

WHITE RIVER WATERSHED PRELIMINARY HABITAT ASSESSMENT

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Prepared for:

The Community Foundation *for* Muskegon County

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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

White River Watershed

344,166 Acres (139,279 Hectares)
or
538 Square Miles (1393 Square Kilometers)

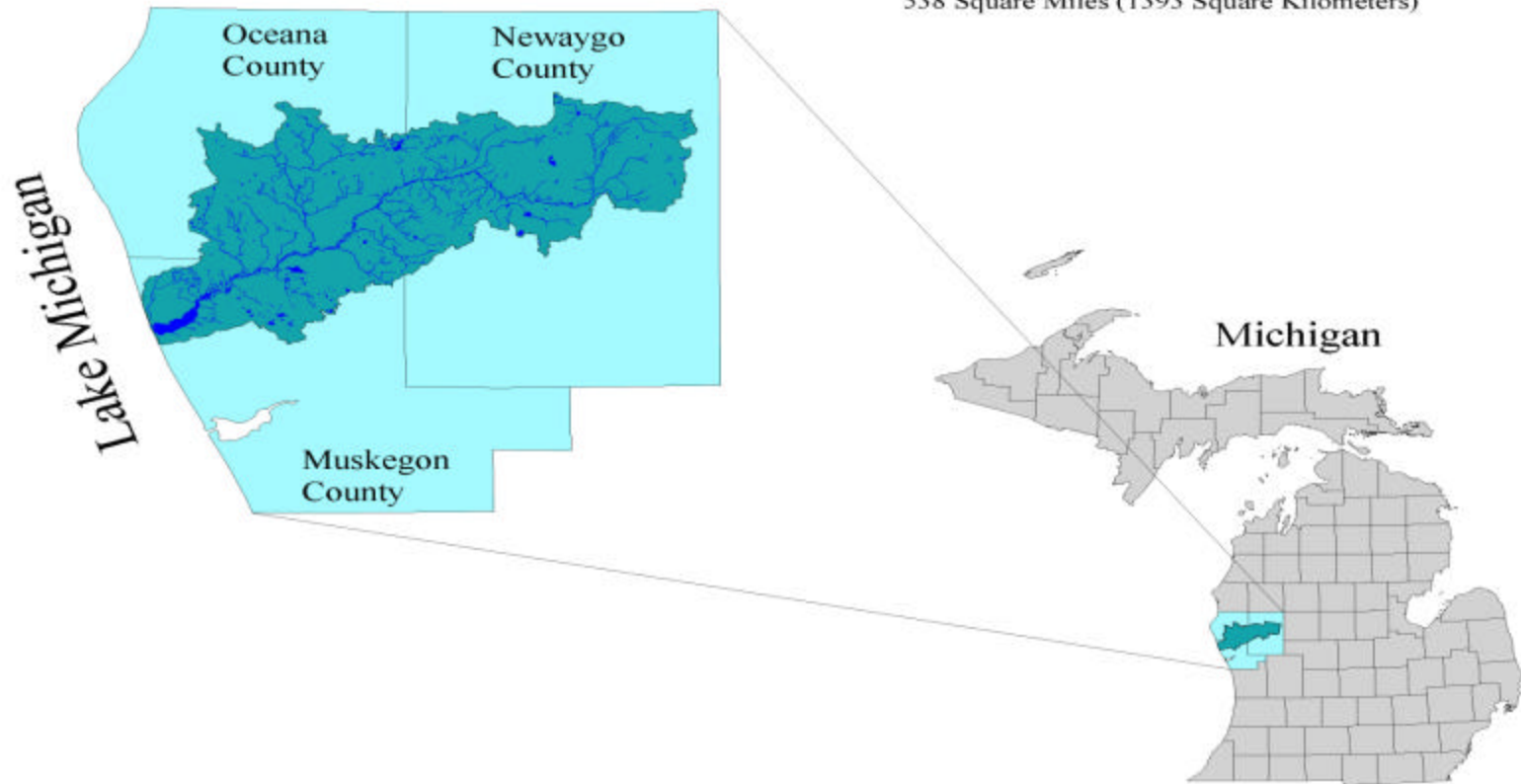


FIGURE 1.1 THE WHITE RIVER WATERSHED.

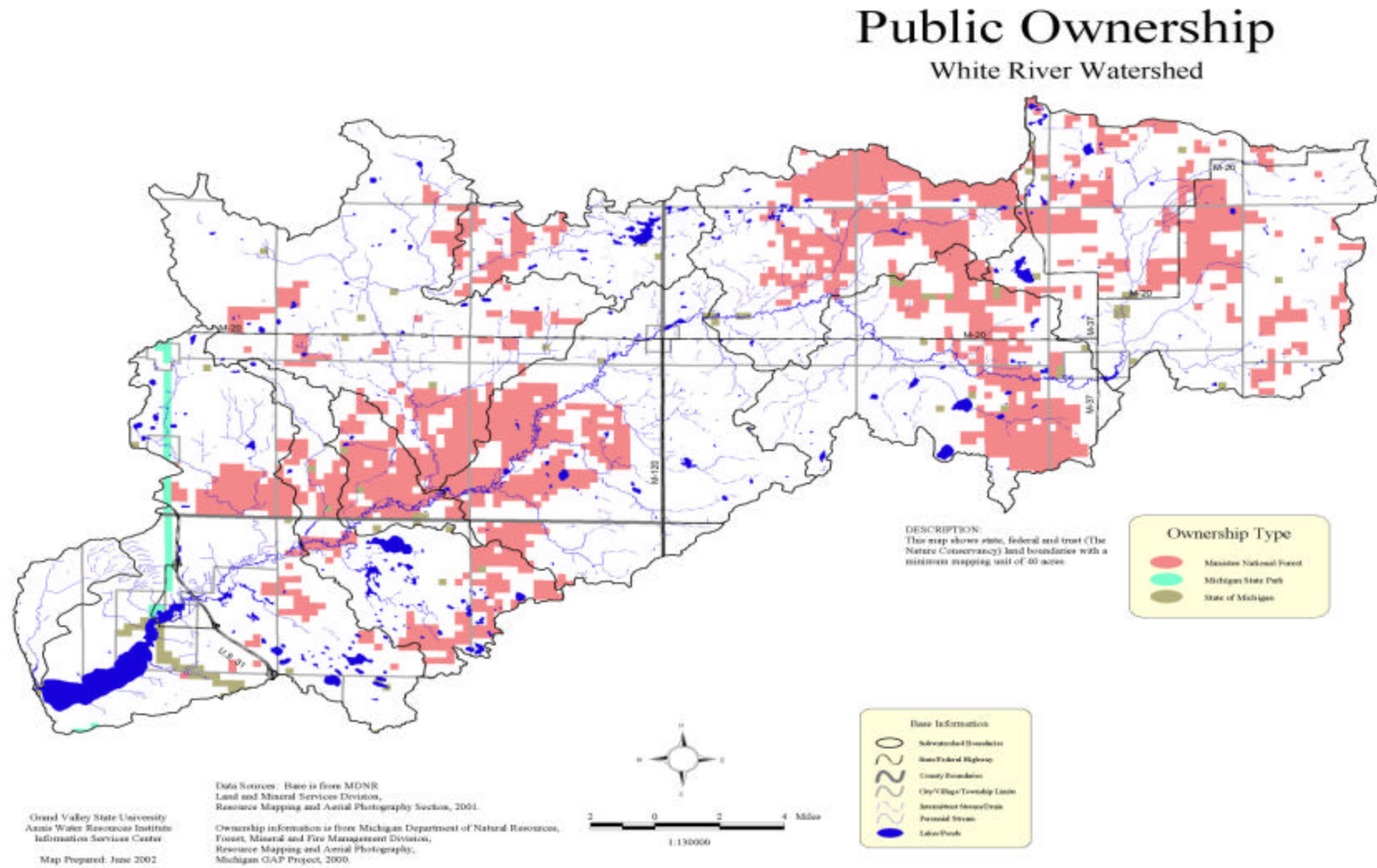


FIGURE 1.2 FEDERAL AND STATE LAND IN THE WHITE RIVER WATERSHED.

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 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

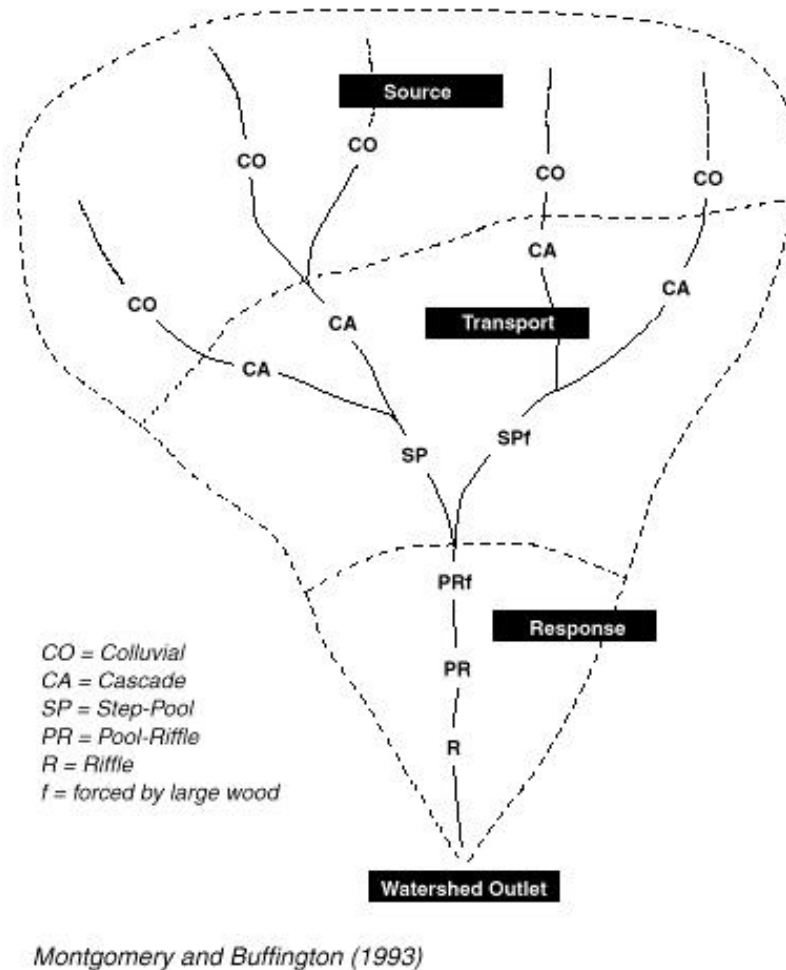


FIGURE 2.0 DIAGRAM OF RIVER ZONES (MONTGOMERY AND BUFFINGTON 1993).

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

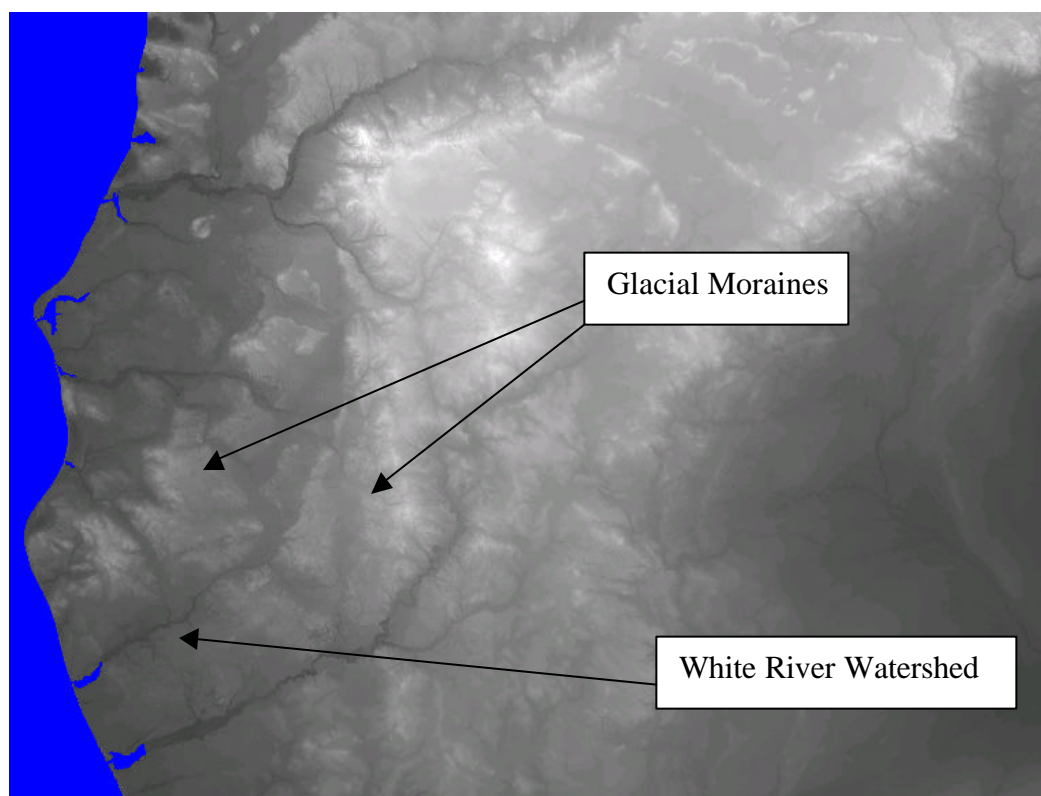
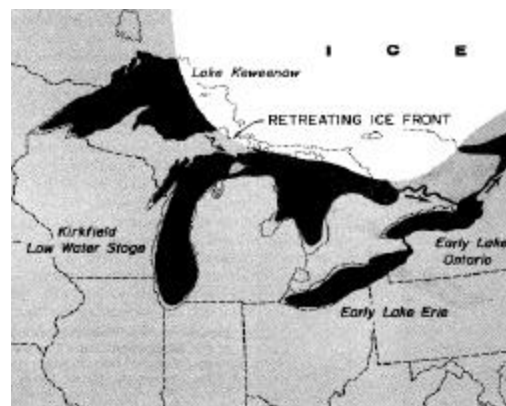


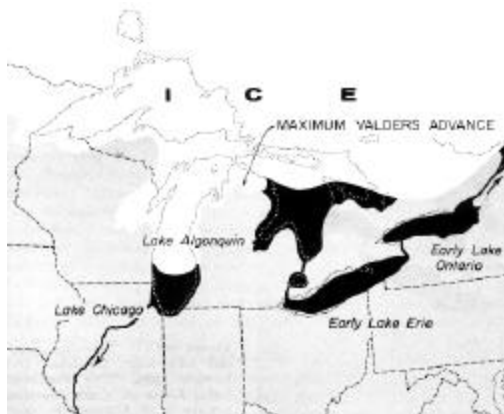
FIGURE 3.1.1. SATELLITE IMAGE OF THE WHITE RIVER WATERSHED.



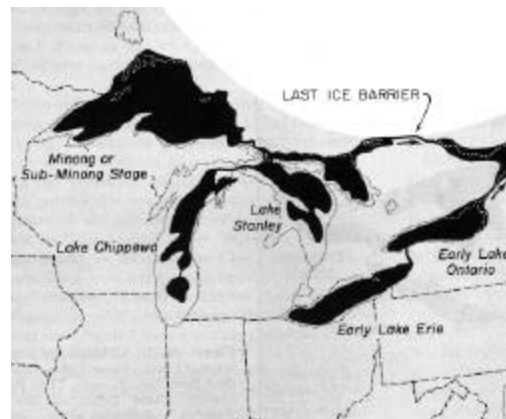
12,000 bp Elevation 620 ft.



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 Nipissing 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.

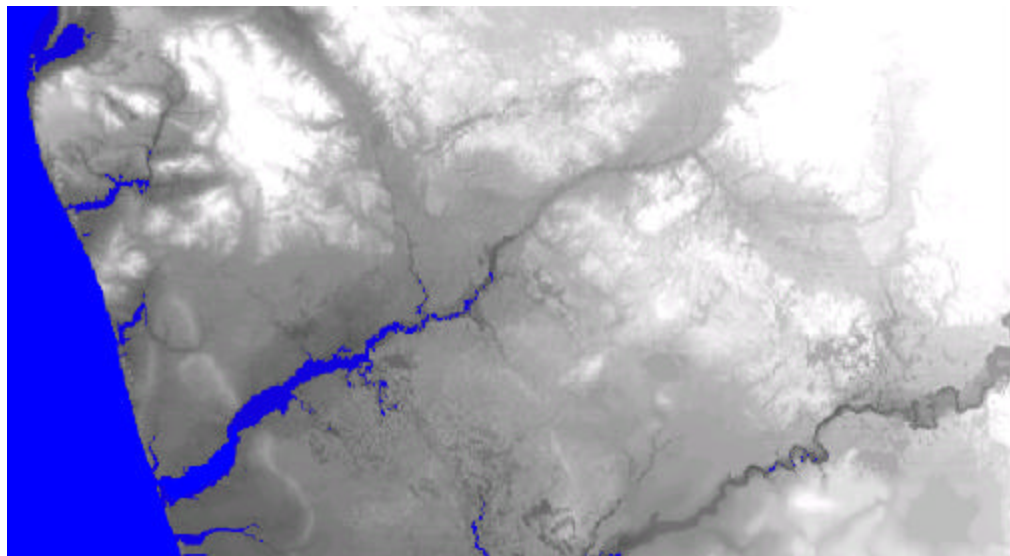


FIGURE 3.1.3. WATER ELEVATION IN THE WHITE RIVER WITH LAKE MICHIGAN AT 605 FT.

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.

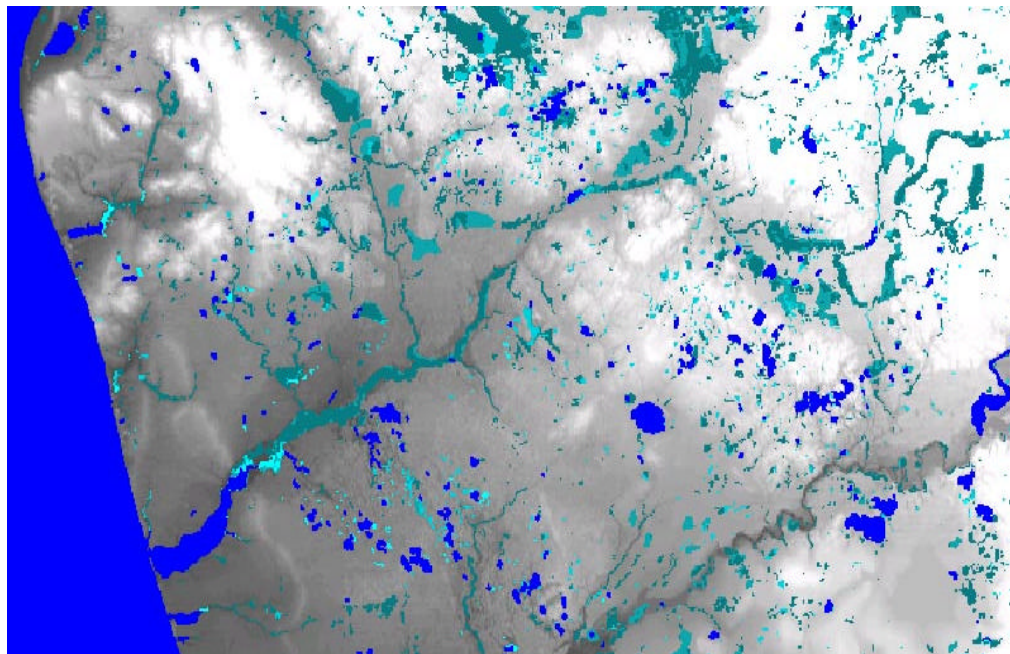


FIGURE 3.1.4 LAKES AND WETLANDS ASSOCIATED WITH THE WHITE RIVER WATERSHED.

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 shown 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)

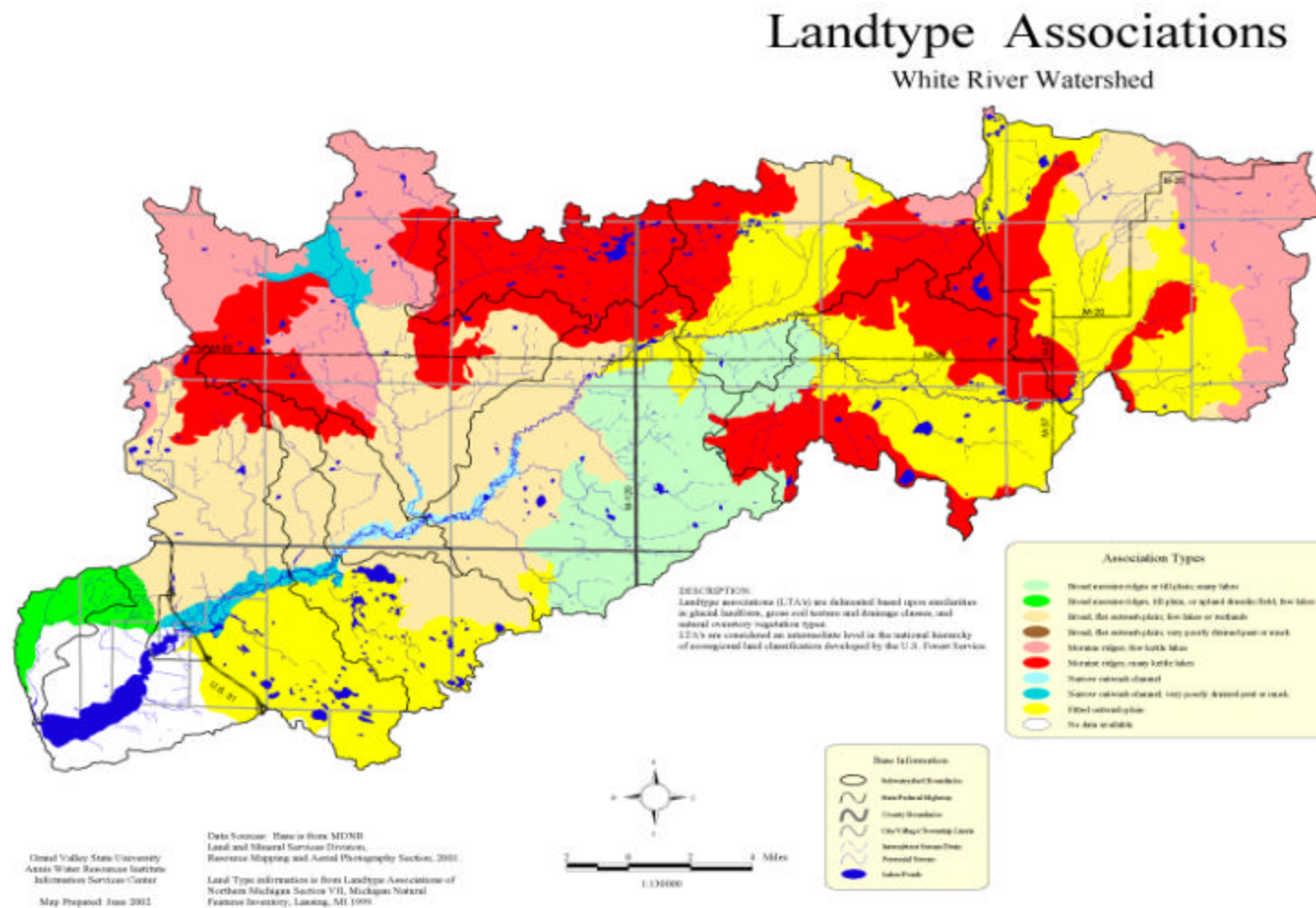


FIGURE 3.2.1 GEOLOGIC ASSOCIATIONS IN THE WHITE RIVER WATERSHED .

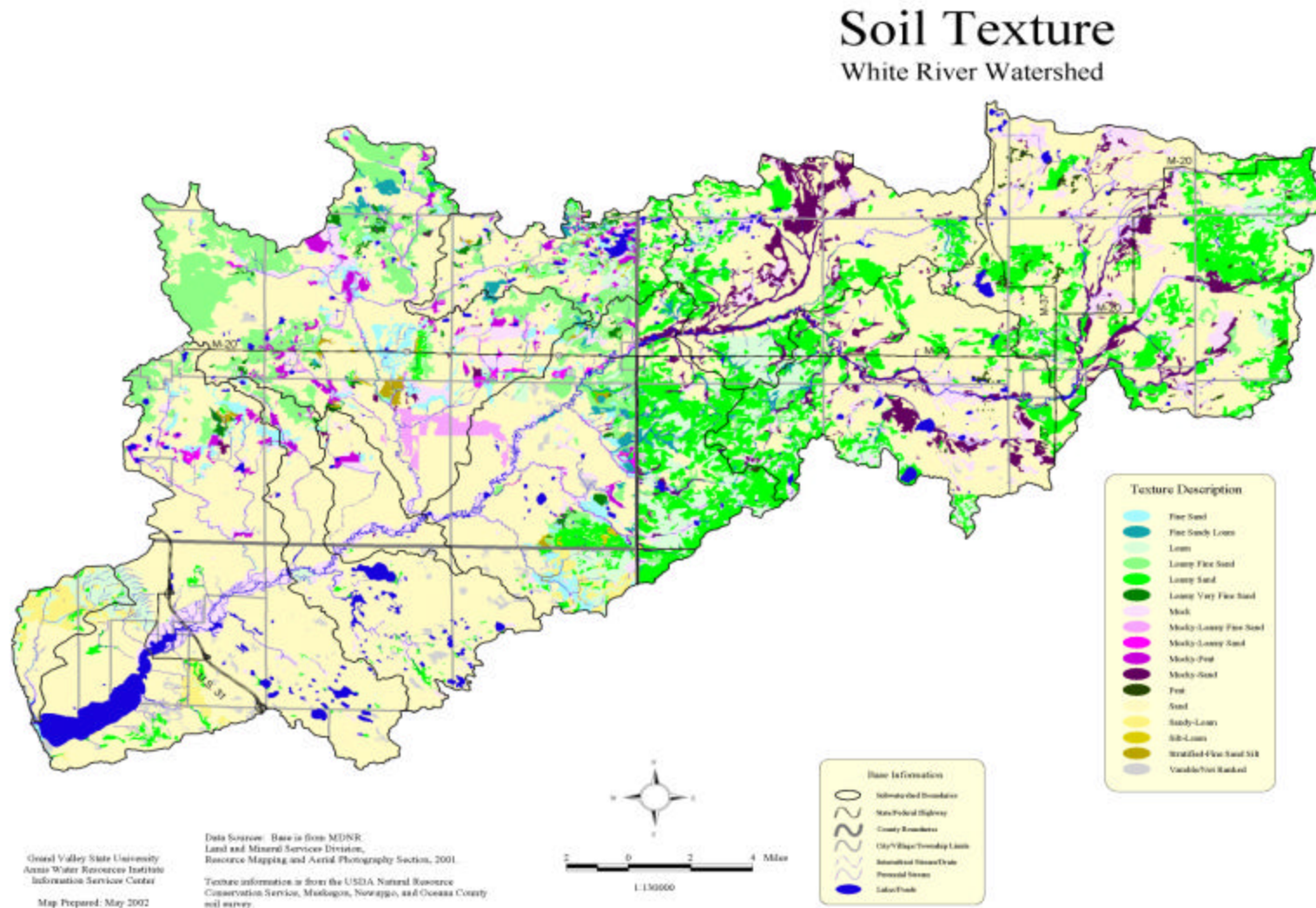


FIGURE 3.3.1 SOIL TEXTURES FOUND IN THE WHITE RIVER WATERSHED.

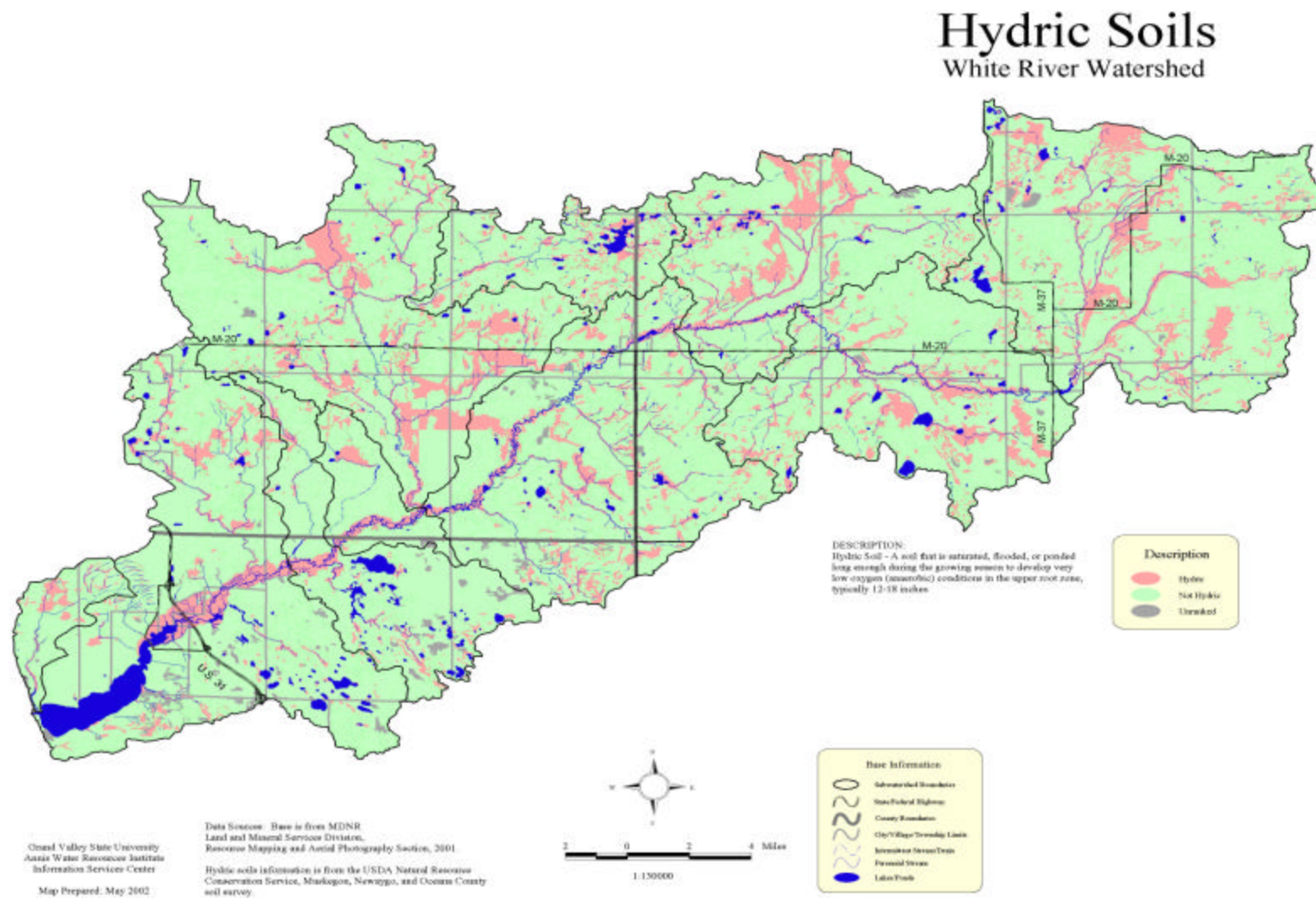


FIGURE 3.3.2 DISTRIBUTION OF HYDRIC SOILS IN THE WHITE RIVER WATERSHED.

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

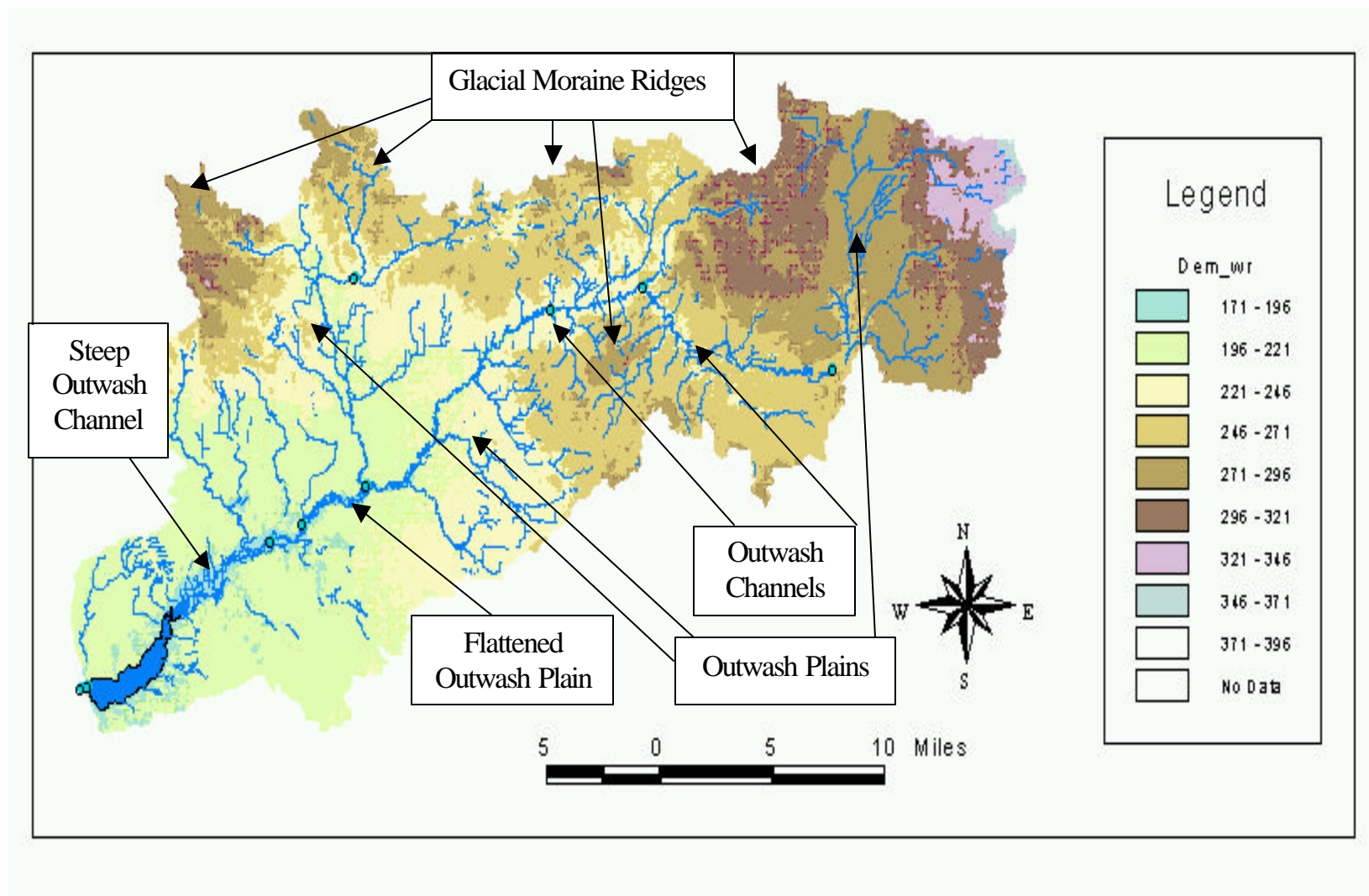


FIGURE 3.4.1 DIGITAL ELEVATION MODEL OF THE WHITE RIVER WATERSHED. ELEVATION IN METERS.

Topographic Slopes White River Watershed

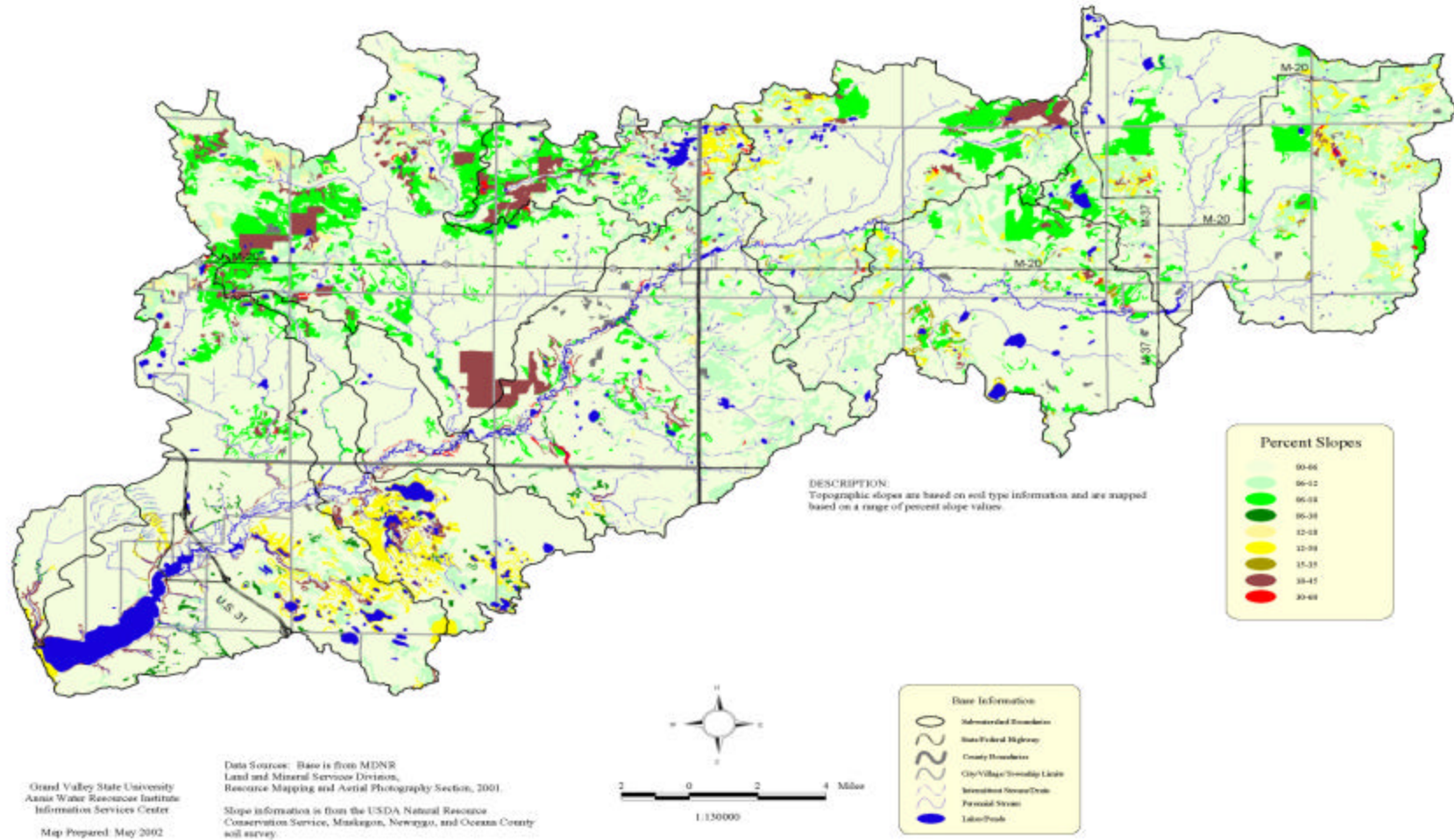


FIGURE 3.4.2 TOPOGRAPHIC SLOPES IN THE WHITE RIVER WATERSHED.

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 |

Subwatersheds

White River Watershed

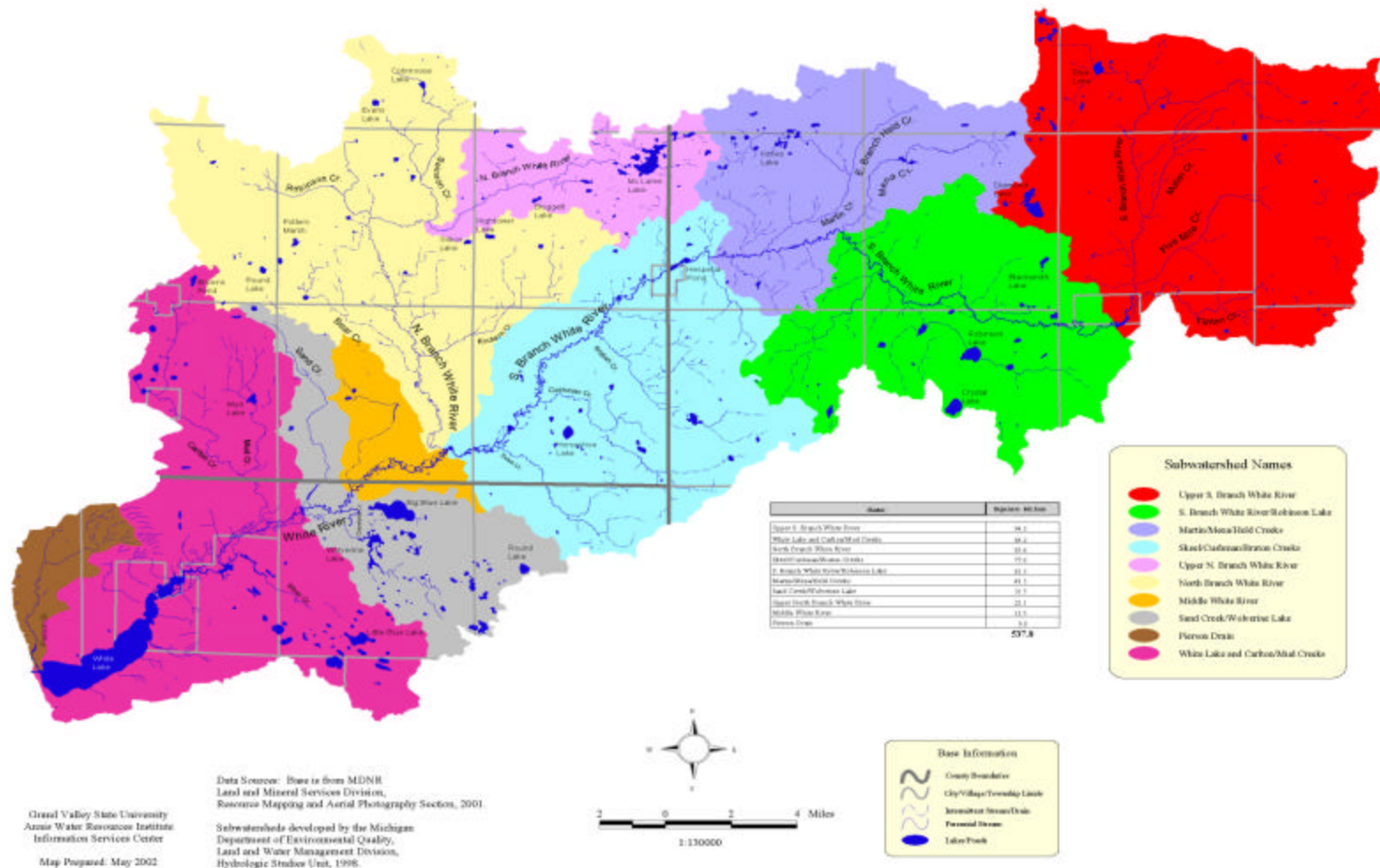


FIGURE 3.5.1 SUBWATERSHEDS IN THE WHITE RIVER WATERSHED.

Stream Valley Slope

White River Watershed

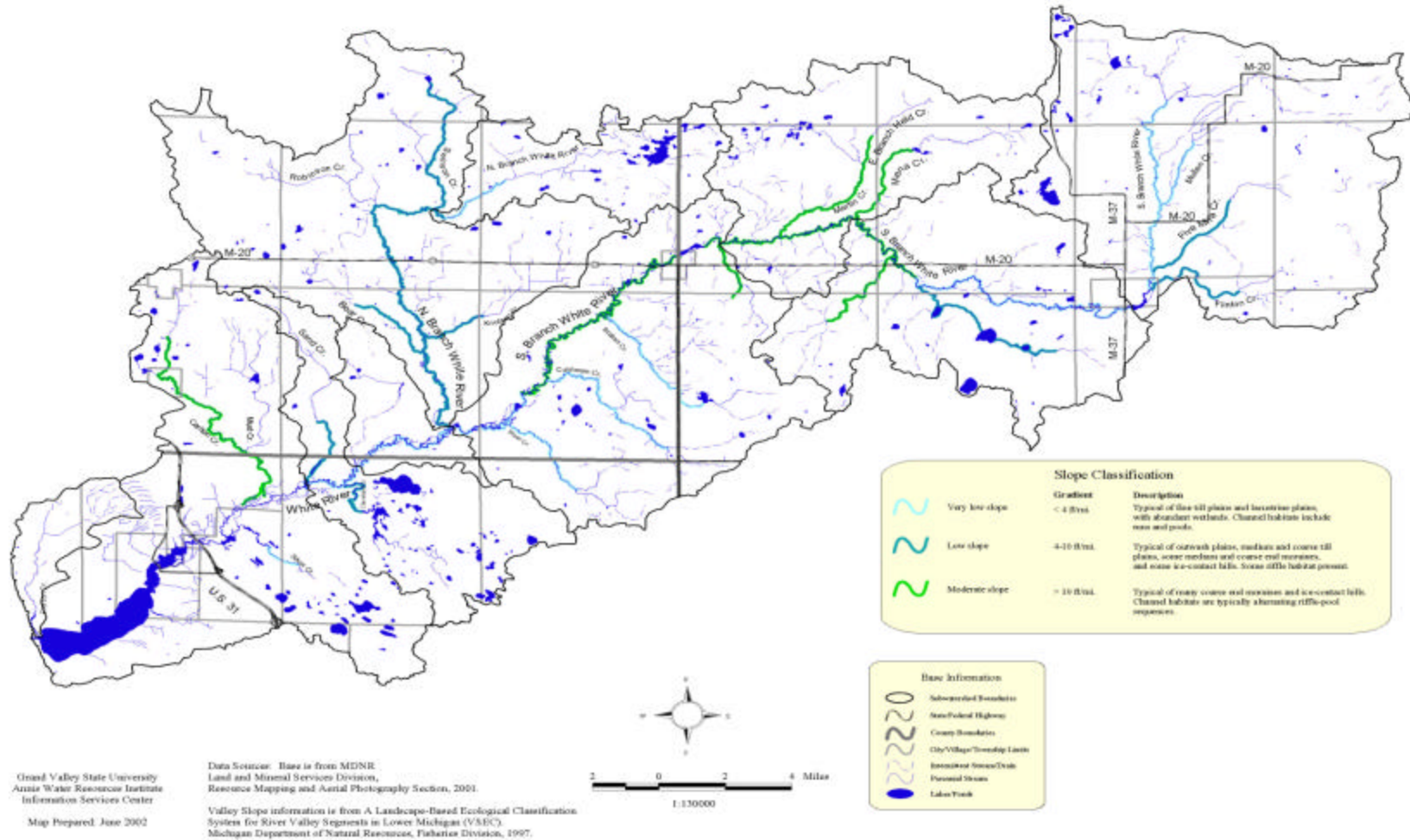


FIGURE 3.5.2 STREAM VALLEY SLOPE IN THE WHITE RIVER WATERSHED.

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Stream Temperature

White River Watershed

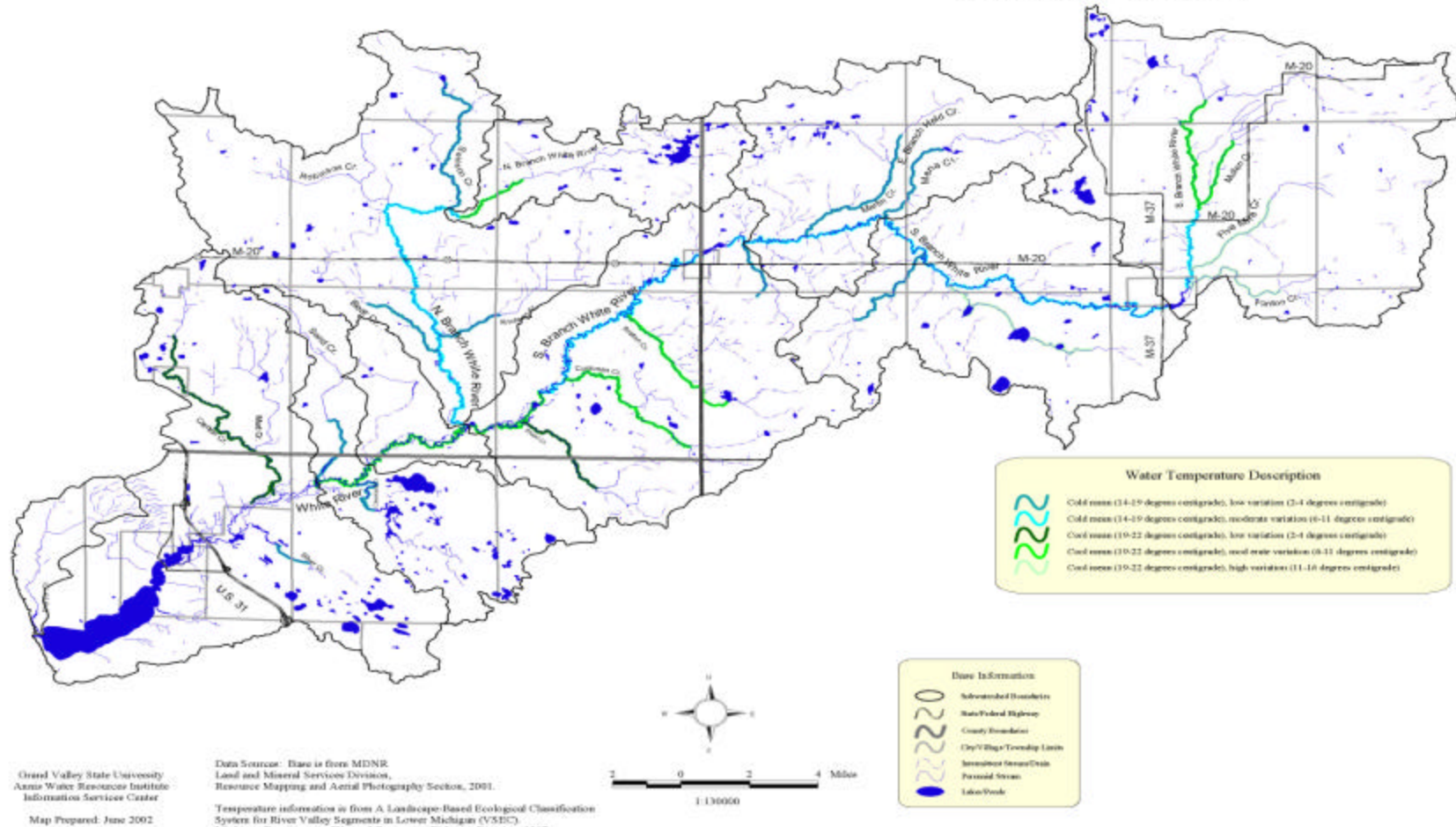


FIGURE 3.5.4 STREAM TEMPERATURE IN THE WHITE RIVER WATERSHED.

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 °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 stream 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 ft ³ /sec |
| Long-term daily minimum flow | 220 ft ³ /sec |
| Long-term daily maximum flow | 602 ft ³ /sec |
| Peak flow | 1834 ft 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 km² and a mean depth of 7.3 m. The lake has an estimated volume of 7.6x10⁷ m³ 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 |

Presettlement Landscape

White River Watershed

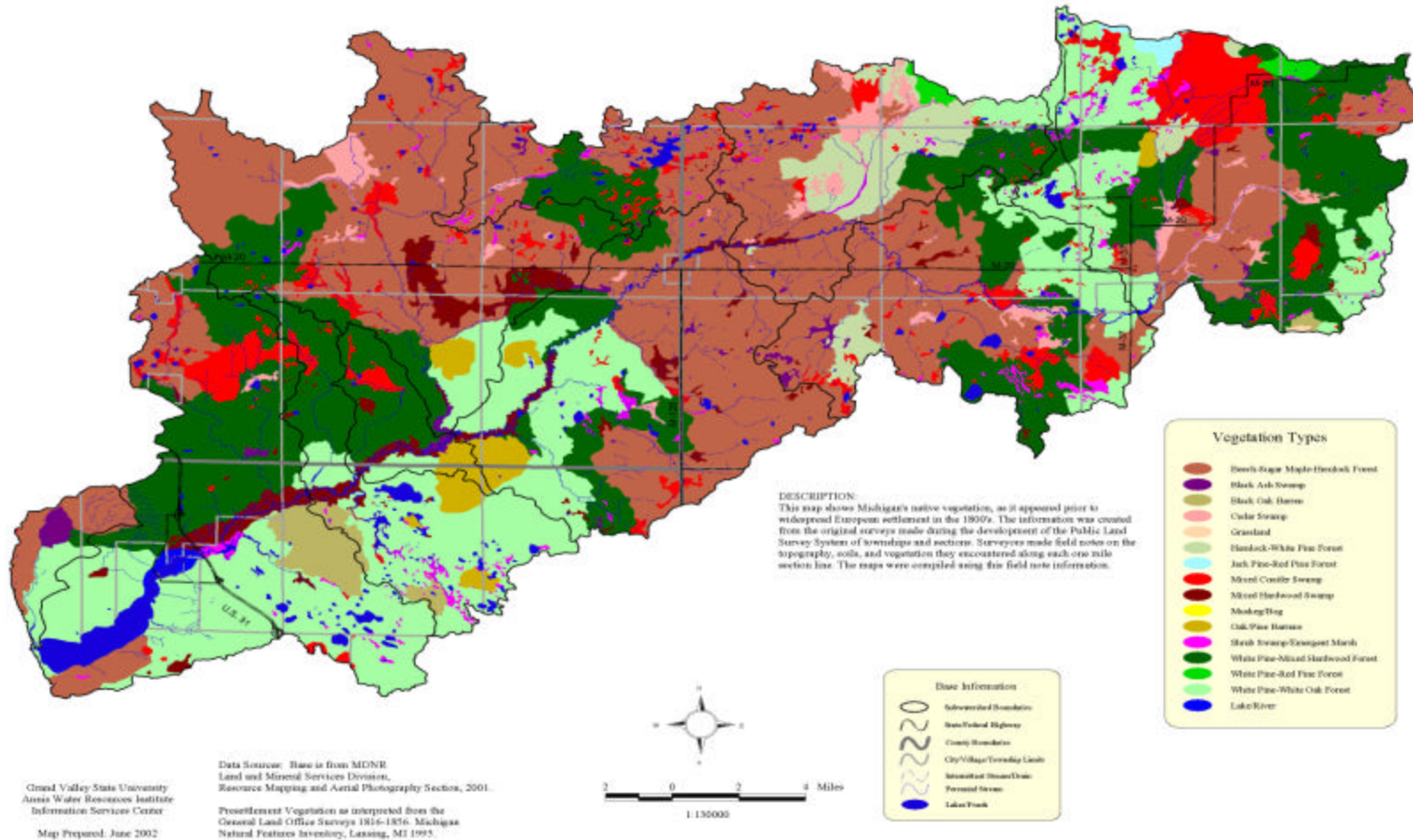


FIGURE 3.6.1 PRESETTLEMENT VEGETATION IN THE WHITE RIVER WATERSHED.

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 |

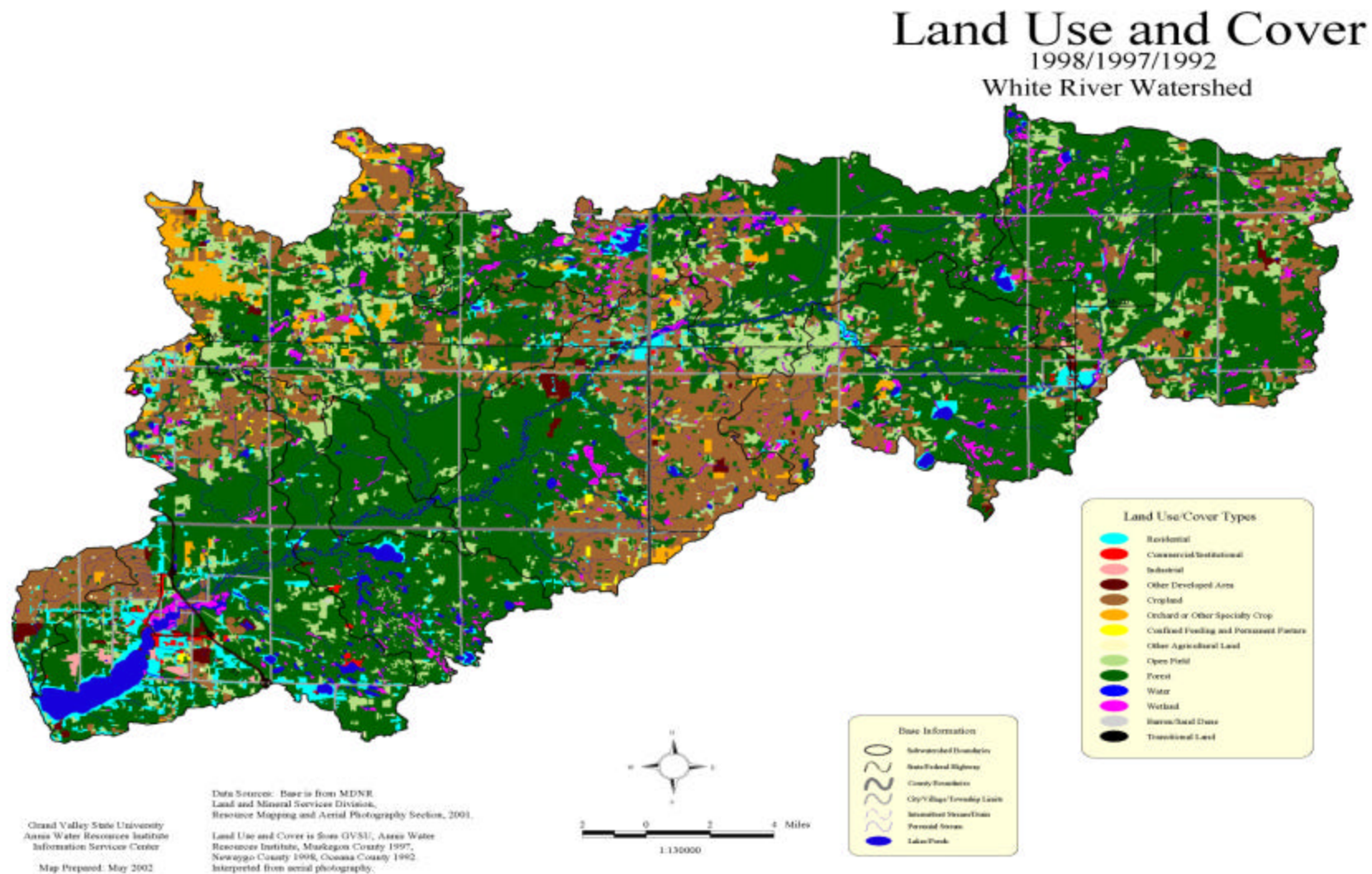


FIGURE 3.6.2 CURRENT LAND COVER IN THE WHITE RIVER WATERSHED (1992/1997/1998).

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 no 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

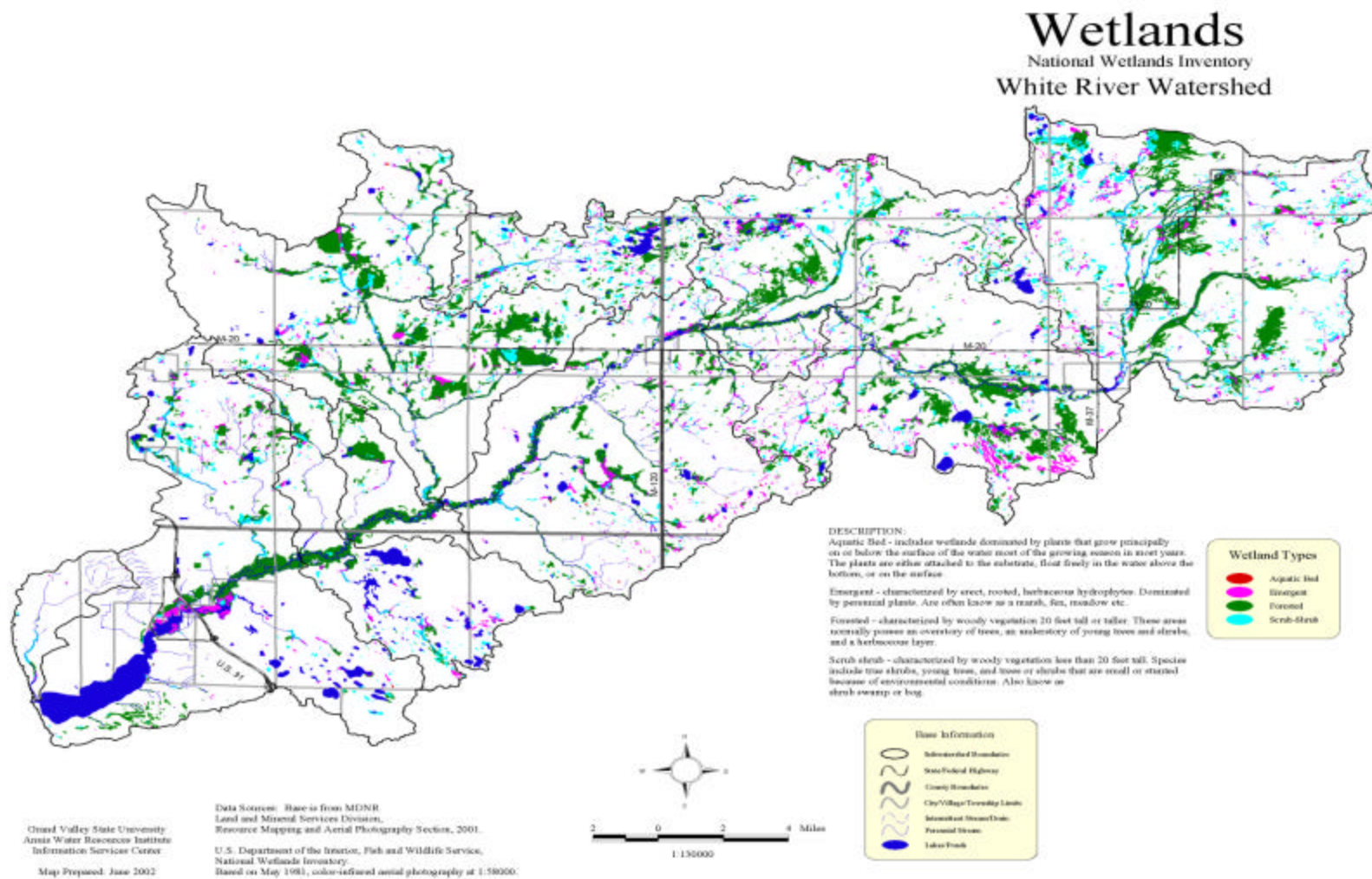


FIGURE 3.6.3 WETLAND CLASSIFICATIONS IN THE WHITE RIVER WATERSHED.

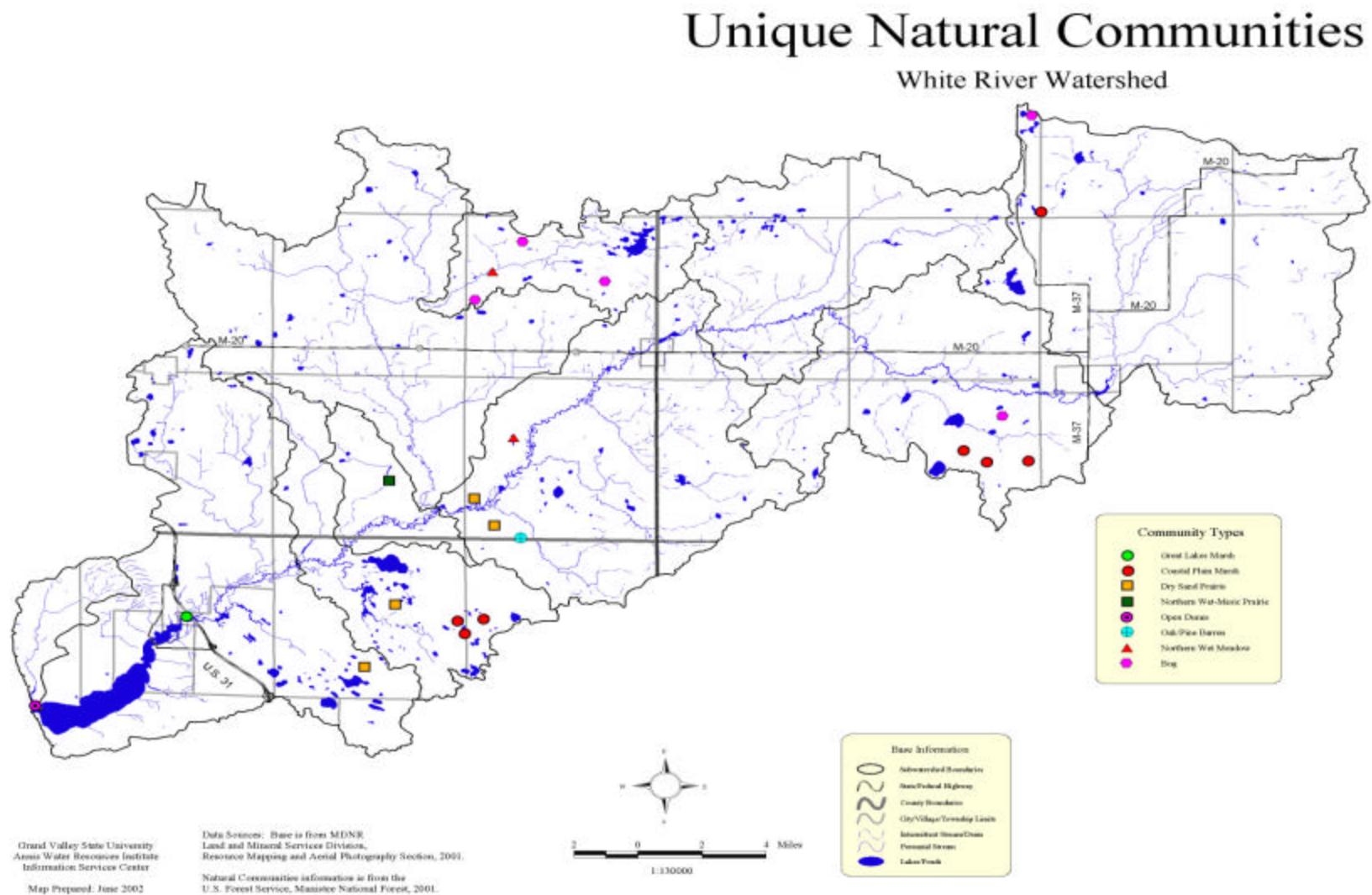


FIGURE 3.6.4 UNIQUE NATURAL COMMUNITIES IN THE WHITE RIVER WATERSHED.

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 was classified 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

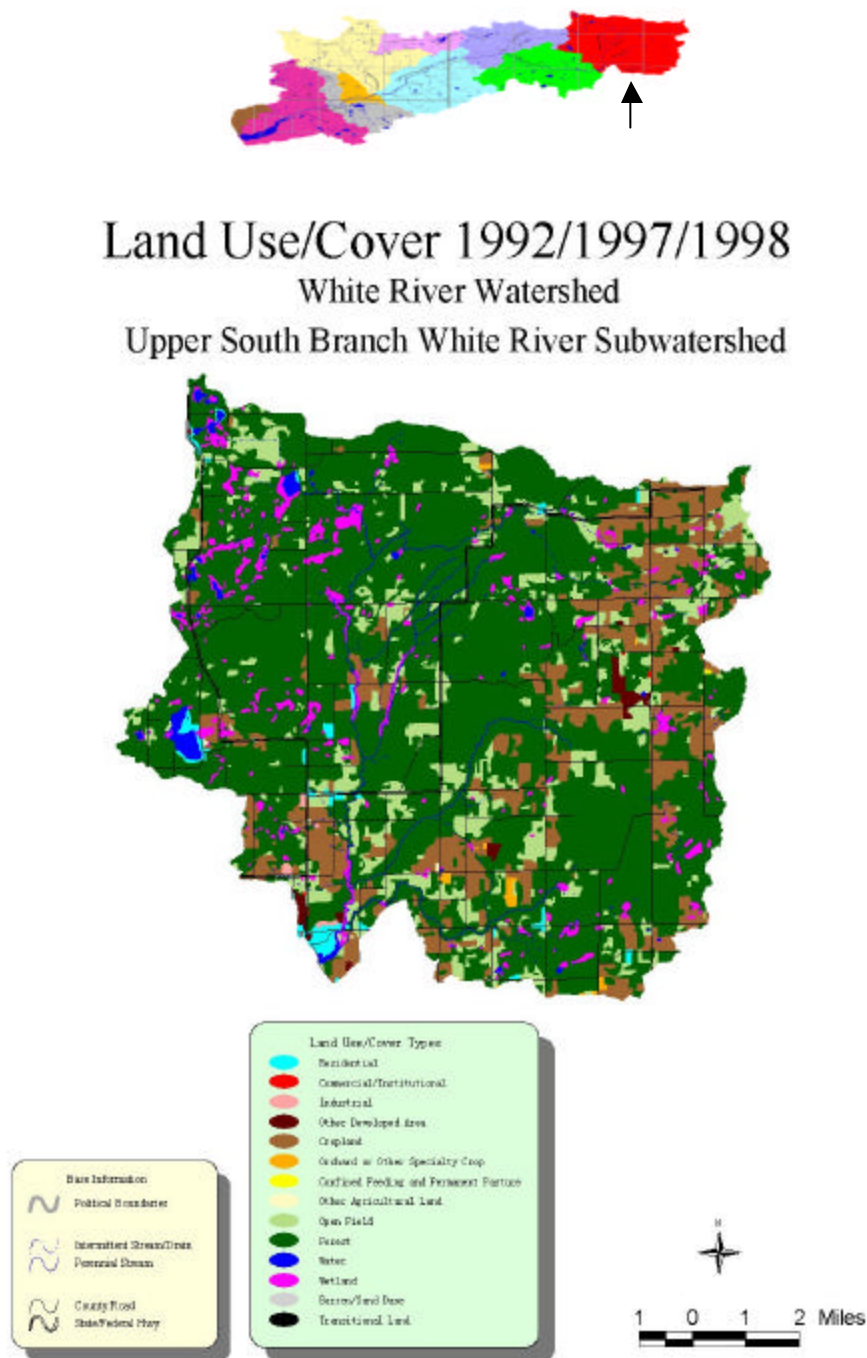


FIGURE 4.1.1 LAND COVER MAP OF UPPER SOUTH BRANCH SUBWATERSHED.

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



Land Use/Cover 1992/1997/1998 White River Watershed South Branch White River - Robinson Lake Subwatershed

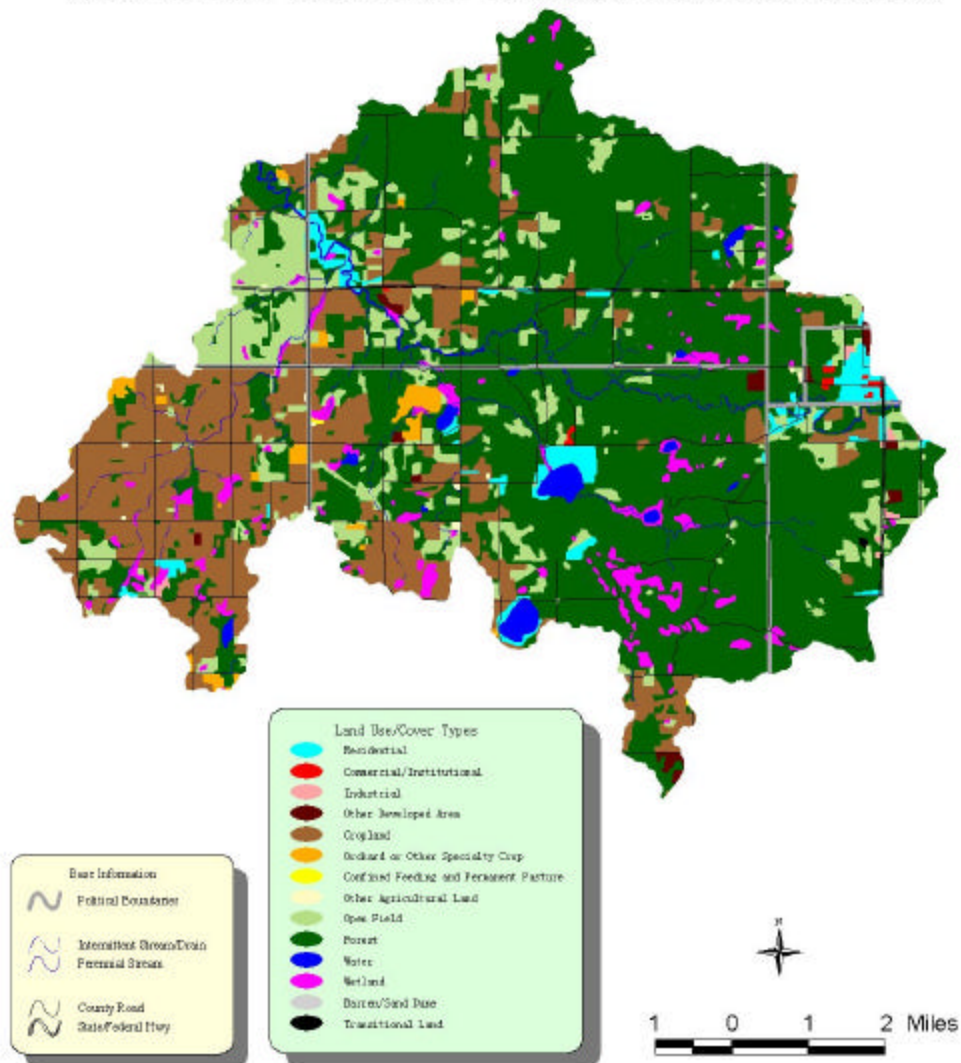


FIGURE 4.2.1 LAND COVER MAP OF SOUTH BRANCH WHITE RIVER / ROBINSON LAKE SUBWATERSHED.



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



Land Use/Cover 1992/1997/1998

White River Watershed

Martin/Mena/Held Creeks Subwatershed

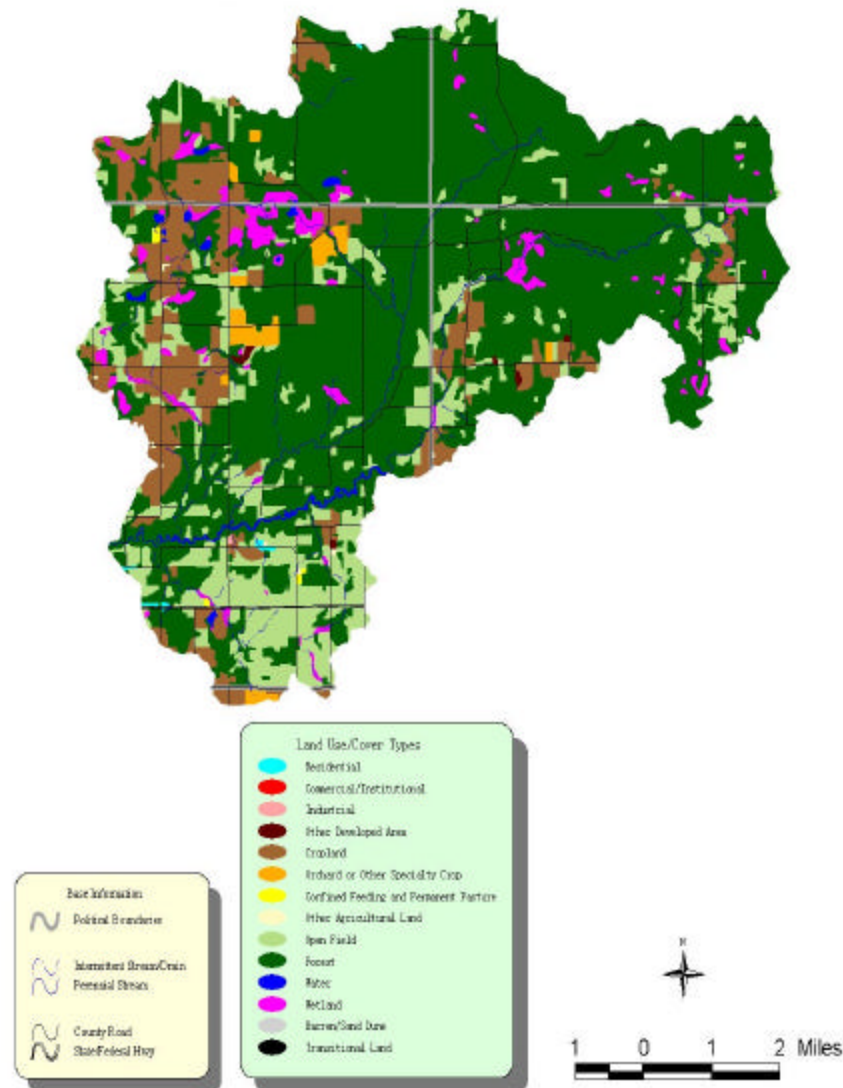
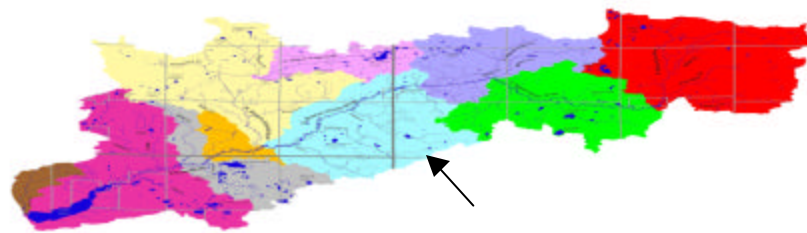


FIGURE 4.3.1 LAND COVER MAP OF THE MARTIN/MENA/HELD CREEKS SUBWATERSHED.

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



Land Use/Cover 1992/1997/1998
White River Watershed
Skeel/Cushman/Braton Creeks Subwatershed

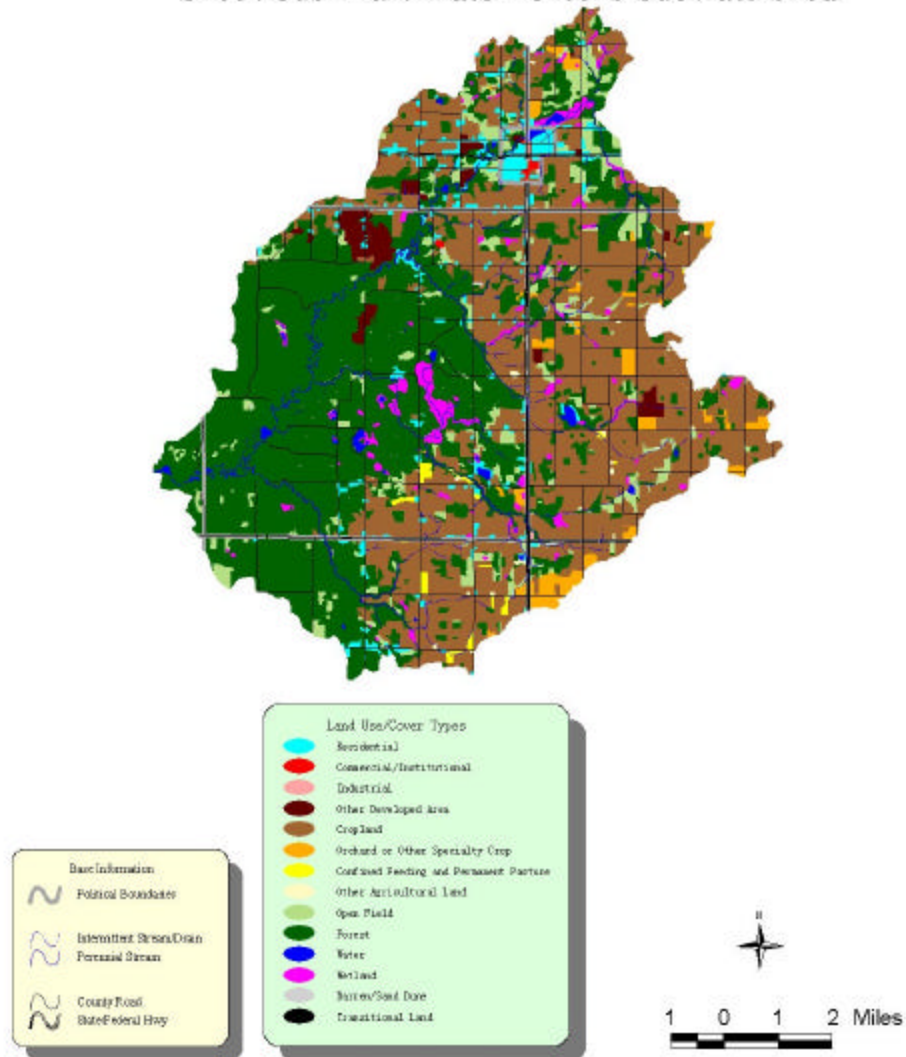


FIGURE 4.4.1 LAND COVER MAP OF THE SKEEL/CUSHMAN/BRATON CREEKS SUBWATERSHED.

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.



Land Use/Cover 1992/1997/1998
White River Watershed
Upper North Branch White River Subwatershed

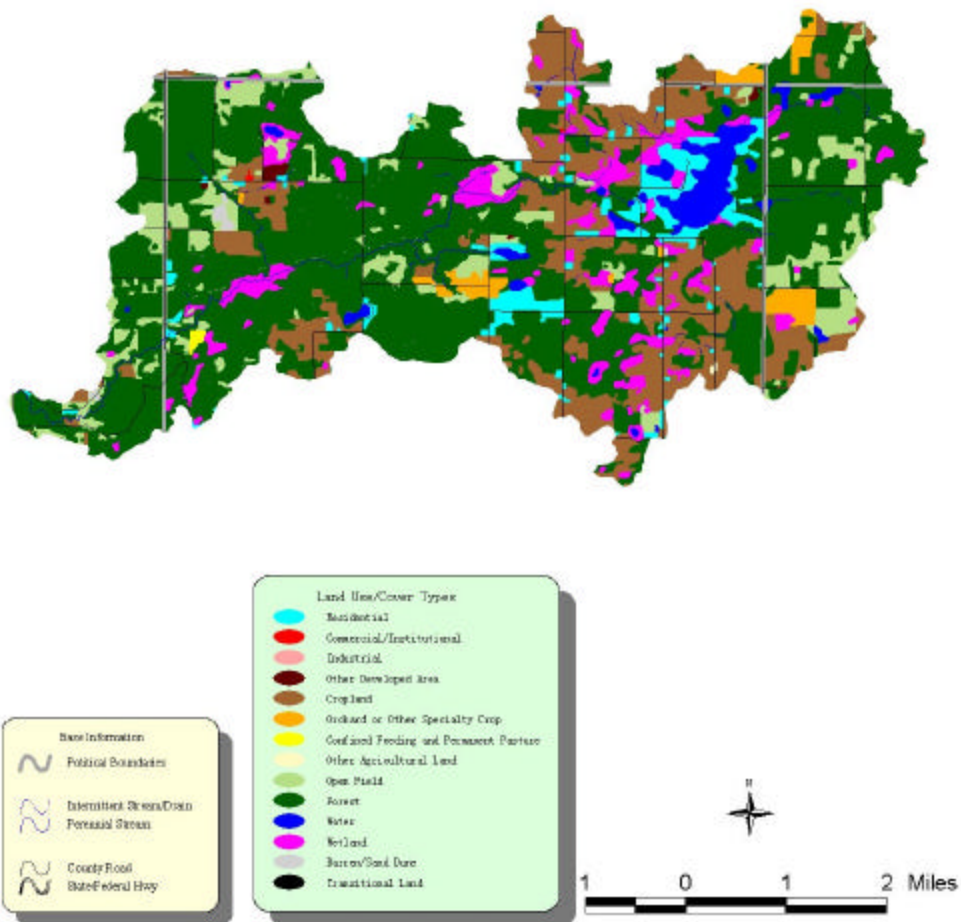


FIGURE 4.5.1 LAND COVER MAP OF THE UPPER NORTH BRANCH SUBWATERSHED.

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.



Land Use/Cover 1992/1997/1998 White River Watershed North Branch White River Subwatershed

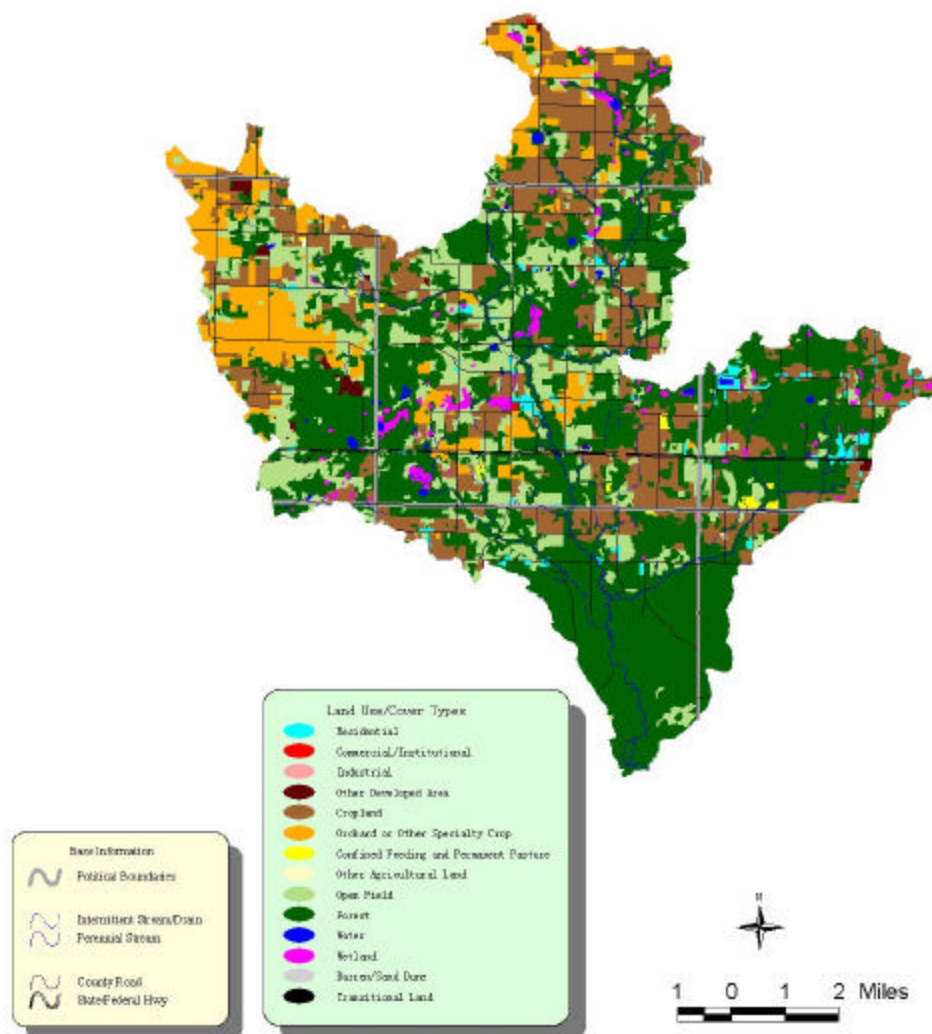


FIGURE 4.6.1 LAND COVER MAP OF THE NORTH BRANCH SUBWATERSHED.

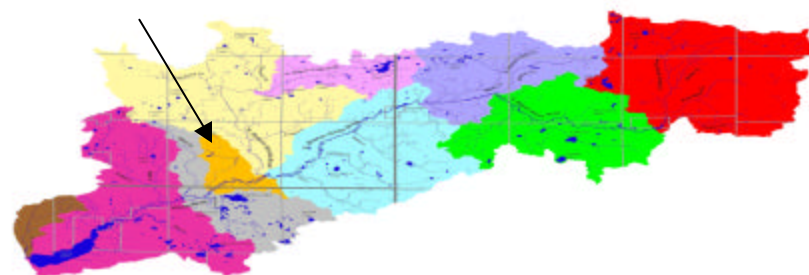
**Table 4.7.1 Land Cover Analysis of the Middle Branch Subwatershed
1978 - 1992/1997/1998.**

| 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.



Land Use/Cover 1992/1997/1998

White River Watershed

Middle White River Subwatershed

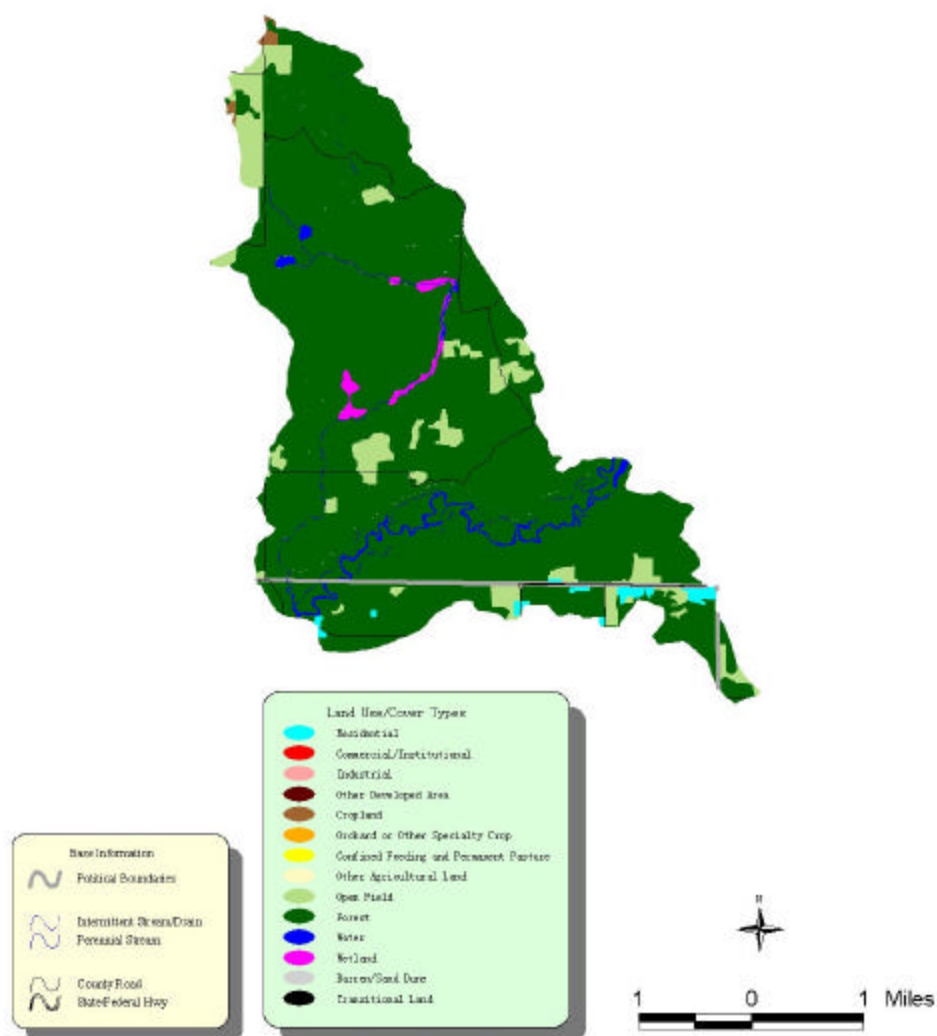


FIGURE 4.7.1 LAND COVER MAP OF THE MIDDLE BRANCH SUBWATERSHED.

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 Coastal 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.



Land Use/Cover 1992/1997/1998 White River Watershed White Lake and Carlton/Mud Creeks Subwatershed

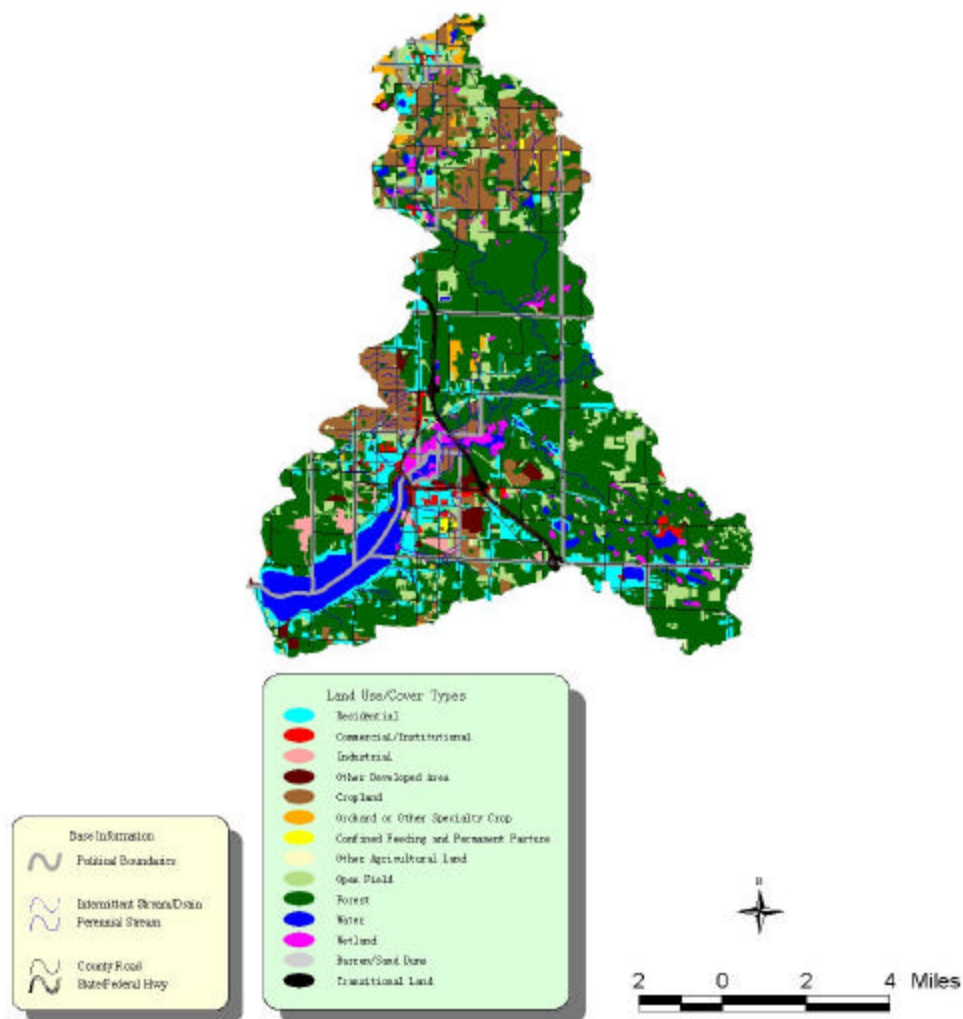


FIGURE 4.8.1 LAND COVER MAP OF THE WHITE LAKE CARLTON/MUD CREEK SUBWATERSHED.

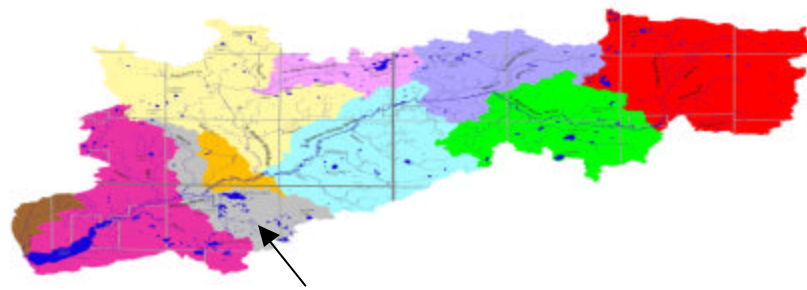
Table 4.9.1 Land Cover Analysis of the Sand Creek/Wolverine Lake Subwatershed 1978 - 1992/1997/1998.

| 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.



Land Use/Cover 1992/1997/1998 White River Watershed Sand Creek/Wolverine Lake Subwatershed

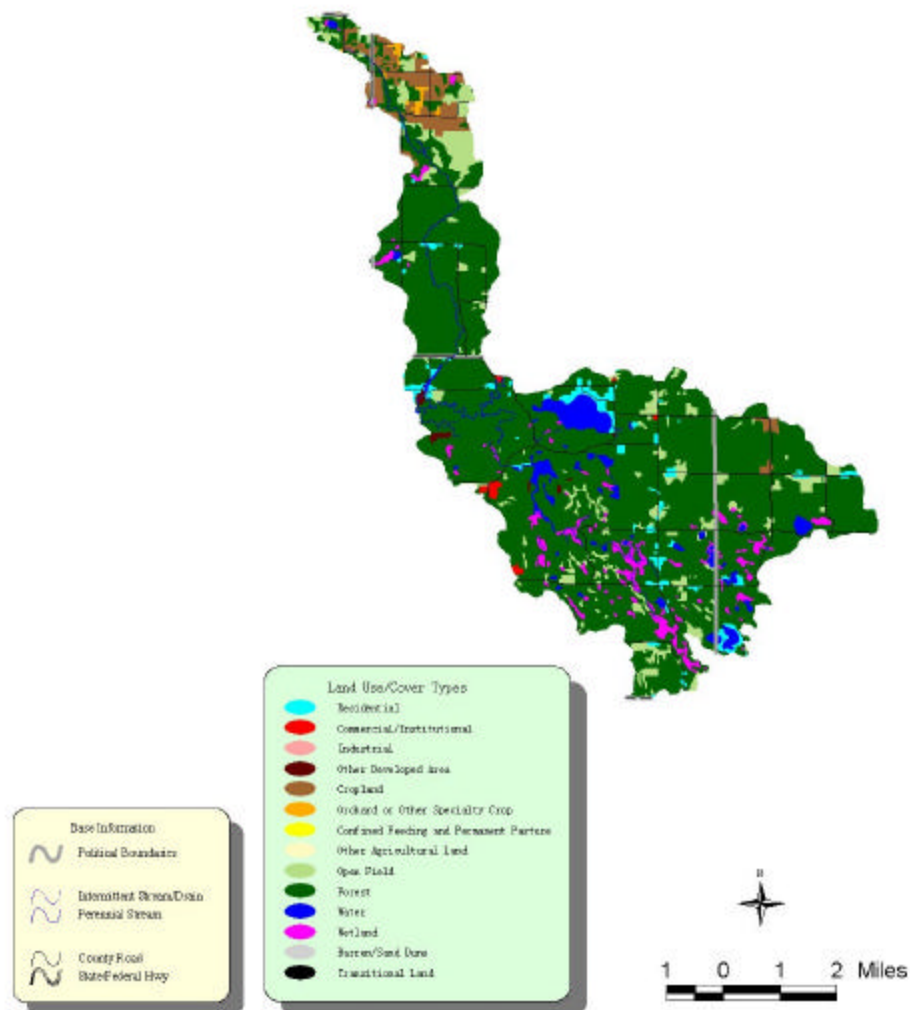


FIGURE 4.9.1 LAND COVER MAP OF THE WHITE LAKE SAND CREEK/WOLVERINE LAKE SUBWATERSHED.

**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



Land Use/Cover 1992/1997/1998 White River Watershed Pierson Drain Subwatershed

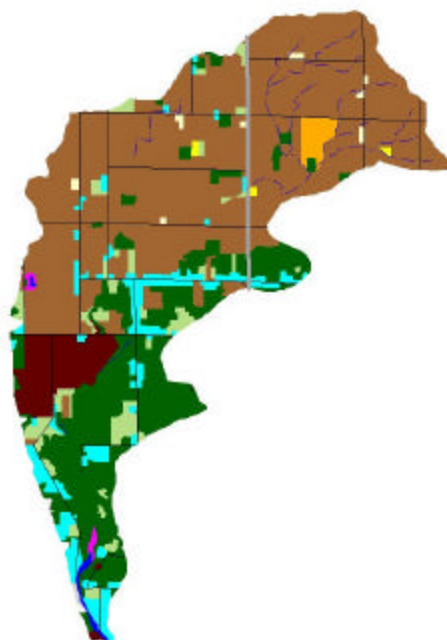


FIGURE 4.10.1 LAND COVER MAP OF THE PEARSON DRAIN SUBWATERSHED.

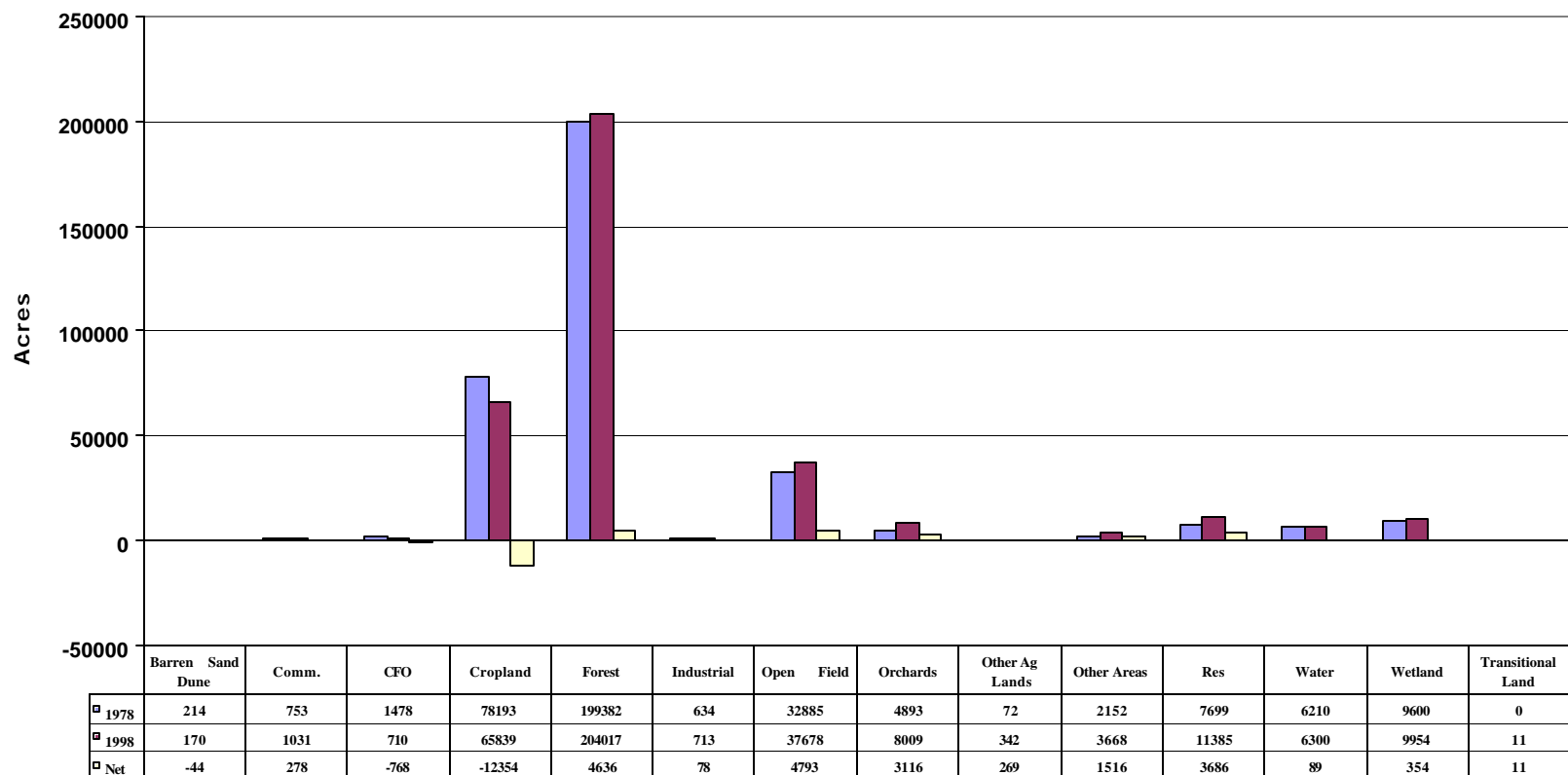
**TABLE 4.10.1 LAND COVER ANALYSIS OF THE WHITE RIVER
SUBWATERSHED 1978 - 1992/1997/1998.**

| 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



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°C until delivery to the laboratory. Analytical methods for nutrient analysis are summarized below

| <u>PARAMETER</u> | <u>METHOD</u> |
|----------------------|---------------|
| 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 epilimnion (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

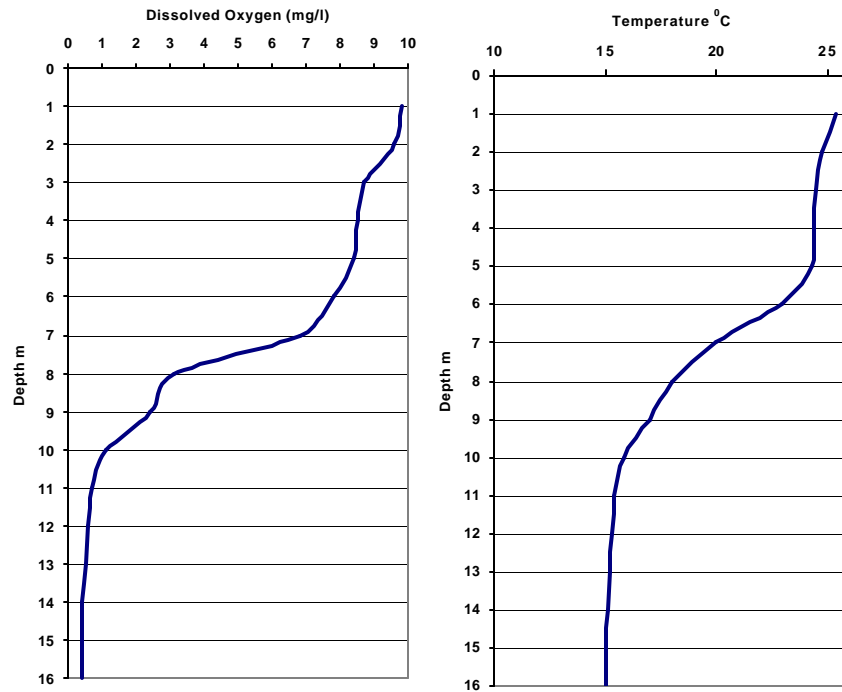


FIGURE 5.3.1 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 2 IN WHITE LAKE. JULY 27, 2002.

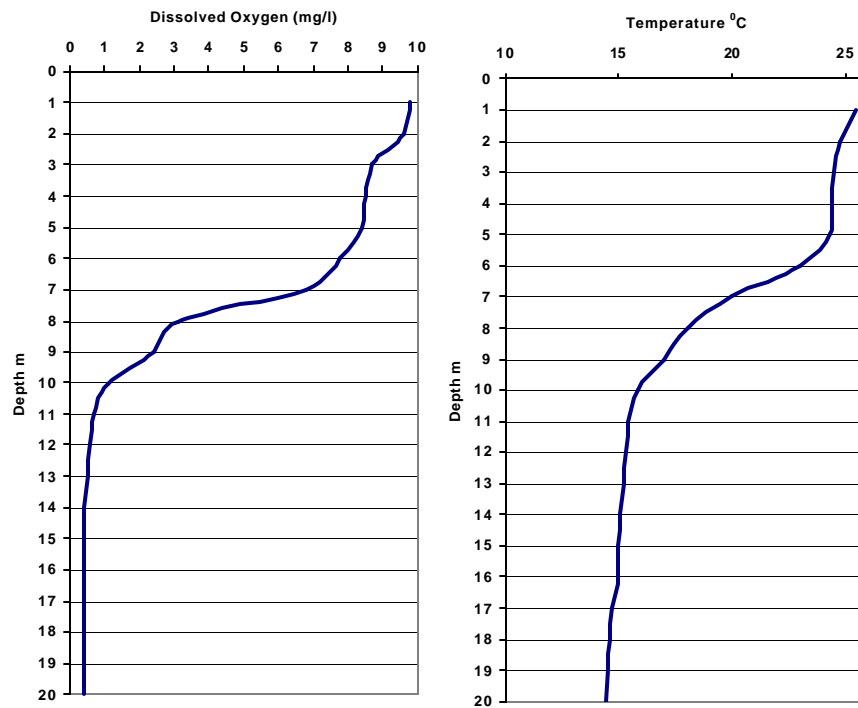


FIGURE 5.3.2 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 3 IN WHITE LAKE. JULY 27, 2002.

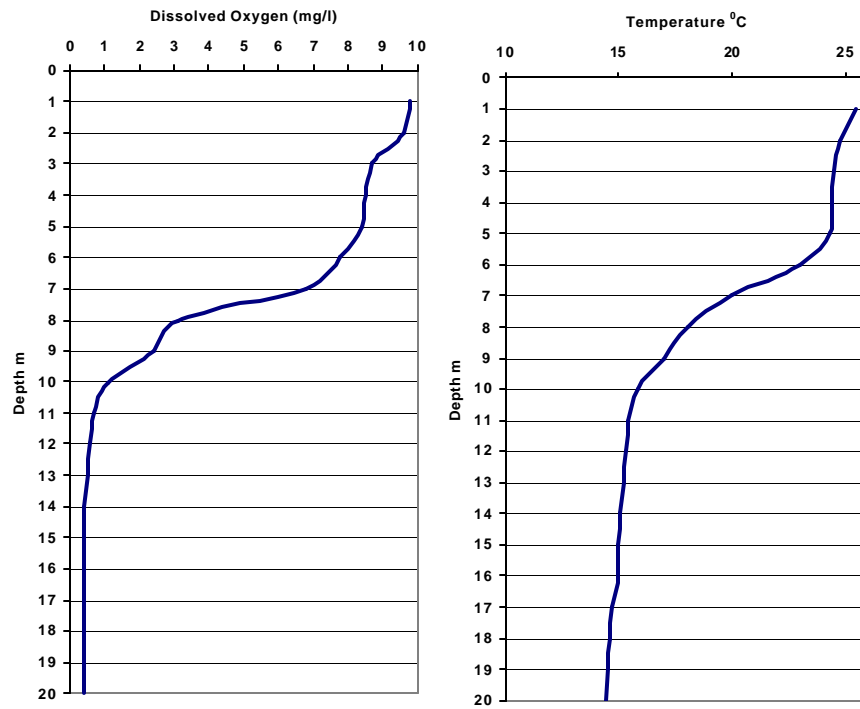


FIGURE 5.3.3 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 4 IN WHITE LAKE. JULY 27, 2002.

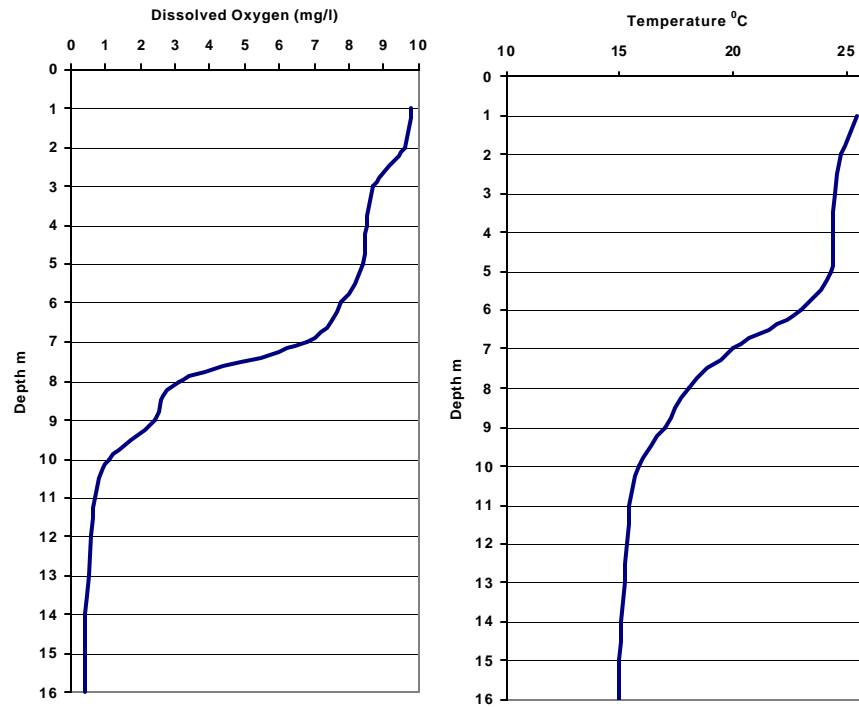


FIGURE 5.3.4 DISSOLVED OXYGEN AND TEMPERATURE PROFILES AT STATION 5 IN WHITE LAKE. JULY 27, 2002.

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

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 km² 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. 6.2.1). 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.

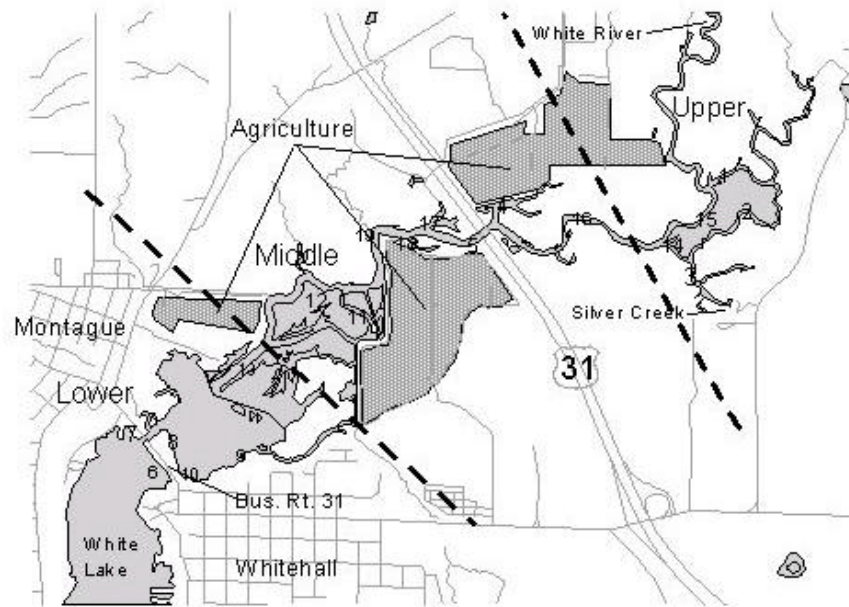


FIGURE 6.2.1 WHITE RIVER DROWNED RIVERMOUTH SAMPLING LOCATIONS, 2001.

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 2001 drowned 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 \pm 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 | <i>Hyallela</i> |
| Upper-Pontederia-1 | 29 | 0.747(0.039) | 0.632(0.006) | Coenagrionidae | <i>Hyallela</i> |
| Upper-Scirpus-1 | 25 | 0.664(0.029) | 0.609(0.035) | <i>Hyallela</i> | Caenidae |
| Upper-Sparganium-1 | 24 | 0.799(0.030) | 0.711(0.009) | <i>Gammarus</i> | <i>Hyallela</i> |
| Upper-Lily-2 | 29 | 0.905(0.051) | 0.746(0.031) | <i>Gammarus</i> | 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) | <i>Gammarus</i> | Caenidae |
| Upper-Lily-15 | 17 | 0.332(0.108) | 0.350(0.091) | Aphididae | <i>Gammarus</i> |
| Middle-Lily-4 | 32 | 0.906(0.028) | 0.693(0.016) | <i>Hyallela</i> | Coenagrionidae |
| Middle-Sparganium-4 | 36 | 0.911(0.098) | 0.700(0.045) | <i>Hyallela</i> | 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) | <i>Gammarus</i> | Corixidae |
| Middle-Scirpus-12 | 32 | 0.556(0.050) | 0.500(0.009) | <i>Gammarus</i> | Corixidae |
| Middle-Sparganium-16 | 24 | 0.573(0.096) | 0.544(0.052) | <i>Gammarus</i> | Corixidae |
| Middle-Lily-17 | 34 | 0.910(0.070) | 0.707(0.053) | <i>Neoplea</i> | <i>Hyallela</i> |
| Middle-Lily-18 | 30 | 0.833(0.024) | 0.695(0.008) | <i>Gammarus</i> | Caenidae |
| Middle-Sparganium-19 | 48 | 1.175(0.010) | 0.828(0.007) | Aphididae | <i>Gammarus</i> |
| Lower-Lily-6 | 24 | 0.876(0.044) | 0.719(0.045) | <i>Gammarus</i> | 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 | <i>Gammarus</i> |
| Lower-Lily-9 | 37 | 0.763(0.177) | 0.609(0.122) | Corixidae | <i>Gammarus</i> |
| 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 | <i>Gammarus</i> |
| Lower-Typha-13 | 21 | 0.442(0.054) | 0.426(0.030) | Corixidae | <i>Gammarus</i> |

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.

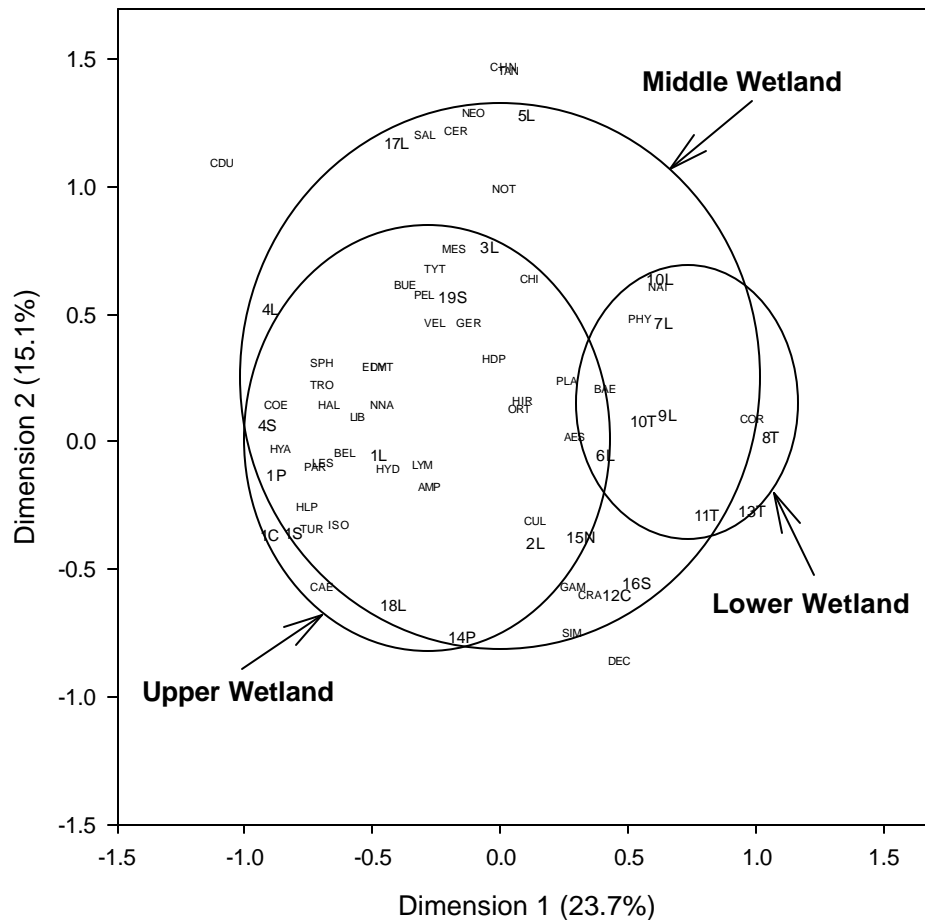


Fig. 6.3.1. Correspondence analysis of 47 invertebrate taxa grouped by wetland region. Labels indicate site location number and vegetation type (L, lily; C, Scirpus; T, Typha; P, Pontederia; S, Sparganium). Overlap of sites indicates similarity between sites.

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 | Hyaella 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 |
| | | Halipidae | | HAL |
| | | | Halipus | HLP |
| | | | Peltodytes | PEL |
| | | Hydrophilidae | | HDP |
| | | | Tropisternus | TRO |
| | Diptera | Ceratopogonidae | | CER |
| | | Chironomidae | | CHI |
| | | | Chironomini | CHN |
| | | | Tanytarsini | TYT |
| | | | Orthoclaadiinae | 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 $34.4 \pm 1.4\%$ 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 $40.4 \pm 2.3\%$ while middle and upper wetland sites %non-insect taxa richness were $31.8 \pm 1.9\%$ and $32.0 \pm 2.0\%$ 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 $\mu\text{S}/\text{cm}$). 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.

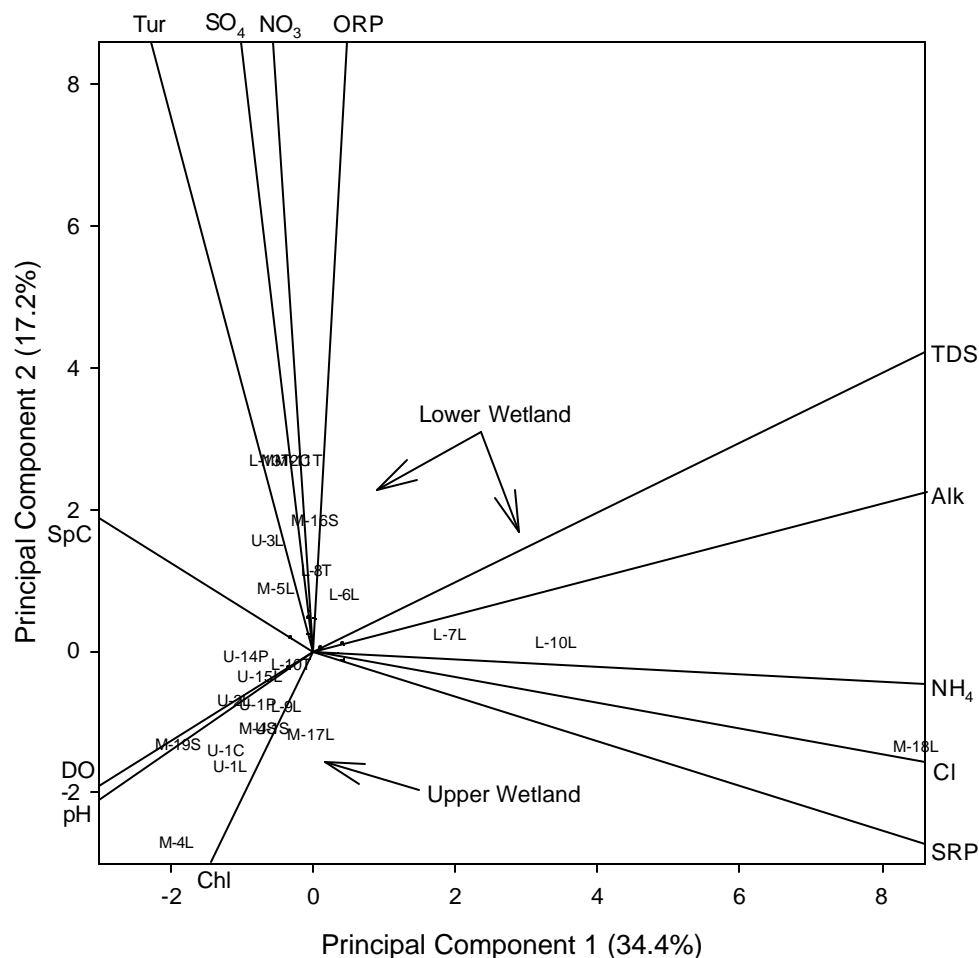


Fig. 6.3.2. Principal components analysis of 13 chemical/physical parameters. Labels indicate wetland region (upper, U-; middle, M-; lower, L-), site location number and vegetation type (L, lily; P, Pontederia; S, Sparganium; C, Scirpus; T, Typha). Overlap of sites indicates similarity between sites.

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 | °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 detection 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 $\mu\text{S}/\text{cm}$. 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.

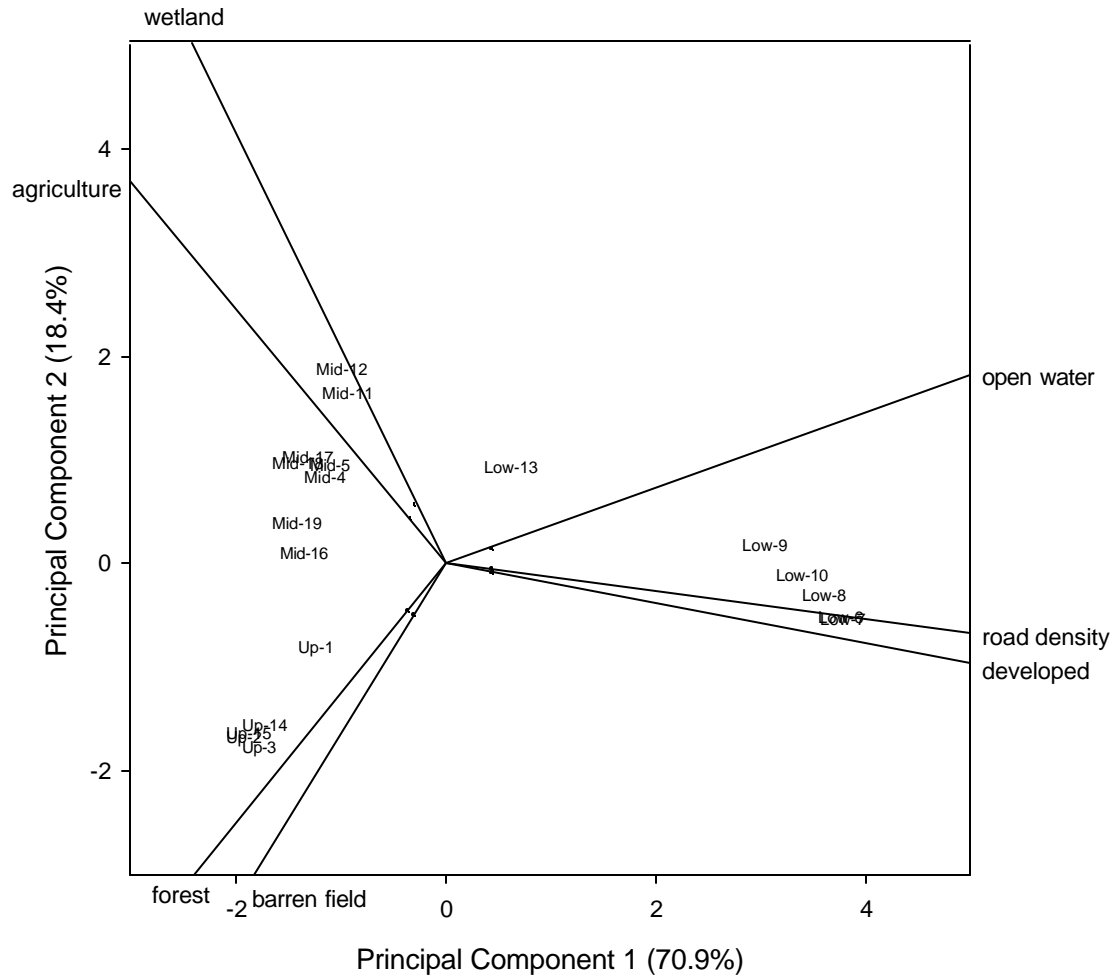


Fig. 6.3.3. Principal components analysis of 7 land-use/cover parameters. Labels indicate wetland region (upper, middle, lower) and site location numbers.

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 Macroinvertebrate 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.

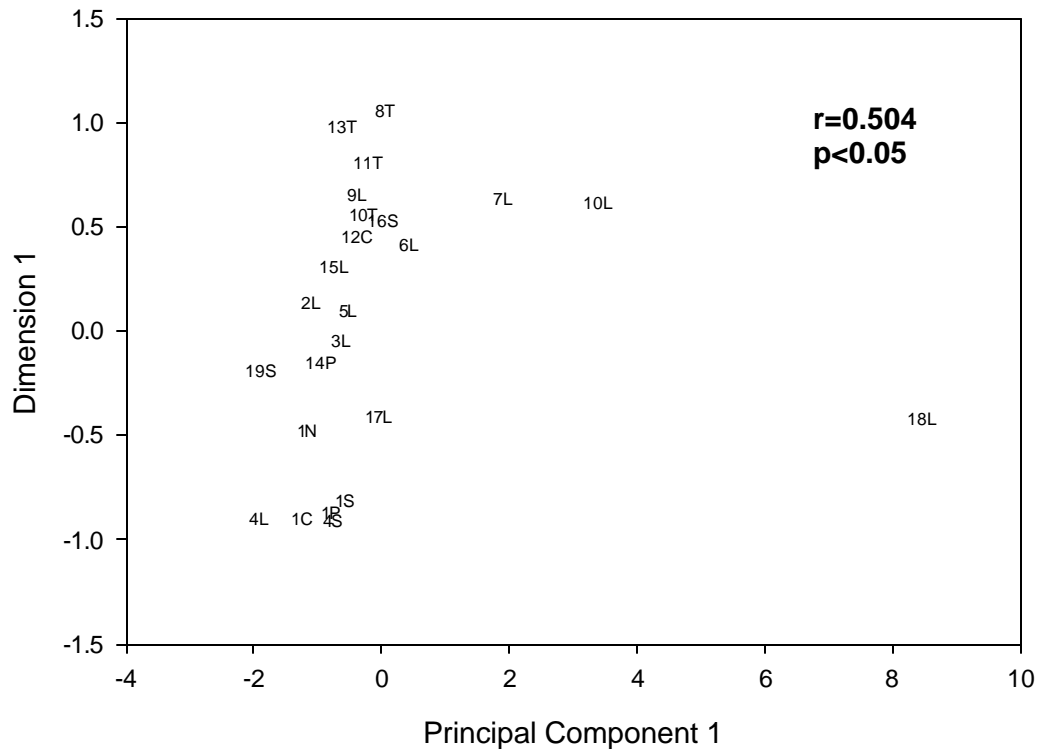


Fig. 6.3.4 Dimension 1 scores from correspondence analysis of invertebrates in response to changes in water quality measured by principal component 1 of the principal components analysis of 13 chemical/physical parameters. Labels refer to site location number and vegetation type (L, lily; C, Scirpus; 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 $50.3 \pm 5.2\%$. 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= $0.56 \pm 0.2\%$). 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 abundance | 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'=Ephemeroptera(mayflies)+ Plecoptera(stoneflies)+Trichoptera(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 $78.2 \pm 6.6\%$ saturation. Specific conductance (SpC) ranged from 203.5 μ S/cm at the South Branch site to 640.3 μ S/cm at the Robinson Creek at Johnson Rd. site. Mean SpC was 328.6 ± 39.0 μ 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 | NH ₄ | SRP | Cl | SO ₄ | Alk | Temp | DO | %DO | SpC | TDS | ORP | Chl | pH |
|--------------------------------------|-----------------|-----------------|-------|------|-----------------|------|------|-------|-------|-------|-------|------|------|------|
| | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | °C | mg/L | % Sat | uS/cm | g/L | mV | ug/L | |
| 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 °C at the Fitzgerald Rd. site to 15.0 °C at the Robinson Creek at Baldwin Rd. site. Mean temperature was $11.6 \pm 0.5.9^{\circ}\text{C}$. 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 $\mu\text{S}/\text{cm}$ 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 *Hyallorella azteca*. Middle-Lily-4, Middle-Sparganium-19, Middle-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 *Hyallorella 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.

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- ✍✍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 be 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 encompass 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 all age 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).

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

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

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

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

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

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

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

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

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| (Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered) | | | | |
| VASCULAR PLANTS (cont'd...) | | | | |
| <i>Grossulariaceae</i> | Ribes cynosbati | Prickly Or Wild Gooseberry | | |
| | Ribes sp. | Gooseberry | | |
| | Ribes triste | Red Currant | | |
| <i>Guttiferae</i> | 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 |
| <i>Haloragaceae</i> | Proserpinaca palustris | Cut-leaved Mermaid weed | | |
| <i>Haloragales</i> | Myriophyllum spicatum | Eurasian Water-milfoil | A | N |
| <i>Hamamelidaceae</i> | Hamamelis virginiana | Witch Hazel | | |
| <i>Hydrocharitaceae</i> | Elodea canadensis | Common Waterweed | | |
| | Vallisneria americana | Eel Grass | | |
| <i>Iridaceae</i> | Iris versicolor | Northern Blue Flag | | N |
| <i>Juglandaceae</i> | Juglans nigra | Black Walnut | | N |
| <i>Juncaceae</i> | 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 | | |
| <i>Labiatae</i> | 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 x piperita [aquatica x 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 | | |
| <i>Lauraceae</i> | Lindera benzoin | Spicebush | | |
| | Sassafras albidum | Sassafras | | |
| <i>Leguminosae</i> | 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 |
| <i>Lemnaceae</i> | Lemna minor | Small Duckweed | | |
| <i>Lentibulariaceae</i> | 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).

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| VASCULAR PLANTS (cont'd...) | | | | |
| <i>Liliaceae</i> | 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 | | |
| <i>Lythraceae</i> | Uvularia grandiflora | Large Bellwort | | |
| | Uvularia sessilifolia | Wild Oats, Sessile Bellwort | | N |
| | | | | |
| <i>Lythraceae</i> | Decodon verticillatus | Swamp Loosestrife, Water-willow | | |
| | Lythrum salicaria | Purple or Spiked Loosestrife | A | |
| <i>Magnoliaceae</i> | Liriodendron tulipifera | Tuliptree, Yellow Poplar, Tulip Poplar | | N |
| <i>Menispermaceae</i> | Menispermum canadense | Moonseed | | |
| <i>Menyanthaceae</i> | Menyanthes trifoliata | Buckbean | | N |
| <i>Monotropeaceae</i> | Monotropa hypopithys | Pinesap | | |
| | Monotropa uniflora | Indian-pipe | | |
| <i>Moraceae</i> | Morus alba | White Mulberry | A | |
| <i>Mulluginaceae</i> | Mollugo verticillata | Carpetweed | A | |
| <i>Myricaceae</i> | Comptonia peregrina | Sweet-fern | | |
| <i>Najadaceae</i> | Najas flexilis | Slender Naiad | | |
| | Najas guadalupensis | Southern Naiad | | N |
| <i>Nymphaeaceae</i> | Nuphar variegatum | Bullhead-lily | | |
| | Nymphaea odorata | Fragrant Water-lily | | |
| | Brasenia schreberi | Water-shield | | |
| <i>Oleaceae</i> | Fraxinus nigra | Black Ash | | N |
| | Fraxinus pennsylvanica | Green Ash | | |
| <i>Onagraceae</i> | 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 | | |
| <i>Orchidaceae</i> | 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 | | |
| <i>Orobanchaceae</i> | Platanthera psvcodes | Small Purple Fringed Orchid | | |
| | | | | |
| <i>Orobanchaceae</i> | Conopholis americana | Squawroot | | |
| | Epifagus virginiana | Beech-drops | | |
| <i>Oxalidaceae</i> | Oxalis sp. | Oxalis, Wood-sorrel | | |
| | Oxalis stricta | Common Yellow Wood-sorrell | | |
| <i>Phytolaccaeae</i> | Phytolacca americana | Pokeweed | | |
| | Phytolacca sp. | Pokeweed | | |
| <i>Pinaceae</i> | 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 | | |
| <i>Plantaginaceae</i> | Plantago lanceolata | English Plantain | A | |
| | Plantago major | Common Plantain | | N |
| | Plantago rugelii | Blackseed Plantain | | |
| <i>Plumbaginaceae</i> | Limonium carolinianum | Sea Lavendar | | N |
| <i>Polemoniaceae</i> | Phlox pilosa | Downy Phlox | | N |

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

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

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

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

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

| | Scientific Name | Common Name | Status | Muskegon County Status (N= New) |
|---|---------------------------------|-------------------------------------|--------|---------------------------------------|
| (Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered) | | | | |
| VASCULAR PLANTS (cont'd...) | | | | |
| <i>Scrophulariaceae</i> | Pedicularis lanceolata | Swamp Lousewort | | |
| | Verbascum blattaria | Moth Mullein | A | |
| | Verbascum thapsus | Common Mullein | A | |
| | Veronica beccabunga | Brooklime | | |
| | Veronica sp. | Speedwell | | |
| <i>Solanaceae</i> | Physalis heterophylla | Clammy Ground-cherry | | |
| | Solanum dulcamara | Nightshade, Bittersweet | A | |
| | Solanum ptychanthum | Black Nightshade | | N |
| <i>Sparganiaceae</i> | Sparganium sp. | Bur-reed | | |
| <i>Tiliaceae</i> | Tilia americana | Basswood | | |
| <i>Typhaceae</i> | Typha angustifolia | Narrow-leaved Cat-tail | A | |
| | Typha latifolia | Common Cattail | | N |
| <i>Ulmaceae</i> | Ulmus americana | American Elm | | |
| <i>Ulmaceae</i> | Ulmus rubra | Red Elm | | N |
| <i>Umbelliferae</i> | Berula erecta | Toothache Root, Giant Water Parsnip | ST | N |
| | Cicuta bulbifera | Bulb-bearing Water-hemlock | | |
| | Cicuta maculata | Spotted Water Hemlock | | |
| <i>Umbelliferae</i> | Daucus carota | Queen Anne's Lace, Wild Carrot | A | |
| | 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 | | |
| <i>Urticaceae</i> | Boehmeria cylindrica | False Nettle | | |
| | Pilea fontana | Lesser Clearweed | | |
| | Urtica dioica | Stinging Nettle | | |
| <i>Verbenaceae</i> | Phryma leptostachia | Lopseed | | |
| | Verbena hastata | Blue Vervain | | |
| | Verbena stricta | Hoary Vervain | | |
| <i>Violaceae</i> | 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 | | |
| <i>Vitaceae</i> | Parthenocissus inserta | Thicket Creeper | | |
| | Parthenocissus quinquefolia | Virginia Creeper | | |
| | Vitis aestivalis | Summer Grape | | |
| | Vitis riparia | River-bank Grape | | |
| | Vitis riparis | Wild Grape | | |
| <i>Xyridaceae</i> | Xyris difformis | Carolina Yellow-eyed grass | | |

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

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

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

| | Scientific Name | Common Name | Status |
|---|---------------------------------|-------------------------------------|--------|
| (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 | |
| | <u>Phaeucticus ludovicianus</u> | <u>Rose-breasted Grosbeak</u> | |
| | Picoides pubescens | Downy Woodpecker | |
| | Picoides villosus | Hairy Woodpecker | |
| | Pipilo erythrophthalmus | Eastern Towhee, Rufous-sided Towhee | |
| | Piranga olivacea | Scarlet Tanager | |
| | <u>Poecile atricapilla</u> | <u>Black-capped Chickadee</u> | |
| | Polioptila caerulea | Blue-gray Gnatcatcher | |
| | Poocetes gramineus | Vesper Sparrow | |
| | Progne subis | Purple Martin | |
| | Quiscalus quiscula | Common Grackle | |
| | <u>Regulus calendula</u> | <u>Ruby-crowned Kinglet</u> | |
| | Riparia riparia | Bank Swallow | |
| | Sayornis phoebe | Eastern Phoebe | |
| | Scolopax minor | American Woodcock | |
| | Seiurus aurocapillus | Ovenbird | |
| | <u>Seiurus motacilla</u> | <u>Louisiana Waterthrush</u> | SR |
| | Seiurus noveboracensis | Northern Waterthrush | |
| | Setophaga ruticilla | American Redstart | |
| | Sialia sialis | Eastern Bluebird | |
| | Sitta canadensis | Red-breasted Nuthatch | |
| | <u>Sitta carolinensis</u> | <u>White-breasted Nuthatch</u> | |
| | Spizella passerina | Chipping Sparrow | |
| | Spizella pusilla | Field Sparrow | |
| | Stelgidopteryx serripennis | Northern Rough-winged Swallow | |
| | Sturnus vulgaris | European Starling | |
| | <u>Tachycineta bicolor</u> | <u>Tree Swallow</u> | |
| | Toxostoma rufum | Brown Thrasher | |
| | Tringa solitaria | Solitary Sandpiper | |
| | Troglodytes aedon | House Wren | |
| | Turdus migratorius | American Robin | |
| | <u>Tyrannus tyrannus</u> | <u>Eastern Kingbird</u> | |
| | Vermivora chrysoptera | Golden-winged Warbler | |
| | Vermivora peregrina | Tennessee Warbler | |
| | Vermivora pinus | Blue-winged Warbler | |
| | Vermivora ruficapilla | Nashville Warbler | |
| | <u>Vireo flavifrons</u> | <u>Yellow-throated Vireo</u> | |
| | Vireo gilvus | Warbling Vireo | |
| | Vireo olivaceus | Red-eyed Vireo | |
| | Vireo philadelphicus | Philadelphia Vireo | |
| | Vireo solitarius | Blue-headed Vireo | |
| | <u>Wilsonia pusilla</u> | <u>Wilson's Warbler</u> | |
| | Zenaidura 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).

| Scientific Name | Common Name | Status |
|---|--|--------|
| (Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered) | | |
| HERPTILES | 33 identified | |
| <i>Ambystoma laterale</i> | Blue-spotted Salamander | |
| <i>Ambystoma maculatum</i> | Spotted Salamander | |
| <i>Apalone spinifera spinifera</i> | Eastern Spiny Softshell Turtle | |
| <i>Bufo americanus</i> | American Toad | |
| <i>Bufo fowleri</i> | Fowler's Toad | |
| <i>Chelydra serpentina serpentina</i> | Common Snapping Turtle | |
| <i>Chrysemys picta marginata</i> | Midland Painted Turtle | |
| <i>Clemmys insculpta</i> | Wood Turtle | |
| <i>Coluber constrictor foxii</i> | Blue Racer | |
| <i>Emydoidea blandingi</i> | Blanding's Turtle | SR |
| <i>Eumeces fasciatus</i> | Five-lined Skink | |
| <i>Graptemys geographica</i> | Common Map Turtle | |
| <i>Hemidactylium scutatum</i> | Four-toed Salamander | |
| <i>Heterodon platirhinos</i> | Eastern Hognose Snake | |
| <i>Hyla crucifer</i> | Spring Peeper | |
| <i>Hyla versicolor</i> | Gray Treefrog | |
| <i>Nerodia sipedon</i> | Northern Water Snake | |
| <i>Notophthalmus viridescens</i> | Eastern Newt (also Red Eft stage) | |
| <i>Plethodon cinereus</i> | Redback Salamander (red & gray phases) | |
| <i>Pseudacris triseriata</i> | Chorus Frog | |
| <i>Rana catesbeiana</i> | Bullfrog | |
| <i>Rana clamitans</i> | Green Frog | |
| <i>Rana palustris</i> | Pickerel Frog | |
| <i>Rana pipiens</i> | Northern Leopard Frog | |
| <i>Rana sylvatica</i> | Wood Frog | |
| <i>Sistrurus catenatus</i> | Eastern Massasauga | |
| <i>Stemotherus odoratus</i> | Common Musk Turtle | |
| <i>Storeria dekayi dekayi</i> | Northern Brown Snake | |
| <i>Storeria dekayi wrightorum</i> | Midland Brown Snake | |
| <i>Terrapene carolina carolina</i> | Eastern Box Turtle | SR |
| <i>Thamnophis sauritus septentrionalis</i> | Northern Ribbon Snake | |
| <i>Thamnophis sirtalis sirtalis</i> | Eastern Garter Snake | |
| <i>Trachemys scripta elegans</i> | 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 |
| | | Mephitis mephitis | 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 | |
| <i>Blattaria</i> | | Parcoblatta pennsylvanica | Pennsylvania Wood Cockroach |
| <i>Coleoptera</i> | | 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 |
| <i>Diptera</i> | | Aedes sp. | Mosquito |
| | | Family: Asilidae | Robberfly |
| | | Chrysops sp. | Deer Fly |
| | | Exoprosopa sp. | Progressive Bee Fly |
| | | Pyrigota undata | Pyrigotid Fly, Light Fly |
| | | Simulium sp. | Black Fly |
| | | Tabanus sp. | Horse Fly |
| <i>Hemiptera</i> | | 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 crosa | Jagged Ambush Bug |
| <i>Homoptera</i> | | Graphacephala coccinea | Scarlet and Red Leafhopper |
| | | Lepyronia gibbosa | Great Plains Spittlebug |
| | | Platypedia sp. | Woodland Cicada |
| | | Tibicen canicularis | Dog-day Cicada |
| <i>Hymenoptera</i> | | Ammophila sp. | Thread-waisted Wasp |
| | | Amphibolips confluenta | Oak-Apple Gall Wasp |
| | | Bombus sp. | Bumblebee |
| | | Camponotus spp. | Carpenter Ant |
| | | Dasymutilla occidentalis | Velvet Ant, Cow Killer |
| | | Dolichovespula maculata | Bald-faced Hornet |
| | | Family: Ichneumonidae | Ichneumonid Wasp |
| | | Family: Myziniinae | 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).**

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

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

| | Scientific Name | Common Name |
|---|--------------------------------|---------------------------|
| (Status: A = alien, SR = state rare, ST = state threatened, SE = state endangered, FE = federally endangered) | | |
| INSECTS | | |
| <i>Zygoptera</i> | <i>Pachydiplax longipennis</i> | Blue Dasher |
| | <i>Perithemis tenera</i> | Eastern Amberwing |
| | <i>Progomphus obscurus</i> | Common Sanddragon |
| | <i>Sympetrum costiferum</i> | Saffron-winged Meadowhawk |
| | <i>Sympetrum obtrusum</i> | White-faced Meadowhawk |
| | <i>Sympetrum rubicundulum</i> | Ruby Meadowhawk |
| | <i>Sympetrum semicinctum</i> | Band-winged Meadowhawk |
| | <i>Sympetrum vicinum</i> | Yellow-legged Meadowhawk |
| | <i>Tramea lacerata</i> | Black Saddlebags |
| | <i>Argia fumipennis</i> | Variable Dancer |
| | <i>Calopteryx maculata</i> | Ebony Jewelwing |
| | <i>Enallagma exsulans</i> | Stream Bluet |
| | <i>Hetaerina americana</i> | American Rubyspot |
| | <i>Ischnura verticalis</i> | Eastern Forktail |
| | <i>Lestes unguiculatus</i> | Lyre-tipped Spreadwing |
| <i>Orthoptera</i> | <i>Lestes vigilax</i> | Swamp Spreadwing |
| | <i>Dissostera carolina</i> | Carolina Locust |
| | <i>Gryllus pennsylvanicus</i> | Fall Field Cricket |
| | <i>Neoconocephalus ensiger</i> | Swordbearing Katydid |
| | <i>Oecanthus pini</i> | Pine Tree Cricket |
| <i>Trichoptera</i> | Family: Tettigonidae | Katydid |
| | 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 |
|-------------|-------------------------------|---------------------|
| | <i>Ambloplites rupestris</i> | Rock Bass |
| | <i>Ameiurus melas</i> | Black Bullhead |
| | <i>Ameiurus melas</i> | Black bullhead |
| | <i>Ameiurus natalis</i> | Yellow bullhead |
| | <i>Ameiurus nebulosus</i> | Brown bullhead |
| | <i>Amia calva</i> | Bowfin |
| | <i>Aphredoderus sayanus</i> | Pirate perch |
| | <i>Aphredoderus sayanus</i> | Pirate perch |
| | <i>Catostomus catostomus</i> | Longnose sucker |
| | <i>Catostomus commersoni</i> | White Sucker |
| | <i>Catostomus commersoni</i> | White sucker |
| | <i>Cottus bairdi</i> | Mottled Sculpin |
| | <i>Cottus bairdii</i> | Mottled sculpin |
| | <i>Couesius plumbeus</i> | Lake chub |
| | <i>Culaea inconstans</i> | Brook Stickleback |
| | <i>Culaea inconstans</i> | Brook stickleback |
| | <i>Cyprinella spiloptera</i> | Spotfin shiner |
| | <i>Cyprinus carpio</i> | Carp |
| | <i>Erimyzon oblongus</i> | Creek Chubsucker |
| | <i>Erimyzon sucetta</i> | Lake chubsucker |
| | <i>Esox americanus</i> | Grass Pike |
| | <i>Esox lucius</i> | Northern Pike |
| | <i>Esox lucius</i> | Northern pike |
| | <i>Etheostoma caeruleum</i> | Rainbow darter |
| | <i>Etheostoma exile</i> | Iowa darter |
| | <i>Etheostoma flabellare</i> | Fantail Darter |
| | <i>Etheostoma flabellare</i> | Fantail darter |
| | <i>Etheostoma microperca</i> | Least darter |
| | <i>Etheostoma nigrum</i> | Johnny Darter |
| | <i>Etheostoma nigrum</i> | Johnny darter |
| | <i>Fundulus daphanus</i> | Banded Killfish |
| | <i>Hybognathus hankinsoni</i> | Brassy minnow |
| | <i>Hypentelium nigricans</i> | Northern hog sucker |
| | <i>Ictalurus punctatus</i> | Channel catfish |
| | <i>Ictiobus niger</i> | Black buffalo |
| | <i>Labidesthes sicculus</i> | Brook silverside |
| | <i>Lepomis gibbosus</i> | Pumpkinseed |
| | <i>Lepomis gulosus</i> | Warmouth |
| | <i>Lepomis macrochirus</i> | Bluegill |
| | <i>Lepomis spp.</i> | Hybrid Sunfish |
| | <i>Luxilus chrysocephalus</i> | Striped shiner |
| | <i>Luxilus cornutus</i> | Common Shiner |
| | <i>Luxilus cornutus</i> | Common shiner |
| | <i>Margariscus margarita</i> | Pearl dace |
| | <i>Micropterus dolomieu</i> | Smallmouth Bass |

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

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

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

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