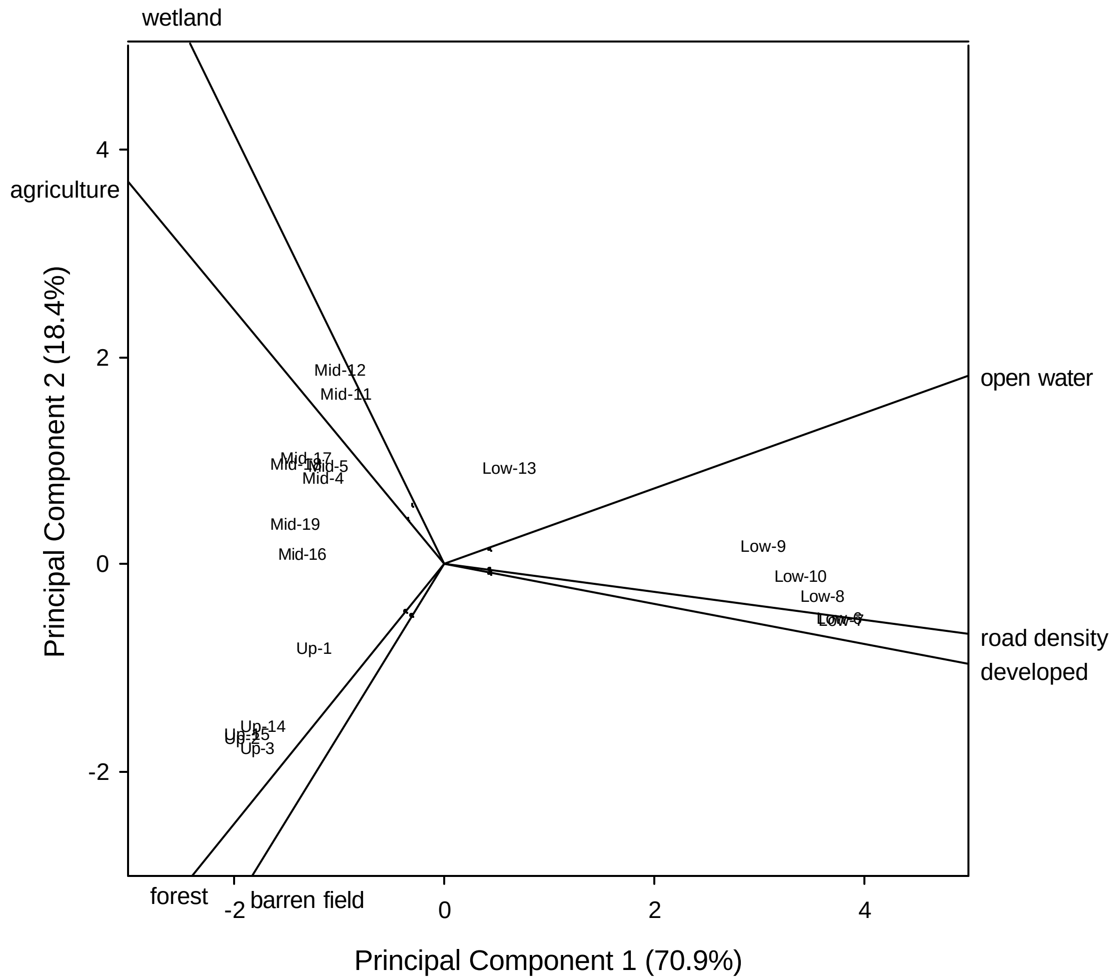


Fig. 6.3.3. Principal components analysis of 7 land-use/cover parameters. Labels indicate wetland region (upper, middle, lower) and site location numbers.

Table 6.3.3. Significant correlations between land-use/cover parameters at $p<0.05$. Value in matrix = r, NS=not significant.

	Developed	Agriculture	Barren	Forest	Open Water	Wetland
Developed	n/a	*	*	*	*	*
Agriculture	-0.72	n/a	*	*	*	*
Barren	-0.57	NS	n/a	*	*	*
Forest	-0.76	NS	0.69	n/a	*	*
Water	0.96	-0.56	-0.69	-0.9	n/a	*
Wetland	-0.76	0.63	NS	NS	-0.6	n/a

6.3.4 Pearson Correlations

Significant correlations ($p<0.05$) were found between dimension 1 scores of the invertebrate CA and PC 1 scores of the physical/chemical PCA. Dimension 1 and PC 2 scores of the physical/chemical PCA were also significantly correlated ($p<0.05$). A significant correlation ($p<0.05$) was also found between dimension 1 and PC 2 scores of the physical/chemical PCA for middle wetland sites when tested independently. PC 1 scores of the physical/chemical PCA for middle wetland sites were not significantly correlated with dimension 1 scores most likely due to site Middle-Lily-18 having an extremely high PC 1 score and a moderate dimension 1 score. A regression was conducted between dimension 1 and PC 1 scores of the physical/chemical PCA to show invertebrate response to changes in water quality (Figure 6.3.4). A significant correlation ($p<0.05$) was also found between dimension 2 scores of the CA and chloride concentrations.

PC 1 scores from the land-use/cover PCA correlated significantly ($p<0.05$) with dimension 1 scores of the CA. A significant correlation ($p<0.05$) was also found between PC1 scores of the land-use/land-cover PCA and dissolved oxygen %saturation. No significant correlations were found for PC 2 of the land-use/cover PCA.

6.4 2002 WATERSHED STREAM AND WETLAND RESULTS

6.4.1 Macroinvertebrates of the Upper Watershed Stream Sites

Of the 15 stream-invertebrate samples taken, none were limited to less than 150 specimens by sampling time (sampling time did not exceed one-half-person-hour). In total, 2,629 specimens, representing 88 taxa were collected at the 5 stream sites. Taxa richness ranged from 32 at Carlton Creek to 48 at Skeels Creek (Table 6.4.1). Mean taxa richness was 35.8?3.1. Shannon diversity indices were similar for all sites (mean: 1.08?0.03) (Table 6.4.1). Chironomidae (Diptera) was the most abundant order and a total of 681 Chironomids (25.9% of the total abundance) were collected. Baetidae (Ephemeroptera) was the second most abundant order and 521 Baetids (19.8% of the total abundance) were collected.

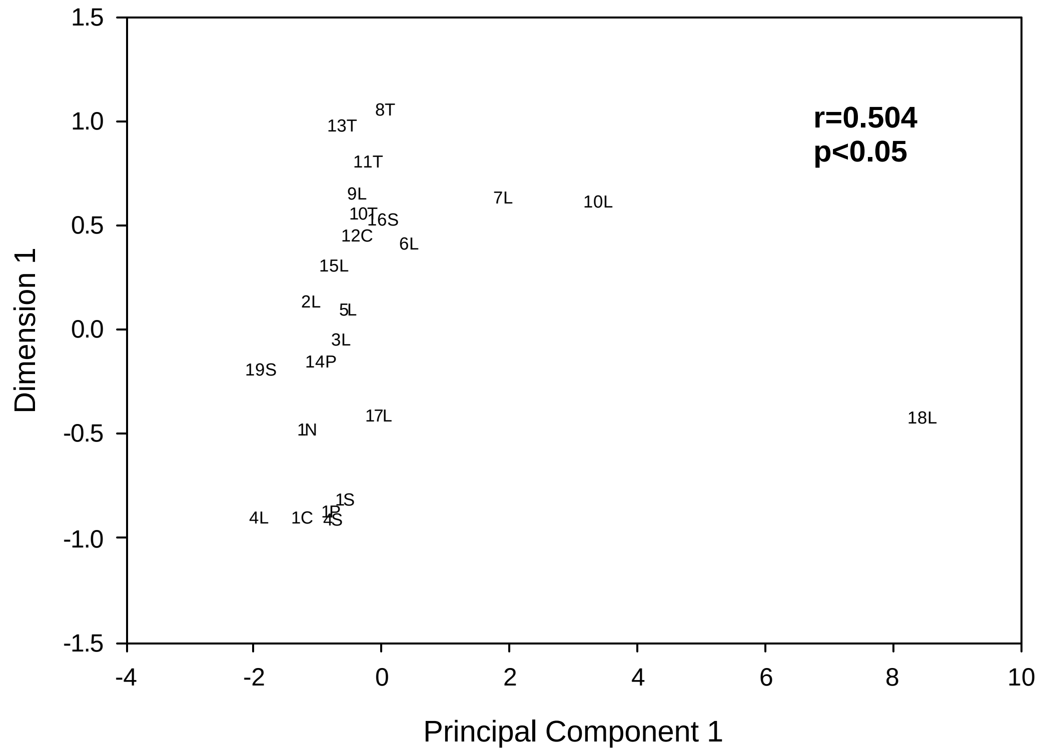


Fig. 6.3.4 Dimension 1 scores from correspondence analysis of invertebrates in response to changes in water quality measured by principal component 1 of the principal components analysis of 13 chemical/physical parameters. Labels refer to site location number and vegetation type (L, lily; C, Scirpus; T, Typha; P, Pontederia; S, Sparganium).

Percent abundance of Ephemeroptera+Plecoptera+Trichoptera (%EPT) ranged from 29.9% at Skeels Creek to 58.2% at the South Branch site (Table 6.4.1). Mean %EPT was 50.3?5.2%. Mayflies were most abundant at the drowned river mouth site (52% relative abundance) and least abundant at the Skeels Creek site (12% relative abundance). Stoneflies were most abundant at the Skeels Creek site (11% relative abundance) and least abundant at the South Branch site (0.8% relative abundance). Caddisflies were most abundant at the South Branch site (40.1% relative abundance) and least abundant at the drowned river mouth site (3.4% relative abundance). Percent abundance of Hirudinea+Gastropods+Isopods (%HGI) was low at all of the stream sites (mean=0.56?0.2%). The Sand Creek site had the most HGI (1.3% relative abundance) and the South Branch site had the least HGI (0.2% relative abundance) (Table 6.4.1).

Table 6.4.1 Macroinvertebrates of 5 White River watershed stream sites.

	full sample	taxa richness	mayfly taxa	%mayfly abundnace	caddisfly taxa	%caddisfly abundance
Carlton Creek	y	32	4	32.1	5	21.1
Sand Creek	y	33	3	34.0	5	10.3
Skeels Creek	y	48	10	12.0	7	6.8
South Branch	y	32	8	17.3	8	40.1
drowned river mouth site 1	y	34	6	52.0	5	3.4

	stonefly taxa	%stonefly abundance	HGI abundance	%HGI abundance	%EPT abundance	shannon diversity
Carlton Creek	3	1.1	3	0.5	54.3	1.042
Sand Creek	3	7.3	6	1.3	51.6	1.087
Skeels Creek	9	11.0	1	0.2	29.9	1.178
South Branch	3	0.8	1	0.2	58.2	1.081
DRM	4	1.9	3	0.6	57.3	1.005

'HGI'=Hirudinea (leaches)+ Gastropoda (snails)+Isopoda. 'EPT'=Ephemoroptera(mayflies)+ Plecoptera(stoneflies)+Tricoptera(caddisflies). 'Full sample' refers to all replicate samples having 150 or more specimens. Site 'DRM'refers to site number 1 in the drowned river mouth wetland.

6.4.2 Macroinvertebrates of Upper Watershed Wetland Sites

Of the 18 watershed wetland invertebrate samples taken (3 replicates per site, 6 sites), 5 were limited to less than 150 specimens by sampling time (Table 6.4.2). In total, 2,553 specimens, representing 99 taxa were collected at the 5 watershed wetland sites. Taxa richness ranged from 26 at the drowned river mouth site (site 1-Nuphar, 2001) to 42 at the Sand Creek site. Mean taxa richness was 30.5?2.5. *Hyallela azteca* was the most abundant taxa and a total of 835 *Hyallela azteca* (32.7% of the total macroinvertebrate abundance) were found at the 5 sites. *Gammarus* was the second most abundant taxa and 382 *Gammarus* (15.0% of the total macroinvertebrate abundance) were found at the 5 sites.

Mayfly taxa richness was three or less per site. Caddisfly taxa richness was three or less for four of the wetland sites and was seven at the Sand Creek wetland site. Percent Amphipod abundance was high for most of the wetland sites and ranged from 0.5% at the South Branch site to 77.6% at the drowned river mouth site (site 1-Nuphar, 2001).

Table 6.4.2 Macroinvertebrates of 5 White River Watershed Wetland Sites

	full sample	taxa richness	mayfly taxa	%mayfly abundnace	caddisfly taxa	%caddisfly abundance
Carlton Creek	y	32	1	1.2	1	3.4
Sand Creek	y	42	3	9.8	7	6.4
Skeels Creek	n	27	3	2.9	3	1.6
South Branch	n	28	0	0.0	0	0.0
DRM (Nuphar)	y	26	3	4.1	0	0.0
DRM (Sparganium)	y	28	3	3.5	1	0.2

	Odonata taxa	%Odonata abundance	HGI abundance	%HGI abundance	%Amphipoda abundance	shannon diversity
Carlton Creek	2	1.0	159	31.8	33.8	1.068
Sand Creek	1	0.4	99	19.8	30.5	1.103
Skeels Creek	1	0.5	119	31.6	49.9	0.866
South Branch	2	2.2	101	54.9	0.5	1.062
DRM (Nuphar)	1	0.2	25	5.2	77.6	0.608
DRM (Sparganium)	2	0.4	26	5.1	70.3	0.690

HGI'=Hirudinea (leaches)+ Gastropoda (snails)+Isopoda.'Full sample' refers to all replicate samples having 150 or more specimens. Site 'DRM' refers to site number 1 in the drowned river mouth wetland where two plant zones were sampled.

6.4.3. Chemical/Physical Data for the Upper Watershed Wetland Sites

Chemical/physical measurements were highly variable among the 10 watershed wetland sites (Table 6.4.3). Dissolved oxygen ranged from 5.21 mg/L (47.9% saturation) at the South Branch site to 10.99 mg/L (107.0% saturation) at the Alger Rd. site. Mean dissolved oxygen was 8.29±0.64 mg/L and 78.2±6.6% saturation. Specific conductance (SpC) ranged from 203.5 *u*S/cm at the South Branch site to 640.3 *u*S/cm at the Robinson Creek at Johnson Rd. site. Mean SpC was 328.6±39.0 *u*S/cm. The highest total dissolved solids (TDS) concentration was also at the Robinson Creek at Johnson Rd. site and the lowest concentration was at the South Branch site. Mean TDS was 0.214±0.028 g/L. The pH was fairly consistent among the wetland sites with a mean of 7.6±0.2. Chloride concentrations were highly variable among wetland sites with the highest concentration (110.0 mg/L) at the Robinson Creek at Johnson Rd. site and the lowest concentration (1 mg/L) at the Cushman Creek site. Nitrate was also variable among the ten wetlands. The highest nitrate concentration was 1.63 mg/L at the 148th Ave. and Garfield Rd. site while four of the ten wetlands had nitrate concentrations below our detection limit of 0.01 mg/L. Mean nitrate concentration was 0.29±0.17 mg/L. Ammonium concentrations tended to be lower than nitrate concentrations and the mean ammonium concentration was 0.01±0.006 mg/L.

Table 6.4.3 Water Chemistry Results for the Upper White River Streams and Wetlands.

Site	NO_3 mg/L	NH_4 mg/L	SRP mg/L	Cl mg/L	SO_4 mg/L	Alk mg/L	Temp °C	DO mg/L	%DO % Sat	SpC uS/cm	TDS g/L	ORP mV	Chl ug/L	pH
Streams:														
Carlton Creek	0.44	<0.01	<0.01	9	16	147	12.2	10.15	93.7	315	0.202	388	7.7	7.90
Sand Creek	0.56	<0.01	<0.01	5	8	135	13.2	10.40	97.8	283	0.181	403	2.4	8.51
Skeels Creek	0.41	0.026	<0.01	24	17	155	12.6	10.80	98.8	384	0.250	4.43	8.9	8.18
Cushman Creek	1.33	<0.01	0.04	15	19	194	12.4	10.29	95.4	450	0.288	447	4.9	7.96
Robinson Creek (Johnson Rd.)	0.22	0.017	<0.01	5	8	145	10.8	9.76	89.8	303	0.194	481	13.9	7.69
148th and Garfield	0.72	<0.01	0.015	9	7	140	11.3	11.05	104	303	0.194	486	9.6	7.65
Fitzgerald Rd.	0.57	0.041	0.01	13	7	134	8.5	12.17	94.2	299	0.191	444	14.3	7.98
Heald Creek	0.02	0.021	<0.01	51	32	135	10.5	11.51	102.6	458	0.908	333	3.5	8.22
South Branch	<0.01	0.012	0.003	11	7	116	9.9	10.63	91.7	271	0.173	310	4.8	8.03
Robinson Creek (Baldwin Rd.)	<0.01	0.02	0.003	21	11	106	15.0	10.60	105.2	318	0.204	327	8.5	8.15
DRM Site 1	0.182	<0.01	0.003	14	13	145	9.3	10.38	89.9	361	0.231	356	3.7	8.07
DRM Site 3	0.189	<0.01	0.001	15	14	147	9.4	10.75	95.8	362	0.231	364	3.8	8.15
DRM Site 4	0.181	0.021	0.002	11	15	153	10.0	10.98	92.6	369	0.237	350	3.0	8.26
DRM Site 13	0.292	0.027	0.003	18	15	149	10.1	11.64	102.4	374	0.240	371	4.1	8.28
Wetlands:														
Carlton Creek Wetland	0.37	<0.01	<0.01	9	16	144	12.3	9.52	87.8	315	0.201	360	4.0	7.98
Sand Creek Wetland	0.75	<0.01	<0.01	5	11	132	13.3	9.94	93.8	283	0.181	380	2.2	8.36
Skeels Creek Wetland	0.04	<0.01	0.016	2	13	131	9.4	6.13	54.2	272	0.177	321	5.2	7.47
Cushman Creek wetland	<0.01	<0.01	0.014	<1	<1	97	13.6	6.89	66	210	0.134	296	7.7	7.03
Robinson Creek Wetland (Johnson Rd.)	0.04	<0.01	<0.01	110	16	197	12.9	8.61	85.9	640	0.440	515	16.9	7.44
148th and Garfield Rd. Wetland	1.63	0.026	<0.01	7	6	148	12.2	9.35	88.3	315	0.201	49.3	8.9	7.59
Fitzgerald Rd. Wetland	<0.01	0.016	0.044	6	4	199	7.9	6.11	53.2	391	0.251	248	7.7	7.18
Alger Rd. Wetland	0.04	<0.01	<0.01	1	11	169	13.3	10.99	107	339	0.216	359	1.7	8.13
South Branch Wetland	<0.01	<0.01	0.015	11	2	86	9.7	5.21	47.9	204	0.130	254	12.3	7.06
Robinson Creek Wetland (Baldwin Rd)	<0.01	0.065	0.001	23	12	106	14.9	10.10	97.7	319	0.205	331	4.0	8.08
DRM Site 1	<0.01	<0.01	0.003	12	11	142	11.0	8.97	83.2	333	0.213	380	11.2	7.40
DRM Site 3	<0.01	0.015	0.003	13	11	136	10.4	7.68	70.7	322	0.206	375	6.9	7.35
DRM Site 4	<0.01	0.054	0.003	14	17	153	12.0	13.22	121.9	357	0.229	338	7.1	8.95
DRM Site 13	<0.01	0.012	0.002	14	13	142	12.5	12.20	113.6	344	0.220	354	4.7	8.24

Seven of the ten wetland sites had ammonium concentrations below detection limit. The highest SRP concentration (0.044 mg/L) was found at the Fitzgerald Rd. site. Six of the ten wetland sites had SRP concentrations that were below our detection limit of 0.01 mg/L.

6.4.3. Chemical/Physical Data for the Upper Watershed Stream Sites

Less chemical/physical variability was found among the stream sites compared to wetland sites of the watershed. Temperatures ranged from 8.5 ºC at the Fitzgerald Rd. site to 15.0 ºC at the Robinson Creek at Baldwin Rd. site. Mean temperature was 11.6±0.5.9ºC. Dissolved oxygen was near saturation for most of the sites with a mean of 10.7±0.2 mg/l (97.3±1.7 %saturation). SpC was variable among stream sites and the highest SpC was found at the Heald Creek site and the Cushman Creek site where SpC levels were 457.6 and 450.2 *u*S/cm respectively. TDS was also highest at the Heald Creek site (0.908 g/L). The remaining stream sites had TDS concentrations between 0.173 and 0.288 g/L. pH ranged from 7.65 to 8.51 with a mean of 8.03±0.08. Chloride concentrations were variable among stream sites, though less variable than the wetland sites. The highest chloride concentration was at the Heald Creek site (50.5 mg/L) and the lowest was at the Robinson Creek at Johnson Rd. site (5.08 mg/L). Mean chloride concentration was 16.4±4.3 mg/L. The highest nitrate concentration was found at the Cushman Creek site (1.33 mg/L). Two sites had nitrate concentrations below our detection limit of 0.01 mg/L (Table 6.4.3). Mean nitrate concentration was 0.43±0.13 mg/L. Ammonium concentrations were lower than nitrate and four of the ten sites had ammonium concentrations below our detection limit of 0.01 mg/L. The highest ammonium concentration was 0.04 mg/L at the Fitzgerald Rd. site (Table 6.4.3). Seven of the ten stream sites had SRP concentrations that were below our detection limit of 0.01 mg/L. The highest SRP concentration was found at the Cushman Creek site (0.04 mg/L) (Table 6.3.2.1).

6.5 DISCUSSION

6.5.1. 2001 Drowned River Mouth

Considerable variability was found among invertebrate communities of the White River drowned river mouth. Water quality was also variable and coincided with differences in surrounding land-use/cover. Correlation between multivariate analyses of water quality and invertebrate assemblages suggest a link between anthropogenic disturbance and biota. Invertebrate communities appeared to respond to the degraded water quality of the lower wetland and some middle wetland sites. Anthropogenic disturbance, based on measured differences in water quality, was determined to be the most important factor in structuring invertebrate communities of the White River drowned river mouth.

Sites in the lower wetland had relatively degraded water quality due to the surrounding urban areas of Whitehall and Montague as well as their proximity to White Lake. Lower wetland sites had relatively similar community composition regardless of dominant vegetation type and local variability in ambient conditions. Upper wetland sites were more pristine than lower sites in terms of water quality; this was most likely due to predominantly forested surrounding land. Sites of the upper wetland were also similar to one another in their community composition regardless of dominant vegetation type. Sites in the middle wetland had the most variability in community composition and water quality and the link between anthropogenic disturbance and biota was most evident among middle wetland sites.

Corixidae comprised significantly more of the invertebrate community at sites that had greater anthropogenic disturbance. Corixids occurred in greater abundances at sites of the lower wetland and at middle wetland sites that had elevated nitrate. In the upper wetland Corixids were only found in large numbers at the Silver Creek site (Upper-Lily-3) where sewage effluent discharge made water quality more similar to the lower wetlands than the upper sites.

Physidae abundances also appeared to be dictated by anthropogenic disturbance. Physids were found at all of the lower sites, but in the upper wetland, were found only at Upper-Lily-2, Upper-Lily-3 and Upper-Lily-14. These were the 3 sites closest to Silver Creek and consequently had relatively high nitrate and/or high turbidity compared to the other upper wetland sites. Upper-Lily-1, Upper-Pontederia-1, Upper-Scirpus-1, Upper-Sparganium-1 and Upper-Lily-15 had comparatively better water quality and had no Physids. Middle-Lily-4 had the best water quality of any middle wetland site and was also void of Physidae.

Sites that had the highest *Hyallela azteca* abundances were those that had the least anthropogenic disturbance. All of the upper wetland sites as well as Middle-Lily-4, Middle-Sparganium-4 and Middle-Lily-17 had high abundances of *Hyallela azteca* and relatively low turbidity, sulfate, nitrate, ammonium, chloride and SRP. *Hyallela azteca* represented significantly less of the invertebrate community composition of the lower wetland and at sites of the middle wetland with degraded water quality. An interesting exception to this trend occurred at Middle-Lily-18 where water quality appeared to be severely degraded, but *Hyallela azteca* made up 13.8% of the macroinvertebrate community. This anomaly suggests that the water quality at Middle-Lily-18 appeared more degraded than it actually was or that the structure of the invertebrate community was dictated by factors that we could not account for in our analysis.

A number of taxa did not respond to variability in water quality but were rather cosmopolitan among our sampling sites. *Gammarus* and Chironomidae, for instance, were found throughout the drowned river mouth. Yet, no specific correlations were found between their abundances and water quality.

The influence of vegetation type on community composition was either masked by the influence of anthropogenic disturbance or was not detected because an insufficient number of plant zones existed across the three regions of the drowned river mouth. Lily was the only plant zone that was sampled in all three regions. Invertebrate community composition among the lily sites was variable and was better predicted by water quality. The effect of plant community on invertebrate assemblages may have been detectable with greater replication of vegetation zones within a given region of the drowned river mouth.

Invertebrate community composition of the middle wetland sites was the most variable of the three regions yet corresponded predictably to water quality. Middle-Scirpus-12, Middle-Typha-11 and Middle-Sparganium-16, had extremely high nitrate concentrations probably due to their proximity to farm fields. Invertebrate communities at these three sites were similar to lower wetland sites and were characterized by their high abundance of Corixidae and low abundance of *Hyallela azteca*. Middle-Lily-4, Middle-Sparganium-19, Midddle-Sparganium-4 and Middle-Lily-17 were low in nutrients and had a high pH and dissolved oxygen, making them more similar to the upper wetland sites in terms of water quality. Invertebrate communities at these 4 middle sites were also similar to those of the upper wetland (low Corixidae abundance, high *Hyallela azteca* and Coenagrionidae abundances).

The link between invertebrate community composition and anthropogenic disturbance among systems is well established. The current study demonstrates that considerable variability in invertebrate communities due to anthropogenic disturbance can occur within a system.

6.5.2 2002 Watershed Sites

Upon preliminary analysis and site observations, four of the wetland sites sampled in the watershed appear to be relatively pristine. The Carlton Creek, Skeels Creek, Cushman Creek and Alger Rd. sites were relatively low in the chemical/physical parameters generally attributed to anthropogenic disturbance (chloride, nitrate, ammonium and phosphorus). Our observations, taken while sampling, support our suggestion that these four wetlands are among the most pristine of the ten wetlands sampled. All four were surrounded by forest and were either upstream of or not adjacent to major roads.

Three of the ten sites appear to be moderately impacted by anthropogenic disturbance. The Sand Creek site was below an artificial impoundment and nitrate concentrations were the second highest of the ten wetlands. The Sand Creek site was also immediately downstream of Skeels Rd., which presumably impacted the wetland. The Fitzgerald Rd. site also appeared to be moderately impacted upon observation and preliminary analysis. SRP at the Fitzgerald Rd site was the highest of the ten-wetland sites. The wetland at the South Branch site did not have obvious anthropogenic impacts. However, moderately high chloride concentration at the site indicated runoff entering the wetland, probably from Monroe Rd.

Three wetland sites appear to be the most impacted of the ten. The Robinson Creek at Johnson Rd. site looked fairly pristine, however, chloride was higher there than any other site. Elevated conductivity and total dissolved solids at the Robinson Creek at Johnson Rd. site reflects the high concentration of chloride in the wetland. The 148th and Garfield Rd site appeared to be impacted from surrounding agricultural fields and houses. This wetland had the highest nitrate concentration of the ten sites. The Robinson Creek at Baldwin Rd. was downstream of Robinson Lake and had relatively high chloride and ammonium.

With respect to stream water chemistry, the elevated chloride level (51 mg/L) at Heald Creek and the nitrate concentration at Cushman Creek (1.33 mg/L) are indicative of anthropogenic enrichment. A series of abandoned oil wells are located west of the Heald Creek sampling location. Brine leakage from these wells may be entering the creek from groundwater influx. The elevated sulfate concentration (32 mg/L) would also indicate brine contamination as fluids from hydrocarbon bearing formations in west Michigan are known to contain high levels of calcium sulfate (Eberts and George 2000). The elevated nitrate concentration found in Cushman Creek is indicative of agricultural runoff. While the sample was collected in a heavily forested area, the stream character changes several kilometers upstream to a channelized agricultural drain. A previous investigation (Walker 2000) reported a nitrate concentration of 2.3 mg/L in the vicinity of 200th Ave. and noted clumps of *Cladophora* present in the stream channel.

7.0 Conclusions and Recommendations

The White River watershed is the product of the interaction of its unique geologic, hydrologic, ecologic systems. Glacial geology formed the moraine ridges in the headwaters and produced the outwash plains, soil associations, tributary systems, and pitted areas where kettle lakes and depressional wetlands are found. The coupling with Lake Michigan and the influence of its water level fluctuations carved the deep river valleys and formed the extensive drowned rivermouth complex of White Lake and its wetlands. The hydrologic system in the watershed focuses local groundwater into the stream channel, maintains cold temperature environments that support a significant trout fishery, sustains the regional lakes and wetlands, and provides the vehicle that transports and deposits carbon and nutrients throughout the watershed. Using these geologic and hydrologic resources, a diverse array of biological communities function and interact in the upland forests and prairies of the catchment, the transitional wetland areas, and the aquatic systems present in lakes and streams. In its current state, the White River watershed contains approximately 200,000 acres of forest, 43,000 acres of wetlands, 6,300 acres of open water (lakes and streams), and 38,000 acres of open field. Lands under agricultural production and urban land use cover only 28% of the watershed area. These anthropomorphic systems interact with the geologic, hydrologic, and ecologic framework of the watershed to define the structure and function of the entire basin.

In this project, a preliminary assessment of habitats in the White River watershed was conducted. Land cover and land use were evaluated using available remote sensing data to provide an assessment of current conditions and an analysis of significant change over a 20 year period (1978 to 1992/1997/1998). Investigations of water and habitat quality were also conducted in White Lake, the drowned rivermouth wetland, and selected streams and wetlands in the tributaries and branches of the White River. Significant findings of these assessments include:

- Land cover/use on a watershed basis appeared to be stable with forested and wetland areas showing slight increases in total acreage. With respect to agriculture, row crop usage declined with a corresponding increase in orchards and open fields.
- Areas of significant change were noted on a subwatershed basis. The areas of greatest urban growth were concentrated in the US 31 corridor, the villages, and around larger lakes.

- Mid and lower stream sections and wetlands were located in forested areas with riparian vegetative cover and buffers. Wetlands and streams in several of the headwater areas have poor riparian zones.
- The watershed contains a number of rare and endangered habitats including coastal plain marshes, bogs, dry sand prairies, barrens, wet meadows, and mesic prairies. The acreage of Pine/Oak Barrens has decreased by almost 50% over the last 20 years.
- Critical data gaps exist with respect to the hydrologic and ecological information needed to develop effective management plans
- White Lake has remained eutrophic and will require a detailed investigation of nutrient loading to develop a plan to improve water quality.
- The drowned rivermouth was found to be impacted by a combination of agricultural and urban sources.
- Cushman Creek and Heald Creek were found to be impacted by anthropogenic pollution.
- Several wetlands in the upper watershed were impacted by adjacent land use practices (agriculture and road/stream crossings).

While land cover/use patterns appear stable on a watershed level, many of the subwatersheds are experiencing pressures from urban growth. Increased residential development was noted around all of the larger inland lakes including Robinson Lake, Crystal Lake, Diamond Lake, Blue Lake, and McLaren Lake. These lakes are not serviced by public utilities and increased usage of private septic fields may impact groundwater and surface water quality. Urban growth was also noted in the villages of White Cloud, Hesperia, Whitehall, and Rothbury. The US 31 corridor will continue to focus development in the western part of the watershed. In order to prevent further degradation of White Lake and the drowned rivermouth wetlands, adequate planning/zoning regulations plus infrastructure related to wastewater and stormwater systems need to be in place. This corridor also contains prime orchard lands that also may require future planning/zoning activities to preserve their agricultural function. Additional urban growth is occurring in the areas of Hesperia and White Cloud. These villages also have limited utilities and continued growth may influence water quality.

The importance of the Manistee National Forest (MNF) was very visible in the watershed. In addition to preserving terrestrial and aquatic habitats, the forested and undeveloped areas facilitate the accrual of groundwater into streams that have been impacted by riparian zone removal and nonpoint source pollution. This process lowers the stream temperature and dilutes nutrient concentrations. The surrounding forest provides shading of the stream channel and a source of carbon and woody debris. Headwater streams that are outside of the MNF have been converted to agricultural drains in many areas of the North Branch, the South Branch, and the Skeel/Cushman/Braton Creek subwatersheds. In these areas, high nutrient concentrations were noted along with biological disturbances in some of the wetlands. It is critical that public education efforts are conducted in these subwatersheds related to importance of headwater streams and the use of riparian buffers to improve water quality. Many state and federal assistance programs are available to provide technical and financial support to land owners that are interested in implementing best management practices.

The watershed contained a number of rare and endangered habitats including coastal plain marshes, bogs, dry sand prairies, barrens, wet meadows, and mesic prairies. The acreage of Pine/Oak Barrens has decreased by almost 50% over the last 20 years. The presence of these rare habitats and recent loss of acreage underscores the need for the protection and management of these lands. This can be accomplished by land acquisition, the establishment of conservation easements, and the implementation of effective land use planning. While some of these rare habitats are protected on federal lands, environments under private holdings need to be evaluated for long term preservation.

The trophic status of White Lake is of concern based on current and past data. The lake remains eutrophic and subject to excessive nutrient loadings from the White River watershed. Anthropogenic impacts to the wetlands plus tributary loadings appear to be the major factors contributing to eutrophication. Given the complex hydrology of the system and size of the drainage basin, a comprehensive hydrologic model and nutrient budget needs to be prepared for the tributaries in the watershed and White Lake. Interactive models are available that can determine sources and evaluate control technologies in order to prioritize restoration plans in the most beneficial and cost effective manner. A modeling study of this magnitude is expensive, however it is essential to establishment of future courses of action. The intrinsic habitat value of the watershed and its linkage to the Great Lakes can be used as justification for obtaining the necessary grant funding for a modeling project.

Along with the condition of the headwaters and White Lake, the hydrologic and ecologic functioning of the drowned rivermouth wetlands merits special attention. This investigation determined measurable impacts to water chemistry and invertebrate communities from the adjacent land use of this wetland. Based on current and historical data, the drowned rivermouth wetland functions as a nutrient source for White Lake. Modifications to the wetland that restore the natural water flow, reduce nonpoint nutrient loading, and stabilize hydrology will have a positive effect on the habitat quality and the wetland's ability to store and process nutrients. In addition, an investigation phosphorus and nitrogen isotherms in the wetland soils and sediments will determine their ability to serve as a source or sink for nutrients.

The presence of alterations to water and habitat quality in the small sampling of streams and wetlands suggests that a more comprehensive assessment needs to be conducted. The MDEQ collected a number of stream samples during a survey of the White River watershed during the summer of 2002. When these results are available, the data from both projects need to evaluated to determine the nature and extent of water quality issues in the watershed. Information gleaned from more detailed assessments of the system will drive the decision making process for the White River watershed. Again, our ability to develop and effectively implement resource management plans for the White River watershed depends on access to detailed hydrologic and ecological information and the formulation of strategies that include these critical variables. We also need to broaden watershed management plans to holistically embellish the entire resource. The Manistee National Forest is currently managed for the preservation of terrestrial and aquatic habitats. Since this area only covers 23% of the watershed, resource management needs to be expanded through public and private partnerships. It is also important to continue the current programs of stream bank stabilization and substrate enhancement to improve fisheries and protect the watershed from flood events.

Based on the above findings, the following recommendations can be made:

- Establish a watershed assembly to promote, prioritize, and coordinate water quality and habitat management/restoration activities throughout the basin.
- Initiate programs involving public education, best management practices, and land acquisition to promote stewardship, improve environmental quality, and preserve rare habitats.
- Conduct the necessary hydrologic modeling and field validation to evaluate nutrient loading to White Lake and identify critical areas to target source control programs in the upper watershed.
- Develop and implement a plan to restore the drowned rivermouth wetland

From the above discussion, it is clear that we need more information about the watershed to develop management plans. Without this information, it is impossible to prioritize issues, formulate mitigation strategies, and initiate changes that are beneficial to the system. Just as the need for data is critical for the development of watershed management plans, it is also important to disseminate this information to decision makers and the general public. An outreach education program must be developed that identifies the issues and answers, fosters long term stewardship of the resource, and builds effective partnerships that are capable of addressing current and future problems. Public commitment to watershed management depends on understanding the issues and appreciating the value of the resource. . It is critical that the educational program should cover age all groups to include children and adults. By focusing education at both age groups, we can address current problems and ensure that future generations have the commitment to preserve the resources of the White River watershed. We must also communicate this information through a public educational process that fosters resource preservation and stewardship. Education will help foster lasting change.

The data from this project also illustrate the importance of a holistic approach to watershed management. It will be impossible to maintain water and habitat quality on a watershed basis if problems in headwater streams and development pressure are not addressed. The future of the White River watershed depends on a detailed assessment of the resource, the development of a holistic preservation plan, and a strong public education component to promote active stewardship. Watershed management will also require considerable financial resources for analysis and mitigation and utilize resources at local, regional, state, and national levels The White River watershed is a unique and diverse resource with important ecologic and economic value that will require a coordinated and holistic approach for preservation and restoration.

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Appendix

Table A-1. Common Flora Species Found Within The White River Watershed(TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	**625 identified**			
Aceraceae	Acer rubrum	Red Maple		
	Acer saccharinum	Silver Maple		
	Acer saccharum	Sugar Maple		
Anacardiaceae	Rhus copallina	Winged Sumac, Shining Sumac, Dwarf Sumac		
	Rhus typhina	Staghorn Sumac		
	Toxicodendron radicans	Poison Ivy		
	Toxicodendron vernix	Poison Sumac		
Apocyanaceae	Apocynum androsaemifolium	Spreading Dogbane		
	Vinca minor	Periwinkle	A	N
Aquifoliaceae	Ilex verticillata	Winterberry, Michigan Holly		
	Nemopanthus mucronata	Common Mountain Holly		
Araceae	Arisaema atrorubens	Woodland Jack-in-the-pulpit		
	Arisaema triphyllum	Swamp Jack-in-the-pulpit		
	Peltandra virginica	Green Arrow Arum		
	Symplocarpus foetidus	Skunk Cabbage		
Araliaceae	Aralia nudicaulis	Wild Sarsaparilla		
	Aralia racemosa	Spikenard		
Asclepiadaceae	Ascelpias exaltata	Poke Milkweed		
	Asclepias amplexicaulis	Blunt-leaved Milkweed		
	Asclepias incarnata	Swamp Milkweed		
	Asclepias syriaca	Common Milkweed		
	Asclepias tuberosa	Butterfly-weed		
	Asclepias verticillata	Whorled Milkweed		
	Asclepias viridiflora	Green Milkweed		
Balsaminaceae	Impatiens capensis	Jewelweed, Spotted Touch-Me-Not		N
Berberidaceae	Berberis thunbergii	Japanese Barberry	A	
	Podophyllum peltatum	Mayapple, Mandrake		
Betulaceae	Alnus rugosa	Speckled Alder; Tag Alder		
	Betula alleghaniensis	Yellow Birch		
	Betula papyrifera	Paper Birch		
	Carpinus caroliniana	Musclewood, Hornbeam		
	Ostrya virginiana	Hop-hornbeam		
Boraginaceae	Lithospermum canescens	Hoary Puccoon		N
	Lithospermum carolinense	Hairy Puccoon		
	Myosotis scorpioides	Water Forget-me-not, True Forget-me-not	A	N
	Myosotis stricta	Blue Scorpion-grass	A	N
	Myosotis sylvatica	Woods Forget-me-not	A	N
Campanulaceae	Campanula aparinoides	Marsh Bellflower, Bedstraw Bellflower		
	Campanula rotundifolia	Harebell		
	Lobelia cardinalis	Cardinal-flower		
	Lobelia siphilitica	Great Blue Lobelia		
	Lobelia sp.	Lobelia		
	Lobelia spicata	Pale-Spike Lobelia		
	Triodanis perfoliata	Round-leaved Triodanis, Venus' Looking-glass		
Cannabaceae	Humulus lupulus	Common Hop		
Caprifoliaceae	Diervilla lonicera	Bush Honeysuckle		
	Lonicera canadensis	Canada Fly-Honeysuckle		N
	Lonicera dioica	Wild Honeysuckle		
	Lonicera tatarica	Tartarian Honeysuckle	A	N
	Sambucus canadensis	Common Elder		
	Symphoricarpos albus	Snowberry		
	Viburnum acerifolium	Maple-leaved Viburnum		
	Viburnum lentago	Nannyberry; Sheepberry		
	Viburnum opulus	Highbush Cranberry		
Caryophyllaceae	Arenaria serpyllifolia	Thyme-leaved Sandwort	A	
	Arenaria stricta	Rock Sandwort		N
	Cerastium fontanum	Mouse-ear Chickweed	A	
	Dianthus armeria	Deptford Pink	A	
	Lychnis coronaria	Mullein Pink	A	
	Saponaria officinalis	Soapwort, Bouncing Bet	A	
	Scleranthus annuus	Knawel	A	
	Silene antirrhina	Sleepy Silene		
	Silene vulgaris	Bladder Campion	A	
	Stellaria longifolia	Chickweed, Stitchwort		

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	(cont'd…)			
Caryophyllaceae	Stellaria media	Common Chickweed	A	
Celastraceae	Celastrus scandens	American Bittersweet		
Chenopodiaceae	Chenopodium album	Lamb's Quarters		
Cistaceae	Helianthemum bicknellii	Bicknell's Frostweed		N
	Helianthemum canadense	Frostweed		
	Lechea villosa	Pinweed, Hairy Pinweed		
Compositae	Achillea millefolium	Common Yarrow		
	Ambrosia artemisiifolia	Common Ragweed		
	Ambrosia psilostachya	Western Ragweed		
	Anaphalis margaritacea	Pearly Everlasting		
	Antennaria howellii	Howell's Field Pussytoes		
	Antennaria parlinii	Plaintain Pussytoes		
	Antennaria sp.	Pussytoes		
	Artemisia campestris	Wild Wormwood		
	Aster dumosus	Bushy Aster		
	Aster laevis	Smooth Aster		
	Aster macrophyllus	Big-leaved Aster		
	Aster ontarionis	Bottomland Aster, Ontario Aster		
	Aster sagittifolius	Arrow-leaved Aster		N
	Aster sp.	Aster		
	Bidens cernuus	Nodding Bur-marigold		
	Bidens connatus	Purplestem Tickseed		
	Bidens sp.	Bidens, Beggar-ticks		
	Centaurea maculosa	Spotted Knapweed	A	
	Chondrilla juncea	Skeleton-weed	A	N
	Chrysanthemum leucanthemum	Oxeye Daisy	A	
	Cirsium arvense	Canada Thistle	A	
	Cirsium hillii	Hill's Thistle	SR	
	Cirsium muticum	Swamp Thistle		
	Cirsium vulgare	Bull Thistle	A	
	Coreopsis lanceolata	Lance-leaved Coreopsis, Sand Coreopsis		
	Erechtites hieracifolia	Fireweed		
	Erigeron canadensis	Horseweed		
	Erigeron strigosus	Daisy Fleabane		
	Eupatorium maculatum	Joe-pye Weed		
	Eupatorium perfoliatum	Boneset		
	Euthamia graminifolia	Grass-leaved Goldenrod		
	Euthamia remota	Lakes Flat-topped Goldenrod		
	Gnaphalium macounii	Clammy Cudweed, Green Everlasting		N
	Gnaphalium obtusifolia	Catfoot, Sweet Everlasting		
	Helianthus divaricatus	Woodland Sunflower		
	Helianthus hirsutus	Hairy Sunflower, Whiskered Sunflower	SC	N
	Helianthus occidentalis	Western Sunflower		
	Hieracium aurantiacum	Orange Hawkweed	A	
	Hieracium caespitosum	Yellow Hawkweed	A	N
	Hieracium gronovii	Hairy Hawkweed		
	Hieracium longipilum	Hairy Hawkweed, Long-bearded Hawkweed		
	Hieracium scabrum	Rough Hawkweek		
	Hieracium venosum	Rattlesnake-weed		
	Hypochaeris radicata	Cat's-ear	A	N
	Krigia biflora	Two-flowered Cynthia		N
	Krigia virginica	Dwarf Dandelion		
	Lactuca canadensis	Canada Lettuce, Wild Lettuce		
	Lactuca sp.	Wild Lettuce		
	Liatris cylindracea	Cylindric Blazing-star		
	Liatris sp.	Blazing-star		
	Prenanthes sp.	Rattlesnakeroot		
	Rudbeckia hirta	Black-eyed Susan		
	Rudbeckia laciniata	Cut-leaved Coneflower		
	Senecio aureus	Golden Ragwort		N
	Senecio plattensis	Prairie Ragwort		
	Solidago caesia	Wreath Goldenrod		
	Solidago canadensis	Canada Goldenrod		N
	Solidago hispida	Goldenrod		

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	(cont'd…)			
Compositae	Solidago juncea	Early Goldenrod		
	Solidago nemoralis	Gray Goldenrod		
	Solidago patula	Rough-leaved Goldenrod		
	Solidago rigida	Stiff Goldenrod		N
	Solidago rugosa	Rough-stemmed Goldenrod		
	Symphyotrichum cordifolium	Common Blue Wood Aster, Heart-leaved Aster		
	Symphyotrichum puniceum	Purplestem Aster		N
	Taraxacum officinale	Common Dandelion	A	
	Tragopogon dubius	Sand Goat's Beard	A	
	Tragopogon pratensis	Yellow Goat's-beard	A	
Cornaceae	Cornus amomum	Pale Dogwood		
	Cornus canadensis	Dwarf Dogwood, Bunchberry		
	Cornus florida	Flowering Dogwood		
	Cornus foemina	Gray Dogwood		
	Cornus stolonifera	Red-osier Dogwood		
Cruciferae	Arabidopsis thaliana	Mouse-ear Cress	A	
	Arabis canadensis	Sickle-pod		
	Arabis glabra	Tower Rockcress, Tower Mustard		
	Arabis lyrata	Lyre-leaved Rock Cress, Sand Cress		
	Arabis sp.	Rock Cress		
	Barbarea vulgaris	Garden Yellowrocket	A	
	Berteroa incana	Hoary Allyssum	A	
	Cardamine bulbosa	Spring Cress		N
	Lepidium campestre	Field Pepperweed	A	
	Lepidium virginicum	Peppergrass		
	Nasturtium officinale	Watercress	A	
	Rorippa palustris	Marsh Watercress		
Cupressaceae	Thuja occidentalis	Arbor Vitae, Northern White-cedar		
Cyperaceae	Carex adusta	Browned Sedge		N
	Carex alata	Winged Sedge		
	Carex aquatilis	Water Sedge		
	Carex atherodes	Wheat Sedge, Slough Sedge		N
	Carex bebbii	Bebb's Sedge		
	Carex blanda	Woodland Sedge		
	Carex brevior	Fescue Sedge, Plains Oval Sedge		N
	Carex bromoides	Brome-like Sedge		
	Carex brunnescens	Brownish Sedge		
	Carex comosa	Bristly Sedge		
	Carex crinita	Fringed Sedge		
	Carex cristatella	Crested Sedge		
	Carex cryptolepis	Little Yellow Sedge		
	Carex debilis	White-edge Sedge		
	Carex deweyana	Dewey's Sedge		N
	Carex disperma	Softleaf Sedge		
	Carex echinata	Star Sedge		
	Carex emmonsii	Sedge		
	Carex foena	Hay Sedge		N
	Carex gracillima	Graceful Sedge		
	Carex hystericina	Porcupine Sedge		
	Carex interior	Inland Sedge		
	Carex intumescens	Bladder Sedge		
	Carex lacustris	Lake-bank Sedge		
	Carex laevivaginata	Smooth-sheathed Sedge		
	Carex lasiocarpa	Sedge		
	Carex leptalea	Bristle-stalked Sedge		
	Carex leptonervia	Sedge		
	Carex lupulina	Hop Sedge		
	Carex muhlenbergia	Muhlenberg's Sedge		
	Carex pedunculata	Longstalk Sedge		
	Carex pensylvanica	Pennsylvania Sedge		
	Carex pseudo-cyperus	Cyperus-like Sedge		
	Carex rugosperma	Rough-seeded Sedge		
	Carex stipata	Awl-fruited Sedge		
	Carex stricta	Tussock Sedge		

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	**(cont'd…)**			
Gramineae	Bromus kalmii	Prairie Brome		
	Bromus pubescens	Canada Brome		
	Bromus sp.	Brome Grass		
	Calamogrostis canadensis	Blue-joint		
	Cinna arundinacea	Large Wood-reed, Common Wood Reedgrass		
	Cinna latifolia	Drooping Wood Reedgrass		
	Dactylis glomerata	Orchard Grass	A	
	Danthonia spicata	Poverty Oatgrass, Common Wild Oatgrass		
	Deschampsia flexuosa	Hair Grass, Wavy Hair Grass		
	Dichanthelium linearifolium	Slimleaf Panicgrass		N
	Dichanthelium oligosanthes	Rosette Grass		
	Digitaria ischaemum	Smooth Crab Grass	A	N
	Eleocharis erythropoda	Creeping Spikerush		
	Eleocharis intermedia	Matted Spikerush		
	Eleocharis olivacea	Bright-green Spikerush		
	Eleocharis robbinsii	Robbins' Spikerush		
	Eleocharis smallii	Small's Spikerush		
	Elymus hystrix	Bottle-brush Grass		N
	Elymus virginicus	Virginia Wild Rye		N
	Eragrostis pectinacea	Small Love Grass		
	Eragrostis spectabilis	Purple Lovegrass		
	Festuca octoflora	Six-weeks Fescue		
	Glyceria borealis	Northern Mannagrass		N
	Glyceria canadensis	Rattlesnake Grass		
	Glyceria septentrionalis	Eastern Mannagrass, Snakegrass		
	Glyceria striata	Fowl Manna Grass		
	Hystrix patula	Bottlebrush Grass		
	Koeleria macrantha	June Grass		
	Leersia oryzoides	Rice Cutgrass		
	Leersia virginica	White Grass		
	Milium effusum	American Milletgrass		
	Muhlenbergia mexicana	Leafy Satin Grass		
	Muhlenbergia schreberi	Nimblewill		
	Muhlenbergia tenuiflora	Slender Satin Grass		N
	Oryzopsis asperifolia	Rough-leaved Ricegrass		
	Oryzopsis pungens	Slender Ricegrass		
	Oryzopsis racemosa	Black-fruited Ricegrass		
	Panicum boreale	Panic grass		
	Panicum capillare	Witch Grass		
	Panicum clandestinum	Deer-tongue Grass		
	Panicum commutatum	Ashe's Panic grass		
	Panicum depauperatum	Starved Panic grass		
	Panicum dichotomum	Forked Panic grass		
	Panicum implicatum	Slender-stemmed Panic grass		
	Panicum latifolium	Broad-leaved Panic grass		
	Panicum meridionale	Mat Panic grass		
	Panicum philadelphium	Tuckerman Panic grass		N
	Panicum praecocius	Early-branching Panic grass		N
	Panicum sp.	Panic grass		
	Panicum sphaerocarpon	Round-fruited Panic grass		
	Panicum virgatum	Switchgrass		
	Phalaris arundinacea	Reed Canary Grass		N
	Phleum pratense	Timothy	A	
	Poa compressa	Canada Bluegrass	A	
	Poa languida	Weak Bluegrass		
	Poa nemoralis	Wood Bluegrass	A	N
	Poa palustris	Fowl Meadow Grass		
	Poa pratensis	Kentucky Bluegrass	A	
	Schizachne purpurascens	False Melic		
	Spartina pectinata	Prairie Cordgrass		N
	Sporobolus cryptandrus	Sand Dropseed		N
	Stipa avenacea	Needlegrass, Black Oat Grass		
	Stipa spartea	Porcupine Grass, Needle Grass		
	Triplasis purpurea	Chapman Purple Sandgrass	SR	N

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	(cont'd…)			
Grossulariaceae	Ribes cynosbati	Prickly Or Wild Gooseberry		
	Ribes sp.	Gooseberry		
	Ribes triste	Red Currant		
Guttiferae	Hypericum majus	Large St. John's-wort		
	Hypericum mutilum	Dwarf St. John's-wort		
	Hypericum perforatum	Common St. John's-wort	A	
	Hypericum punctatum	Spotted St. John's-wort		
	Triadenum fraseri	Marsh St John's-wort		
	Triadenum virginicum	Marsh St. John's-wort		N
Haloragaceae	Proserpinaca palustris	Cut-leaved Mermaid weed		
Haloragales	Myriophyllum spicatum	Eurasian Water-milfoil	A	N
Hammamelidaceae	Hamamelis virginiana	Witch Hazel		
Hydrocharitaceae	Elodea canadensis	Common Waterweed		
	Vallisneria americana	Eel Grass		
Iridaceae	Iris versicolor	Northern Blue Flag		N
Juglandaceae	Juglans nigra	Black Walnut		N
Juncaceae	Juncus balticus	Lakeshore Rush		
	Juncus brachycephalus	Short-headed Rush		N
	Juncus bufonius	Toad Rush		
	Juncus canadensis	Canadian Rush		
	Juncus effusus	Soft Rush		
	Juncus nodosus	Joint Rush		
	Juncus tenuis	Poverty Rush, Path Rush		
Labiatae	Ajuga reptans	Carpet Bugle	A	N
	Clinopodium vulgare	Wild-basil		
	Glechoma hederacea	Gill-over-the-ground	A	N
	Lycopus americanus	Water Horehound		
	Lycopus sp.	Water-horehound		
	Lycopus uniflorus	Horehound, Northern Bugleweed		
	Mentha ×piperita [aquatica ×spicata]	Peppermint	A	
	Mentha arvensis	Common Mint, Field Mint		
	Mentha spicata	Spearmint	A	
	Monarda fistulosa	Wild Bergamot		
	Monarda punctata	Horsemint		
	Prunella vulgaris	Common Selfheal		
	Satureja vulgaris	Basil	A	
	Scutellaria galericulata	Marsh Skullcap		
	Scutellaria lateriflora	Mad-dog Skullcap		
	Stachys hyssopifolia	Hyssop Hedge-nettle		
	Teucrium canadense	American Germander, Wood-sage		
Lauraceae	Lindera benzoin	Spicebush		
	Sassafras albidum	Sassafras		
Leguminosae	Amphicarpaea bracteata	Hog-peanut		
	Apios americana	Groundnut		
	Desmodium glutinosum	Wood Pointedleaf Tick-trefoil		
	Desmodium nudiflorum	Naked-flowered Tick-trefoil		
	Desmodium paniculatum	Panicled Tick-trefoil		
	Desmodium rotundifolium	Prostrate Tick-trefoil		
	Lathyrus palustris	Marsh Pea		
	Lespedeza hirta	Hairy Bush-clover		
	Lespedeza violacea	Violet Lespedeza		N
	Lupinus perennis	Wild Lupine		
	Melilotus alba	White Sweet Clover	A	
	Melilotus officinalis	Yellow Sweet Clover	A	
	Robinia pseudoaccacia	Black Locust	A	
	Tephrosia virginiana	Goat's Rue		
	Trifolium arvense	Rabbit-foot Clover		
	Trifolium pratense	Red Clover	A	
	Trifolium repens	White Clover		
	Vicia cracca	Cow Vetch	A	N
Lemnaceae	Lemna minor	Small Duckweed		
Lentibulariaceae	Utricularia gibba	Humped Bladderwort		
	Utricularia intermedia	Flatleaf Bladderwort		
	Utricularia sp.	Bladderwort		

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	(cont'd…)			
Liliaceae	Asparagus sp.	Asparagus	A	
	Clintonia borealis	Blue-bead Lily; Clintonia		
	Convallaria majus	Lily-of-the-Valley	A	N
	Lilium michiganense	Michigan Lily		
	Maianthemum canadense	Canada Mayflower		
	Medeola virginiana	Indian Cucumber Root		
	Polygonatum biflorum	Solomon's-seal		N
	Polygonatum pubescens	Hairy Solomon's-seal, Downy Solomon-seal		
	Smilacina racemosa	False Solomon's-seal		
	Smilacina stellata	Starry False Solomon-seal		
	Smilax ecirrata	Upright Carrion-flower		
	Smilax sp.	Smooth Greenbrier		
	Smilax tamnoides	Bristly Greenbrier		
	Trillium cernuum	Nodding Trillium		N
	Trillium grandiflorum	Common Trillium		
	Uvularia grandiflora	Large Bellwort		
	Uvularia sessilifolia	Wild Oats, Sessile Bellwort		N
Lythraceae	Decodon verticillatus	Swamp Loosestrife, Water-willow		
	Lythrum salicaria	Purple or Spiked Loosestrife	A	
Magnoliaceae	Liriodendron tulipifera	Tuliptree, Yellow Poplar, Tulip Poplar		N
Menispermaceae	Menispermum canadense	Moonseed		
Menyanthaceae	Menyanthes trifoliata	Buckbean		N
Monotropeaceae	Monotropa hypopithys	Pinesap		
	Monotropa uniflora	Indian-pipe		
Moraceae	Morus alba	White Mulberry	A	
Mulluginaceae	Mollugo verticillata	Carpetweed	A	
Myricaceae	Comptonia peregrina	Sweet-fern		
Najadaceae	Najas flexilis	Slender Naiad		
	Najas guadalupensis	Southern Naiad		N
Nymphaeceae	Nuphar variegatum	Bullhead-lily		
	Nymphaea odorata	Fragrant Water-lily		
	Brasenia schreberi	Water-shield		
Oleaceae	Fraxinus nigra	Black Ash		N
	Fraxinus pennsylvanica	Green Ash		
Onagraceae	Circaea alpina	Smaller Enchanter's nightshade		
	Epilobium ciliatum	Northern Willow-herb		N
	Oenothera clelandii	Cleland's Evening-primrose		
	Oenothera parviflora	Small-flowered Evening-primrose		N
	Oenothera perennis	Sundrops		
Orchidaceae	Corallorhiza maculata	Spotted Coralroot		
	Cypripedium acaule	Pink Lady's-slipper, Moccasin-flower		
	Cypripedium reginae	Showy Lady's-slipper		
	Epipactis helleborine	Broadleaf Helleborine		N
	Platanthera clavellata	Club-spur Orchid		
	Platanthera hyperborea	Tall Northern Bog Orchid		
	Platanthera orbiculata	Large Round-leaved Orchid		
	Platanthera psycodes	Small Purple Fringed Orchid		
Orobanchaceae	Conopholis americana	Squawroot		
	Epifagus virginiana	Beech-drops		
Oxalidaceae	Oxalis sp.	Oxalis, Wood-sorrel		
	Oxalis stricta	Common Yellow Wood-sorrell		
Phytolacceae	Phytolacca americana	Pokeweed		
	Phytolacca sp.	Pokeweed		
Pinaceae	Larix laricina	Tamarack; Larch		
	Picea abies	Norway Spruce	A	N
	Pinus banksiana	Jack Pine		
	Pinus resinosa	Red Pine		
	Pinus strobus	White Pine		
	Tsuga canadensis	Eastern Hemlock		
Plantaginaceae	Plantago lanceolata	English Plantain	A	
	Plantago major	Common Plantain		N
	Plantago rugelii	Blackseed Plaintain		
Plumbaginaceae	Limonium carolinianum	Sea Lavendar		N
Polemoniaceae	Phlox pilosa	Downy Phlox		N

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

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	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	(cont'd…)			
Polygalaceae	Polygala paucifolia	Fringed Polygala, Gaywings		
	Polygala polygama	Racemed Milkwort		
Polygonaceae	Polygonella articulata	Jointweed		
	Polygonum amphibium	Water Smartweed		
	Polygonum aviculare	Prostrate Knotweed	A	
	Polygonum douglassii	Douglas Knotweed		
	Polygonum hydropiperoides	Mild Waterpepper		
	Polygonum persicaria	Lady's thumb	A	
	Polygonum punctatum	Dotted Smartweed		
	Polygonum sagittatum	Arrowleaf Tearthumb		
	Polygonum scandens	Climbing False Buckwheat		
	Polygonum tenue	Pleatleaf Knotweed, Slender Knotweed		
	Rumex acetosella	Sheep Sorrel	A	
	Rumex crispus	Curly Dock	A	
	Rumex orbiculatus	Great Water Dock		
	Rumex verticillatus	Water Dock		
Pontederiaceae	Pontederia cordata	Pickerel-weed		
Potamogetonaceae	Potamogeton amplifolius	Large-leaved Pondweed		
	Potamogeton crispus	Curly Pondweed	A	
	Potamogeton filiformis	Slender Pondweed		N
	Potamogeton foliosus	Leafy Pondweed		N
	Potamogeton illinoensis	Illinois Pondweed		
	Potamogeton natans	Floating Pondweed		
	Potamogeton nodosus	Longleaf Pondweed		
	Potamogeton pectinatus	Sago Pondweed		
	Potamogeton richardsonii	Richardson's Pondweed		
	Potamogeton strictifolius	Straight-leaved Pondweed		N
Primulaceae	Lysimachia ciliata	Fringed Loosestrife		
	Lysimachia lanceolata	Lance-leaved Loosestrife		
	Lysimachia thyrsiflora	Tufted Loosestrife		
	Trientalis borealis	Starflower		
Pyrolaceae	Chimaphila umbellata	Pipsissewa		
	Orthilia secunda	One-sided Shinleaf, Sidebells Wintergreen		
	Pyrola clorantha	Greenish-flowered Shinleaf		
Ranunculaceae	Actaea pachypoda	White Baneberry		
	Actaea rubra	Red Baneberry		
	Actaea sp.	Baneberry		
	Anemone canadensis	Canada Anemone		
	Anemonella thalictroides	Rue-anemone		N
	Aquilegia canadensis	Wild Columbine		
	Caltha palustris	Marsh-marigold		
	Coptis trifolia	Goldthread		
	Hepatica americana	Round-lobed Hepatica		
	Ranunculus fascicularis	Early Buttercup		
	Ranunculus flabellaris	Aquatic Buttercup		N
	Ranunculus longirostris	White Water Crowfoot		
	Ranunculus recurvatus	Blisterwort		
	Thalictrum dasycarpum	Purple Meadow-rue		
	Thalictrum sp.	Meadow-rue		
Rhamnaceae	Ceanothus americanus	New Jersey Tea		
	Rhamnus alnifolia	Alder Buckthorn		N
Rosaceae	Agrimonia gryposepala	Tall Hairy Agrimony		
	Amelanchier arborea	Serviceberry		
	Amelanchier laevis	Smooth Juneberry		N
	Amelanchier sp.	Juneberry		
	Aronia prunifolia	Chokeberry		
	Crataegus sp.	Hawthorn		
	Fragaria virginiana	Wild Strawberry		
	Geum aleppicum	Yellow Avens		
	Geum sp.	Avens		
	Geum triflorum	Prairie-smoke	ST	
	Malus sp.	Apple		
	Physocarpus opulifolius	Ninebark		
	Potentilla anserina	Silverweed		

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

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	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	(cont'd…)			
Rosaceae	Potentilla argentea	Silvery Cinquefoil	A	
	Potentilla norvegica	Norwegian Cinquefoil		
	Potentilla palustre	Purple Marshlocks		
	Potentilla simplex	Common Cinquefoil		
	Prunus americanum	American Plum		N
	Prunus avium	Sweet Cherry; Mazzard		N
	Prunus pumila	Sand Cherry		
	Prunus serotina	Wild Black Cherry		
	Prunus virginiana	Choke Cherry		
	Rosa blanda	Meadow Rose		
	Rosa carolina	Carolina Rose		
	Rosa palustris	Swamp Rose		
	Rosa sp.	Wild Rose		
	Rubus allegheniensis	Common Blackberry		
	Rubus flagellaris	Northern Dewberry		
	Rubus hispidus	Bristly Dewberry		
	Rubus pubescens	Dwarf Raspberry		
	Rubus sp.	Raspberry, Bramble		
	Rubus strigosus	Wild Red Raspberry		
	Spiraea ×vanhouttei	[cantoniensis × trilobata]		N
	Spiraea alba	Meadowsweet		
	Spiraea tomentosa	Steeplebush		
Rubiaceae	Cephalanthus occidentalis	Buttonbush		
	Galium aparine	Cleavers	A	
	Galium asprellum	Rough Bedstraw		
	Galium circaezans	White Wild Licorice		
	Galium pilosum	Hairy Bedstraw		
	Galium sp.	Bedstraw		
	Galium tinctorium	Stiff Marsh Bedstraw		
	Galium triflorum	Fragrant Bedstraw		
	Houstonia longifolia	Long-leaved Bluets		N
	Houstonia sp.	Bluets		
	Mitchella repens	Partridgeberry		
Salicaceae	Populus deltoides	Cottonwood		
	Populus grandidentata	Big-toothed Aspen		
	Populus tremuloides	Quaking Aspen		
	Salix amygdaloides	Peach-leaf Willow		
	Salix bebbiana	Bebb's Willow, Beaked Willow		
	Salix discolor	Pussy Willow		
	Salix eriocephala	Heart-leaved Willow		
	Salix exigua	Sandbar Willow		
	Salix humilus	Upland Willow, Prairie Willow		
	Salix lucida	Shining Willow		
	Salix nigra	Black Willow		
	Salix petiolaris	Slender Willow, Meadow Willow		
	Salix sp.	Willow		
Santalaceae	Comandra umbellata	Bastard-toadflax; Star-toad Flax		
Sarraceniaceae	Sarracenia purpurea	Pitcher-plant		
Saxifragaceae	Chrysosplenium americanum	Golden Saxifrage		
	Mitella diphylla	Bishop's-cap, Miterwort		
	Mitella nuda	Naked Miterwort		
	Parnassia glauca	Grass-of-Parnassus		N
	Saxifraga pensylvanica	Swamp Saxifrage		
Scrophulariaceae	Agalinis purpurea	Purple Gerardia		
	Aureolaria flava	Yellow False Foxglove		
	Aureolaria pedicularia	Fern-leaved False Foxglove		
	Chelone glabra	White Turtlehead		
	Linaria canadensis	Blue Toadflax		
	Linaria dalmatica	Dalmatian Toadflax	A	
	Linaria vulgaris	Butter-and-Eggs	A	
	Melampyrum lineare	Cow-wheat		
	Mimulus glabratus var. jamesii	James' Monkey-flower		
	Mimulus sp.	Monkey-flower		
	Pedicularis canadensis	Wood-betony, Lousewort		N

Table A-1 (continued). Common Flora Species Found Within The White River Watershed (TNC 2002).

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	Scientific Name	Common Name	Status	Muskegon County Status (N= New)
VASCULAR PLANTS	(cont'd…)			
Scrophulariaceae	Pedicularis lanceolata	Swamp Lousewort		
	Verbascum blattaria	Moth Mullein	A	
	Verbascum thapsus	Common Mullein	A	
	Veronica beccabunga	Brooklime		
	Veronica sp.	Speedwell		
Solanaceae	Physalis heterophylla	Clammy Ground-cherry		
	Solanum dulcamara	Nightshade, Bittersweet	A	
	Solanum ptychanthum	Black Nightshade		N
Sparganiaceae	Sparganium sp.	Bur-reed		
Tiliaceae	Tilia americana	Basswood		
Typhaceae	Typha angustifolia	Narrow-leaved Cat-tail	A	
	Typha latifolia	Common Cattail		N
Ulmaceae	Ulmus americana	American Elm		
Ulmaceae	Ulmus rubra	Red Elm		N
Umbelliferae	Berula erecta	Toothache Root, Giant Water Parsnip	ST	N
	Cicuta bulbifera	Bulb-bearing Water-hemlock		
	Cicuta maculata	Spotted Water Hemlock		
	Daucus carota	Queen Anne's Lace, Wild Carrot	A	
Umbelliferae	Erigenia bulbosa	Harbinger-of-spring		N
	Hydrocotyle americana	Pennywort, Water Pennywort		
	Osmorhiza sp.	Sweet Cicely		
	Sanicula marilandica	Black Snakeroot		
	Sium suave	Water-parsnip		
	Taenidia integerrima	Yellow-pimpernel		
Urticaceae	Boehmeria cylindrica	False Nettle		
	Pilea fontana	Lesser Clearweed		
	Urtica dioica	Stinging Nettle		
Verbenaceae	Phryma leptostachia	Lopseed		
	Verbena hastata	Blue Vervain		
	Verbena stricta	Hoary Vervain		
Violacea	Viola adunca	Hooked-spurred Violet		
	Viola arvensis	Field Pansy	A	N
	Viola blanda	Sweet White Violet		
	Viola conspersa	Dog Violet		
	Viola cucullata	Marsh Violet		
	Viola lanceolata	Lance-leaved Violet		
	Viola macloski var. pallens	Wild White Violet		N
	Viola palmata	Early Blue Violet		N
	Viola pedata	Bird's-foot Violet		
	Viola pubescens	Yellow Violet		
	Viola sagittata	Arrowhead-violet		
	Viola sororia	Common Blue Violet		
Vitaceae	Parthenocissus inserta	Thicket Creeper		
	Parthenocissus quinquefolia	Virginia Creeper		
	Vitis aestivalis	Summer Grape		
	Vitis riparia	River-bank Grape		
	Vitis riparis	Wild Grape		
Xyridaceae	Xyris difformis	Carolina Yellow-eyed grass		

Table A-2 Bird, Amphibian, And Reptile Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status
BIRDS	118 identified		
	Accipiter striatus	Sharp-shinned Hawk	
	Actitis macularia	Spotted Sandpiper	
	Agelaius phoeniceus	Red-winged Blackbird	
	Aix sponsa	Wood Duck	
	Anas platyrhynchos	Mallard	
	Archilochus colubris	Ruby-throated Hummingbird	
	Ardea herodias	Great Blue Heron	
	Baeolophus bicolor	Eastern Tufted Titmouse	
	Bombycilla cedrorum	Cedar Waxwing	
	Bonasa umbellus	Ruffed Grouse	
	Branta canadensis	Canada Goose	
	Bubo virginianus	Great Horned Owl	
	Buteo jamaicensis	Red-tailed Hawk	
	Buteo lineatus	Red-shouldered Hawk	ST
	Caprimulgus vociferus	Whip-poor-will	
	Cardinalis cardinalis	Northern Cardinal	
	Carduelis tristis	American Goldfinch	
	Carpodacus mexicanus	House Finch	
	Cathartes aura	Turkey Vulture	
	Catharus fuscescens	Veery	
	Catharus guttatus	Hermit Thrush	
	Catharus minimus	Gray-cheeked Thrush	
	Catharus ustulatus	Swainson's Thrush	
	Ceryle alcyon	Belted Kingfisher	
	Chaetura pelagica	Chimney Swift	
	Charadrius vociferus	Killdeer	
	Chordeiles minor	Common Nighthawk	
	Coccyzus americanus	Yellow-billed Cuckoo	
	Coccyzus erythropthalmus	Black-billed Cuckoo	
	Colaptes auratus	Northern Flicker, Yellow-shafted Flicker	
	Contopus virens	Eastern Wood-Pewee	
	Corvus brachyrhynchos	American Crow	
	Cyanocitta cristata	Blue Jay	
	Cygnus olor	Mute Swan	
	Dendroica caerulescens	Black-throated Blue Warbler	
	Dendroica castanea	Bay-breasted Warbler	
	Dendroica cerulea	Cerulean Warbler	SR
	Dendroica coronata	Yellow-Rumped Warbler, Myrtle Warbler	
	Dendroica fusca	Blackburnian Warbler	
	Dendroica magnolia	Magnolia Warbler	
	Dendroica palmarum	Western Palm Warbler	
	Dendroica pensylvanica	Chestnut-sided Warbler	
	Dendroica petechia	Yellow Warbler	
	Dendroica pinus	Pine Warbler	
	Dendroica striata	Blackpoll Warbler	
	Dendroica tigrina	Cape May Warbler	
	Dendroica virens	Black-throated Green Warbler	
	Dolichonyx oryzivorus	Bobolink	
	Dryocopus pileatus	Pileated Woodpecker	
	Dumetella carolinensis	Gray Catbird	
	Empidonax flaviventris	Yellow-bellied Flycatcher	
	Empidonax minimus	Least Flycatcher	
	Empidonax virescens	Acadian Flycatcher	
	Gavia immer	Common Loon	ST
	Geothlypis trichas	Common Yellowthroat	
	Haliaeetus leucocepalus	Bald Eagle	ST
	Hirundo rustica	Barn Swallow	
	Hylocichla mustelina	Wood Thrush	
	Icterus galbula	Baltimore Oriole, Northern Oriole	
	Larus spp.	Gull	
	Larus delawarensis	Ring-billed Gull	
	Melanerpes carolinus	Red-bellied Woodpecker	
	Melanerpes erythrocephalus	Red-headed Woodpecker	
	Meleagris gallopavo	Wild Turkey	
	Melospiza georgiana	Swamp Sparrow	

Table A-2 (continued). Bird, Amphibian, And Reptile Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status
BIRDS (cont'd…)			
	Melospiza melodia	Song Sparrow	
	Mniotilta varia	Black-and-white Warbler	
	Molothrus ater	Brown-headed Cowbird	
	Myiarchus crinitus	Great Crested Flycatcher	
	Oporornis philadelphia	Mourning Warbler	
	Otus asio	Eastern Screech Owl	
	Parula americana	Northern Parula Warbler	
	Passerina cyanea	Indigo Bunting	
	Petrochelidon pyrrhonota	Cliff Swallow	
	Phalacrocorax auritus	Double-crested Cormorant	
	Pheucticus ludovicianus	Rose-breasted Grosbeak	
	Picoides pubescens	Downy Woodpecker	
	Picoides villosus	Hairy Woodpecker	
	Pipilo erythrophthalmus	Eastern Towhee, Rufous-sided Towhee	
	Piranga olivacea	Scarlet Tanager	
	Poecile atricapilla	Black-capped Chickadee	
	Polioptila caerulea	Blue-gray Gnatcatcher	
	Pooecetes gramineus	Vesper Sparrow	
	Progne subis	Purple Martin	
	Quiscalus quiscula	Common Grackle	
	Regulus calendula	Ruby-crowned Kinglet	
	Riparia riparia	Bank Swallow	
	Sayornis phoebe	Eastern Phoebe	
	Scolopax minor	American Woodcock	
	Seiurus aurocapillus	Ovenbird	
	Seiurus motacilla	Louisiana Waterthrush	SR
	Seiurus noveboracensis	Northern Waterthrush	
	Setophaga ruticilla	American Redstart	
	Sialia sialis	Eastern Bluebird	
	Sitta canadensis	Red-breasted Nuthatch	
	Sitta carolinensis	White-breasted Nuthatch	
	Spizella passerina	Chipping Sparrow	
	Spizella pusilla	Field Sparrow	
	Stelgidopteryx serripennis	Northern Rough-winged Swallow	
	Sturnus vulgaris	European Starling	
	Tachycineta bicolor	Tree Swallow	
	Toxostoma rufum	Brown Thrasher	
	Tringa solitaria	Solitary Sandpiper	
	Troglodytes aedon	House Wren	
	Turdus migratorius	American Robin	
	Tyrannus tyrannus	Eastern Kingbird	
	Vermivora chrysoptera	Golden-winged Warbler	
	Vermivora peregrina	Tennessee Warbler	
	Vermivora pinus	Blue-winged Warbler	
	Vermivora ruficapilla	Nashville Warbler	
	Vireo flavifrons	Yellow-throated Vireo	
	Vireo gilvus	Warbling Vireo	
	Vireo olivaceus	Red-eyed Vireo	
	Vireo philadelphicus	Philadelphia Vireo	
	Vireo solitarius	Blue-headed Vireo	
	Wilsonia pusilla	Wilson's Warbler	
	Zenaida macroura	Mourning Dove	
	Zonotrichia albicollis	White-throated Sparrow	

Table A-2 (continued). Bird, Amphibian, And Reptile Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status
HERPTILES	**33 identified**		
	Ambystoma laterale	Blue-spotted Salamander	
	Ambystoma maculatum	Spotted Salamander	
	Apalone spinifera spinifera	Eastern Spiny Softshell Turtle	
	Bufo americanus	American Toad	
	Bufo fowleri	Fowler's Toad	
	Chelydra serpentina serpentina	Common Snapping Turtle	
	Chrysemys picta marginata	Midland Painted Turtle	
	Clemmys insculpta	Wood Turtle	
	Coluber constrictor foxii	Blue Racer	
	Emydoidea blandingi	Blanding's Turtle	SR
	Eumeces fasciatus	Five-lined Skink	
	Graptemys geographica	Common Map Turtle	
	Hemidactylium scutatum	Four-toed Salamander	
	Heterodon platirhinos	Eastern Hognose Snake	
	Hyla crucifer	Spring Peeper	
	Hyla versicolor	Gray Treefrog	
	Nerodia sipedon	Northern Water Snake	
	Notophtalamus viridescens	Eastern Newt (also Red Eft stage)	
	Plethodon cinereus	Redback Salamander (red & gray phases)	
	Pseudacris triseriata	Chorus Frog	
	Rana catesbeiana	Bullfrog	
	Rana clamitans	Green Frog	
	Rana palustris	Pickerel Frog	
	Rana pipiens	Northern Leopard Frog	
	Rana sylvatica	Wood Frog	
	Sistrurus catenatus	Eastern Massasauga	
	Sternotherus odoratus	Common Musk Turtle	
	Storeria dekayi dekayi	Northern Brown Snake	
	Storeria dekayi wrightorum	Midland Brown Snake	
	Terrapene carolina carolina	Eastern Box Turtle	SR
	Thamnophis sauritus septentrionalis	Northern Ribbon Snake	
	Thamnophis sirtalis sirtalis	Eastern Garter Snake	
	Trachemys scripta elegans	Red-eared Slider	

Table A-3. Common Mammal and Insect Species Found Within The White River Watershed (TNC 2002).

MAMMALS	18 identified		
	Blarina brevicauda	Short-tailed Shrew	
	Canis latrans	Coyote	
	Castor canadensis	American Beaver	
	Chiroptera	Bats	
	Erethizon dorsatum	Common Porcupine	
	Glaucomys sp.	Flying Squirrel	
	Lutra canadensis	Northern River Otter	
	Marmota monax	Woodchuck, Groundhog, Marmot	
	Mephitus Mephitus	Striped Skunk	
	Odocoileus virginianus	White-tailed Deer	
	Ondatra zibethicus	Muskrat	
	Peromyscus leucopus	White-footed Mouse	
	Procyon lotor	Common Raccoon	
	Sciurus carolinensis	Eastern Gray Squirrel	
	Sciurus niger	Eastern Fox Squirrel	
	Spermophilus tridecemlineatus	Thirteen-lined Ground Squirrel, Striped Gopher	
	Tamias striatus	Eastern Chipmunk	
	Vulpes vulpes	Red Fox	
	Scientific Name	Common Name	Status
(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)			
INSECTS	154 identified		
Blattaria	Parcoblatta pennsylvanica	Pennsylvania Wood Cockroach	
Coleoptera	Calopteron reticulatum	Net-winged Beetle	
	Calopteron terminale	End-banded Netwing Beetle	
	Family: Carabidae	Ground Beetle	
	Chauliognathus sp.	Soldier Beetle	
	Cicindela formosa	Big Sand Tiger Beetle	
	Curculia sp.	Acorn Weevil	
	Diabrotica undecimpunctata howardi	Spotted Cucumber Beetle	
	Geotrupis splendidus	Earth-boring Dung Beetle	
	Gyrinus sp.	Small Whirligig Beetle	
	Hydrophilus triangularis	Giant Water Scavenger	
	Family: Melonidae	Blister Beetle	
	Monochamus scutellatus	Whitespotted Sawyer	
	Nicrophorus orbicollis	Burying Beetle	
	Onthophagus sp.	Dung Beetle	
	Silpha americana	American Carrion Beetle	
	Tetraopes sp.	Milkweed Beetle	
Diptera	Aedes sp.	Mosquito	
	Family: Asilidae	Robberfly	
	Chrysops sp.	Deer Fly	
	Exoprosopa sp.	Progressive Bee Fly	
	Pyrgota undata	Pyrgotid Fly, Light Fly	
	Simulium sp.	Black Fly	
	Tabanus sp.	Horse Fly	
Hemiptera	Acrosternum hilare	Green Stink Bug	
	Belostoma flumineum	Giant Water Bug	
	Gerris sp.	Water Strider	
	Lygaeus kalmii	Small Milkweed Bug	
	Family: Mesoveliidae	Water Treader	
	Family: Nepidae	Water Scorpion	
	Phymata erosa	Jagged Ambush Bug	
Homoptera	Graphacephala coccinea	Scarlet and Red Leafhopper	
	Lepyronia gibbosa	Great Plains Spittlebug	ST
	Platypedia sp.	Woodland Cicada	
	Tibicen canicularis	Dog-day Cicada	
Hymenoptera	Ammophila sp.	Thread-waisted Wasp	
	Amphibolips confluenta	Oak-Apple Gall Wasp	
	Bombus sp.	Bumblebee	
	Campontus spp.	Carpenter Ant	
	Dasymutilla occidentalis	Velvet Ant, Cow Killer	
	Dolichovespula maculata	Bald-faced Hornet	
	Family: Inchneumonidae	Ichneumonid Wasp	
	Family: Myzininae	Wasp	
	Pelecinus polyturator	Pelecinid Wasp	
	Family: Pompilidae	Spider Wasp	
	Family: Sphecidae	Digger Wasp	
	Sphex procerus	Thread-waisted Wasp	
	Vespula spp.	Yellow Jacket	

Table A-3 (continued). Common Mammal and Insect Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

		Scientific Name	Common Name	Status
INSECTS				
		Pachysphinx modesta	Big Poplar Sphinx	
		Paonias excaecatus	Blind-eyed Sphinx	
	(butterflies)	Boloria selene myrina	Silver-bordered Fritillary	
		Celastrina argiolus	Spring Azure	
		Celastrina neglecta	Summer Azure	
		Cercyonis pegala nephele	Wood Nymph	
		Colias eurytheme	Orange Sulphur	
		Colias philodice	Clouded Sulphur	
		Danaus plexippus	Monarch	
		Enodia anthedon	Northern Pearly Eye	
		Everes comyntas	Eastern Tailed Blue	
		Limenitis archippus	Viceroy	
		Limenitis arthemis astyanax	Red-spotted Purple	
		Lycaeides melissa samuelis	Karner Blue	ST, FE
		Lycaena hyllus	Bronze Copper	
		Lycaena phlaeas americana	American Copper	
		Megisto cymela	Little Wood Satyr	
		Nymphalis antiopa	Mourning Cloak	
		Papilio canadensis	Canadian Swallowtail	
		Papilio glaucus	Tiger Swallowtail	
		Papilio polyxenes asterius	Black Swallowtail	
		Papilio troilus	Spicebush Swallowtail	
		Phyciodes selenis	Northern Pearl Crescent	
		Phyciodes tharos	Pearl Crescent	
		Pieris rapae	Cabbage Butterfly / Cabbage White	
		Satyrium calanus falacer	Banded Hairstreak	
		Satyrium titus	Coral Hairstreak	
		Satyrodes appalachia leeuwi	Appalachian Eyed Brown	
		Speyeria aphrodite	Aphrodite Fritillary	
		Speyeria cybele cybele	Great Spangled Fritillary	
		Vanessa atalanta rubria	Red Admiral	
		Vanessa virginiensis	American Painted Lady	
	(skippers)	Ancyloxypha numitor	Least Skipper	
		Hesperia leonardus	Leonard's Skipper	
		Hesperia sassacus	Indian Skipper	
		Epargyreus clarus	Silver-spotted Skipper	
		Erynnis juvenalis	Juvenal's Duskywing	
		Euphyes vestris metacomet	Dun Skipper	
		Poanes hobomok	Hobomok Skipper	
		Polites mystic	Long Dash	
		Thymelicus lineola	European Skipper	
		Wallengrenia egeremet	Northern Broken Dash	
Mecoptera		Panorpa sp.	Scorpion-Fly	
Mantodea		Family: Mantidae	Praying Mantid	
Neuroptera		Family: Chrysopidae	Green Lacewing	
		Family: Myremeleontidae	Antlions	
Odonata	Anisoptera	Aeshna tuberculifera	Black-tipped Darner	
		Aeshna verticalis	Green-striped Darner	
		Anax junius	Common Green Darner	
		Boyeria vinosa	Fawn Darner	
		Celithemis elisa	Calico Pennant	
		Celithemis eponina	Halloween Pennant	
		Celithemis fasciata	Banded Pennant	
		Dorocordulia libera	Racket-tailed Emerald	
		Erythemis simplicicollis	Eastern Pondhawk	
		Gomphus exilis	Lancet Clubtail	
		Hagenius brevistylus	Dragonhunter	
		Leucorrhinia frigida	Frosted Whiteface	
		Leucorrhinia hudsonica	Hudsonian Whiteface	
		Leucorrhinia proxima	Red-waisted Whiteface	
		Libellula cyanea	Splendid Skimmer / Spangled Skimmer	
		Libellula incesta	Slaty Skimmer	
		Libellula lydia	Common Whitetail	
		Libellula luctuosa	Widow Skimmer	
		Libellula pulchella	Twelve-spotted Skimmer	
		Libellula quadrimaculata	Four-spotted Skimmer	

Table A-3 (continued). Common Mammal and Insect Species Found Within The White River Watershed (TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

		Scientific Name	Common Name
INSECTS			
		Pachydiplax longipennis	Blue Dasher
		Perithemis tenera	Eastern Amberwing
		Progomphus obscurus	Common Sanddragon
		Sympetrum costiferum	Saffron-winged Meadowhawk
		Sympetrum obtrusum	White-faced Meadowhawk
		Sympetrum rubicundulum	Ruby Meadowhawk
		Sympetrum semicinctum	Band-winged Meadowhawk
		Sympetrum vicinum	Yellow-legged Meadowhawk
		Tramea lacerata	Black Saddlebags
	Zygoptera	Argia fumipennis	Variable Dancer
		Calopteryx maculata	Ebony Jewelwing
		Enallagma exsulans	Stream Bluet
		Hetaerina americana	American Rubyspot
		Ischnura verticalis	Eastern Forktail
		Lestes unguiculatus	Lyre-tipped Spreadwing
		Lestes vigilax	Swamp Spreadwing
Orthoptera		Dissostiera carolina	Carolina Locust
		Gryllus pennsylvanicus	Fall Field Cricket
		Neoconcocephalus ensiger	Swordbearing Katydid
		Oecanthus pini	Pine Tree Cricket
		Family: Tettigonidae	Katydid
Trichoptera		Family: Hydropsychidae	Caddisfly

Table A-4. Common Fish Species Found Within The White River Watershed (MDNR 1989 and TNC 2002).

FISH	Scientific Name	Common Name
	Ambloplites rupestris	Rock Bass
	Ameiurus melas	Black Bullhead
	Ameiurus melas	Black bullhead
	Ameiurus natalis	Yellow bullhead
	Ameiurus nebulosus	Brown bullhead
	Amia calva	Bowfin
	Aphredoderus sayanus	Pirate perch
	Aphredoderus sayanus	Pirate perch
	Catostomus catostomus	Longnose sucker
	Catostomus commersoni	White Sucker
	Catostomus commersoni	White sucker
	Cottus bairdi	Mottled Sculpin
	Cottus bairdii	Mottled sculpin
	Couesius plumbeus	Lake chub
	Culaea inconstans	Brook Stickleback
	Culaea inconstans	Brook stickleback
	Cyprinella spiloptera	Spotfin shiner
	Cyprinus carpio	Carp
	Erimyzon oblongus	Creek Chubsucker
	Erimyzon sucetta	Lake chubsucker
	Esox americanus	Grass Pike
	Esox lucius	Northern Pike
	Esox lucius	Northern pike
	Etheostoma caeruleum	Rainbow darter
	Etheostoma exile	Iowa darter
	Etheostoma flabellare	Fantail Darter
	Etheostoma flabellare	Fantail darter
	Etheostoma microperca	Least darter
	Etheostoma nigrum	Johnny Darter
	Etheostoma nigrum	Johnny darter
	Fundulus daphanus	Banded Killfish
	Hybognathus hankinsoni	Brassy minnow
	Hypentelium nigricans	Northern hog sucker
	Ictalurus punctatus	Channel catfish
	Ictiobus niger	Black buffalo
	Labidesthes sicculus	Brook silverside
	Lepomis gibbosus	Pumpkinseed
	Lepomis gulosus	Warmouth
	Lepomis macrochirus	Bluegill
	Lepomis spp.	Hybrid Sunfish
	Luxilus chrysocephalus	Striped shiner
	Luxilus cornutus	Common Shiner
	Luxilus cornutus	Common shiner
	Margariscus margarita	Pearl dace
	Micropterus dolomieui	Smallmouth Bass

Table A-4. Common Fish Species Found Within The White River Watershed (MDNR 1989 and TNC 2002).

FISH	Scientific Name	Common Name
	Micropterus salmoides	Largemouth Bass
	Minytrema melanops	Spotted sucker
	Moxostoma anisurum	Silver redhorse
	Moxostoma carinatum	River redhorse
	Moxostoma duquesnii	Black redhorse
	Moxostoma erythrurum	Golden redhorse
	Moxostoma macrolepidotum	Shorthead redhorse
	Moxostoma valenciennesi	Greater redhorse
	Nocomis biguttatus	Hornyhead Chub
	Nocomis biguttatus	Hornyhead chub
	Nocomis micropogon	River chub
	Notemigonus crysoleucas	Golden Shiner
	Notemigonus crysoleucas	Golden shiner
	Notropis anogenus	Pugnose shiner
	Notropis atherinoides	Emerald shiner
	Notropis dorsalis	Bigmouth shiner
	Notropis heterodon	Blackchin Shiner
	Notropis heterodon	Blackchin shiner
	Notropis heterolepis	Blacknose shiner
	Notropis rubellus	Rosyface shiner
	Notropis stramineus	Sand shiner
	Notropis texanus	Weed shiner
	Notropis volucellus	Mimic shiner
	Oncorhynchus kisutch	Coho salmon
	Oncorhynchus mykiss	Rainbow trout
	Oncorhynchus tshawytscha	Chinook salmon
	Perca flavescens	Yellow Perch
	Perca flavescens	Yellow perch
	Percina maculata	Blackside darter
	Phoxinus eos	Northern redbelly dace
	Phoxinus neogaeus	Finescale dace
	Pimephales notatus	Bluntnose minnow
	Pimephales promelas	Fathead minnow
	Pimephlaes notatus	Bluntnose Minnow
	Pomoxis annularis	White crappie
	Pomoxis nigromaculatus	Black crappie
	Rhinichthys atratulus	Blacknose dace
	Rhinichthys cataractae	Longnose dace
	Salmo trutta	Brown trout
	Salvelinus fontinalis	Brook trout
	Salvelinus namaycush	Lake trout
	Semotilus atromaculatus	Creek chub
	Stizostedion vitreum	Walleye
	Umbra limi	Central Mudminnow

Table B-5. Common Bird Species Found Within The White River Watershed (MDNR 1989 and TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

	Scientific Name	Common Name	Status
BIRDS	118 identified		
	Accipiter striatus	Sharp-shinned Hawk	
	Actitis macularia	Spotted Sandpiper	
	Agelaius phoeniceus	Red-winged Blackbird	
	Aix sponsa	Wood Duck	
	Anas platyrhynchos	Mallard	
	Archilochus colubris	Ruby-throated Hummingbird	
	Ardea herodias	Great Blue Heron	
	Baeolophus bicolor	Eastern Tufted Titmouse	
	Bombycilla cedrorum	Cedar Waxwing	
	Bonasa umbellus	Ruffed Grouse	
	Branta canadensis	Canada Goose	
	Bubo virginianus	Great Horned Owl	
	Buteo jamaicensis	Red-tailed Hawk	
	Buteo lineatus	Red-shouldered Hawk	ST
	Caprimulgus vociferus	Whip-poor-will	
	Cardinalis cardinalis	Northern Cardinal	
	Carduelis tristis	American Goldfinch	
	Carpodacus mexicanus	House Finch	
	Cathartes aura	Turkey Vulture	
	Catharus fuscescens	Veery	
	Catharus guttatus	Hermit Thrush	
	Catharus minimus	Gray-cheeked Thrush	
	Catharus ustulatus	Swainson's Thrush	
	Ceryle alcyon	Belted Kingfisher	
	Chaetura pelagica	Chimney Swift	
	Charadrius vociferus	Killdeer	
	Chordeiles minor	Common Nighthawk	
	Coccyzus americanus	Yellow-billed Cuckoo	
	Coccyzus erythropthalmus	Black-billed Cuckoo	
	Colaptes auratus	Northern Flicker, Yellow-shafted Flicker	
	Contopus virens	Eastern Wood-Pewee	
	Corvus brachyrhynchos	American Crow	
	Cyanocitta cristata	Blue Jay	
	Cygnus olor	Mute Swan	
	Dendroica caerulescens	Black-throated Blue Warbler	
	Dendroica castanea	Bay-breasted Warbler	
	Dendroica cerulea	Cerulean Warbler	SR
	Dendroica coronata	Yellow-Rumped Warbler, Myrtle Warbler	
	Dendroica fusca	Blackburnian Warbler	
	Dendroica magnolia	Magnolia Warbler	
	Dendroica palmarum	Western Palm Warbler	
	Dendroica pensylvanica	Chestnut-sided Warbler	
	Dendroica petechia	Yellow Warbler	
	Dendroica pinus	Pine Warbler	
	Dendroica striata	Blackpoll Warbler	
	Dendroica tigrina	Cape May Warbler	
	Dendroica virens	Black-throated Green Warbler	
	Dolichonyx oryzivorus	Bobolink	
	Dryocopus pileatus	Pileated Woodpecker	
	Dumetella carolinensis	Gray Catbird	
	Empidonax flaviventris	Yellow-bellied Flycatcher	
	Empidonax minimus	Least Flycatcher	
	Empidonax virescens	Acadian Flycatcher	
	Gavia immer	Common Loon	ST
	Geothlypis trichas	Common Yellowthroat	
	Haliaeetus leucocepalus	Bald Eagle	ST
	Hirundo rustica	Barn Swallow	
	Hylocichla mustelina	Wood Thrush	
	Icterus galbula	Baltimore Oriole, Northern Oriole	
	Larus spp.	Gull	
	Larus delawarensis	Ring-billed Gull	
	Melanerpes carolinus	Red-bellied Woodpecker	
	Melanerpes erythrocephalus	Red-headed Woodpecker	
	Meleagris gallopavo	Wild Turkey	
	Melospiza georgiana	Swamp Sparrow	
	Scientific Name	Common Name	Status

Table B-5 (continued). Common Bird Species Found Within The White River Watershed (MDNR 1989 and TNC 2002).

(Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered)

BIRDS (cont'd…)			
	Melospiza melodia	Song Sparrow	
	Mniotilta varia	Black-and-white Warbler	
	Molothrus ater	Brown-headed Cowbird	
	Myiarchus crinitus	Great Crested Flycatcher	
	Oporornis philadelphia	Mourning Warbler	
	Otus asio	Eastern Screech Owl	
	Parula americana	Northern Parula Warbler	
	Passerina cyanea	Indigo Bunting	
	Petrochelidon pyrrhonota	Cliff Swallow	
	Phalacrocorax auritus	Double-crested Cormorant	
	Pheucticus ludovicianus	Rose-breasted Grosbeak	
	Picoides pubescens	Downy Woodpecker	
	Picoides villosus	Hairy Woodpecker	
	Pipilo erythrophthalmus	Eastern Towhee, Rufous-sided Towhee	
	Piranga olivacea	Scarlet Tanager	
	Poecile atricapilla	Black-capped Chickadee	
	Polioptila caerulea	Blue-gray Gnatcatcher	
	Pooecetes gramineus	Vesper Sparrow	
	Progne subis	Purple Martin	
	Quiscalus quiscula	Common Grackle	
	Regulus calendula	Ruby-crowned Kinglet	
	Riparia riparia	Bank Swallow	
	Sayornis phoebe	Eastern Phoebe	
	Scolopax minor	American Woodcock	
	Seiurus aurocapillus	Ovenbird	
	Seiurus motacilla	Louisiana Waterthrush	SR
	Seiurus noveboracensis	Northern Waterthrush	
	Setophaga ruticilla	American Redstart	
	Sialia sialis	Eastern Bluebird	
	Sitta canadensis	Red-breasted Nuthatch	
	Sitta carolinensis	White-breasted Nuthatch	
	Spizella passerina	Chipping Sparrow	
	Spizella pusilla	Field Sparrow	
	Stelgidopteryx serripennis	Northern Rough-winged Swallow	
	Sturnus vulgaris	European Starling	
	Tachycineta bicolor	Tree Swallow	
	Toxostoma rufum	Brown Thrasher	
	Tringa solitaria	Solitary Sandpiper	
	Troglodytes aedon	House Wren	
	Turdus migratorius	American Robin	
	Tyrannus tyrannus	Eastern Kingbird	
	Vermivora chrysoptera	Golden-winged Warbler	
	Vermivora peregrina	Tennessee Warbler	
	Vermivora pinus	Blue-winged Warbler	
	Vermivora ruficapilla	Nashville Warbler	
	Vireo flavifrons	Yellow-throated Vireo	
	Vireo gilvus	Warbling Vireo	
	Vireo olivaceus	Red-eyed Vireo	
	Vireo philadelphicus	Philadelphia Vireo	
	Vireo solitarius	Blue-headed Vireo	
	Wilsonia pusilla	Wilson's Warbler	
	Zenaida macroura	Mourning Dove	
	Zonotrichia albicollis	White-throated Sparrow	

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