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Kalamazoo River Assessment

Jay K. Wesley

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EXECUTIVE SUMMARY

This is one of a series of river assessments being prepared by the Fisheries Division of the Michigan Department of Natural Resources (MDNR) for Michigan rivers. This report describes the characteristics of the Kalamazoo River and its biological communities.

River assessments are prepared to provide a comprehensive reference for citizens and agency personnel who desire information about a particular aquatic resource. These assessments will provide an approach to identifying fishery management opportunities and solving fishery related problems. This river assessment will increase public awareness of the Kalamazoo River and its challenges and serve to promote a sense of public stewardship and advocacy for the resources of this watershed. The ultimate goal is to provide information to enable increased public involvement in the decision making process to benefit the river and its resources.

This document consists of four parts: an introduction, a river assessment, management options, and public comments and response. The river assessment is the nucleus of the report. The characteristics of the Kalamazoo River and its watershed are described in twelve sections: geography, history, geology and hydrology, soils and land use, channel morphology, dams and barriers, water quality, special jurisdictions, biological communities, fishery management, recreational use, and citizen involvement.

The management options section of the report identifies a variety of challenges and opportunities. These management options are categorized and presented following the organization of the main sections of the river assessment. It must be stressed that MDNR, Fisheries Division does not necessarily recommend the options listed. Rather, they are intended to provide a foundation for public discussions and comment.

The Kalamazoo River and its tributaries form a network draining approximately 2,020 square miles of southwest Michigan. The mainstem is 175 miles long and there are 899 miles of tributaries. Major tributaries include North Branch Kalamazoo, Battle Creek, Gun, and Rabbit rivers and Rice, Wabascon, Augusta, and Portage creeks. There are 287 lakes greater than 10 acres within the basin. Gun Lake is the largest lake at 2,661 acres.

For purpose of discussion, the Kalamazoo River mainstem is divided into five sections called mainstem valley segments. Mainstem valley segments represent portions of a river that share common channel and landscape features and were identified using major changes in hydrology, channel and valley shapes, land cover, and surficial geology. The headwater segment consists of the South Branch Kalamazoo River, which is cold with stable flows. The upper segment begins near Albion and continues 30 miles downstream to the city of Battle Creek. The river in this segment meanders freely and is warm with stable flows. The middle segment is 50 miles long and extends to the town of Otsego. The river here is large as it picks up a major portion of the watershed drainage. The river also becomes cooler through this segment as groundwater flows to the river increase. The lower segment is in a confined glacial-fluvial valley and extends 24 miles to Lake Allegan. The last 24 miles of river flow across a lake plain and make up the mouth segment.

The history of the watershed is very rich and can be traced back as far as the Paleo-Indians almost 10,000 years ago. Indian communities were drawn to the Kalamazoo River area because of its valuable natural resources. Hunting and fishing camps were common in the watershed. European settlers used the area as early as 1680 for trapping and fur trade. By the mid-1800s, communities and cities began to emerge in Battle Creek, Kalamazoo, and Plainwell. Kalamazoo and Plainwell became sites for paper production, which helped spur economic development and later led to contamination problems in the river.

The hydrology of the Kalamazoo River watershed is strongly influenced by glacial deposits. A majority of the surficial geology is composed of outwash sand and gravel. These glacial deposits contribute to the stable flows of the Kalamazoo River by providing permeable soils that allow groundwater inflow. Less permeable soils coupled with agricultural land use lead to stream flow instability. Fine glacial till material and channelization have led to some flow instability in both the Battle Creek and Rabbit rivers. Tributaries in the middle segment have the most stable flows and include Seven Mile, Augusta, and Portage creeks. Urbanization, stream channelizations, filling of wetland retention areas, and installation of drainage systems for agriculture and urban development also contribute to stream flow instability. Seasonal flooding occurs throughout the watershed, but most damage occurs to developments within the floodplain.

Soils and land use have a significant effect on river hydrology and water quality. Soils consist of 71% loamy type (sandy, silty, and clay loams), which is 10% less than its neighboring St. Joseph watershed. Land use is dominated by agriculture (58%) with forest land comprising the second most frequent land use at 25%. Intensive agriculture with poor management practices has led to bank erosion and sedimentation problems. Channelization, drainage of wetlands, and installation of artificial drainage systems have altered stream temperature regimes and decreased flow stability. Most large cities are located along the mainstem, and many significantly affect water quality. The middle segment is threatened by increased development pressure. The continual increase of impervious surfaces (roofs, parking lots, and roads) will change the hydrology of several groundwater fed streams in this area. With increased development also come more stream crossings. There are 2,755 road and utility stream crossings over the Kalamazoo River and tributaries. Improper crossing installations can lead to channel and fish habitat degradation.

The average gradient of the Kalamazoo River mainstem is 3.0 feet per mile with a range of 0-40 feet per mile. The highest gradients on the mainstem (5-40 feet per mile) are in the headwaters upstream of Mosherville and in short reaches near Homer, Marshall, and Plainwell. The mainstem of the Kalamazoo River is mostly low-gradient channel; 113.0 miles (62%) have a gradient less than three feet per mile. Fish and other aquatic animals are typically most diverse and productive in river sections with gradient between 10 and 70 feet per mile. This highly desirable gradient class is now found in only 5.5 miles (3.0%) of the mainstem. Dams in Mosherville, Marshall, Ceresco, Kalamazoo, and Plainwell have inundated many of the high-gradient areas. These dams and their impoundments have eliminated and fragmented some of the best pool and riffle habitat.

The channel cross section of the Kalamazoo River is normal, based on stream widths compared to average discharge. The headwaters are characterized as having a narrow channel that is straight to meandering. The channel widens going downstream through the upper and middle segments. The river channel narrows in the middle and lower segments as it meanders confined in a narrow glacial valley and widens again near the mouth. Substrates in the headwaters consist of mostly sand and gravel. The upper segment has more diverse substrates that are made up of more sand and gravel with some cobble. The middle segment near Plainwell has the greatest abundance of gravel and cobble. The mouth is dominated by sand and silt substrate as the river begins to lose power and deposits its bedload. Woody cover is common in the mainstem but varies in tributaries. Agricultural activities such as stream dredging and riparian vegetation clearing has removed or reduced the availability of woody structure. Woody cover creates excellent fish habitat and provides good substrate for production of aquatic insects and other fish food organisms.

There are 110 dams in the Kalamazoo River watershed registered with Michigan Department of Environmental Quality. Fifteen are on the mainstem. Dams fragment river systems and turn high gradient river habitat into slow flowing habitat more typical of a shallow lake. Dams were generally constructed in areas of highest stream gradient. These high-gradient riverine areas are essential spawning habitat for several species of fish. Dams impede fish movements to refuge habitats, fragment populations, and block spawning migrations. Mortality or injury often results while passing through or over dams, especially those with hydroelectric turbines. Great Lakes migratory fish can move from Lake Michigan upstream 26 miles to the Lake Allegan Dam. Impoundments can increase stream temperatures resulting in an elimination of certain aquatic species below dams. Dams also act as sediment and woody structure traps. Sediment-free water released below dams has high erosive power and can cause bank and bed erosion. Dams and lake-level control structures disrupt seasonal flow patterns by reducing incidence and severity of flooding.

Point source water pollution from industrial and municipal sources in the watershed has decreased significantly over the past 20 years. Pollution from point sources will continue to be reduced as municipal wastewater treatment plants upgrade their facilities and technology and industrial discharge permits are tightened. However, PCB contaminated sediments from historical discharges have continued to degrade wildlife populations and have resulted in nearly a complete ban on fish consumption between the city of Kalamazoo and Lake Allegan.

Nonpoint source pollution is the greatest factor that degrades water quality. This type of pollution generally consists of sediments, nutrients, bacteria, organic chemicals, and inorganic chemicals from agricultural fields, livestock feedlots, construction sites, parking lots, urban streets, septic seepage, and open dumps. Implementing best management practices with farmland, construction sites, and urban development designs can significantly reduce runoff, erosion, and influxes of sediment, nutrients, and other chemicals to lakes and streams.

Based on Michigan Fish Commission surveys as early as the 1880s and fish collections from the University of Michigan, Museum of Zoology, the Kalamazoo River watershed originally had 89 fish species. The watershed now contains 102 species of fish due to intentional and accidental introductions. Rare species such at the lake sturgeon (threatened) and creek chubsucker (endangered) can be found within the watershed while the weed shiner has been extirpated. Although present fish species diversity in the watershed remains high, certain species of fish have declined. Dams on the mainstem create barriers to upstream migration of potamodromous fish. Dams have inundated high-gradient areas that have gravel, cobble, and rock substrates. These high-gradient areas are of critical importance to certain species as spawning habitat and for the production of aquatic insects and other macroinvertebrates that are important fish food organisms. Silt-tolerant fish species have increased in the watershed, whereas fishes requiring clean gravel substrate or clean water with aquatic vegetation at some point of their life cycles have declined. Agricultural and urban development activities have reduced flow stability and increased sediment load in streams throughout the watershed. Introduced pest species including sea lamprey, zebra mussels, rusty crayfish, purple loosestrife, and Eurasian milfoil have had negative affects on native fishes and macroinvertebrates. Draining and filling of wetlands has negatively affected populations of fish, amphibians, reptiles, birds, and mammals.

Fishery management of the Kalamazoo River mainstem and tributaries ranges from minimal in the headwater and upper segments to more active in the middle, lower, and mouth segments. Stocking fish is the main management tool used throughout the watershed. Coldwater fishery management has been vigorous at times and continues to be a high priority for tributary streams. Development and enhancement of warmwater fishing opportunities are needed in the upper, middle, and lower mainstem and tributaries. Dam removal and PCB contaminated sediment clean-up are the two most important management options for the middle and lower segments. They would significantly improve the resident fishery and angler use, provide a potamodromous fishery up to the city of Kalamazoo, and increase available habitat for lake sturgeon rehabilitation. The lower 26 miles has an excellent fishery that consists of Chinook salmon, steelhead, walleye, and channel catfish. The salmon fishery is primarily supported by stocking with some natural reproduction from tributaries such as Rabbit River, Sand, and Bear creeks.

Recreational use of the river is highest within the mouth segment. The Allegan State Game Area provides 48,000 acres of state-owned land in the lower river and mouth areas. Many people use the river corridor and area lakes for fishing, canoeing, motor boating, swimming, picnicking, and hunting. Lack of assured public access is the largest deterrent to the recreational potential of upstream areas and tributaries. There are only 17 boat and canoe launches on the mainstem. This is an average of one launch site every 10 miles of river. Most recreation plans strive for at least one access site every six miles.

The Kalamazoo River’s public image was tainted until the late 1990s. A growing public interest for the river has begun to change the river’s image. Several organizations now work on various aspects of the river including fishing, hunting, and other recreational use. The Kalamazoo Valley Chapter of Trout Unlimited has been improving coldwater fisheries in the watershed since 1965. The Kalamazoo River Protection Association and several other local organizations have been instrumental in keeping PCB river clean-up plans moving forward. With decreases in government funding and personnel, public involvement through local and watershed organizations will continue to be important to ensure that habitat protection and enhancement of water quality and recreational opportunities move forward in the Kalamazoo River watershed.

INTRODUCTION

This river assessment is one of a series of documents being prepared by Fisheries Division, Michigan Department of Natural Resources, for rivers in Michigan. We have approached this assessment from an ecosystem perspective, as we believe that fish communities and fisheries must be viewed as parts of a complex aquatic ecosystem. Our approach is consistent with the mission of the Michigan Department of Natural Resources, Fisheries Division, namely to "protect and enhance the public trust in populations and habitat of fishes and other forms of aquatic life, and promote optimum use of these resources for benefit of the people of Michigan".

As stated in the Fisheries Division Strategic Plan, our aim is to develop a better understanding of the structure and functions of various aquatic ecosystems, to appreciate their history, and to understand changes to systems. Using this knowledge we will identify opportunities that provide and protect sustainable fishery benefits while maintaining, and at times rehabilitating, system structures or processes.

Healthy aquatic ecosystems have communities that are resilient to disturbance, are stable through time, and provide many important environmental functions. As system structures and processes are altered in watersheds, overall complexity decreases. This results in a simplified ecosystem that is unable to adapt to additional change. All of Michigan's rivers have lost some complexity due to human alterations in the channel and on surrounding land; the amount varies. Therefore each assessment focuses on ecosystem maintenance and rehabilitation. Maintenance involves either slowing or preventing losses of ecosystem structures and processes. Rehabilitation is putting back some structures or processes.

River assessments are based on ten guiding principles of Fisheries Division. These are: 1) recognize the limits on productivity in the ecosystem; 2) preserve and rehabilitate fish habitat; 3) preserve native species; 4) recognize naturalized species; 5) enhance natural reproduction of native and desirable naturalized fishes; 6) prevent the unintentional introduction of invasive species; 7) protect and enhance threatened and endangered species; 8) acknowledge the role of stocked fish; 9) adopt the genetic stock concept, that is protecting the genetic variation of fish stocks; and 10) recognize that fisheries are an important cultural heritage.

River assessments provide an organized approach to identifying opportunities and solving problems. They provide a mechanism for public involvement in management decisions, allowing citizens to learn, participate, and help determine decisions. They also provide an organized reference for Fisheries Division personnel, other agencies, and citizens who need information about a particular aspect of the river system.

The nucleus of each assessment is a description of the river and its watershed using a standard list of topics. These include:

> **Geography** - a brief description of the location of the river and its watershed; a general overview of the river from its headwaters to its mouth. This section sets the scene.
>
> **History-** a description of the river as seen by early settlers and a history of human uses and modifications of the river and watershed.
>
> **Geology and Hydrology -** patterns of water flow, over and through a landscape. This is the key to the character of a river. River flows reflect watershed conditions and influence temperature regimes, habitat characteristics, and perturbation frequency.

Soils and Land Use Patterns - in combination with climate, soil and land use determine much of the hydrology and thus the channel form of a river. Changes in land use often drive change in river habitats.

Channel Morphology - the shape of a river channel: width, depth, sinuosity. River channels are often thought of as fixed, apart from changes made by people. However, river channels are dynamic, constantly changing as they are worked on by the unending, powerful flow of water. Diversity of channel form affects habitat available to fish and other aquatic life.

Dams and Barriers - affect almost all river ecosystem functions and processes, including flow patterns, water temperature, sediment transport, animal drift and migration, and recreational opportunities.

Water Quality - includes temperature, and dissolved or suspended materials. Temperature and a variety of chemical constituents can affect aquatic life and river uses. Degraded water quality may be reflected in simplified biological communities, restrictions on river use, and reduced fishery productivity. Water quality problems may be due to point source discharges (permitted or illegal) or to nonpoint source runoff.

Special Jurisdictions - stewardship and regulatory responsibilities under which a river is managed.

Biological Communities - species present historically and today, in and near the river; we focus on fishes, however associated mammals and birds, key invertebrate animals, threatened and endangered species, and pest species are described where possible. This topic is the foundation for the rest of the assessment. Maintenance of biodiversity is an important goal of natural resource management and essential to many fishery management goals. Species occurrence, extirpation, and distribution are also important clues to the character and location of habitat problems.

Fishery Management - goals are to provide diverse and sustainable game fish populations. Methods include management of fish habitat and fish populations.

Recreational Use - types and patterns of use. A healthy river system provides abundant opportunities for diverse recreational activities along its mainstem and tributaries.

Citizen Involvement - an important indication of public views of the river. Issues that citizens are involved in may indicate opportunities and problems that the Fisheries Division or other agencies should address.

Management Options follow and list alternative actions that will protect, rehabilitate, and enhance the integrity of the watershed. These options are intended to provide a foundation for discussion, setting priorities, and planning the future of the river system. Identified options are consistent with the mission statement of Fisheries Division.

Copies of the draft assessment were distributed for public review beginning March 8, 2005. Four public meetings were held June 6, 2005 at Allegan Community Center, June 7, 2005 at the Battle Creek Department of Public Works, June 8, 2005 at the Oshtemo Public Library, and June 9, 2005 at Albion City Hall. Written comments were received through July 15, 2005. Comments were either incorporated into this assessment or responded to in the Public Comment and Response section.

A fisheries management plan will be written after completion of this assessment. This plan will identify options chosen by Fisheries Division, based on our analysis and comments received, that the

Division is able to address. In general, a Fisheries Division management plan will focus on a shorter time period, include options within the authority of Fisheries Division, and be adaptive over time.

Individuals who review this assessment and wish to comment should do so in writing to:

Michigan Department of Natural Resources
Fisheries Division
621 N. 10th St.
Plainwell, MI 49080

Comments received will be considered in preparing future updates to the Kalamazoo River Assessment.

RIVER ASSESSMENT

Geography

The Kalamazoo River basin, situated between the Grand and St. Joseph rivers in southwest Michigan, is the seventh largest river basin in Michigan. The river begins as a spring fed pond in northern Hillsdale County, and flows in a northerly arc through the cities of Albion and Battle Creek (Figure 1). The river flows west to Kalamazoo and makes an abrupt turn to the north toward Plainwell. It meanders northwest from there until it reaches Kalamazoo Lake and Lake Michigan at the city of Saugatuck. The Kalamazoo River mainstem is 175 miles long, and its tributary streams total an additional 899 miles (Brown 1944). The river drains a watershed of 2,020 square miles (Blumer et al. 2000) that include all or parts of Hillsdale, Jackson, Eaton, Calhoun, Barry, Kalamazoo, Kent, Ottawa, Van Buren, and Allegan counties. Its major tributaries are the North Branch Kalamazoo, Gun, and Rabbit rivers and Rice, Battle, Wabascon, Augusta, and Portage creeks (Figure 2).

There are 287 lakes greater than 10 acres within the basin (Figure 3). Two hundred are between 10 and 50 acres, 40 are between 50 and 100 acres, and 47 are greater than 100 acres in size. Gun Lake is the largest lake at 2,661 acres followed by Gull Lake at 2,046 acres and Lake Allegan at 1,711acres.

The large size of the Kalamazoo River watershed makes it difficult to describe in detail; therefore, the river was split into five sections or mainstem segments (Figure 4). These mainstem segments were determined using an ecological classification procedure (Seelbach et al. 1997). Mainstem segments represent portions of the river that share some common channel and landscape features and therefore represent fairly distinctive and homogeneous ecosystems. Mainstem segments were identified using major changes in hydrology, river channel and valley shapes, changes in river size at tributary junctions, and surficial geology that were viewed and interpreted using the Michigan Rivers Inventory Geographical Information System database (Seelbach et al. 1997; Wiley and Seelbach 1997). The segments only describe the Kalamazoo River mainstem reaches and not the vast network of streams and rivers that are tributary to the segments. The network of tributary streams and characteristics of the land they drain were incorporated in the classification process; however, the general characteristics of a mainstem segment may not describe a contributing individual stream. For example, middle segment is described as cool and stable supporting smallmouth bass and rock bass. However, Spring Brook, which enters the Kalamazoo River within this segment, is cold and stable supporting brown trout and mottled sculpins. Although the same type of descriptions will be provided for all major tributaries, only the five mainstem river segments are described below.

Headwaters

The headwaters consist of the South Branch Kalamazoo River and Beaver and Swains creeks. This segment is 45 miles long and freely meanders in a broad glacial-fluvial valley through the small towns of Moscow, Mosherville, and Homer (Figure 1). The river begins small with moderate gradient and is characterized by cold summer temperatures and moderately stable flows. Runoff increases in the lower part of this segment shifting the river to cool in temperature (see **Geology and Hydrology** and **Channel Morphology**).

Upper

The upper segment begins at the confluence of the South and North branches of the Kalamazoo River near Albion. The segment is 30 miles long and flows though Marshall to the town of Battle Creek. The river is medium-sized as it picks up the drainage of the North Branch Kalamazoo River; and

Wilder, Rice, and Harper creeks. The mainstem freely meanders, is warm in summer, and has fairly stable flows.

Middle

This segment begins at the confluence of the Battle Creek River in the City of Battle Creek and proceeds 50 miles downstream through Kalamazoo and Plainwell to just beyond Otsego. The river becomes larger as it picks up the drainage from Wabascon, Augusta, and Portage creeks and Battle Creek and Gun rivers. The river channel is sporadically confined as it meanders between moraine features in some sections and meanders freely in broad valleys through other sections within this segment. Groundwater inflows increase in this segment, which buffers the rate of stream temperature warming.

Lower

This segment begins downstream of the town of Otsego and extends in a northwesterly direction for 24 miles through the town of Allegan to Allegan (Calkins) Dam. The river channel's ability to meander is constricted in a relatively narrow glacial-fluvial valley and remains cool. Miner, Rossman, and Dumont creeks join the river within this segment.

Mouth

The mouth segment has very low gradient as it meanders freely across a lacustrine plain. The river shifts back to warm as it flows along vast wetlands. It begins at Lake Allegan Dam and flows 26 miles through New Richmond, Douglas, and Saugatuck before entering Lake Michigan. The Rabbit River and Swan, Bear, and Mann creeks connect to the mainstem within this section.

History

The Kalamazoo River basin was formed by glacial events. During the Wisconsinan stage of glaciation in the Pleistocene Epoch (10,000 to 75,000 years ago), most of Michigan was covered by several ice lobes (Farrand and Eschman 1974). About 14,800 years ago, the ice edge was at the Kalamazoo and Mississinewa moraines (Farrand and Eschman 1974). A narrow ice-free area developed in south-central Michigan that is now part of the Kalamazoo River drainage system. The Kalamazoo River basin was an interlobate region; its landscape was shaped by three glacial lobes. The Saginaw lobe came from the north, the Huron-Erie lobe from the east, and the Michigan lobe from the west (Taylor 1984). Meltwater from the three glacial lobes flowed south into the Kankakee River and then to the Mississippi River and the Gulf of Mexico. Eventually, during glacial retreat, water was no longer forced by the wall of ice to flow down to the Kankakee River and it changed course. As water levels decreased, the flow was forced between the Tekonsha and Kalamazoo moraines, which changed the flow to a northwesterly direction to the now lower elevation of Lake Michigan. The glacial retreat also left varied moraine and outwash deposits that strongly influence local hydrology, channel morphology, and gradient of the mainstem and tributaries (see **Geology and Hydrology**).

The Kalamazoo River watershed is rich with archaeological sites with over 1,108 on record. Most sites are within the mouth segment (43%). The middle segment of the river has 24% of the sites followed by the lower (14%), upper (10%), and headwater (9%) (B. Mead, Department of State, Office of the State Archaeologist, personal communication). Archaeological accounts provide insight to early settlement of the watershed.

> The Kalamazoo River drainage, like the rest of the Midwest, has a long history of human occupation. Most of the story is known only through archaeological evidence and the oral traditions of native peoples. Archaeologists from Western Michigan University have examined about 5% of the drainage. Their work documented over 1000 sites where evidence of human occupation is preserved. Only a few sites have been excavated; very little is known about the others.
>
> The earliest sites are camps and butchering sites of the Paleo-Indians. At this time, over 10,000 years ago, the land was recovering from the Pleistocene ice age. Many animals from this era are now extinct; others later moved northward as the climate grew warmer. Our earliest residents hunted mastodon and caribou as well as deer and other game. About 5% of the native sites in the Kalamazoo River drainage are Paleo-Indian sites.
>
> During the next 6000 to 7000 years people lived by hunting and gathering, living in small family groups and moving their camps frequently. People learned more about the habits of the plants and animals, and became more efficient at timing their movements to take advantage of seasonal resources. Styles of stone tools changed frequently, and people began using slate, copper, bone and other materials as well. Religious and ceremonial beliefs developed and changed, sometimes influenced by ideas from more southern areas. During this period, called the Archaic, people chose to live along the middle reaches of the Kalamazoo River. About 35% of Native American sites in the Kalamazoo drainage are Archaic in age.
>
> By 500 BC, major changes were taking place in southern North America. The population had grown, and people were living in more concentrated areas within defined territories. People were coming to depend on gardening to provide more of their diet. Religious ideas now included commemoration of the dead by building earthen burial mounds. Pottery became more commonly used, and the bow and arrow became the weapon of choice. These ideas spread to Michigan as well. This is referred to as the Woodland period.
>
> During the Woodland period in Michigan people developed a seasonal cycle involving large warm season camps on the Great Lakes to take advantage of fishing, and winter movements by family groups into the interior to trap and hunt. In the Kalamazoo region we see that larger sites appeared on the lower reaches of the river, closer to Lake Michigan, and small sites were common in the headwater areas. The population appears to have grown during Late Woodland times. By then there were two peoples using the Kalamazoo area, one with a strong indigenous tradition, related to other groups in Michigan; and another with closer ties to peoples in Illinois. About 50% of Native American sites are Woodland period occupations.
>
> By the time Europeans appeared on the scene, the Kalamazoo region was home to Potawatomi and related Odawa people. About 10% of Native American sites date to this period. Pioneers in the early nineteenth century moved into areas that had been cleared and farmed by native peoples for centuries. Many modern communities have their roots in the Potawatomi and Odawa villages that preceded them.

The Kalamazoo River watershed was heavily used by Native Americans. The lower and mouth segments of the Kalamazoo River were used in the Upper Mississippian (1250 AD) by Ottawa (Odawa) and Potawatomi hunting in winter and fishing and maple sap collection in spring. Fauna found at archaeological sites based on bone fragments include mammals: elk, black bear, white-tailed deer, beaver, woodchuck, muskrats, and either a coyote or wolf; Fish: lake sturgeon, channel catfish, and freshwater drum; Turtles: snapping, softshell, box, Blanding’s, map, and painted; Birds: wild turkey and ruffed grouse; Mussel: deertoe, which uses the freshwater drum as a host (refer to

Biological Communities). Lake sturgeon bones were very abundant suggesting that the lower and mouth segments were used for spring fishing and possible as spawning grounds for fish (Barr 1979; Higgins 1980). Archaeological sites dating back to 1420 AD also found a significant presence of lake sturgeon bones (Walz 1991). There was also a "portage effect" in the headwater segment of the Kalamazoo River. Prehistoric inhabitant evidence from the Middle Woodland Period was high in this area due to the proximity of the St. Joseph, Grand, and Raisin rivers for transportation (Cremin and Dinsmore 1981). However, the food resource base at that time was greater in the mouth and lower Kalamazoo River segments, as evidenced by the increased number of archaeological sites in that area.

By the time European settlers arrived, the Potawatomi occupied villages throughout the watershed. One large village known as "Indian Fields" was located just south of present day Kalamazoo. The Potawatomi named the Kalamazoo River "ki-ka-ma-sung", which meant "Boiling Water" and may have referred to the rapids or riffles of the river. It was also translated as "Race of the boiling kettle". Indian boys would have foot races from their village to the river and would have to make it back to the village before a pot of water began to boil over a fire (Dunbar 1959).

The French were probably the first European settlers in the Kalamazoo River valley beginning with La Salle in 1680 (Dunbar 1959). However, French exploration began as early as 1654 in the St. Joseph River area, and those explorers may have made trips within the Kalamazoo River watershed. These early settlers primarily used the area to collect and trade furs. Indians often traded cranberries, maple sugar, deer-skins, and wild fruit in exchange for flour, salt, tobacco, lead, and whiskey (Dunbar 1959).

The British took over the area from the French in 1760. America gained its independence from Britain in 1776 and again after the War of 1812. President Madison offered veterans of the War of 1812 six million acres of "bounty lands" in the West, which included two million acres of potential farmland in the Michigan Territory. Surveyors began exploring Michigan for good farmland. The middle segment of the Kalamazoo River Watershed was viewed as worthless according to the following description by a surveyor named Edward Tiffin in 1815 (Massie and Schmitt 1984):

> The country is, with some few exceptions, low wet land with very thick growth of underbrush, inter-mixed with very bad marshes…the number and extent of swamps increase with the addition of a number of lakes from 20 chains to two or three miles across…. The intermediate space between these swamps and lakes, which is probably near one-half the country, is, with a very few exceptions, a poor, barren, sandy land on which scarcely any vegetation grows except very small scrubby oaks. In many places that part which may be called dry land is composed of little short sand hills forming a kind of deep basin, the bottom of many of which are composed of a marsh similar to those above described. The streams are generally narrow and very deep compared with their width, the shores and bottoms of which are with a very few exceptions swampy beyond description and it is with difficulty that a place can be found over which horses can be conveyed.

In the 1820s, reports of dry ground called "oak openings" were found with tall grass prairies, which attracted settlers to begin agriculture (Massie and Schmitt 1984). The increase of settlements in the area created conflicts with Native Americans. In 1821, the Treaty of Chicago gave all land south of the Grand River to the United States except five reservations. One reservation was in Kalamazoo and designated in the treaty as "Match-e-be-nash-e-wish" reserve. Six years later, the Potawatomi agreed to consolidate scattered reservations to Nottawasepee Reserve South of Kalamazoo in the St. Joseph River watershed (Dunbar 1959; Kubiak 1970).

After southwestern Michigan was surveyed in 1829, settlement of the area by European Americans began to increase. Prairies and oak openings were settled first. Clearing of land for agriculture and lumber became more profitable after the invention of steam engines. Several dams were constructed along tributaries of the Kalamazoo River to supply power for saw and grain mills. The river was used as a highway to transport logs and grain. In 1836, the first flat bottom boat was used on the middle and lower river. "Pole Rafts" and flat boats were mainly used due to the shallowness of the Kalamazoo River (Lane 1993). The trip from Kalamazoo to the mouth took 3 days (Dunbar 1959). Ship building was well underway by 1837 in Saugatuck at the mouth of the river (Lane 1993). A new channel had to be formed in 1906 at the mouth to aid navigation because the old channel had two meanders that frequently filled with wind-blown dune sand (Armstrong and Pahl 1985).

Cook (1974) gives an interesting rendition of what life was like in the forests of Allegan County in 1839. Parts of that county were still very wild with a flora and fauna that is much different than today. Indians lived in small bands within the forest. Hemlock forests, tamarack swamps, bears, and gray wolves were still common as well as deer, porcupine, and the occasional beaver.

By the mid-1800s, several communities had grown up along the river as mill towns and commercial centers: Battle Creek, Kalamazoo, Parchment, Plainwell, and Otsego. After the Civil War and into the 20^{th} century, various industries, from cereal production to pharmaceuticals to automobile parts, flourished. Several communities became sites for paper production, which used the river for water intake and waste discharge. De-inking practices (no longer in use today) led to PCB contamination of the river. For many years in the 1940s, 50s, and 60s, the river was an "eyesore" and most people did their best to avoid it. Beginning in the 1970s with the federal Clean Water Act, serious efforts were made to clean up the river. Although today the river is cleaner, the persistent PCB contamination has led to Superfund designation of a 35-mile section from Kalamazoo to Allegan Dam. (KRWC 1998).

Geology and Hydrology

Geology and Physiography

The retreat of glaciers 10,000 years ago shaped the contemporary landscape and left deposits that make up the surficial geology in the Kalamazoo River basin (Figure 5). These glacial moraines elevate as much as 700 ft above Lake Michigan (Albert et al. 1986). The basin consists of an assortment of glacial outwash sands, coarse end moraine (sands and gravel), fine end moraine (loamy), ice contact material (sorted sands and gravel), clayey till, and lake plain (sand and gravel) (Lineback et al. 1983). About 41% of the surficial geology is made up of outwash, which is less than the St. Joseph River (52%). However, there is more lacustrine geology in the Kalamazoo (6%) than the St. Joseph basin (2%) (Gooding 1995).

These glacial deposits have strong influences on the behavior of streams and rivers, as well as on land use patterns. Outwash and fine-textured end moraine areas are associated with sandy loam and loam type soils typically used for agriculture. The high, steep-sloped moraines, that are associated with coarse texture and ice contact material, are usually forested because of rough terrain, low moisture content, and low soil fertility.

Groundwater contribution to a stream determines the stability of both temperature and water flow. Glacial moraines with moderate elevation and pervious material have high water infiltration capacities and head pressure, which combine to produce high groundwater yields to low lying water bodies (Figure 6). Basins, like the Kalamazoo, with surficial geologic material dominated by outwash, coarse end moraine materials, and ice contact have higher groundwater yields compared to basins with less pervious materials like fine till (Bent 1971; Richards 1990; Wiley and Seelbach 1997). In well-drained soils, a large amount of precipitation percolates to the groundwater, which is ultimately delivered to streams, lakes, and wetlands. Poorly drained soils, characteristic of fine till deposits, have low infiltration capacities, so most precipitation reaches the stream channel as surface runoff. Glacial outwash and coarse-textured glacial till are the dominant geologic materials in the basin contributing to moderately high groundwater deliveries to the river system.

The headwaters (South Branch Kalamazoo) and upper Kalamazoo River segments mainly drain medium to coarse till and coarse end moraine and flow across outwash sands. These segments receive moderate to high groundwater inflows. The North Branch also drains coarse and medium textured end moraines, but its catchment has less relief and more medium till plains, providing it with less groundwater inflows than the South Branch. Rice Creek drains coarse end moraines and coarse till plains with moderate relief over outwash plains, and as a result has moderate groundwater inflows.

The middle mainstem segment flows across outwash sands between a mixture of medium to coarse end moraines and ice contact hills with moderate relief. The Battle Creek has low base flow as it drains medium to fine textured till plains and low relief end moraines. Wabascon Creek catchment composition is a mixture of moderate-relief coarse-end moraines, coarse till plains, and outwash plains. Augusta Creek receives moderate to high groundwater inflows from relatively high-relief coarse-end moraines draining onto an outwash plain with some coarse till plains. Portage Creek, Gun River, and a few small tributaries in this segment have very high base flow as a result of moderate-to high-relief coarse-textured end moraines surrounding extensive outwash plains with some ice contact hills.

The lower mainstem segment is similar to other segments in the watershed with moderate-relief coarse end moraines and till plains, but it flows in a narrow valley through end moraines. Miner Creek has fair groundwater inflows with a similar composition as the mainstem. Dumont and Rossman creeks are primarily runoff driven and drain fine till and lacustrine plains.

Lacustrine plains and fine till characterizes the drainage of the mouth mainstem segment. Most of the Rabbit River catchment can be characterized the same way except the Upper Rabbit River has higher groundwater inflows from moderate relief coarse end moraines and till plains. Swan Creek also has coarse end moraines but has high inflows of groundwater compared to the mainstem.

Climate

Climate in the Kalamazoo River basin is primarily controlled by its latitude, Lake Michigan, air masses and atmospheric disturbance, and its location within the interior of North America (Eichenlaub 1979). Latitude accounts for seasonal changes that are the most important feature of this state’s climate (Eichenlaub 1990). This basin is one of the warmest in Michigan with a mean annual air temperature of 8.8 °C (48 °F); the neighboring Black River watershed is the warmest at 10 °C (50 °F) (Gooding 1995). Precipitation is also high at 33 inches, and the Black River watershed is again the highest at 35 inches (Gooding 1995). It has a long growing season (151 days) with a high growing heat sum (2,630 °C-days). During the growing season, most precipitation is associated with passing cold fronts and showers caused by air-mass instability. The annual average extreme minimum temperature for the entire watershed is -23 °C (-9.4 °F) thus mild winters prevail (Albert et al. 1986).

The lower and mouth segments of the Kalamazoo River have a unique climate that is moderated by Lake Michigan. The long (157 days) and warm (heat sum 2,560 °C-days) growing season with an early last freezing date between April and June create a maritime climate that is ideal for flowering fruits. Winters in the lower and mouth segments are milder than the rest of the watershed with an extreme minimum temperature of -22 °C (-7.6 °F) (Albert et al. 1986). However, Lake Michigan also causes an increase in cloudiness and precipitation in the form of lake effect snow during fall and winter months. There is a definite increase in annual snowfall due to lake effect from 40 inches per year in the headwaters to 80 inches per year at the mouth (Eichenlaub 1979).

Net precipitation, because it is the source of surface runoff, throughflow, and groundwater recharge, is the ultimate factor controlling stream flow. Therefore, differences in precipitation are important considerations when comparing stream flows within the watershed. Annual mean precipitation in the headwaters is 35 inches, which is based on the average for all weather stations located within this segment area. Precipitation decreases in the upper (32 inches) and middle segments (34 inches). The lower and mouth segments receive the highest annual precipitation (36 inches) compared to the rest of the watershed. The heaviest precipitation occurs during June and July for most of the basin. On average 34 inches of precipitation fall on the 2,020 square mile watershed of the Kalamazoo River, which equates to 1.2 trillion gallons of water per year. However, only a fraction of that water actually makes it to the river. Most is evaporated back to the atmosphere from the surface or from vegetation by transpiration (Hynes 1970). Evapotranspiration accounts for 61% of the annual precipitation (Albert et al. 1986). Only about 468 billion gallons actually reach the river by groundwater or runoff in a year, which is a yield of 0.98 cfs per square mile per year.

Annual Water Flow

The United States Geological Survey (USGS) maintains continuous stream flow gauges at 13 locations throughout the Kalamazoo River basin (Figure 7). Data from these gauges have been collected for up to 69 years. Daily mean stream discharges measured in cubic feet per second (cfs) are published annually by USGS. Six additional continuous gauges were operated in the basin in the past, and many miscellaneous discharge measurements have been recorded throughout the basin. All USGS gauge data discussed are through water year 1999.

Annual stream flow in the Kalamazoo River watershed is fairly stable. Precipitation and how that precipitation reaches the stream influence these flows. Watersheds dominated by pervious soils and well-vegetated landscapes typically have stable annual flows. Streams with stable flows are characterized by having lower peak flows and higher base flows because precipitation is delivered slowly to the stream through the ground. Streams with unstable flows have higher and sharper peak flows and low base flows because precipitation is transported overland as run-off, which is a faster process.

High flows are typical in March and April with low (base) flows in August through October, as shown by the mean monthly flow in the mainstem at Comstock just below Morrow Dam (Figure 8). Similar patterns exist for the gauges at Marengo on the Kalamazoo River (located between Albion and Marshall) and the Battle Creek River. High discharge in early spring is a function of snowmelt and storm water flowing over frozen soils. The peak month for precipitation is June; however, infiltration and evapotranspiration absorb and slow transport of storm water to the stream during summer and fall.

The average discharge of the Kalamazoo River is 1,925 cfs at the mouth making it the seventh largest river in Michigan with the Saginaw River as the largest (Table 1). Using the active continuous gauge sites (Table 1), the upper segment has the highest discharge per square mile for the mainstem. The lowest discharge per square mile (0.48) was found in the West Fork Portage Creek near Oshtemo, which is a small subwatershed in the middle segment that receives 34 inches of precipitation per year. The West Fork is seasonally intermittent. There is a high rate of evaporation as the creek flows through several lakes and impoundments. The highest discharge per square mile was 1.83 in Portage Creek near Portage. Portage Creek only receives 34 inches of precipitation, but it has significant amounts of groundwater yield that increases the annual average discharge. More extreme yields are 0.26 for Davis Creek and 3.51 for Pine Creek (Table 1). However, these data are from miscellaneous discharge measurements with short periods of record and may not be reliable.

Seasonal Water Flow

Streamflow is an important factor in the characteristics of a stream because of its relationship to stream channel formation. Stream flows increase and channels become larger in a downstream direction. Stream flow patterns also have a direct influence on stream organisms. Streams with stable flows tend to have less variation in stream temperature and have more stable channels. As a result, fishes in stable streams have more specialized feeding and reproductive behaviors compared to fishes in streams with more variable flow patterns (Gordon et al. 1992).

Stability of flow provides or represents a tool to examine the combined effects of stream characteristics, including source of flow, channel shape and gradient, geology, temperature, and land cover in the watershed. If similar seasonal climatic patterns exist in a watershed, differences in flow stability can be attributed to surficial geology, land cover, or human influences such as storm sewers, stream channelization, or land use. The Kalamazoo River watershed has some seasonal climatic variability between the lower and mouth segments, which are near Lake Michigan, and the rest of the segments, which are more inland. Nearshore areas have more moderate air temperatures and generally receive more rainfall. The differences between nearshore and inland climates do not appear to have a significant influence on flow stability as much as geology, land cover, and human influences have within the watershed.

Flow stability can be characterized using flow duration curves built from percent exceedence data from USGS gauging stations. An exceedence value is discharge that can be expected to be exceeded for a given percentage of the time. For example, the 5% exceedence value is that discharge that can be expected to be exceeded 5% of the time within a given water year (October - September). A 5% or less exceedence value represents relatively rare high flow events, for example, during snowmelt or extraordinary storm events. The 50% exceedence value represents median discharge for a particular station, as half of the time it is higher, and half of the time flow is less than this value. The 95% exceedence value is referred to as base flow (or low flow) and indicates steady contributions of groundwater to the stream, meaning that 95% of the time discharge is expected to be greater than this value.

When comparing exceedence values for streams of varying sizes, it is necessary to standardize values for direct comparison. One method of standardization requires dividing exceedence values by median exceedence. This number represents the magnitude of discharge variance from the median flow at each exceedence range. For exceedence flow over 50%, the smaller the standardized value, the more stable the stream. For example, (5% exceedence)/(50% exceedence)=standardized discharge at the 5% exceedence level - if this value is equal to 2, then flood flow is two times greater than median flow (Wesley and Duffy 1999).

Exceedence flows vary greatly among tributaries and the mainstem (Figures 9-16). The most stable USGS station on the mainstem is at Marengo in the upper segment, which has a standardized discharge at 5% exceedence of 2.0 (i.e., flood flow is 2.0 times greater than median flow (Figure 9)). The Battle Creek gauge station on the mainstem in the middle segment had the highest standardized discharge at 5% exceedence of 2.8 (Figure 13). This indicates a stable system, regardless of watershed size at this location. For comparison, the most stable streams in Michigan (e.g., the Au Sable, Manistee, and Jordan rivers) have standardized 5% exceedence (high) flows that are slightly less than twice their median flows, whereas the flashy (unstable) Lower Rouge River in southeast Michigan shows a standardized 5% exceedence of 13.7 (Beam and Braunscheidel 1998).

Flow stability can also be analyzed using low-flow or base-flow patterns. In general, the higher the base flow relative to overland flow, the more stable the stream. The higher the ratio between each exceedence rate and the median discharge, the less variation there is in stream flow. For USGS stations in the Kalamazoo River watershed, the standardized 95% exceedence ranges from 0.3 to 0.7. Hence, streams in the Kalamazoo River basin vary from fairly unstable to stable in flow. The Rouge River has a standardized 95% exceedence of 0.2, whereas the groundwater-fed South Branch Au Sable River near Luzerne has a value of 0.6.

Exceedence flows are described more thoroughly for the Kalamazoo River and tributaries by mainstem segments:

Headwaters and Upper

The mainstem at Albion and Marengo have stable flows with standardized 5% exceedence flows less than 2.5 (Figure 9). The Kalamazoo River at Marengo receives more groundwater than the South Branch Kalamazoo River based on the higher standardized 95% exceedence of 0.6 (Figure 10).

Middle

The middle segment begins with the confluence of the Battle Creek River, which is the flashiest gauged tributary in the Kalamazoo River basin. The Battle Creek River at Charlotte and Bellevue both have high standardized 5% exceedence flows with values above 6.5 (Figure 11). Flows are more stable near the city of Battle Creek with standardized 5% exceedence flows for the Battle Creek being 30% lower than the Battle Creek at Bellevue. Wanadoga Creek is 50% lower than the Battle Creek at Bellevue. The upper Battle Creek River has been extensively channelized, which may increase flashiness of seasonal flows (see **Channel Morphology**). Wanadoga Creek and Battle Creek River near the city of Battle Creek also have higher standardized 95% exceedence flows. These flows were 17% higher at the city of Battle Creek compared to the Battle Creek River at Charlotte and Bellevue (Figure 12). This may give some support that the difference between the two areas is due to channelization and not entirely to groundwater yield.

The Kalamazoo River at the Battle Creek gauge has the highest standardized 5% exceedence value compared to the rest of the mainstem. With a value of 2.8, it is still considered to be stable compared to other southern Michigan streams. The slight increase may be due to the confluence of the Battle Creek (which experiences more flashy flows) just upstream from the gauge location. Augusta, Portage, and West Fork Portage creeks have very stable flows with standardized 5% exceedence values between 1.5 and 1.9 (Figure 13). Portage Creek had a low flow value of 0.7, indicating good groundwater inflows (Figure 14).

Lower and Mouth

There is no exceedence flow data for the mainstem or tributaries within the lower segment, and the mainstem mouth segment continues to have stable flows with a high flow value of 2.3 (Figure 15). Therefore, the lower segment is also presumed to be stable. The Rabbit River is flashier with a high flow value of 4.0. There is extensive channelization in the Rabbit River subwatershed, which contributes to the flashiness of the system. Both of these streams receive average groundwater inflows as indicated by the standardized 95% exceedence flows above 0.4 (Figure 16).

Another index of flow stability is defined by the ratio of mean high flow to mean low flow (Tables 2a and 2b). Using short-term and miscellaneous flow data, the highest mean monthly flow and lowest mean monthly flow for a year are averaged for several years at a specific site to calculate the overall mean high and low flows. High ratios of these two numbers indicate unstable flows dominated by rainfall runoff, low numbers indicate stable flows dominated by groundwater (Tables 2a and 2b) (P. Seelbach, Michigan Department of Natural Resources (MDNR), Fisheries Division, personal communication). Data further support the exceedence flow data indicating the stable nature of the Kalamazoo River system (Tables 2a and 2b). Most sites were rated as good or very good and could support good warmwater fisheries or even sustain trout, based on flow stability. Stability problems are present in the Battle Creek and Rabbit rivers as indicated by the poor and fair ratings (Tables 2a and 2b). Both the Battle Creek and Rabbit rivers have extensive mainstem and tributary channelization as well as a higher composition of clay type soils in their watersheds.

The dominance of stable streams in the Kalamazoo River basin is mainly due to abundant permeable surficial geology and soils, both important ingredients for groundwater flow. Broad floodplains and large amounts of wetlands also contribute to stable stream flows by providing good water storage. Large streams also tend to be more average in flow than small streams because they have heterogeneous catchments. The few unstable streams in the basin are small-to medium-sized streams with agricultural and urban land uses. Channelization also contributes to unstable flows.

Several of the more stable tributaries to the Kalamazoo River, such as Seven Mile, Augusta, and Portage creeks are coldwater systems that support trout populations. A significant contribution of groundwater to stream flow ensures steady flows and cool water throughout the year. The flow of Portage Creek is especially stable for having a watershed with increasing urban land use. Streams with less stable flow often have less permeable soils in the watershed, fewer wetlands, and human-induced disturbances such as channel dredging and construction in the floodplain. Battle Creek River near Bellevue has the highest flow index value at 14.0. This stream has been channelized and has some clay based soil on glacial till, which combine to produce unstable stream flows.

Daily Water Flow

Flows tend to be more consistent in natural streams compared to those that are channelized or dammed. Streams with hydroelectric operations and lake-level control structures can have substantial flow fluctuations. These daily fluctuations can destabilize banks, create abnormally large moving sediment bedloads, disrupt habitat, strand organisms, block movements of aquatic organisms, and interfere with recreational uses of the river. Aquatic production and diversity are profoundly reduced by such extreme daily fluctuations (Cushman 1985; Gislason 1985; Nelson 1986; Bain et al. 1988).

Hydrographs (graphs of daily discharge over time) are used to analyze stream flow stability, characteristics of a river channel, and the source of flow. Flow peaks for the mainstem tend to be asymmetrical during summer and fall and indicate a rapid rise in discharge followed by a more gradual decline (Figure 17). The rapid rise occurs after a heavy rain event and indicates immediate runoff into the river system. Watersheds with more impervious surfaces tend to have a quicker response and higher flows associated with rain events. The descending or falling limb also can tell a story about the hydrology of a stream. The hydrograph curve or flow declines more gradually in watersheds with permeable soils due to the slow release of water from the surrounding soils. Water takes longer to flow through soils compared to over land flow. Watersheds with more impermeable land cover (i.e., parking lots, rooftops, frozen ground, etc) tend to have hydrographs or flows with a steeper descending limb because there are no permeable soils slowly releasing water after the rain event. For example, flow in the Kalamazoo River watershed during March and April will be more unstable compared to summer and fall. Peaks are more symmetric in late winter and early spring when the ground is frozen or saturated and less permeable. As a result, snowmelt can release more water into a river and at a faster rate than rainfall. Snowmelt from a brief warm up coupled with a 1.5-inch rain event in late January of 1999 caused the spikes in the hydrographs in Figures 17 and 18. The largest spike in the hydrograph occurred in late April after a 2.0-inch storm event. The Rabbit River, which drains predominately heavily drained farmland, has symmetric flow peaks (Figure 18). Water in this stream is delivered quickly to the river through drainage tiles causing rapid increases in flow, and flow rapidly declines because drain tiles quickly drain water stored in saturated soils. The Rabbit

River mainstem is also channelized, which bolsters the rapid increase and decrease in flow. Peak flow is also 18 times higher than base flow in the Rabbit River. The groundwater driven Portage Creek shows some evidence of symmetric peaking, especially after the late April storm event, which may be a result of increased impervious surfaces from the predominant urban land use within the watershed (Figure 19).

Another indication of a groundwater source to a system is the amount of summer base flow on hydrographs. The yield of the Portage Creek (Figure 19) never descends below 1.2 in August when precipitation is low and evaporation and transpiration are high. Streams without base flow typically run dry in the summer.

Daily flow can also be influenced by hydroelectric dams that operate in peaking mode, causing severe habitat degradation (Cushman 1985; Gislason 1985; Nelson 1986; Bain et al. 1988). These dams release high flood flows during peak electrical demand (generally 8 am to 8 pm) and store flow during non-peak periods (generally at night) creating drought flows. Historically, most projects on the Kalamazoo River mainstem operated as peaking projects. Now all projects operate in run-of-river mode (outflow of water roughly equals inflow of water) as required by licenses issued by the Federal Energy Regulation Commission (FERC). However, some projects continue to cause severe flow fluctuations due to operation of computerized turbines. The computer senses water level changes in the impoundment and change flow by as much as 250 cfs by turning on or off a turbine. During low flow situations, the activation of one or two turbines can instantly double the discharge downstream causing unsafe conditions for wading anglers and boaters. Fish spawning success is also adversely affected by these periods of fluctuating flow. Fish and other aquatic organisms may even become stranded and die in shallow pools during extreme low flow conditions.

Morrow Dam in Comstock has a history of causing severe flow fluctuations even though it is only licensed for run-of-river flow. Instantaneous flow data indicated 20-25% increases and decreases in flow below the dam that correlate with peak electrical demands (Figure 20). In just over a 24-hr period, flow below the dam fluctuated over 46% from a high of 985 cfs to a low of 530 cfs. Typically, STS Corporation fills the impoundment during early morning hours causing decreases in flow below the dam. Turbines are turned on at about 8:15 a.m. and run until late evening causing increases in flow. These fluctuations are most damaging during low flow periods when downstream land owners report no flow in the river and stranded fish as a result of turning off turbines with no overflow gates being open. Reports of non-compliance with run-of-river and minimum flow requirements have been filed with FERC.

Flooding and Floodplains

Floods are part of the natural cycle of river systems and are vital in shaping the physical characteristics and biotic communities of rivers (Ward 1978, Junk et al. 1989, Wohl 2000). Most floods occur naturally by excessively heavy or prolonged rainfall and spring snowmelt (Ward 1978). Flood flows are important for sediment transport in river systems, distributing sediments downstream and onto a floodplain. Floodplains act as a major storage area for sediments and nutrients. Floods are also important in movement of gravel, cobble, boulders, and other items such as woody structure commonly referred to as bedload. There is a direct relationship between bedload movement and flood discharge. Once stream flows drop below a certain threshold, bedload stops moving and will remain in place until the next flood of equal or greater value (Ward 1978).

Water flowing into a floodplain expands the area available for fish feeding and breeding, and can wash additional food items into a stream or river. Large woody structure washes into and is moved within streams during high flow periods; this wood is an important component of river ecosystems. Wood is often used by fish as cover habitat and as substrate for aquatic invertebrates. Floods contribute to the diversity of insects and fish found in a stream and contribute to downstream colonization of some species.

Floods can also occur unnaturally by the failure of dams and other control structures. Dams on the mainstem and tributaries alter natural flow regimes of systems and sometimes contribute to flood problems. Dams also interrupt sediment transport by floods, and their operation can modify the effects of floods to the detriment of the natural stream flow cycle.

In areas where the floodplain is intensively farmed, flooding may contribute to pollution problems in a basin. Erosion from cropland that has been heavily fertilized, or where animal waste is disposed or stored, releases excess nutrients to rivers, and increases sedimentation. There is also potential for the transport of contaminated sediments or hazardous material from polluted areas within the floodplain (refer to **Water Quality**).

Forty-nine communities within the basin participate in the National Flood Insurance Program (Table 3). Most of these communities have flood plain maps that delineate 100- and 500-year flood boundaries for the rivers within their municipal limits. These are used by state, local agencies, and individuals for planning purposes, general floodplain management, and to determine the need for flood insurance. It is important that communities review these maps and prevent development in the 100-year flood plain. Flood plains are a part of an active river system and should be treated accordingly.

The severity of flooding is influenced by channel and land use processes. Channelization causes increased water velocity reducing the height of flooding in smaller stream reaches, but it increases the magnitude of downstream floods in larger rivers. Roads and construction along rivers act as levees and prevent high flows from expanding across floodplains. Filling wetlands and floodplains decreases the water storage capacity of a watershed, which reduces retention time and increases runoff. Development also increases runoff by creating impervious surfaces such as roads, parking lots, and rooftops. Precipitation that is delivered to streams as runoff enters the channel more quickly and can contribute to severe flooding (Wohl 2000).

Floods create hazards for persons living along rivers. Flood mitigation measures in turn may create hazards for nonhuman aquatic and riparian communities (Wohl 2000). Seawalls and levees are often used to protect against floods and eroding banks. Levees prevent floodwaters from entering a floodplain and constrict water flow causing flood peaks in areas downstream. They do not allow sediments to be deposited in the floodplain and prevent fish access to seasonally flooded areas, which are important for spawning and feeding. River systems require 100-year floods for valley maintenance, and levees prevent this from happening causing an imbalance to the river system. Seawalls eliminate shallow water areas and natural diverse edge habitat that can be important to macroinvertebrates. They also block animal access to and from a stream. Through permitting processes, zoning procedures, and education, riparian property owners should be encouraged or required to use less intrusive and more natural looking methods to stabilize banks. Rock riprap, log and whole tree revetments, and vegetative plantings are good alternatives to seawalls (Alexander et al. 1995).

New policies are needed to facilitate reclamation of low elevation floodplains. These floodplain areas could be recovered if policies were developed to regulate land use activities after large floods (Doppelt et al. 1993). Reconstruction or reoccupation of floodplain roads, homes, businesses, and other structures should be restricted after flood inundation to prevent future disasters and promote open space floodplains with no human structural development.

Water Use

With all the streams and lakes within the Kalamazoo River watershed, it seems odd that water could ever become a rare resource. Water as a renewable resource is not always available nor is it always of suitable quality for the intended use. Sources of water may be stressed by withdrawals from an aquifer or diversions from lakes and streams to meet the needs of homes, cities, farms, and industries. There are also fish, wildlife, and recreational needs for that same water, so it is important that one use does not interfere with or prevent other uses of water.

The Kalamazoo River Watershed is rated highest in the State of Michigan in regards to groundwater withdrawals. It also has the second highest number of wells in glacial deposits and bedrock in Michigan (Bedell 1982). Most water withdrawals within the watershed are used for industrial, public (city water), irrigation, domestic (homestead well), commercial, livestock, and mining (Figure 21). These withdrawals total over 153 million gallons a day (MGD) of which 78% is from groundwater sources (Solley et al. 1998). Total water use has increased 10% between 1990 and 1995, while the population in the watershed increased 9% in that same time period. Public, domestic, and livestock water uses declined with industrial, commercial, mining (gravel), and irrigation increasing. Nationally, water uses have declined, but continue to increase in the Kalamazoo River watershed (Solley et al. 1998).

Irrigation can have a significant effect on local groundwater and stream levels, although it only accounts for 17% of the total use in the watershed. Bedell and Van Til (1979) found that 85.5% of the irrigated water use in Michigan in 1977 was for agriculture. Calhoun and Allegan counties were among the top ten counties in Michigan for number of irrigated acres (Bedell and Van Til 1979). Irrigation is used more in southwest Michigan because of the well-drained character of the sandy loam soils and availability of groundwater. Irrigation is used to increase yields of row crops by increasing soil moisture when needed.

Water use for irrigation is especially significant considering the high consumptive losses. At least 90% of the water used for irrigation is lost through evapotranspiration (Bedell and Van Til 1979). Effects of irrigation are especially critical during summer low flow periods, when aquatic habitats are stressed. Direct withdrawals from streams have the most direct effect, reducing amount of habitat available and magnifying effects of sedimentation and pollution. Wells that tap groundwater reserves can also have long-term affects on streams, possibly affecting groundwater discharge. Most irrigators in the Kalamazoo River basin use wells, but some surface water withdrawals exist on smaller tributaries. Irrigators have been known to illegally dam small streams to increase water depth for more efficient pumping. Leaching of nitrates and other by-products of fertilizers to groundwater is a problem in several heavily irrigated portions of the basin, resulting in contamination of drinking water wells. Irrigation in summer months saturates soils and increases runoff peaks during summer storm events.

New technologies are needed in the industrial and commercial sector that require less water, improve efficiencies, and increase water recycling. Laws and regulations that reduce discharge of pollutants also need to become more stringent regarding water use and improve the quality of water being returned to a river after use (see **Water Quality**). Conservation programs should continue with their objectives to enhance the awareness of the general public to reduce water use and demand. These programs appear to be working with reduction in public and domestic use of water from 1990 to 1995. More work is needed to educate and regulate irrigators within the watershed to maintain minimum flows in streams to support fish and wildlife habitat.

Soils and Land Use Patterns

Soils

Soil type is an important component of hydrology and can also direct land use patterns in a watershed. Sandy soils typically lead to more groundwater flow to streams compared to less permeable clay soils. Sandy soils are also less fertile than loamy soils. General soil maps are available for each county in Michigan. The soils in the Kalamazoo River watershed consist of 71% loamy type (sandy, silty, or clay loams), which is 10% lower than its neighboring St. Joseph River watershed (Gooding 1995).

> Soils in the watershed are as diverse as the glacial materials in which they are found. They range from clay and silt to sand and organic materials. About 25% have clay loam or clay textures (found mostly in Eaton County and to a lesser extent in Allegan and Van Buren counties). Forty percent are sandy loams and loams of intermediate texture (found primarily in Calhoun, Allegan, Barry, and Kalamazoo counties). Soils with loamy sand and sandy textures make up approximately 30% of the land (found mostly in the western part of the basin). The remaining 5% are organic and are distributed throughout the basin, usually in river bottoms. (KRWC 1998).

The Kalamazoo River watershed is predominately outwash plains with many small end- and ground-moraine ridges. Land is gently to moderately sloping with sandy loam and loam soils. Drainage conditions are mostly moderately well-drained with variable areas from poorly to excessively well-drained. Moderately well to well-drained portions of the outwash are used for agriculture, but poorly drained outwash deposits remain as swamp or marsh (Albert et al. 1986). The distribution of soils in the watershed has been mapped (Figure 22); however, this is a general description. For specific soil associations and distributions, review county soil survey maps that are available from soil and water conservation districts. In this assessment, soils have been lumped into three groups based on composition of sand, loam, or clay: Group A (sandy, loamy sand, or sandy loam), Group B (silt loam or loam), and Group C (clay loam, silty clay loam, sandy clay, silty clay, or clay).

The Kalamazoo River watershed is comprised of 52% (677,161 acres) Group A and 34% (441,732 acres) Group B soils. The remaining 14% (180,405 acres) is Group C soils and less than 1% is characterized as water, where soil surveys were not conducted due to existence of large lakes (i.e., Gull and Gun lakes)(MDNR, SDL 1994).

Headwaters

The headwaters consist of medium to coarse-textured end moraine ridges interspersed with deposits of outwash sand. Consequently, a majority of the headwaters is made up of patches of Groups A and B soils. These soils are moderately well-drained and are fertile for agriculture. There is one small pocket with Group C soils in the upper portion that has very slow infiltration rates and is found in an old lake bed.

Upper

The soils in the upper segment are similar to those in the headwaters and are made up of predominately Group A and B soils. Medium to coarse-textured end moraines and outwash sands are common. The northern edge of Rice Creek drains Group C soils, which is made up of loamy clay and clay soils. This area has slower infiltration rates that lead to more run-off in the North Branch of Rice Creek.

Middle

Soils in the middle segment are mainly characterized by Group A soils but with a mixture of Group B. The upper part of this segment has medium to coarse end moraines with outwash sands. The middle part of the segment consists of broad outwash sands. The lower section of the middle segment contains a band of ice-contact and end moraine ridges that stretches through Kalamazoo into Barry County, creating ridges that rise abruptly from outwash sands. Infiltration and groundwater flow rates are high.

Lower

The lower segment consists of a mix of Group A, B, and C soils. This segment lies in a transition area, leaving medium to coarse end moraines and entering flat lake plains. As a result, precipitation infiltration rates vary from high to very low.

Mouth

Sandy lake plains cover most of the mouth segment with some steep, coastal sand dunes and end moraines. Most soils are Group A with some areas of Group C and B soils. The Rabbit River headwaters drain Group A outwash sands, while the middle mainstem and Little Rabbit rivers drain predominately Group B and C soils. This area has less infiltration capacity than the rest of the watershed. The lower Rabbit River drains mostly Group A soils as it enters a flat lake plain with some medium to fine textured end moraines.

Land Use

Land use in the Kalamazoo River basin is dominated by various forms of agriculture (58%), with forested lands comprising the second most frequent land use at 25% (Figure 23; MDNR, SDL 1999). The headwater, upper, and lower have mostly agricultural land use while the middle has most of the urban and the lower is primarily forested. Wetlands and urban areas make up smaller portions of the basin. Agricultural land use includes croplands (row and close-grown crops, hayfields, cultivated crops, horticulture), pasture, and fallow grasslands. Dominance of agriculture as a land use has significant affects on the Kalamazoo River and its tributaries, including increased sediment loads, nutrient influx, and water withdrawals for irrigation (see **Water Quality**).

Ninety-six percent of the land in the Kalamazoo River watershed is privately owned. The remaining 55,000 acres are publicly owned (KRWC 1998). These areas are managed as recreation or game areas by either MDNR Parks and Recreation Division or Wildlife Division. Management techniques employed to diversify forest habitat in these and private forests include clear-cutting, shelter woods, selection, and thinning. Best management practices are important to consider in these forested areas. Improper forest management can lead to stream degradation through soil erosion and sedimentation, especially if buffer strips are not maintained.

Wetlands are critical to any river for floodwater control, ground water recharge and discharge, water quality improvement, sediment entrapment, shoreline stabilization, fish and wildlife habitat, aquatic invertebrate production (fish food), and recreation. Wetlands make up only 5% of the land area in the basin. Development in wetlands in Michigan is governed by Part 303, Wetland Protection, of the Natural Resource and Environmental Protection Acts of 1994 and Section 404 of the Clean Water Act, which regulate filling or draining of wetlands (see **Special Jurisdictions**). Wetlands are threatened by draining, filling, dredging and excavation, and dewatering through the use of high-capacity wells located in the wetland. The growth of the marina industry is also threatening critical wetlands in the lower Kalamazoo River. MNDR, Fisheries Division encourages off-river basins for new marinas, with single outlets to the river, to protect wetlands.

Comparing wetland acreage from the late 1800s to 1978, there has been a moderate decline within the Kalamazoo River watershed. Using the method described by Comer (1996), presettlement vegetation maps showed over 197,232 acres of wetland within the watershed. In 1978, the area of wetland was down 17% to 164,078 acres (MDNR, SDL 1999 and MDNR, SDL 2000). This rate of loss is lower than the state average of about 30% and is also lower than the southern Lower Michigan average of 43% (Comer 1996). Much of the wetland area in Allegan County has been preserved by the Allegan State Game Area.

Urban areas compose about 9% of the land area in the Kalamazoo River watershed. Most large cities in the basin are located along the mainstem, and many have significant affects on the water quality. There are several point sources of pollution in urban areas from municipal and industrial wastewater discharges. Urbanization also increases the amount of impervious surfaces in the watershed leading to increased runoff and loadings of a variety of pollutants from urban non-point sources (see **Water Quality**).

There is a major concern for increased development pressure in the middle mainstem segment. The cities of Battle Creek and Kalamazoo continue to sprawl. Furthermore, sprawl from Grand Rapids is beginning to encroach into the watershed from the north. Along with increased development comes an increase in impervious surfaces (roofs, parking lots, and roads) that could change the hydrology of streams. Groundwater fed streams could receive more runoff that would in turn increase water temperature and flashiness of flows. The middle segment has the highest density of coldwater streams in the watershed, and these could be jeopardized by this development pressure. Programs should be supported to educate local land use planners to direct development to areas that reduce effects on critical groundwater recharge and discharge areas.

Bridges and Other Stream Crossings

There are 2,755 road and utility stream crossings of the Kalamazoo River and tributaries, according to intersect counts using MIRIS county transportation and utility data (Table 4) (MDNR, SDL 1992). County road crossings make up 60% of these, while utility crossings only make up 9.5%. Allegan County has the most road and utility crossings with 1,187 with 65% of these being county roads. Calhoun and Kalamazoo counties also had high numbers of crossings with 515 and 513, respectively.

Gravel road crossings are potential problem sites because of the amount of sediment that can wash off roads into streams. Crossings also add sediment if approaches are not maintained or properly stabilized. Some bridges and railway crossings can also lead to stream bank erosion. Improperly designed bridges or culverts redirect channel flow and increase water velocities and may even cause flooding if too small for expected flood flows. Culverts and bridge pillars tend to become blocked with debris and can lead to flooding and erosion problems by restricting natural stream flow. This is especially true at multiple culvert crossings. Eaglin and Hubert (1993) reported that trout abundance had a negative relation with density of culverts. Culverts can be physical barriers to fish passage because of excessive water velocity at the crossings or because improper placement and erosion downstream of the culvert results in a "perched" culvert. Culverts can also become behavioral barriers to fish because culverts are generally long dark tubes that fish are reluctant to enter. Hundreds of these crossings exist in the basin.

Through the MDEQ construction permit review process, effects associated with road crossings are being minimized when replacement of a crossing becomes necessary. Fisheries Division routinely requests that bridges be used in lieu of culverts. Wooden bridges are a good choice because they have sufficient waterway area and are more economical than concrete or steel bridges. However, due to potential loss of creosote from wooden structures, only fully cured timbers should be used.

Inventories of stream bank erosion at bridge sites or improperly placed stream crossings are not routinely maintained by any agency. Watershed and sport fishing groups in the past have conducted inventories of stream crossings and have applied for grant funds to address any problem crossings. Allegan, Calhoun, and Kalamazoo counties would be wise choices if groups want to conduct a road and stream crossing inventory for the Kalamazoo River watershed. With these three counties, over 80% of the road and utility crossings within the watershed could be evaluated.

Abandonment of road and especially railway bridges are a major concern. As these structures deteriorate, banks will begin to cave in and eventually, bridge structures will fail completely. Streams will be forced to cut new channels through large amounts of sediment. Dams could be created at railway bridges because of the large amounts of coarse material used to build railroad grades and crossings.

Submerged crossings (pipelines) are usually less evident unless erosion of the stream bottom has exposed them. The number and location of submerged crossings in the Kalamazoo River watershed are unknown. Depending on diameter and amount of pipe exposed in a stream channel, some crossings can act as low head dams or catch debris. Sometimes pipes can be exposed enough to prevent navigation. Installation of submerged crossings can also be a major source of sedimentation to a stream. Through Part 301 of the Natural Resources and Environmental Protection Act (1994 PA 451), proposed crossings are reviewed to ensure that proper techniques are used to minimize stream degradation. Erosion control and bank stabilization measures as well as boring techniques have limited sedimentation at new crossings.

Another concern with road crossings, especially on major transportation routes, is the potential for accidental spills along those routes. The Kalamazoo River Watershed Council (KRWC 1998) gives a good description of the major routes of transportation within the watershed:

> Automobile, truck, train, and airplane transportation is readily available in the watershed. A major portion of Interstate 94 traverses the watershed from Jackson to Kalamazoo. Major intersections include interstate 69 at Marshall and U.S. 131 at Kalamazoo. Lesser state highways include M-89 from Battle Creek to Allegan, M-43 and M-96 in Kalamazoo County, M-99 and M-60 in Calhoun and Jackson counties. Amtrak/Conrail parallels Interstate 94 from Jackson to Kalamazoo, with a major rail yard in Battle Creek and a smaller one adjacent to the river in Kalamazoo. Primary air passenger service is at Kalamazoo/Battle Creek International Airport, with major air freight service from Battle Creek. Local airports are located at Albion, Marshall, Plainwell, and Allegan.

Channel Morphology

Gradient

Stream gradient (drop in elevation with distance, usually in feet per mile) is an important factor determining river channel form and streambed composition. Gradient is related to streambed particle size, discharge, channel pattern (meandering), and sediment transport (Hynes 1970; Knighton 1984). Gradient is one of the most important factors in determining distribution and abundance of various fish species, such as smallmouth bass (Trautman 1942; Edwards et al. 1983), flathead catfish (Lee and Terrell 1987), bluegill and green sunfish (Stuber et al. 1982a; Stuber et al. 1982b), black crappie (Edwards et al. 1982), northern pike (Inskip 1982), warmouth (McMahon et al. 1984), white sucker (Twomey et al. 1984), blacknose dace (Trial et al. 1983), and creek chub (McMahon 1982).

The average gradient of the Kalamazoo River mainstem is 3.0 ft/mi, which is similar to both the Huron and Flint rivers. The gradient range is 0-40 ft/mi. These areas of different gradient types create diverse channels, and hence different kinds of habitat for fish and other aquatic life. Typical channel patterns with gradient are listed below (G. Whelan, MDNR, Fisheries Division, unpublished data). In these descriptions, hydraulic diversity refers to a variety of water velocities and depths found at a particular site in the river. The most productive river habitat offers a good variety to support different life histories of different species. Fish and other life are typically most diverse and productive in those parts of a river with gradient between 10 and 69.9 ft/mi (G. Whelan, MDNR, Fisheries Division, personal communication; Trautman 1942). Such gradients are rare in Michigan because of low-relief landscape, and these areas are also the most likely to have been dammed.

Gradient class	Fish habitat	Channel characteristics
0.0- 2.9 ft/mi	low	mostly run habitat with low hydraulic diversity
3.0 - 4.9 ft/mi	fair	some riffles with modest hydraulic diversity
5.0 - 9.9 ft/mi	good	riffle-pool sequences with good hydraulic diversity
10.0-69.9 ft/mi	excellent	established, regular riffle-pool sequences with excellent hydraulic diversity
70.0 -149.9 ft/mi	fair	chute and pool habitats with only fair hydraulic diversity
> 150 ft/mi	poor	falls and rapids with poor hydraulic diversity

The Kalamazoo River is predominately low gradient, 113.0 river miles (62.0%) are described by the lowest gradient class (<3.0 ft/mi) (Figure 24). Gradient gradually decreases as the river descends 540 ft from the headwaters to the mouth (Figure 25a and 25b). Gradients between 3.0 and 4.9 ft/mi constitute 42.3 mi (23.2%) of the mainstem, and 21.3 mi (11.7%) are in the good hydraulic diversity class (5.0-9.9 ft/mi). The most desirable gradient between 10.0 and 69.9 ft/mi is found in only 5.5 mi (3.0%) of the river. However, 53.1 mi (29.2%) of the river are impounded by dams for lake-level control structures or hydroelectric facilities. This includes 18.2 mi (28.6% of the gradient class between 3 and 9.9 ft/mi) and 2.4 mi (43.3% of the gradient class between 10 and 69.9 ft/mi) of river with the best type of hydraulic diversity. The river (free-flowing) portions of the Kalamazoo include 80.4 mi of the low gradient run habitat, 45.5 mi of run-riffle habitat with gradient between 3.0 and 9.9 ft/mi, and 3.1 mi of riffle-pool habitat with gradient between 10.0 and 69.9 ft/mi. Run-riffle and riffle-pool habitats are limited to the headwaters and small mainstem reaches near Homer, Marshall, and Plainwell.

The stream gradient of the Kalamazoo River channel varies from less than 1 ft/mi to over 40 ft/mi. The variation in gradient is a result of diversified landforms with low gradient across lake plains and higher gradients at the edges of moraines. Mainstem segments are characterized as follows:

Headwaters

This segment has the most diverse gradient with nearly all (8.0%) of the excellent gradient habitat compared to other mainstem segments (Figure 26a). Low gradient (58.3%) and fair to good gradients (33.7%) make up this segment. The steepest gradient for the watershed is found in this segment.

Upper

The upper segment has the largest proportion (83.9%) of fair to good gradient (Figure 26b). Low gradient habitat exists in 15.4% of this segment (5.1 mi), and only 0.7% (0.2 mi) consists of excellent hydraulic diversity (10.0 - 69.9 ft/mi). Marshall Hydroelectric Impoundment floods the entire excellent habitat reach.

The North Branch Kalamazoo River also has its largest proportion (63.2%) in the fair to good gradient class. Low gradient habitat exists in 35.8% of this tributary (9.6 mi), and only 1.0% (0.3 mi) consists of excellent hydraulic diversity. Horton Impoundment covers all this 0.3 mi high gradient reach.

Middle

Low gradient constitutes most (74.6%) of this segment (Figure 27a). Fair to good gradient makes up 11.2 mi (22.3%). There are 1.6 mi (3.1%) of excellent habitat with 0.6 mi flooded by Plainwell Dam.

Battle Creek is the largest tributary within this segment. Most (32.1 mi) of the Battle Creek is within the low gradient class (0.0 – 2.9 ft/mi). The remaining 9.1 mi are within the fair to good gradient class. Over 50% of the good gradient habitat (1.9 mi) is inundated by the Bellevue Impoundment.

Lower

The lower segment is dominated by low gradient (63.7%) (Figure 27b). Fair gradient (3.0 – 4.9 ft/mi) exists in 20.8% (5.4 mi), and good gradient constitutes 15.5%. Over 60% of the lower segment is flooded by the City of Allegan and Lake Allegan (Calkins) dams.

Mouth

The mouth segment flows across a glacial lake plain and is all low gradient (0.0 - 2.9 ft/mi) (27 mi). No dams exist on the mainstem within this segment.

Rabbit River is the largest tributary in this segment. It has more diverse gradient than the mouth segment with 57.5% (29.2 mi) within the low and 42.5% (21.6 mi) fair to good gradient classes. The Hamilton Dam impounds 2.2 mi of the low gradient habitat.

Channel Cross Section

Channel cross section is another measurement of quality fish habitat. Natural channels typically provide better habitat than degraded or manipulated channels. Channel morphology is determined by stream flow and magnitude, channel structures, gradient, streambed and bank stability, and size and type of transported sediment. Undisturbed channels typically have stable widths even though the stream may be migrating laterally. Stream width can remain relatively constant where the role of erosion on one bank is compensated with sediment deposition along the opposite bank. Channel widths generally increase in a downstream direction as discharge increases with a larger watershed area. Although width remains relatively constant, mean depth of streams varies greatly within reaches due to the sequence of riffle and pool features (Rosgen 1996).

Degraded or manipulated channels and watersheds typically have varying widths. Unstable flows will create flood channels that are over wide and shallow during average flow periods. Unusually narrow channels are produced by bulkheads or channel dredging. Sand channels are typified by higher velocities and more laminar flows, and have parabolic cross sections (Alexander and Hansen 1988). Abnormal sediment loads (either too much or too little) will also modify channels by causing deposition or erosion. Bridges, culverts, bank erosion, channel modifications, and armored substrates will cause deviations from expected channel form. To examine the effects of these modifying factors, more channel cross-section observations are needed in each valley segment.

Channel width comparisons were done for each valley segment and many tributaries (Table 5). Data are from discharge studies of Towns (1984), Blumer et al. (2000), and MDEQ (2000a). Expected width was estimated from a relation with mean daily discharge (G. Whelan, MDNR, Fisheries Division, unpublished data). Channel diversity indices were calculated from counts of cross-section data points in classes of velocity intervals of 0.5 ft/s and depth in intervals of 0.5 ft. The diversity index ranges from 0.00, representing constant depth and velocity across a channel, such as in a flume, to 5.00, representing a highly variable hydraulic channel. Generally, 1.00 would be a simple box-shaped channel; any value of 2.50 or greater would indicate a complex channel (Hay-Chmielewski et al. 1995). This index is somewhat biased in that the potential for high diversity increases with stream size. Valley segments and tributaries have channel habitat as characterized below; cover and substrate measurements are mainly from Towns (1984) for the mainstem and MDEQ (2000a) unless specified:

Headwaters

This segment has a normal channel width characterized as straight to meandering. The channel width ranges from 2 ft at its beginnings to 75 ft near Albion with an average width of 25 ft (Herman 1994). From Moscow to Homer, vegetative cover is moderate, substrate is mostly silt to sand, and fish habitat is rated as fair or impaired. A small section within the Moscow to Homer reach between Stoney Point Road to Mosherville Road has the best habitat consisting of pools, runs, and riffles with cobble and gravel (Herman 1994). Downstream of Homer to Albion, substrate is mostly sand and gravel with some cobble, cover is moderate with more woody structure, and fish habitat is rated as good. Gradient and stream velocities are higher in this lower reach creating more pool and riffle habitat with gravel and cobble substrate. Beaver Creek and Swains Lake Drain have poor habitat ratings due to silty substrates. Beaver Creek has a significantly wide channel due to channelization and cattle access (Table 5).

Upper

The upper segment is medium in size as it picks up drainage from several tributaries, and the channel meanders unconfined. Channel width varies from 77 to 100 ft, and depth varies from 0.5 to 4.5 ft. With fair to good gradient classes present, riffles are common with some deeper pools. Overhanging brush is common. The substrate consists of gravel and cobble (75%), sand (15%), silt (4%), and clay (1%). Hydraulic diversity of the mainstem near Marengo is good at 2.41. Although not significant, the Kalamazoo River width near Battle Creek is narrow possibly due to bank stabilization projects. North Branch Kalamazoo River is 11 to 35 ft wide, and the habitat rates between good and excellent. Overhanging brush is abundant with some under cut banks and root wads. Substrate is mostly sand (50%) with some gravel (40%) and silt (10%). Wilder Creek is 16 ft wide on average and has a fair habitat rating due to high sand embeddedness of the gravel. Rice Creek averages about 20 ft wide with a 1 to 3 ft depth. The lower creek near Marshall has excellent habitat with gravel substrate. The North Branch is rated as good with more sand embeddedness. South Branch Rice Creek ranges from fair to poor for habitat ratings. Sedimentation and channelization have degraded the habitat. Channelization has removed most of the woody structure and has created a wide channel for its average discharge (Table 5).

Middle

The river meanders as it flows within moraine features and broad valleys. It becomes larger as it picks up drainage from the Battle Creek River and several smaller tributaries. Width nearly triples between Battle Creek (68 ft) and Plainwell (202 ft). Depth averages 2-4 ft. Width is significantly narrow through the constructed channel portion of Battle Creek and below Morrow Dam in Comstock (Table 5). The channel becomes significantly wide near Galesburg as the river enters Morrow

Impoundment. Habitat rates as good to excellent through most of the middle mainstem segment. Cobble and gravel are very common averaging 50% of the substrate composition. Sand and silt comprise 10 to 20% of the substrate and becomes more prevalent near impounded areas. Below Morrow Pond in Comstock, the Kalamazoo River has a complex channel with excellent hydraulic diversity. Overhanging brush, woody structure, pools, and riffles are all common with some boulders present.

Battle Creek River ranges from 21 ft wide upstream of Charlotte to 85 ft wide in Bellevue with an average depth between 1 and 3.5 ft. Gravel and cobble substrates are present throughout most of the creek but are mostly embedded with sand. Woody structure is available at most sites allowing for good habitat ratings. A reach downstream of Charlotte has a fair habitat rating due to a lack of woody structure from a recent channel clearing. Wanadoga Creek starts (10 ft wide) with a poor habitat rating from sedimentation, and it increases to a good habitat rating through the middle and lower reaches (44 ft wide) with more overhanging brush and gravel type substrate.

Wabascon and Seven Mile creeks are similar in size (10-14 ft wide, 1 ft deep) and have habitat ratings of fair from high sand embeddedness. Augusta, Gull, and Silver creeks and Spring Brook are rated from good to excellent with substrates dominated by gravel and cobble. Silver Creek averages 14 ft wide with the upper half exhibiting the best habitat of logs, root wads, and overhanging brush (Dexter 1993a). Spring Brook has excellent channel structure consisting of under cut banks, logs, and riffle/pool sequences (Dexter 1992). Gun River has habitat ratings between poor and fair. Sedimentation, channelization, and lack of a forested riparian corridor contribute to its low habitat quality. Pine Creek averages 17 ft wide and 1.5 ft deep and has a fair habitat rating. The headwater substrate of Pine Creek consists of gravel (40%) and sand (60%) with some woody structure in the channel, while the lower creek is 100% sand and silt (Dexter 1991a).

Lower

The mainstem channel is narrow through this segment as it meanders confined within a relatively narrow glacial valley. Width at Allegan is more than 50 feet narrower than at Plainwell and the river discharges 500 cfs more at Allegan than at Plainwell. The channel ranges from 148 to 171 ft wide and 0.3 to 6 ft deep. Substrate is composed of 70% rock and gravel, 20% clay, and 10% silt. Cover mainly consists of logs, stumps, and deep holes. Schnable Brook is about 15 ft wide with mostly gravel (90%) and sand (10%) substrate. Dumont Creek has an excellent habitat rating due to its gravel substrate, overhanging brush, and woody structure.

Mouth

The channel is generally wide in this segment as it meanders unconfined across a lacustrine plain. The mainstem channel averages 190 ft wide and reaches widths over a half-mile wide in Kalamazoo Lake near Douglas. Habitat is generally good with fallen trees and deep holes (over 10 ft deep). Substrate becomes more sandy (84%) with some silt (11%) and gravel (5%). Hydraulic diversity is excellent near New Richmond, which had the highest recorded diversity for the watershed at 3.12 (Table 5).

Swan and Bear creeks have good habitat ratings. Swan Creek, which averages 18 ft in width, has some woody structure but sand dominates the substrate. Bear Creek is smaller at 10 ft wide and has much better substrate with more gravel and cobble. The Rabbit River ranges in width from 5 ft near Wayland to 120 ft at its mouth. The upper third of the river has a habitat rating of good while the rest of the river has not been rated (MDEQ 1999a). Undercut banks, logs, and overhanging brush are common. The substrate generally consists of rock and gravel in the headwaters with more sand and silt in the lower river. The hydraulic diversity index was 2.76 at Hopkins indicating a complex channel through that section of river (Table 5).

Dams and Barriers

There are 110 dams in the Kalamazoo River basin registered under MDEQ with 15 on the Kalamazoo River mainstem (Table 6; Figure 28). Some dams are classified by MDEQ, Dam Safety Section according to their purpose: 4 for hydroelectric power generation, 11 retired hydroelectric dams, 60 for recreation (including lake-level control structures), 4 flood-control dams, 2 for water supply, and 30 for other reasons (private ponds, county park ponds, hatchery ponds, etc.). It is not known how many small unregistered dams exist in the basin.

The first dam in the watershed on record was built in 1830 on the North Branch Kalamazoo River in Concord. Early dams were built across small creeks at high gradient locations to power grain mills. Construction of mill dams continued until 1900. From 1890 to 1940, several large dams were constructed to generate electricity. All of the now retired hydroelectric dams were built between 1856 and 1906. These dams were originally made to power grain, saw, and paper mills and were later converted to electrical power. Because of their age and inefficiencies, these dams are no longer being used for power generation. The last phase of dam building was between 1945 and 1980; these dams were built to control lake levels for recreation and waterfront development.

Dams are regulated under Michigan's Dam Safety, Part 315 of the Natural Resources and Environmental Protection Act, 1994 P.A. 451 as amended; and the Federal Energy Regulatory Commission (FERC) Regulation 18 of Part 12 of the Code of Federal Regulations. Most existing hydroelectric dams on the Kalamazoo River are under FERC authority.

The Dam Safety section of GLMD, MDEQ, considers the safety of all dams in the watershed. Some dams are listed with a higher hazard potential. Twelve dams are of hazard type 1 (dam failure would cause the loss of life), 13 are of hazard type 2 (dam failure would cause severe property damage), and the remaining 85 dams are of hazard type 3 (have low heads in remote areas). Most high hazard dams have a head of over 12 ft and are hydroelectric or retired hydroelectric facilities.

Dams have many detrimental affects on aquatic communities in rivers. They impede fish movements to refuge habitats causing segmented fish populations and block spawning migrations (Goldman and Horne 1983; Schlosser 1991). Dams fragment river systems and turn high quality river habitat into lentic habitat. Some fish and aquatic insects migrate up or downstream to reach different feeding and temperature habitats throughout the year. Mortality or injury can result while passing through dams, especially with hydroelectric turbines. Entrainment often causes mortality or injury as a result of fish being struck by turbine blades, pressure changes, sheer forces in turbulent flows, and water velocity accelerations (Cadwallader 1986; Cada 1990).

Impoundments that discharge water from the surface typically increase downstream water temperatures by spilling warm surface waters. This is especially critical in the warm summer months. Increased water temperatures can lead to elimination of certain aquatic species including fish (Ward 1984). Evaporation rates increase with the higher temperatures and much greater impoundment surface area. Dissolved oxygen levels in impoundments are usually lower than those in moving streams, and this change can alter fish populations in impounded portions of a river system. Impoundments also act as sediment and debris traps. Sediment-free water released below the dam has high erosive power causing increased scour and bank erosion. Woody structure is caught in impoundments and eventually sinks, depriving downstream segments of important fish habitat (Wesley and Duffy 1999).

The ability of dams to control flows can disrupt the incidence and increase severity of flooding both up and downstream if the reservoir has storage capacity. Reduced inundation of floodplains can decrease available backwater habitat for fish spawning and juvenile rearing. The decrease in flooding also reduces the amount of food deposited into the river from the floodplain. Intense short-term flow fluctuations immediately below dams can strand aquatic organisms during severe low flows and destroy habitat during extremely high flows (Wesley and Duffy 1999).

Many dams were built on areas of highest gradient in the Kalamazoo River and its tributaries in order to create the largest hydraulic head possible for the lowest cost. Some segments of the Kalamazoo River had rapids and fast riffle areas before being impounded. These areas were high quality spawning areas, used by potamodromous fish and other aquatic species in the river, and are now lost. Lake Allegan Dam in the lower river blocks potamodromous fish from Lake Michigan from accessing high quality riverine habitat.

Natural stream systems strive to reach equilibrium, where the amount of water and sediment that enter a stream equals what leaves it. Many southern Michigan rivers are still trying to reach equilibrium and channel forms are still changing. Dams interrupt the natural evolution of stream channels. Aggradation takes place above dams as sediments are deposited in the reservoirs and the stream tries to re-establish a new equilibrium downstream. Sediment deposition in these river segments makes the stream channel wider and shallower, with few deep holes, and habitat heterogeneity is lost. This loss of heterogeneity adversely affects fish populations as different life stages of river fish species need many habitat types to survive (Wesley and Duffy 1999).

Dams also interfere with free navigation and recreation on rivers. A canoe trip from the headwaters to the mouth would require 15 portages around dams. Some canoe portages are provided, but some are not clearly marked or are poorly maintained. Boat launches are more prevalent in the lower and middle sections, where impoundments and the river are deep enough to support use by larger boats (refer to **Recreation Use**).

Some dams are constructed to maintain unnatural water levels of lakes, or to deepen natural lakes, with no regard to river levels below lakes. These lakes have legally-established water levels and dams are operated to assure the level is maintained through the year. A few lakes have lower winter levels established to allow dock and seawall maintenance and to protect these structures and riparian shorelines from ice damage. These legal levels are determined with little regard to effects on fish and wildlife above and below the structures. Critical spring spawning areas for fish such as northern pike are eliminated on some lakes when water levels are kept artificially low to protect riparian property. Naturally, water levels rise in lakes during spring and gradually decline in level through summer and fall. Stretches of streams below some of these lake-level control structures have little or no flow in summer months due to seasonal regulation of outflows; more water is held back in summer for recreation (Wesley and Duffy 1999).

Other barriers to fish movement are also in the Kalamazoo River watershed. Perched culverts and poorly designed bridges sometimes create physical barriers or velocity barriers to fish movement (see **Soils and Land Use Patterns**, *Bridges and other stream crossings*). Beaver or other natural events such as severe logjams sometimes create barriers. Severe logjams are not a significant problem within the Kalamazoo River system, but beaver populations are on the rise especially on small tributaries within the middle mainstem segment. Effects of beavers on fish communities are discussed more thoroughly in the **Biological Communities**, *Mammals* sub-section.

Dams on the Kalamazoo River are further described within each mainstem valley segment below.

Headwaters

The three mainstem dams in the headwaters are no longer being used to produce mechanical or hydroelectric power and are maintained to create small recreational impoundments. These dams are old, having been built in the mid-to late-1800s, and their hazard levels range from low to significant.

This segment has some of the highest gradient, but most of it is flooded under impoundments. These impoundments increase water temperatures and prevent downstream movements of woody structure. More investigations of effects of dams are needed for the headwaters.

Upper

There are 12 dams within this segment with two on the Kalamazoo River proper. Ceresco Dam is the largest dam with a head of 15 ft. It was built in 1906 and is currently a retired hydroelectric facility owned by a private individual. The dam and impoundment are currently being maintained for aesthetic purposes. The City of Marshall operates the only hydroelectric dam in this segment. The Marshall Dam is licensed through FERC and is up for re-licensing in 2005. The following issues need to be addressed during the re-licensing process: 1) establishment of run-of-river flow; 2) a minimum flow study in the bypass channel; 3) entrainment and impingement studies to estimate fish mortality and to mitigate for losses; 4) upstream fish passage options; 5) woody structure passage; 6) dam retirement funding proposal; 7) funding for installation and maintenance of a stream gauge below the project. The Marshall hydroelectric facility only produces 2-3% of the electric needs for the city.

Most remaining dams are from old mills that created small impoundments or are lake-level control structures used for recreation. These dams have the potential to reduce summer flows in small creeks, increase water temperatures, and prevent fish access to important habitat. Most of the dams are listed as safe. Marshall, Horton, and Concord dams are listed as creating a significant hazard (Type 2).

Calhoun Conservation District received a 2005 Inland Fisheries Grant to remove the City of Marshall Dam on Rice Creek. This is the lower most dam and would open most of Rice Creek to the Kalamazoo River. The stream is expected to have cooler temperatures and higher gradient after removal, which will favor the existing brown trout management.

Middle

This segment has 75 recorded dams with 7 on the mainstem. Morrow Dam near Kalamazoo and Bellevue Dam on Battle Creek are the only operating hydroelectric dams in the middle mainstem segment. The Morrow and Bellevue projects operate under an exempt FERC license, meaning that they do not have an official operating license, but still are under the control of FERC. The remaining dams are for recreation and consist of old mill dams and lake-level controls. The Brook Lodge Dam on Ransom Creek and the Monarch Paper Mill on Portage Creek are used for water supply. Eight dams are listed as high hazard types including Morrow, Plainwell, and Otsego dams on the mainstem. Dams severely fragment the middle segment of the Kalamazoo River basin and prevent free movement of fish between the mainstem and tributaries.

Elm Street Dam on the Battle Creek River was removed in 2005 with the assistance of Consumers Power, MDNR, MDEQ, and Calhoun Conservation District. This removed the lower most structure in the Battle Creek River allowing for a free flowing and barrier free river from the confluence of the Kalamazoo River up to Verona Impoundment. The Calhoun Conservation District also received an Inland Fisheries Grant in 2005 to remove the Charlotte Dam on the Battle Creek River.

The Morrow Dam, which is owned by STS Hydropower, is still under FERC control although it does not possess an operating license with FERC. Under FERC review, STS Hydropower must also follow the recommendations of the United States Fish and Wildlife Service (USFWS) and MDNR. Some key issues with this facility are run-of-river flow, entrainment and impingement, and public access. Currently, the project is creating drastic flow fluctuations below the dam, although the facility has remained in compliance with their impoundment elevation requirements. The problem occurs when a turbine comes on or off line during low flow conditions. This event can instantly change the flow below the dam by 20% or more (Figure 20), but the impoundment level will remain nearly constant. This problem can be fixed by changing the requirements of run-of-river flow for the project to mean instantaneous outflow must equal instantaneous inflow rather than trying to maintain a certain impoundment level. Variable speed turbines will also help the project meet the run-of-river flow requirement. A fish entrainment study using tailwater netting estimated 45,987 fish passing the facility consisting of 21 species, ranging in size from 1.8 to 32.4 inches, in 6.5 months of sampling (Bohr and Liston 1987). This is a significant loss of fish for one area of the Kalamazoo River. These losses need to be reduced with the installation of protection devices. Tailwater angler access is also a problem at the Morrow Project. Signs warn anglers and other river users of trespassing. STS Hydropower only allows canoe portaging around the dam and specifically says “No Fishing”. Although the project has provided excellent access to the impoundment via parks and public boat launches, their cooperation is needed to provide tailwater angler access with a parking area.

MDNR owns the Lower Plainwell and Otsego dams within this section. These dams were purchased from Consumers Power Company in 1966 to ensure their retirement and future removal. Both dams were removed to sill level (approximately five feet of head) in 1987 and will be completely removed once PCB contaminated sediments are removed from their impoundments (see **Water Quality**).

The Upper Plainwell Dam located upstream of the town of Plainwell is also at sill level (one foot of head). This dam served as a diversion structure so water would flow down the mill race to Plainwell Paper. The mill is closed and a water supply is no longer needed. At sill level, some fish can probably navigate up through this dam. However, currents remain strong and the dam poses some risk to boaters navigating the river. This dam could be partially removed to promote fish passage and safe navigation. The City of Plainwell is known as the “Island City”, so dam removal engineering should consider continued flow down the mill race.

Lower

Seven dams exist in this segment. Three dams exist on the mainstem with Lake Allegan (Calkins) Dam being the only operating hydroelectric dam. Lake Allegan Dam was relicensed under FERC in 1980 and is up for renewal in 2010. The Trowbridge and Allegan City dams located upstream of the Lake Allegan Dam are retired hydroelectric facilities. The State of Michigan bought Trowbridge dam, like Plainwell and Otsego dams, from Consumers Power to ensure its retirement and future removal. It has been removed to sill level (approximate head of 10 ft) and will be completely removed once the contaminated sediments behind this dam are removed. The remaining dams are used for recreation and lake-level control. These dams also severely fragment this segment of the Kalamazoo River basin and prevent free movement of fish between the mainstem and tributaries.

The Allegan City Dam, formally named Imperial Carving dam, was built in 1900 for hydro mechanical power to run machinery in a furniture manufacturing facility. The dam was converted to hydroelectric power in 1920. The dam ceased operation of electricity in 1997 and was purchased by the City of Allegan to maintain the waterfront as an attraction for the city. Due to its poor condition, the dam was upgraded and repaired by the city in 2002. MDNR, Fisheries Division recommended removal, but the city was interested in maintaining its waterfront. A free flowing river system with off channel ponds and a greenway park could have created a more attractive downtown area compared to the existing sediment filled impoundment.

Lake Allegan Dam is owned and operated by Consumers Energy Company. It is the largest dam in the watershed with a head of 33 ft, and it creates the largest impoundment (Lake Allegan) at 1,587 surface acres. With the relicensing process in 1980, improvements were made below the dam to create better public access to the river. A stairway and fishing area were established on the west side of the river to provide access to the powerhouse tailwaters. A MDNR boat launch and parking area were also created on the east side of the river below the dam. Improvements could still be made on the east bank below the dam to remove the steel sheet piling that prevents angler access in some areas and is aesthetically unappealing. During the last relicensing, MDNR concurred with Consumers Energy that construction of a new fish ladder should be deferred until water quality improvements were made on the river above the dam. The existing ladder is not effective. With recently improved water quality in the Kalamazoo River (see **Water Quality**), MDNR should use their right under the 1980 agreement to evaluate the need to construct an adequate fish passage facility that could pass salmonids, lake sturgeon, and warmwater species. The next relicensing phase begins in 2005.

Mouth

All 13 registered dams in this segment are within subwatersheds with none on the mainstem. Three dams are operated by MDNR, Wildlife Division to create waterfowl habitat; two are for the Palmer Bayou and one is on Swan Creek to create the Highbanks Flooding. Some steelhead and salmon can migrate past the Highbanks Diversion Dam, but are stopped by the Swan Creek Pond Dam about three miles upstream from the Kalamazoo River. The Hamilton Dam is a retired hydroelectric facility and is the only registered dam on the Rabbit River. The dam has been removed to sill level (approximately five ft of head remains) and provides some movement for steelhead and salmon through the old mill race; velocities are too high to pass other species. Hamilton Dam is a good candidate for removal. The remaining dams are privately owned and are used for recreation or other purposes. The Monterey Lake level control has a head of 15 ft and is the only dam in this segment with a high hazard rating.

Water Quality

Overview

Water quality in the Kalamazoo River basin is influenced by many human uses of land and water including agriculture, industry, and suburban development. Each of the surface waters in the Kalamazoo River watershed is protected by Michigan Water Quality Standards (Part 31 of 1994 PA 451) for the following designated uses: warm and cold water fisheries, other aquatic life, and wildlife; agriculture, industrial, and municipal water supply; navigation; and recreation. Waters of the state designated as trout streams by the Director of MDNR (Table 7) have more stringent dissolved oxygen and temperature standards to protected coldwater fish (Table 8 a and b). The mouth segment from Lake Allegan to Lake Michigan is also designated as a migratory route for potamodromous salmon and is protected for that purpose.

State and federal laws have been developed to protect water quality for a variety of given uses (NREPA 1994 PA 451; MDEQ 2004). Regulatory agencies monitor river water quality and water uses in a basin to ensure minimum water quality standards are met, to determine compliance with the law, and to document water quality conditions in the basin. Michigan Department of Environmental Quality (MDEQ), Water Division (WD) (formerly Surface Water Quality Division) is the lead regulatory agency for water quality in Michigan with assistance from Waste and Hazardous Materials and Remediation and Redevelopment divisions. MDEQ, WD has conducted biological and chemical surveys of a number of streams in the Kalamazoo River watershed. Aquatic habitat and water quality varies throughout the watershed, with some areas being quite healthy, while other areas are seriously degraded and not supporting designated uses. The entire mainstem from the upper segment to Lake Michigan and numerous tributaries are not attaining designated uses (Table 9).

The Kalamazoo River basin has historically suffered from poor water quality due to unregulated discharges by industries and municipalities. Water quality in the basin is improving and virtually all point source discharges are regulated. Major effects on water quality continue to be PCB contaminated sediments, nonpoint source pollution, and adjacent sites of contamination.

PCB Contamination

> Identified as a problem in 1971, PCB discharges into the Kalamazoo River from paper industry de-inking processes created very serious pollution problems. PCBs were released directly to the river from the mid-1950s to the mid-1970s via process discharges, and into groundwater and surface water from landfills where contaminated waste products were disposed. PCB discharges to the Kalamazoo River from process streams have been essentially eliminated because of a ban on their production and other regulatory point source controls. Paper company landfills, river sediments and floodplain sediments, however, are still heavily contaminated with PCBs, and serve as ongoing sources of contamination to aquatic and terrestrial wildlife. Consumers of fish (i.e., mink) are the most sensitive aquatic species, and fish consumption advisories for humans remain along large stretches of the Kalamazoo River due to the PCB contamination.
>
> MDNR (now MDEQ) provided oversight for a 1986 Remedial Investigation/Feasibility Study (RI/FS) on the PCB problem, which was conducted by three potentially responsible parties (PRPs) Allied Paper, Inc./Millennium Holdings, the Georgia Pacific Corporation, and Simpson Plainwell Paper Company. The RI/FS was never completed by the potentially responsible parties.
>
> In June, 1990 the Michigan Department of Natural Resources notified three potentially responsible parties (PRPs), Allied Paper, Inc./Millennium Holdings, the Georgia-Pacific Corporation, and Simpson Plainwell Paper Company, of their intent to spend public funds to conduct a RI/FS.
>
> In August 1990, the Allied Paper, Inc/Portage Creek/Kalamazoo River site was included on the National Priorities List, commonly known as Superfund. In December1990, the State of Michigan entered into an Administrative Order by Consent with Allied Paper, Inc., Georgia-Pacific Corporation, and the Simpson Plainwell Paper Company. These potentially responsible parties agreed to fund and conduct a remedial investigation/feasibility study consistent with the Superfund process, in a proper and timely manner. Although not named in the order, James River Corporation has also been participating in these studies as a PRP. In 1997 the Michigan Department of Environmental Quality discovered that Rock-Tenn Corporation was discharging PCBs to the Kalamazoo River. Rock-Tenn is therefore being designated a party to the Superfund actions.
>
> The Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site is a 35-mile stretch of the Kalamazoo River and a three-mile stretch of Portage Creek contaminated with PCBs. This area includes Portage Creek from Cork Street just above Bryant Mill Pond in the city of Kalamazoo, to its mouth at the Kalamazoo River, and from Morrow Dam on the Kalamazoo River downstream to the Allegan City Dam. Because studies show that PCBs have migrated downstream, the MDEQ has expanded the study area to include these locations. Groundwater testing was recently completed within the Superfund Site; at this time PCB concentrations in groundwater do not appear to warrant any cleanup action. (KRWC 1998)

Due to the complexity of the Superfund site, individual areas of contamination known as Operable Units (OU) have been identified. There are four land-based OUs and the river is considered a fifth OU. The land-based OUs are landfills where PCB contaminated wastes were disposed in the 1950s, 1960s, and 1970s. Some of the OUs also include adjacent PCB-impacted areas, such as the five former Georgia-Pacific Mill Lagoons located adjacent to the King Highway Landfill OU. Removal actions occurred at the Georgia-Pacific Mill Lagoons in 1999 when 33,000 cubic yards of materials were excavated and another 5,000 cubic yards were removed from the Kalamazoo River floodplain area between the lagoons and the river. Approximately 7,000 cubic yards of material were removed from the Kalamazoo River near the Willow Boulevard site; 11,300 cubic yards were excavated from the King Mill Lagoons; and 5,000 cubic yards were removed from the King Street Storm Sewer Site. All contaminated soils were placed in the King Highway Landfill site, which subsequently has been capped. In addition, the Bryant Mill Pond time-critical removal action along Portage Creek was completed in 1999. Approximately 4,000 ft of Portage Creek was diverted to conduct dry excavation of the creek bed and floodplain. Excavated material (150,000 cubic yards) was placed in former residual dewatering lagoons on the Allied Paper OU, which were subsequently capped. The banks and floodplain were planted with wetland vegetation to rehabilitate the riparian ecosystem in the disturbed area.

In 2000, the Potentially Responsible Parties drafted a Remedial Investigation and Feasibility Study that reported investigation results and possible clean-up alternatives for the contaminated river sediments (OU 5). Unfortunately, the study appeared to favor a natural attenuation remedy, which does not significantly remove contaminated sediments from the river and riverbanks. The MDEQ rejected the draft document. Natural attenuation makes use of natural processes to reduce the concentration and amount of pollution at contaminated sites. Natural attenuation processes may reduce contaminant mass by biodegradation; reduce contaminant concentrations through dilution or dispersion; or bind contaminants to soil particles by adsorption. Fisheries Division does not favor natural attenuation. It is an unacceptable remedy to address contamination of the river because it would take too long and require the permanent maintenance of all dams within the site to prevent PCB contaminated sediment, that is trapped in the current and former impoundments, from migrating downstream as far as Lake Michigan. The goal of Fisheries Division is to restore the river ecosystem, which includes a healthy, diverse fish population and no fish consumption advisories. To accomplish this, MDNR favors a remedial action plan that addresses contaminated areas within the river including impoundments. Contaminated sediments need to be removed from the river and adjacent floodplains and contained outside the floodplain. Once the contaminated material is removed, all unnecessary dams should be removed, including all MDNR-owned dams, to restore a more natural river ecosystem.

The Kalamazoo River has also been identified by the International Joint Commission as a Great Lakes Area of Concern due to releases of PCBs into Lake Michigan. During the Remedial Action Plan Process, eight of the 14 Great Lakes Water Quality Agreement beneficial uses are being impaired. Beneficial use impairments included restrictions on fish and wildlife consumption; degradation of fish, aquatic and terrestrial wildlife populations; bird or animal deformities or reproductive problems; degradation of benthos; restrictions of dredging activities; beach closings; degradation of aesthetics; and loss of fish and wildlife habitat.

A Lake Michigan mass balance project conducted in 1994 and 1995 found elevated loadings of pollutants coming from the Kalamazoo River into Lake Michigan. The mass balance study focused on PCBs, atrazine, mercury, and nutrients. These substances among others were studied because they are representative of classes of pollutants (i.e., pesticides, herbicides, metals, etc.) of environmental significance in Lake Michigan and throughout the Great Lakes. The Kalamazoo River was rated second in total PCB loads to Lake Michigan at 84 lbs per year, which was significantly lower than the Fox River in Wisconsin at 441 lbs per year. PCB cleanups began in the Fox River system in 2003. Total nitrogen loads were rated the fourth highest at 7.7 million pounds per year for the Kalamazoo River, which was below the Grand, St. Joseph, and Fox rivers. The agricultural herbicide atrazine had the highest concentration in the St. Joseph River followed by the Grand, Kalamazoo, and Fox rivers.

The Kalamazoo River consistently rated in the top five for various pollutant loadings to Lake Michigan according to the mass balance study (USEPA 2003).

The Superfund program provides authority to trustees to seek damages for injuries to the Kalamazoo River resulting from the release of hazardous substances into the river. The Director of the MDNR; the Director of the MDEQ; the Attorney General of the State of Michigan; the U.S. Department of Interior, represented by the U.S. Fish and Wildlife Service; and the U.S. Secretary of Commerce, represented by the National Oceanic and Atmospheric Administration; comprise the trustees for the Natural Resource Damage Assessment (NRDA).

The purpose of the NRDA is to restore, replace, or acquire the equivalent of the natural resources that have been injured by PCBs and to compensate the public for past and future lost use of the resources through additional restoration. Any funds recovered in the NRDA are used to restore or enhance natural resources to compensate for effects of PCBs.

The trustees completed a Stage 1 Injury Assessment in 2005. The types and magnitude of injuries and damages to the Kalamazoo River were measured. The assessment concluded that injuries have occurred to surface water, fish, benthic invertebrates, Bald Eagles, mink, and floodplain soils. Possible injuries have occurred to other birds that consume fish or are carnivorous. Fish have incurred damages to their reproductive systems and there have been toxic effects detected with smallmouth bass. The effect of PCB contamination on waterfowl and sub-lethal effects on some fish, passerine birds, muskrats, and shrews is unknown. Indirect effects on the habitats of mollusks and other aquatic animals have also occurred by maintaining dams that would be removed if there were no PCB contamination of river sediments.

A Stage 1 Economic Assessment was also conducted. It measured the damages or restoration costs to bring the resource to its condition prior to the release of PCBs. Compensable value for interim losses has been calculated, which includes the value of lost river uses to the public. The assessment calculated the loss of recreational fishing use and surveyed area residents for other losses associated with PCB contamination and developed the framework for future selection of restoration projects (http://www.fws.gov/midwest/KalamazooNRDA/ [Accessed July 2005]).

Point Source Pollution

There are 94 municipal and industrial discharges to surface waters in the Kalamazoo River basin (Table 10). These discharges are commonly referred to as point source pollution, because the source of the pollutants is distinct. Discharges are permitted by the State of Michigan through the National Pollution Discharge Elimination System (NPDES), which regulates discharges to surface waters.

Discharges to the Kalamazoo River include effluent from municipalities: wastewater treatment plants, water treatment facilities, and storm sewers; industrial discharges: contact and non-contact cooling waters, process wastewater, sanitary wastewater, groundwater remediation sites; and miscellaneous discharges from trailer parks, campgrounds, concentrated animal feeding operations, and highway rest areas. Permits issued to these dischargers contain limits for parameters of concern (metals, organics, dissolved oxygen (DO), carbonaceous biochemical oxygen demand, solids, nutrients, oil and grease, temperature, and chlorine) and are specific to each discharge. Limits for these parameters are based on the assimilative capacity of the receiving water and may incorporate mixing zones in rivers. Permits are issued for five years, and are reviewed by WD staff before being reissued. Permits in the Kalamazoo River basin were reviewed in 2001. In general, permitted dischargers are in compliance with specified limits.

Nonpoint Source Pollution

Nonpoint source pollution does not originate from a specific point, rather from many points, and enters surface water through atmospheric deposition or water transport. Nonpoint source pollution is contamination consisting of sediments, nutrients, bacteria, organic chemicals, or other inorganic chemicals including metals. Sources of these pollutants include: agricultural fields, livestock feedlots, surface runoff from construction sites, parking lots, urban streets, uncontrolled septic seepage, groundwater contamination, open dumps, industrial sites, and inadvertent chemical spills.

Many pollutants from these nonpoint sources use oxygen during their breakdown process. This can limit or even eliminate oxygen needed by fish and other aquatic organisms. Nutrients can lead to excessive aquatic vegetation growth that can further deplete oxygen concentrations through decay and bacterial respiration. Metals, pesticides, and other toxics can accumulate in the aquatic food chain and may have harmful affects on fish or lead to consumption advisories for anglers. Increased sedimentation can limit fish and macroinvertebrate habitat by covering gravel riffles and filling pools. Sediment particles often also have nutrients attached to them.

Urban and agricultural runoff contributes significantly to water quality problems in the Kalamazoo River. In the Kalamazoo River Area of Concern, nonpoint source pollution is partially responsible for five of the eight beneficial use impairments: degradation of fish and wildlife populations and habitats, degradation of benthos, restrictions on body contact, and degradation of aesthetics (USEPA 2000).

Construction activities can also be a source of nonpoint pollution along rivers. MDEQ, Geological and Land Management and Water divisions regulate construction activities adjacent to waterways and in floodplains. The biggest threat to the basin from construction activities is sedimentation from uncontrolled runoff. Erosion control permits are required under Part 91 of the Michigan Natural Resources and Environmental Quality Protection Act (1994 PA 451), but too often local administrators of the law do not enforce permit conditions, do not monitor construction, or work is simply done without required permits.

Section 319 of the federal Clean Water Act provides funding for addressing nonpoint source problems. Grants to local agencies or organizations are awarded and administered by the Water Division of the MDEQ. There are currently one completed and ten on-going 319 Grants within the watershed:

The Little Rabbit River watershed project was completed in 2000. This project focused on addressing livestock waste management practices.

The Rabbit River project began in 1999 and is in the implementation phase. This watershed is affected by phosphorus. The goal of the project is to implement BMPs to improve water quality.

Upper Rabbit River watershed project goals are to locate sources of pollution, prioritize critical areas within the watershed, and to build and maintain stakeholder awareness.

The Kalamazoo River watershed project began in 1999 and encompasses two 319 Grants. The first grant is with Western Michigan University and focuses on data compilation and geographical information system development. The second grant addresses storm water runoff in the Kalamazoo area.

The Davis Creek project in the city of Kalamazoo is implementing urban BMPs, developing multi-agency coordination of erosion control enforcement at construction sites, and public education activities such as stream clean-ups, storm drain stenciling, creek-side signs, water quality monitoring, and a watershed stewardship award.

The Lake Allegan Project began in 2000 and addresses the phosphorus problems in the lake and Kalamazoo River. The goal is to build on the momentum created by the Total Maximum Daily Load process that began in 1998 to implement phosphorus reductions throughout the watershed.

The Portage and Arcadia creeks project is to develop a watershed management plan for both creeks to help reduce nonpoint source pollution.

The Gun River watershed project is in the planning phase to create a management plan to reduce nonpoint source pollution.

The Rice Creek watershed project is in the planning phase to develop a comprehensive watershed inventory, identify and prioritize contaminants and their sources, and develop and implement a watershed management plan.

The Battle Creek River watershed project is developing a watershed management plan that will identify the problems, impairing pollutants, and nonpoint sources of pollution and will demonstrate effective restoration techniques.

As mentioned above, Lake Allegan and the Kalamazoo River are under going a Total Maximum Daily Load (TMDL) process to reduce phosphorous level in Lake Allegan. Lake Allegan has been on Michigan's impaired waters list for several years for excessive algae growth and low seasonal dissolved oxygen levels. As a result, the State of Michigan is mandated by the federal Clean Water Act to develop a TMDL for Lake Allegan and its watershed. In 1997, MDEQ conducted studies to determine the lake's natural capacity to use phosphorus. Phosphorus in excess of that capacity must be eliminated. Phosphorus reduction targets are being set for waste load and load sources. Waste load sources consist of 28 industrial and municipal waste treatment facilities that discharge to the Kalamazoo River and tributaries. The load sources are nonpoint sources including naturally-occurring levels of phosphorus. These load sources could come from fertilizers, detergents, animal waste, or naturally be bound to soils (MDEQ 1999b).

Storm Water Control

Storm water sewers collect both point and nonpoint sources of pollution and discharge them to the river. These discharges typically have high chloride concentrations (possibly from road salt), high nutrient and sediment loads, and can increase biological oxygen demand in the receiving stream. They also contribute oils, grease, and tars from roadways. Because storm water sewers usually drain large paved areas, during storm events they can occasionally contribute a significant portion of the flow in some small streams. This can have short-term effects on aquatic communities in these streams, which may develop into long-term effects. Increased discharges from several small sewer influenced streams can have cumulative effects by increasing flows to larger receiving rivers. NPDES permits are required for storm water discharges where large municipalities and industrial activities exist. There are 150 permitted industrial storm water discharges within the watershed (Table 11).

Sites of Environmental Contamination (Part 201 Sites)

MDEQ, Remediation and Redevelopment Division, has identified 189 sites of environmental contamination within the Kalamazoo River watershed as of 2000 (Table 12). These sites are regulated under Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451. Part 201 provides laws and promulgated rules for the identification and remediation of sites of environmental contamination, determines liable party responsibilities, and provides the regulatory framework for the remediation of these sites. Many sites have the potential to contaminate groundwater and consist of leaking underground storage tanks, spills of waste products from industries, leaking solid waste management facilities, or improperly constructed wastewater treatment facilities. There is high potential for groundwater contaminants to migrate to the river and tributaries, especially in reaches with high groundwater inflows. Long-term monitoring is required to assess any ecological effects to the system. Cleanup has begun at several sites, but it will take many years to complete. Some cleanups will result in a discharge of treated groundwater to surface waters, under a NPDES permit. There is the potential for trace amounts of contaminants to be discharged into the Kalamazoo River system through these clean up efforts – collectively, these traces may add up.

There are 22 sites (Table 13) within the basin, including Portage Creek and the Kalamazoo River (see **Water Quality**, PCB Contamination), that are listed under the Comprehensive Environmental Response Compensation and Liability Act of 1980 as amended (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) of 1986. The United States Environmental Protection Agency administers this Act. Its purpose is to identify and prioritize contaminated sites as well as establishing plans and funding for contaminant removals.

Dissolved Oxygen, Temperature, Nutrients, and Bacteria

Chemical and physical characteristics of water, such as temperature and oxygen, are important parts of fish habitat. Physiologically, fish operate in certain temperature regimes that can be generally characterized into two categories - warmwater and coldwater. Warmwater species can be found in mean water temperatures greater than 70 °F (21 °C); whereas, coldwater species require mean water temperatures below 70 °F (21 °C) during summer months. Further, most fish require moderate levels of dissolved oxygen (above 3 mg/l) in order to survive. Standards for DO and other parameters have been established to protect fish and other aquatic organisms. These standards are included in Part 4 Water Quality Standards (Part 31 of 1994 PA 451). Standards are used when developing water quality based effluent permit limits for NPDES permitted discharges. The water quality standard for DO in warmwater streams is 5.0 (Table 8).

MDNR, MDEQ, and USGS have collected stream temperature data for several tributaries in the basin. These data show that South Branch Kalamazoo, Battle Creek, Gun, and Rabbit rivers, and Rice, August, and Portage creeks and several small Kalamazoo River tributaries are coldwater streams with little variation in summer temperature (Table 14). This is consistent with the considerable groundwater flow to these streams, which provides steady water flows. It is imperative that the temperature regimes of these coldwater streams remain undisturbed by human effects. Coldwater streams are a rare resource in southern Michigan and are important in maintaining the highly diverse biological community of the Kalamazoo River basin and for trout fisheries.

MDNR and MDEQ collected monthly water samples between 1970 and 1996 that were analyzed for temperature, DO, solids, chlorides, ions, and nutrients. Organic contaminants, metals, and toxics were sampled less frequently. Data were stored in the US Environmental Protection Agency's STORET computer system. This information is available on the Water Quality Data Access System through Michigan State University Extension.

Summary of River Segments

<u>Headwaters</u>

The water quality of the South Branch Kalamazoo River is generally good. The water temperature is cool to cold with the reach between Concord and Strait roads designated as a trout stream, which gives that area a higher water quality standard. There are no areas of non-attainment and only two NPDES permits issued within this segment. All six Part 201 sites involve leaks or spills from gas and oil containment facilities. Marathon Oil Corporation maintains an oil storage facility on the river. An oil spill occurred at this location in 1957, while under previous ownership. High chloride levels were still found in the river below the site in 1971 (MDNR 1972). Chemical tests taken in 1994 did not reveal detectable levels of contamination, but a petroleum odor and oily sheen were noted when personnel disturbed the sediments (MDNR 1994).

Upper

Water quality is also good in this segment, but there are more contaminated sites than compared to the headwaters. There are 13 NPDES and 20 storm water permits, 5 Superfund sites, and 27 Part 201 Sites of Environmental Contamination within the upper portion of the Kalamazoo River. Most sites are located within the cities of Albion and Marshall. No effects to the river have been documented as a result of any of these contaminated sites. A 1982 report noted chlorine, heavy metal, and cyanide presence and oily sludge deposits in the river below Albion (MDNR 1982a). Conditions were considered good below Albion and Marshall in 1989 based on macroinvertebrate samples (MDNR 1990a). Water quality was also rated good in this section in 1994, but there were high levels of copper and zinc detected in sediments downstream of the Marshall Waste Water Treatment Plant (MDNR 1994). Water temperature on the mainstem is characterized as cool to warm with July mean temperatures of 72 °F (22 °C).

Nonpoint source pollution is a problem on tributaries within this segment. Crooked and Rice creeks are on the non-attainment list due to biological degradation from agricultural sources. High nutrient levels have also been detected in Wilder (MDNR 1994) and Harper (MDEQ 1999b) creeks.

Rice Creek is a coldwater stream with July temperatures averaging 65°F (18°C). The south branch is a designated trout stream up to Concord Road. Minges Brook is also designated as a trout stream and has good water quality. The North Branch Kalamazoo River is characterized as cool to warm with July temperatures averaging 73 °F (23 °C).

Middle

The middle segment and tributaries flow through the major urban areas of Battle Creek and Kalamazoo, which explains the 58 NPDES permits issued within this section (Table 10). The mainstem received 55% of permitted discharges, the Battle Creek River received 17%, and the much smaller sized Arcadia and Portage creeks each received 4%. Further, 110 industrial storm water permits were issued; most of these were in the Kalamazoo Area with the Kalamazoo River receiving 52% and the much smaller sized Davis Creek receiving 16%. A total of 11 industrial storm water permits were issued for the Battle Creek River near the city of Battle Creek. Historically, this segment was plagued with low dissolved oxygen levels due to the discharge of excessive plant nutrients from municipal wastewater discharges (MDNR 1972; MDNR 1979; MDNR 1982b; MDNR 1988), but water quality in terms of dissolved oxygen has improved significantly since the late 1980s.

The majority of Part 201 contaminated sites are also near the cities of Kalamazoo (45%) and Battle Creek (20%). There are 14 Superfund sites – eight in Kalamazoo and three in Battle Creek (Table 13). Portage Creek and the Kalamazoo River are listed as Superfund sites from Morrow Pond downstream (see **Water Quality**, *PCB Contamination*).

There are 14 sites not meeting designated uses and 43% of these involved PCB contaminations (Table 9). The entire length of the mainstem segment including the Battle River and Portage Creek as well as Fenner, Gull, and Morrow lakes are in non-attainment due to PCBs. Biological degradation was reported in several tributaries including Wanadoga Creek and Gun River. Mercury was another cause of non-attainment for Gull and Selkirk lakes (MDEQ 2002).

A 2000 sediment sampling of Portage Creek found parameters exceeding the lowest effect level at one or more sites that included arsenic, chromium, copper, mercury, lead, and zinc (MDEQ 2001a). The lowest effect level value indicates a level of contamination, which has no effect on the majority of the sediment dwelling organisms. Values greater than the lowest effect level imply a potential effect to sediment dwelling organisms.

Seventeen designated trout streams are located in this segment including Augusta and Portage creeks and the Gun River. Several small tributaries have July average temperatures below 68 °F (20 °C), which is an ideal temperature and major habitat component for trout (Table 14). The Kalamazoo River is a warmwater system in this segment with July temperatures averaging 76 °F (24 °C). These warmer temperatures are in part due to the number of mainstem impoundments of river.

Nutrient loading is a large concern in the middle segment, especially for phosphorus. Total for all water bodies combined (Portage, Pine, Davis, and Arcadia creeks and Battle Creek and Gun rivers) was over 1000 pounds of phosphorus. Industrial and residential nonpoint sources are the main contributors for Portage and Davis creeks (MDEQ 1999b). Agricultural nonpoint sources are likely cause for the other tributaries.

Lower

Water quality of the lower mainstem segment is determined from upstream segments and the city of Allegan. There are four NPDES (Table 10) and five industrial storm water (Table 11) permits that discharge directly to the Kalamazoo River or to a small tributary called Fields Brook. The entire river through this segment is a Superfund site and the river is in non-attainment due to PCB contamination. Lake Allegan is also in non-attainment for PCBs and nutrients (Table 9). The Kalamazoo River is characterized as warm and has an average July temperature of 75 °F (24 °C) (Table 14). There are no designated trout streams within this segment.

Lake Allegan has had a long history of nutrient problems from both point and nonpoint sources within its watershed, which includes 1,550 square miles of the Kalamazoo River watershed. This nutrient problem led to the establishment of the TMDL for phosphorus in Lake Allegan (see **Water Quality**, *Nonpoint Source*).

An eutrophication survey of Lake Allegan was conducted by U.S. EPA in 1972. The lake was classified as hypereutrophic. The major contributing pollutant to the eutrophication of Lake Allegan was phosphorus. Additional data collected by the Michigan Department of Natural Resources in 1988 indicated that the lake had not improved. Monitoring information collected in 1994, 1996, and 1997 by Michigan Department of Environmental Quality also indicated the condition of the lake had not changed from the early 1970s. The lake was still extremely nutrient enriched due to phosphorous resuspension within the lake and continued loadings from the watershed (MDEQ 1999b).

Mouth

There are 17 NPDES permits issued for this segment, and most of them are for wastewater treatment plants on the Kalamazoo River and within the Rabbit River watershed (Table 10). Most of the 12 industrial storm water permits are for sites in Douglas and Saugatuck (Table 11). The Part 201 contaminated sites are mainly from leaking underground storage tanks and pollutants like lead, DDT, and chlorides (Table 12). PCBs again were the cause of the Kalamazoo River and Kalamazoo Lake for not attaining designated uses (Table 9). The Upper Rabbit and Little Rabbit rivers were also in non-attainment for biological degradation from agricultural nonpoint source pollution.

The mainstem Kalamazoo is warm but a few degrees cooler than the lower mainstem segment with a July average of 73°F (23 °C) (Table 14). Most tributaries are cold with July average temperatures below 68 °F (20 °C). The Rabbit River and most of its tributaries are also cold. Due to the coldwater streams in this area, the segment has 10 designated trout streams that include the Rabbit River and Swan Creek.

Fish Contaminants

Fish are a highly nutritious food enjoyed by many anglers. However, some species of fish in certain waters can accumulate and store contaminants in their body tissue. Older fish often have the highest concentrations. By eating these fish, some of these contaminants can be transferred to humans and can cause health risks. Therefore, fish contaminant advisories are posted for waters in Michigan. Fish have been collected and analyzed for contaminants since 1980 through Michigan's Fish Contaminant Monitoring Program (FCMP). FCMP is coordinated by MDEQ, WD, in cooperation with MDNR, Fisheries Division, Michigan Department of Community Health (MDCH); Michigan Department of Agriculture; and U.S. Environmental Protection Agency.

The goals of FCMP are to: (1) evaluate whether fish contamination problems exist in specific surface waters; (2) identify spatial differences and temporal trends in the quality of Michigan's surface waters with respect to persistent, bioaccumulative chemicals; (3) evaluate whether existing pollution prevention, regulatory, and remedial programs are effectively eliminating or reducing chemical contamination in the aquatic environment; and (4) support the establishment or removal of public health sport fish consumption advisories by the MDCH (MDEQ 1995).

The Michigan fish contaminant monitoring program consists of both fish collections from streams and caged fish studies. MDCH is responsible for establishing, modifying, and removing sport fish consumption advisories for Michigan's surface waters. Fish samples are analyzed for contaminants and compared to the fish consumption advisory trigger levels (Table 15). If a concentration of contaminants exceeds a trigger level, a consumption advisory is issued for that species and waterbody.

Most fish consumption advisories in the Kalamazoo River watershed are for PCBs and mercury. The Kalamazoo River from Battle Creek to Lake Michigan has an advisory for carp and from Morrow Pond to Lake Michigan there are advisories for eating catfish, suckers, northern pike, smallmouth bass, and other species due to PCBs (Figure 29). Battle Creek River, Portage Creek, Ceresco Impoundment and Fenner, Gull, and Selkirk lakes also have fish consumption advisories. Most advisories limit consumption of contaminated fish to one meal per week or one meal per month for women and children. However, the Kalamazoo River has advisories between the city of Kalamazoo and Lake Allegan for no consumption. Anglers should consult the latest Michigan Fish Advisory published by the Michigan Department of Community Health, Environmental Epidemiology Division before eating fish in the Kalamazoo River or other water bodies listed above. Fish Consumption Advisories are published on the internet at: http://www.michigan.gov/mdch/1,1607,7-132-2944_5327-13110--,00.html.

In addition, there is an advisory on mercury for all inland lakes and reservoirs in Michigan. No one should eat more than one meal per week of rock bass, yellow perch, or crappie over nine inches or bass, walleye, northern pike, or muskellunge of any size. Mercury is an airborne pollutant that can contaminate lakes and reservoirs regardless of the environmental health of a watershed.

River Classification by Fisheries Division

Fisheries Division classified water quality throughout Michigan in 1964 for the purpose of fishery management (Figure 30). This system has been useful in considering water quality with respect to stream temperature and fisheries use. Designations are: 1) top quality coldwater streams that are capable of supporting self-sustaining populations of trout; 2) second quality coldwater streams that contain significant trout populations maintained by stocking; 3) top quality warmwater streams that contain self-sustaining populations of warmwater (and coolwater) sport fish; 4) second quality warmwater streams that have limited sport fish populations due to pollution, competition, inadequate reproduction, or lack of suitable habitat. The entire mainstem of the Kalamazoo River is classified as top quality warmwater, and the headwaters (South Branch Kalamazoo) is classified as second quality coldwater according to this system.

A landscape-based ecological classification has been developed for rivers in lower Michigan, including the Kalamazoo River (Seelbach et al. 1997). This system uses valley segments to describe homogeneous portions of a river channel that share some common features and flow through specific landscape units (see **Geography**). This classification is based on the fact that rivers are strongly influenced by the configuration (i.e., geology, topography, landform type) of the landscape. This system also takes into account predictable changes in physical (discharge, flow patterns, channel morphology, water temperature, and energy sources) and biological (fish community structure) characteristics with stream size.

Special Jurisdictions

There are several federal, state, and local jurisdictions regarding rivers, riparian zones, and floodplains. MDEQ, Geological and Land Management and Water divisions (Table 16) administer some federal laws and several state statutes giving MDEQ authority over several aspects of the Kalamazoo River system.

Navigability

Fisheries Division is interested in the definition of a navigable stream because anglers have the common interest of fishing in a navigable stream, subject to the restraints and regulations of state laws. For the waterways to best serve the public, recreational uses should be considered in the determination of navigability. There should be a means of determining the public accessibility of a stream without the need for judicial determination. “A statutory determination of a navigable stream is urgently needed to clarify the fishing, boating, and recreational rights of the public, as well as provide criteria of navigability, and direction to state agencies in the implementation of existing laws and regulations (MDNR 1993).”

Michigan riparian law describes navigable streams as the following:

> A navigable inland stream is 1) any stream declared navigable by the Michigan Supreme Court; 2) any stream included within the navigable waters of the United States by the U.S. Army Engineers for administration of the laws enacted by Congress for the protection and preservation of the navigable waters of the United States; 3) any stream which floated logs during the lumbering days, or a stream of sufficient capacity to the floating of logs in the condition which it generally appears by nature, notwithstanding there may be times when it becomes too dry or shallow for that purpose; 4) any stream having an average flow of approximately 41 cubic feet per second, an average width of some 30 feet, and average depth of about one foot, capacity of floatage during spring seasonal periods of high water limited to loose logs, ties and similar products, used for

> fishing by the public for an extended period of time, and stocked with fish by the state; 5) any stream which has been or is susceptible to navigation by boats for purposes of commerce or travel; 6) all streams meandered by the General Land Office Survey in the mid 1800's. (MDNR 1993).

Historical records indicate that the Kalamazoo River was navigable as far upstream as Marshall before construction of dams on the river. Most navigation occurred between Kalamazoo and Saugatuck. Flat bottom boats and pole rafts were used to transport grain to Lake Michigan as early as 1836 (Lane 1993). The middle and lower mainstem segments were also used to transport logs.

Today, the Michigan Supreme Court and Legislature declare the mainstem of the Kalamazoo River legally navigable. All waters in the Kalamazoo River basin are presumed navigable unless legally declared non-navigable. The Michigan Supreme Court has judged certain streams or portions of streams navigable. Only a small part of the mouth segment of the Kalamazoo River from Kalamazoo Lake to Lake Michigan has been declared navigable by the Michigan Supreme Court (Sewers v Hacklander, 219 Mich. 143; 1922). In 1837, the Michigan Legislature declared the Kalamazoo River navigable from Marshall (Calhoun County T2S, R6W, Sec. 26) downstream to the mouth (MDNR 1993). The Army Corps of Engineers exercises jurisdiction for navigation on the Kalamazoo River up to Lake Allegan (Calkins) Dam in Allegan. However, maintenance dredging by the Corp of Engineers is limited to the Kalamazoo River below Bluestar Highway in Saugatuck.

Natural Rivers

Under the authority of the Natural Rivers Act (Table 16), the Kalamazoo River was designated a Natural River in 1981. The natural rivers district begins at Lake Allegan Dam and ends 22 miles downstream at the Hacklander Landing in Saugatuck Township Section 15. The designation also includes the Rabbit River (36^{th} Street downstream 17 mi), Mann (128^{th} downstream 2 mi), Bear (36^{th} Street downstream 5 mi), Sand (M89 downstream 2 mi), and Swan (112^{th} downstream 7 mi) creeks. The Kalamazoo River Natural River District includes an area 300 ft wide on each side of and parallel to all channels of the designated mainstem and tributaries.

State land within the designated area shall be administered and managed according to the Lower Kalamazoo River Natural River Plan (MDNR 1981). State management of fisheries, waters, wildlife, and boating should follow the plan. No new building structures, such as houses, campgrounds, or access sites, are permitted within 200 ft of the river except for riverbank protection. To protect the natural character of the river and the natural flow, no damming, dredging, filling, or channelization of the stream is permitted. Natural materials should be used in stream bank stabilization projects, or to enhance fisheries habitat. On private land, new structures must be 200 ft from the water's edge and new lots must be at least 150 ft in width. Vegetation within 50 ft of the water's edge must be maintained in a natural condition. The above standards are held in local township zoning ordinances, which can be more restrictive or have more requirements. Compliance to date has been good.

Designated County Drains

There are over 855 designated drains that make up over 1,100 miles of streams within the Kalamazoo River watershed (Table 17). In Michigan, these streams fall under the authority of the Michigan Drain Code, Act 40 of the Public Acts of 1956, as amended, which is executed by a County Drain Commissioner. County Drain Commissioners in Michigan have the authority to designate, extend, and maintain all designated drains. Maintenance activities include dredging, straightening, widening, and enclosing. In Michigan, these activities do not require MDEQ approval, if applied to drains designated before 1972. The average establishment date for drains in the Kalamazoo River watershed is 1903.

The artificial drainage and drain maintenance activities promote sedimentation and nutrient loading to rivers and contribute to loss and degradation of wetlands. County drains are sometimes responsible for draining entire wetlands systems. The Drain Code was written and passed by the legislature well before the need to control erosion and protect ecological functions was recognized. It does, however, provide mechanisms for short-term fixes to problems created by nonpoint source pollution (see **Water Quality**).

Efforts are underway by conservation groups and some legislators to rewrite the Drain Code to include sound environmental practices while continuing to serve the agricultural industry and urban development. The procedures of drain commissioners are also beginning to be challenged by riparian land owners and resource protection groups concerned about the short-sightedness of the present Drain Code. As a result of this resource protection pressure, drain commissioners have been incorporating alternative (environmental friendly) drain cleaning practices such as stream obstruction removal (AFS 1983) rather than channelization. One drain commissioner has gone as far as to abandon a drain that no longer requires maintenance. The Kalamazoo County Drain Commissioner abandoned the Upper Portage Creek Drain in 2000. Portage Creek is a coldwater trout stream that is stocked with brown trout and is used as a waterway by canoeists. Alternative drain maintenance practices that preserve fish habitat and consider drain abandonment are encouraged to protect and restore streams in the Kalamazoo River watershed.

Michigan drain commissioners are also responsible for maintenance and operation of many lake-level control structures, particularly those set by the Inland Lake Level Act (PA 146 of 1961). Methods of operation are at the discretion of each Drain Commissioner. This can be a problem when riparian owners petition the Drain Commissioner to maintain unnatural lake levels. For example, it is common for riparian owners to want high-water levels maintained during summer months for recreational boating and to maintain low-water levels during winter and spring to prevent ice damage and flooding. Maintaining high-water levels in summer can reduce or eliminate flow to an outlet, and low water levels in spring may prevent fish access to wetlands for spawning.

Habitat restoration projects that involve designated drains and lake-level control structures should be approved by the appropriate drain office. If applicable, a memorandum of understanding should be established between the restoring agency or group and the drain office. This will provide a record of any maintenance agreements and locations of habitat structures for future drain commissioners. It should also be understood that the drain commissioner has ultimate authority on drains established before 1972 and could remove and/or manipulate habitat structures if needed to improve drainage. For example, a group of volunteers installed habitat structures on the Little Rabbit River in 2000 to protect an eroding stream bank. The next year, under pressure from land owners, the Allegan County Drain Commissioner straightened the river and cut off the meander that contained the bank stabilization. As a result, hours of volunteer labor and important fish habitat were wasted. The risk of this type of action should be evaluated for any project conducted on a designated drain.

Parks and Natural Areas

Within the basin, the State of Michigan operates three game areas (Allegan, Gourdneck, and Barry) and the Augusta Creek Fishing Area (see **Recreational Use**). There are also two state parks in the watershed. Fort Custer Recreation Area, a 2,960-acre state park, is located on the Kalamazoo River between Kalamazoo and Battle Creek. Yankee Springs Recreation Area, a 5,000 acre state park (of which about 1,000 acres are in the watershed along the Gun River), is located northeast of Plainwell. The Kal-Haven Trail Sesquicentennial State Park is also in a portion of the watershed. Allegan State Game Area is the largest state-owned area in the watershed at 48,000 acres and is traversed by the Kalamazoo River and several tributaries (KRWC 1998).

There are several major city and county parks. These include: Markin Glen, River Oaks, Coldbrook, Milham, Verberg, and Kindleberger parks in Kalamazoo County and Littlejohn Lake, Dumont Lake, and Oval Beach in Allegan County. City and village parks and river walks providing access to the river are found in Albion, Marshall, Battle Creek, Kalamazoo, Parchment, Plainwell, Otsego, Allegan, and Saugatuck (KRWC 1998).

These public lands are not only important as access points to the river, but are also important green belts that act as buffer zones between the water and adjacent developed areas. Trees in riparian zones stabilize stream banks, moderate water temperatures on small streams by providing shade, and catch nutrients and sediments. Undeveloped floodplains absorb water during high flows and reduce severity of flooding downstream. It should be a high priority to maintain and promote more natural riparian areas in the Kalamazoo River system.

Tribal

The Kalamazoo River watershed is within an area described by the Treaty of Chicago 1821. This treaty was made and concluded at Chicago between Lewis Cass and Solomon Sibley, Commissioners of the United States, and the Ottawa, Chippewa, and Potawatomi Nations of Indians. The Treaty gave all land south of the Grand River to the United States except for five reservations. One reservation was in Kalamazoo and was designated as “Match-E-Be-Nash-She-Wish” reserve. Six years later, the Potawatomi people agreed to consolidate scattered reservations to Nottawasepee Reserve south of Kalamazoo in the St. Joseph River watershed. In 1998, the Match-E-Be-Nash-She-Wish Band (Gun Lake Tribe) of the Potawatomi Nation was recognized as a tribe by the U.S. Department of Interior, Bureau of Indian Affairs. The Gun Lake Tribe purchased property in the Rabbit River headwaters near Wayland and has plans for future development. The tribe is a growing stakeholder and will be an important watershed protection partner.

Biological Communities

Original Fish Communities

Fish collections from the University of Michigan, Museum of Zoology, and results from Michigan Fish Commission surveys were used to describe the original fish community. These surveys date back to the 1880s and used gill nets, seines, and hook and line sampling techniques. Common names were used in the early Fish Commission survey reports, and only major groups of fish (minnows, shiners, chubs, suckers, etc.) were recorded, not individual species. Fishes that were difficult to catch, such as native lampreys, are probably under-represented in historical collections. Eighty-nine species of fish were native to the Kalamazoo River Basin (Table 18).

A description of the fish community before European settlement (mid-1700s) is not available. Historic literature mentions fish as a popular food source, but only a few species were usually noted. Fish bones found with Potawatomi artifacts (1250 AD) in the lower and mouth mainstem segments indicate that lake sturgeon, channel catfish, and freshwater drum were present at that time (Barr 1979). Sturgeon bones were very abundant indicating a large seasonal migration (Barr 1979; Walz 1991).

Lake sturgeon spawn in areas of swift water or rapids (Scott and Crossman 1973). Before construction of dams on the Kalamazoo River, lake sturgeon entering the river to spawn would have had access to suitable spawning habitat 130 miles up river as far as Calhoun County. Construction of dams has now limited their spawning grounds to the 26 miles of river immediately below Lake Allegan.

The following descriptions of the original fish community are based on historical documentation (see **History**) and through predictive models based on landscape features (see **Soils and Land Use Patterns**, **Geology and Hydrology**).

Headwaters

Presettlement land cover of the South Branch Kalamazoo River consisted of mixed oak forest, black oak barrens, and oak savanna. The riparian corridor was wet prairie and conifer swamp. The headwaters were clear, often vegetated, and cool due to groundwater inflows. Woody structure density was probably low due to the type of wetlands that lined the river. Substrate was a mix of sand and gravel with silt on the edges. Coolwater riverine species probably included western blacknose dace, mottled sculpin, rainbow darter, and hornyhead chub.

Upper

Upland and riparian cover consisted of oak savanna prior to settlement. The Kalamazoo River was in transition from cool to warm water. The water was clear with vegetation, and woody structure densities higher than the headwaters. Common species included rosyface shiner, creek chub, white sucker, smallmouth bass, and rock bass. Rice Creek had similar characteristics as the South Branch Kalamazoo and supported a coolwater fishery. A cool to warm water community was in the lower North Branch Kalamazoo River with a lentic community in the Upper North Branch Kalamazoo River due to several lake connections. The lentic community probably consisted of northern pike, largemouth bass, bluegill, pumpkinseed, rock bass, brown bullhead, yellow bullhead, yellow perch, creek chub, central mudminnow, common shiner, and johnny darter.

Middle

The Kalamazoo River mainstem was probably a warm river that was slightly turbid water from the surrounding wetlands and loamy soil landscape. Woody habitat was abundant as the river meandered through a mixed hardwood swamp surrounded by oak savanna and oak-hickory forest. Gravel riffles were present as the river worked through the Kalamazoo Moraine. A warmwater fish community existed with some potamodromous fishes from Lake Michigan seasonally present to spawn (i.e., walleye, lake sturgeon, and white sucker). Coolwater communities were probably present in Portage Creek and Lower Gun River. Several small tributaries including Spring Brook, Sand, and Silver creeks had cold water from high groundwater flows. These streams had low species diversity that may have include mottled sculpin and blacknose dace. The upper Battle Creek and Gun rivers consisted of swamps and lakes providing good habitat for a lentic fish community. The upper Gun River near Gun Lake consisted of a huge marsh that would have been ideal habitat for northern pike and muskellunge (Seelbach 1988). The Great Lakes (spotted) subspecies of muskellunge once inhabited Gun Lake and presumably migrated into the lake and marsh area from Lake Michigan. The marsh and connection to Lake Michigan have since been lost, and the last known Great Lakes muskellunge was caught in 1939 based on historical pictures (McEnaney and Foreman 1983).

Lower and Mouth

The lower and mouth mainstem segment meandered through mostly a white pine and white oak forest with scattered hardwood swamps. Woody structure was probably plentiful with large logjams from white pine. The river had deep holes and runs with slightly turbid to turbid water from tannic acid and natural soil erosion processes throughout the watershed. Species diversity was high with substantial populations of large bodied fish including lake sturgeon, walleye, smallmouth bass, golden redhorse, northern hog sucker, black buffalo, and northern pike. Smaller fishes included logperch, blackside darter, johnny darter, common shiner, bluntnose minnow, creek chub, stonecat, and brook stickleback. Potamodromous fauna included lake whitefish, round whitefish, lake trout, white sucker, longnose sucker, lake sturgeon, walleye, and freshwater drum.

Lakes within the Kalamazoo River watershed were also once home to cisco or lake herring. Cisco are now only abundant in a few lakes. Stable populations exist in Green Lake (Allegan County) and Barlow and Fish lakes (Barry County). Cisco have been extirpated in Gull Lake (Barry County) and Swain's Lake (Jackson County). The Gull Lake population may have disappeared due to competition or predation from salmonid and smelt stocking (Dexter 1991b), and it is unknown why the Swain's lake population disappeared. Habitat deterioration or eutrophication is the common reason for the extirpation of cisco in southern Michigan (Latta 1995). These fish inhabit oligotrophic lakes that develop thermoclines with summer temperatures below 20°C. Cisco are limited in southern Michigan to kettle-hole lakes in moraines left by the retreating Wisconsin glacier (Latta 1995). Use of this fish by Native Americans was probably limited because of the water depth inhabited until gill netting and hook and line techniques were developed.

Factors Affecting Fish Communities

The Kalamazoo River watershed went through dramatic changes during European settlement. These changes caused alterations in the physical character of the river and affected the fish community. Influence of point source pollution, nonpoint source pollution, dams, agricultural and urban land use, and non-native species introductions are covered in greater detail in **Geology and Hydrology**, **Channel Morphology**, **Pest Species**, **Dams and Barriers**, **Soils and Land Use Patterns**, and **Water Quality**. A summary of these effects is appropriate here in order to understand present fish communities and fish distributions.

Past water quality problems have had a major effect on the fish community. Wastewater from industries and municipalities polluted the river making it unsuitable for most fish species. Fish kills, including those for hardy species like common carp, were frequent due to low dissolved oxygen levels. Water quality began to improve in the 1980s and the number and frequency of fish die-offs decreased. However, PCBs from contaminated sediments, banks, and floodplains continue to bioaccumulate in fish and other wildlife. Impacts from PCBs affect the entire biological community in the middle, lower, and mouth segments.

PCBs have been documented to cause mortality and deformities, as well as adverse reproductive, developmental, physiological, biochemical, and immunological effects on fish. PCB concentrations in Kalamazoo River fish exceed threshold levels known to have many of these effects. Studies have revealed that several species of fish from Portage Creek and the Kalamazoo River contain whole body PCB concentrations often in excess of 10 mg/kg. Research has shown that adverse effects, including egg and fry mortality, occur at egg total PCB concentrations greater than 2-3 mg/kg. These data indicate that PCB concentrations in Portage Creek and Kalamazoo River fish may be sufficient to cause adverse effects on fish viability (KRWC 1998).

Alterations of or barriers to specific habitats have also affected the fish community of the Kalamazoo River. Fish require several types of habitats throughout their life cycle. Stream species need distinct spawning, feeding and growth, and refuge habitats. Equally as important is the ability to move from one habitat to another (Schlosser 1991). If any one area is lacking or if the ability to migrate from one to another is restricted, the species becomes locally extinct (Hay-Chmielewski et al. 1995).

> Settlement in the watershed brought a need for small dams to power grain and lumber mills. In the 1880s, large dams were built for hydroelectric power. Dams fragment a river system and prevent movement of fish to critical habitats. Access to spawning areas was

> lost for all potamodromous fish species. Migrations to seasonal habitats within the river itself for resident species were also blocked by dams. Dams also affect fish communities by altering flow regimes, flooding, temperature, and sediment transport (Gordon et al. 1992). Only tolerant species, typically large, adult, warmwater species, can tolerate these harsh conditions, eliminating small species and juveniles of large species (Cushman 1985; Gislason 1985; Nelson 1986; Bain et al. 1988).
>
> Drainage of land for agricultural and urban use has altered natural flow regimes. Channelization of streams is typically carried out to improve conveyance and flood-carrying capacity. This practice drains wetland areas for agricultural production and urban development. Channelization and draining of wetlands affect fish by eliminating instream and juvenile nursery habitats. Structural diversity is reduced by elimination of meanders, smoothing of riffles and pools, and removal of snags and riparian vegetation (Gordon et al. 1992). Fish no longer have backwaters, pools, or woody debris for refuge against high flows (Newbury and Gaboury 1988). Increased peak flows cause accelerated erosion and increase sediment load in the river. Sediments increase turbidity and cover critical habitat (gravel and cobble) for certain fish and invertebrate species. Summer water temperatures also have become warmer due to stream widening, removal of riparian vegetation and shading, and reduced base flows.
>
> Clearing and development of land for agriculture, urban, and suburban uses had a significant effect on fisheries. As a result of unvegetated ground and increased impervious surfaces (roof tops, roads, and parking lots) rainwater is delivered to streams more quickly as surface run-off rather than through the ground. This causes higher peak stream flow, decreased flow duration, increased water temperatures, and lower base flow that can alter habitat. Expanding agricultural and urban land use also brought an increase in nonpoint source pollution. Pesticides, herbicides, and fertilizers that were not used by crops and lawns eventually washed into the river. Pesticides and herbicides can be toxic to fish and fertilizers increase aquatic vegetation growth in lakes and streams. With increased cultivation and construction, soils were left bare, causing accelerated erosion and increased stream sediment loads. Fine sediment reduces fish feeding efficiency, covers spawning substrates, and may cause fish mortality by clogging gills (Waters 1995). (Wesley and Duffy 1999).

Change in annual flow is a factor that affects fish habitat. High flow in spring floods riparian wetlands and provides good nursery areas for fish. These flooded wetlands are nutrient rich from the decomposition of detritus material and support a large community of macroinvertebrates and plankton. Fish use these areas for feeding and to escape high water velocities in the main river channel. Riparian wetlands also have warmer water temperatures that reduce egg incubation time and increase the growth rate of fish. Change in annual flows is a problem for fish when flow becomes inconsistent with the season (e.g., loses its high flow character in spring). Dams, stream channelization, and dikes can alter spring flooding and affect important fish nursery areas (Junk et al. 1989).

Several non-indigenous fish species (Table 18) have been intentionally or inadvertently introduced into the Kalamazoo River watershed and have a strong influence on fish communities through predation or competition. Inadvertent introductions result from ship ballast water, shipping canals, bait buckets, and illegal stockings. Some indigenous and non-indigenous species are intentionally stocked (Table 19) through fishery management to enhance fisheries, maintain populations, or to fill an unused ecological niche.

Present Fish Communities

The Kalamazoo River basin now contains 102 species of fish (Table 18), based on biological surveys by MDNR (Towns 1984; Herman 1994); Michigan Department of Environmental Quality (MDEQ, formerly part of MDNR), Water Division (WD) (MDNR 1994); University of Michigan Museum of Zoology records; and observations by Fisheries Division personnel. Several fish surveys were conducted within the Kalamazoo River watershed in 2000 and 2001 by Fisheries Division to update records. Many species can be found throughout the entire watershed, while others are only found in isolated areas as shown in distribution maps of each species (Appendix 1). Many native species are still abundant, but some are rare, of special concern, threatened, or endangered (Table 18 and Table 20). Lake sturgeon is considered threatened, creek chubsucker is endangered, and weed shiner has been extirpated. Fish communities have been characterized more extensively within the following mainstem segments.

Headwaters

This segment has moderate groundwater inflows that keep the river cool to cold with reasonably stable flows. Cold and coolwater fish species are present. The coolest water and best habitat in the form of pools and riffles is found between Stoney Point Road in Jackson County and Mosherville Road in Hillsdale County. The fish population in this section is composed mostly of brown trout (40.0%) followed by mottled sculpin (20.9%) and common white sucker (14.3%). This area has a species diversity of 17 fish (Herman 1994). The lower section of this segment from Homer to Albion is composed more of coolwater fish with a higher species diversity of 24. Common species consisted of stonecat (122 individuals/acre of water surveyed), rock bass (110/acre), and white sucker (109/acre) (Table 21). Substrate and woody structure was rated as good in this section; however, water quality was poor due to a petroleum spill that occurred in the 1970s (Towns 1984). More recent surveys rate the fish community as good (MDNR 1994). One rare species (pugnose shiner) had been found in this mainstem segment and the endangered creek chubsucker had been observed.

Swains Creek, a small tributary that connects from the south between Mosherville and Homer, contains a warm water fishery. Largemouth bass, rock bass, grass pickerel, and bluntnose minnow are present. This stream is limited by sand and silt substrates.

Upper

This segment consists of more run type habitat with few pools and riffles. Woody structure and overhanging brush are common. The substrate consists of mostly gravel and rock. Moderate amounts of groundwater continue to enter the stream keeping temperatures cool. The mainstem was surveyed at B Avenue, 15 Mile Road, and Raymond Road by a fish toxicant called rotenone in 1982 (Towns 1984) and again below the Marshall Dam in 2001 using stream-shocking gear (MDNR, FD (Fisheries Division), unpublished data). Species diversity ranged from 22 to 28 during the 1982 survey (Table 21). Northern hog sucker, white sucker, and stonecat were common species. Rock bass, smallmouth bass, and northern pike were the most common game fish. Only 19 species were collected below the Marshall Dam in 2001, which was less than 1982 probably due to less efficient sampling gear. Rock bass (23.5/acre) and smallmouth bass (5.5/acre) were still the most common game fish, but northern pike were not found in the 2001 survey. Habitat below the dam consisted of mostly runs with few deep holes and sluggish water to hold northern pike. Bluegills were most abundant at 45% of the catch. Combining all survey sites, there were 35 different species of fish represented within this mainstem segment. The extinct weed shiner was last found in this segment in 1929.

The North Branch, one of two large tributaries to the upper segment, is characterized as a warm water stream. It receives moderate amounts of groundwater, but it is affected thermally by several small impoundments. Habitat consists of aquatic vegetation, overhanging brush, and woody structure. The substrate is composed of 50% gravel, 40% sand, and 10% silt. A rotenone survey was conducted in 1982 at Warner Road near the town of Concord (Towns 1984). Twenty-six species of fish were observed (Table 21). Species not found on the upper mainstem included chestnut lamprey and brook stickleback. The most abundant species were common shiner (632/acre), rock bass (488/acre), and hornyhead chub (221/acre). A good population of smallmouth bass (72/acre) was also present. The North Branch was surveyed again using electrofishing gear in 1986 at Reynolds, Bowerman, and Albion roads (MDNR, FD, unpublished data). Habitat and species composition were similar to the 1982 survey except Reynolds Road had mottled sculpin and blacknose dace, indicating cooler water temperatures. The endangered creek chubsucker is also found within the North Branch. The Spring Arbor and Concord Drain is the main tributary to the North Branch. This creek is a warmwater system with poor habitat due to excessive sedimentation. Sport fish are limited in this small creek. Bluntnose minnow and common shiner are the most abundant species.

Rice Creek is another large tributary that enters the upper segment at the town of Marshall. It is characterized as a cool to coldwater stream. It has been extensively surveyed since 1952. The most recent general survey occurred in 1997 for the main branch and in 1983 for the South and North branches (MDNR, FD, unpublished data). Rice Creek has fair habitat due to channelization and excessive sedimentation. Overhanging brush, undercut banks, and aquatic vegetation are available for cover. White sucker and mottled sculpin are the most common species, while brown trout and rock bass are the most numerous game fish. South Branch Rice Creek is also a cool water stream with a similar species composition at the main branch with the addition of blackside darter. The South Branch also contains northern brook lamprey, which is not common within the watershed. The North Branch is more of a warm water stream and contains rock bass, yellow perch, common shiner, and bluntnose minnow. Blackchin shiner and northern brook lamprey are also found in low numbers. The extinct weed shiner was last seen in the North Branch in 1952.

Wilder, Bear, Brickyard, Talmadge, Pigeon, and Dickinson creeks and Minges Brook are characterized as coldwater streams. These streams have species compositions consisting mostly of mottled sculpin, blacknose dace, and blackside darter. Minges Brook and Brickyard, Bear, and Wilder creeks have populations of brown trout. Crooked and Squaw creeks are warm water streams and contain species such as common white sucker, creek chub, bluntnose minnow, largemouth bass, bluegill, and johnny darter. Harper Creek appears to be a cool to cold water system and contains mottled sculpin, blacknose dace, northern hog sucker, smallmouth bass, and rock bass (MDNR, FD, unpublished data).

Middle

The middle mainstem segment starts as a medium sized warmwater river and changes to a large sized river as it collects drainage from several tributaries including the Battle Creek River. Habitat consists of overhanging brush, woody structure, deep pools and runs with some riffle areas. The substrate is primarily gravel and rock. The river near Galesburg begins to become impounded from Morrow Dam. Substrate becomes more sandy and silty, and aquatic vegetation plays a larger role as fish habitat. Below the dam, the substrate becomes composed of more rock and gravel. The mainstem was surveyed at Custer Road, 38th Street, Sprinkle Road, Mosel Avenue, US 131, and below Otsego Dam by rotenone in 1982 (Towns 1984). Morrow Pond was surveyed using trap and gill nets and electroshocking gear in 1999 (MDNR, FD, unpublished data). Species diversity ranged from 10 to 27 and total standing crop ranged from 38 to 809 fish per acre (Table 21). Common white sucker, golden redhorse, common carp, common shiner, and striped shiner were the most abundant species while smallmouth bass and rock bass were the most common game fish. Bluegill and common carp were the most abundant species in Morrow Pond. Channel catfish, smallmouth bass, northern pike, and walleye were common game fish. The highest fish standing crop was at Custer Road. This section had good water quality and habitat. The pugnose shiner, a species of special concern, was also found in that area. The lowest standing crop and species diversity for this segment and the entire river was found at Mosel Avenue, which was just downstream of the Kalamazoo Wastewater Treatment Plant. Common carp made up 73% of the catch by number. Based on angler reports, it is presumed that the river and fishery have improved significantly since improvements were made to the wastewater treatment plant.

Battle Creek River is characterized as a coolwater stream from its headwaters to Bellevue. Downstream of Bellevue, the Battle Creek becomes large in size and is distinguished as warm water. Habitat is limited to some woody structure as the entire river in Eaton County is a designated drain and has been channelized. Riffle and pool sequences become more evident below Bellevue. The Battle Creek River was extensively surveyed using rotenone in 1986 (Towns 1987). The survey began just upstream of Charlotte and extended down to the mouth at the city of Battle Creek. Common shiner were the most numerous species, while rock bass were the most numerous game fish. A good population of northern pike occurs downstream of Charlotte. Smallmouth bass, rock bass, and black crappie were common game fish found in the lower river. Mottled sculpin were found in the upper half indicating cool to cold water conditions. The spotted gar, a species of special concern, was present in Duck Lake based on a 1863 voucher specimen but was not found in a 1991 survey (Towns 1992). The lower Battle Creek within Verona Impoundment was surveyed again in 2001 using fyke nets and boomshocking gear (MDNR, FD, unpublished data). Species composition was similar to Towns (1987) with the addition of channel catfish. White sucker were the most abundant species by weight followed by channel catfish, greater redhorse, and northern pike. Big, Indian, and Wanadoga creeks are characterized as cool to cold water systems. Mottled sculpin, blacknose dace, and white sucker are common. These creeks also connect to some wetlands and lakes so grass pickerel, bluegill, and yellow bullhead also tend to be common.

Wabascon Creek is a warm water system that connects to several lakes and swamps. Survey information is limited to one MDNR, FD survey that was conducted in 1960 in Barry County. Bluegill, pumpkinseed sunfish, and lake chubsucker were found. University of Michigan, Museum of Zoology records indicate that blacknose dace and mottled sculpin are also present indicating a cool water fish community.

Seven Mile Creek is a coldwater stream with excellent habitat in the form of overhanging brush, undercut banks, and gravel substrate. Blacknose dace, brown trout, and mottled sculpin make up the majority of fish collections by number. The brown trout population is good with an average of 255 trout per acre combining all sites (MDNR, FD, unpublished data). The pugnose shiner, a species of special concern, was found in this stream in a 1999 MDNR, FD survey.

Augusta Creek is a cool to coldwater stream. The most common species represented by catch by number were creek chub (25%), white sucker (18%), and blacknose dace (12%). Brown trout are also present in modest numbers with a population of 32 trout per acre (MDNR, FD, unpublished data).

Gull Creek is a warm water stream that begins at Gull Lake. This stream is heavily affected by lake-level control structures and other instream dams. Largemouth bass and smallmouth bass are present in small numbers, and common shiner and rainbow darter are most abundant. Gull Lake is classified as a mesotrophic lake that is deep and has excellent water quality. Over 55 different species of fish have been identified in Gull Lake (Dexter 1991b). Rock bass, yellow perch, and bluegill are the most abundant species by number, and the lake also contains brown trout, largemouth bass, smallmouth bass, and northern pike. Unusual species include cisco, blackchin shiner, pugnose shiner (special concern), least darter, and ninespine stickleback. Weed shiner, which is now extirpated from Michigan, was last collected in the 1970s (Dexter 1991b).

Comstock Creek is a warm water system that drains a few small lakes. It contains creek chub, rock bass, and bluegill as well as some unusual species such as blackstripe topminnow and creek chubsucker. Davis Creek begins as cold water and becomes degraded in the lower half with a warmwater fish community. The watershed is classified as 85% urban land use. Historically, Davis Creek suffered from inadequately treated industrial waste discharges and fish kills (MDEQ 2001b). The fish community consists of hornyhead chub, blacknose dace, white sucker, creek chub, and some mottled sculpin.

Portage Creek is a cold water system for most of its length and changes to a warm water system in its lower four miles (MDEQ 2001a). Impoundments and PCB contamination affect this lower section, decreasing fishery quality. Water quality conditions are expected to improve with on-going clean-up efforts. Mottled sculpin, blacknose dace, and johnny darters are common species together making up 63% of the catch by number (MDNR, FD, unpublished data). Stocked brown trout are the most common game fish representing 3.5% of the catch by number and 23% of the catch by weight.

Spring Brook is a high quality cold water stream with excellent habitat (Dexter 1992). Habitat components include undercut banks, logs, overhanging brush, riffles, and pools. Habitat characteristics rank in the top five for the entire state (MDNR 1991a). Species diversity is low consisting of brown trout (1,146/acre), mottled sculpin, white sucker, and brook trout. Silver Creek, located north of Spring Brook, is also a high quality trout stream with similar species. Brown trout populations at 1,500/acre in Silver Creek rival Spring Brook (Dexter 1993a; MDNR, FD, unpublished data).

Gun River begins with a warmwater fish community as it flows through several lakes including Barlow, Payne, and Gun. Gun Lake is the largest lake in southwest Michigan at 2,680 surface acres. The lake is diverse with at least 37 species of fish. Early records indicate that there were native populations of both muskellunge and walleye (Duffy 1990). A good panfish and forage fish community exists. From Gun Lake to a point six miles downstream, the warmwater fish community remains and is degraded due to channel straightening, agricultural non-point source pollution, and irrigation practices. The remaining length (approximately seven miles) to the mouth supports a coldwater fishery including brown trout. Several tributaries in this section sustain wild populations of both brown and brook trout. Spotted gar, a species of special concern, was found in Gun Lake in 1999 (MDNR, FD, unpublished data). cisco are found in Fish Lake, which connects to Gun River by Orangeville Creek (Wesley 2000a).

Pine Creek is a marginal trout stream classified as cold water. Habitat varies considerably from section to section. The headwaters and middle reaches offer undercut banks, overhanging brush, logs, and pools. Homogenous deep water with some logs characterizes the lower section. Pine Creek has been channelized to drain muck soils in the upper watershed. The fish community has not changed for 50 years (Dexter 1991a). Brown trout are the main game fish, and there is some natural reproduction in the Kalamazoo County section. The mouth is impounded and contains more of a small lake fishery with bluegill and northern pike being most abundant.

Lower

The lower mainstem segment is a large warm water system. Logs, stumps, and holes are common through the segment. Rocky stretches can be found in swift areas between impoundments. Most habitat is backwater or impounded by the city of Allegan and Lake Allegan dams. The Bridge Street rotenone-sampling site was below the city of Allegan Dam in a high current section (Towns 1984). A total of 19 species were observed. Common carp were the most abundant species consisting of 27% of the catch by number and 96% by weight. Common white sucker and blackside darter were also common. Spotfin shiner was the only unusual species found. The diversity and standing crop of game fish were surprising low because the habitat appeared to be excellent. Poor water quality from upstream wastewater discharges and PCB contamination may have affected game fish populations. Water quality conditions have improved in terms of dissolved oxygen levels since the rotenone survey, and anglers are reporting better catches of smallmouth bass and walleye.

Lake Allegan contains a degraded warmwater fish community. Water quality remains poor due to excessive nutrients, which are causing eutrophication of the lake (KRWC 1998). Dissolved oxygen levels are continually reported to be below standards. A general fisheries survey was conducted in 1996 (MDNR, FD, unpublished data). Common carp were most abundant consisting of 63% of the catch by number and 61% by weight. Channel catfish represented 22% of the catch by number and weight. Bluegills, smallmouth bass, and walleye were also reported in fair numbers. Spotted gar, a species of special concern, was observed with 19 other more common species in 1996.

Schnable Brook and Dumont Creek are warm water systems with excellent habitat consisting of gravel substrate, pool and riffle sequences, and overhanging brush. Both begin as outlets from lakes. White sucker, creek chub, and common shiner are common in both streams. The mimic shiner is the only unusual species, which is found in Dumont Creek. Miner and Dumont lakes have typical warmwater fish communities dominated by centrarchids (Wesley 2000b).

Mouth

The fish community in this segment reflects its large size and barrier free connection to Lake Michigan. Flathead catfish, walleye, quillback carpsucker, freshwater drum, gizzard shad, alewife, and migratory salmon make up a major portion of the community. Towns (1984) collected mostly common carp, gizzard shad, spottail shiner, spotfin shiner, and channel catfish. Lake sturgeon, a threatened species in Michigan, is also found in this mainstem segment.

Rabbit River is the largest tributary. The Rabbit River mainstem is a cool water stream with a fair habitat rating. Channelization and current agricultural practices have degraded this system (MDNR 1990b; MDEQ 1999a). The mainstem contains smallmouth bass, hornyhead chub, stonecat, and johnny darter. The presence of riparian wetlands provides some habitat for northern pike. The fish community below Hamilton Dam is influenced by its proximity to the lower Kalamazoo River and Lake Michigan. Potamodromous salmonids have access to the lower Rabbit River. Some steelhead and Chinook salmon also make it over Hamilton Dam and have access up to the town of Wayland. The headwaters are characterized as coldwater with a good to excellent habitat rating (MDEQ 1999a). Brown trout, common white sucker, central mudminnow, and johnny darter make up 71.5% of the catch by number (Dexter 1996a).

There are also a few small cold water tributaries within this segment. Mann and Sand creeks are both high quality streams that contain wild populations of brook trout (Dexter 1993b; Wesley 2001). Swan and Bear creeks support populations of both rainbow and brown trout.

Aquatic Invertebrates

Invertebrates are an important and diverse component of lakes and streams. Organisms in this grouping include sponges, moss animals, worms, arthropods (scuds, sowbugs, spiders, and crayfish), insects, and mollusks. They are an important food source for fish and other animals including birds, mammals, reptiles, and amphibians.

Invertebrates are less mobile than other aquatic species and often are better indicators of water and habitat quality (Statzner and Higler 1986). Most mayfly, caddisfly, and stonefly species are only found in streams with good water quality. Several surveys of aquatic invertebrates have been conducted on major tributaries within the Kalamazoo River basin. MDNR, FD personnel note presence and abundance of major fish food species during fisheries surveys. Staff of the MDEQ, WD inventory invertebrates as part of their water quality studies. Since 1991, WD, Great Lakes Environmental and Assessment Section (GLEAS) has used Procedure No. 51 (MDNR 1991b), a standardized method to conduct biological investigations on wadeable streams. These data were compiled by mainstem segment (Tables 22, 23, 24, 25).

The Kalamazoo basin is home to several threatened and endangered insects including the American burying beetle, frosted elfin, karner blue butterfly, and Mitchell’s satyr butterfly. The diversity and abundance of insects is high in southwest Michigan because it is in the junction of three major ecoregions. Aquatic insect data on the Kalamazoo River mainstem are non-existent for lower and mouth segments.

The distributions of snails and mussels have been documented by several MDEQ, WD, GLEAS reports and by Sherman-Mulcrone and Mehne (2001) (Tables 22 and 26). Only Sherman-Mulcrone and Mehne (2001) have conducted comprehensive surveys of mussel distributions on the Kalamazoo River (Table 26). Twenty-three species of native clams (16 live species and 7 shell only) have been recorded along with two introduced species, the zebra mussel and Asian clam. Presence of mussels indicates good water quality because they are sessile and sensitive to pollution and siltation. Mussels are also long lived, so older individuals can document the water quality history of a river section. Mussel distributions can be affected by fluctuating water levels caused by dams. Dams also restrict access to suitable fish hosts required to complete their lifecycle. The invasion of zebra mussels (see *Pest Species*) is also expected to have negative effects by attaching to and hindering movements and feeding of native species.

Michigan Natural Features Inventory lists two snails of special concern, spindle lymnaea and watercress snail, and six mussels, the threatened wavy-rayed lampmussel and purple wartyback, ellipse, rainbow, round pigtoe, and slipper shell of special concern (Table 20). Sherman-Mulcrone and Mehne (2001) found a live specimen of the elktoe, a species of special concern not listed in Table 26, and shells of purple wartyback, pigtoe, ellipse, and rainbow. The only endangered species found has been a worn specimen of the snuffbox mussel found below Lake Allegan Dam. Its host fish, the log perch, is also located in that area. “Host fish are a significant factor influencing mussel populations. Mussels have a parasitic larval stage (glochidia) and must attach to the gills or fins of a fish to metamorphose into juveniles. Certain mussel species metamorphose on a narrow range of fish species. Channel catfish and yellow bullhead have been found to be suitable fish hosts for the purple wartyback….Both stable substrate areas (flow refugia) and host fish influence the persistence of mussel populations. These characteristics must be maintained to ensure the survival of the mussel populations” (Sherman-Mulcrone and Mehne 2001).

Mussel faunas in the Kalamazoo River did not show an increase in diversity from upstream to downstream, which usually occurs in mussel populations. The diversity was lowest in the middle reaches of the river, from Plainwell to Allegan City Dam. Historically poor water quality and impoundments in this reach have likely affected mussel diversity (Sherman-Mulcrone and Mehne 2001).

Sherman-Mulcrone and Mehne (2001) further describe the potential effect on mussels due to dams and PCB cleanup efforts in the superfund portion of the river: “Dams and other habitat alterations have likely impacted mussel populations. Dam removal to return the river to its “natural” state would likely improve water quality and access to fish hosts for mussels. However, removing dams could release PCB buried in sediments behind the impoundments. Dredging behind dams to remove PCB-contaminated sediment before dam removal could physically destroy mussel beds and may increase suspended solids in the water column. However, present mussel species could be transplanted, and populations could recolonize after dam removal. Keeping dams in place and reinforcing banks to prevent erosion and release of additional PCBs may damage fish habitat and affect mussels by reducing populations of potential fish hosts. Reinforcing stream banks using standard engineering techniques (sheet pile walls, stone rip rap, etc.) will also increase stream velocity at high flows, which may result in a loss of instream habitat due to streambed erosion."

It is unlawful to harvest or attempt to harvest living or dead mussels (except zebra mussels) in Michigan without a scientific collector permit. Pressures from the pearl industry have brought poachers to the state, particularly in the neighboring Grand River watershed. Thick-shelled species are harvested and sold as slugs for pearl oysters.

The introduction of zebra mussels may cause a decline in the number of mussels in the Kalamazoo River watershed (Horvath et al. 1994). Zebra mussel attachment to native mussels could negatively affect local native mussel populations. Added weight from attached zebra mussels causes increased stress. Zebra mussels also cover valves of native mussels and decrease efficiency of feeding which results in starvation or decreased growth. The apparent absence of large populations of unionids in tributaries and the Kalamazoo River proper leaves them vulnerable to local extinction if the invasion of zebra mussels proceeds throughout the river system. Zebra mussels have only been identified in the lower and mouth mainstem, but populations are known to occur in Duck, Gull, and Gun lakes in the middle segment. Badra and Goforth (2002) found zebra mussels and the exotic Asian clams between Plainwell and Kalamazoo in the Kalamazoo River.

Invertebrate communities are discussed below by mainstem valley segment.

Headwaters

The macroinvertebrate community in the headwaters has improved near Homer from good (slightly impaired) to excellent. The middle and upper S.B. Kalamazoo River have acceptable communities due to sedimentation and lack of hard gravel substrates (MDNR 1994; MDEQ 2000a). Mitchell's satyr butterfly and ellipse, rainbow, pigtoe, slippershell, and wavy-rayed mussels are listed as present within this segment (Table 20).

Upper

The mainstem invertebrate community was rated as good at Albion and excellent at Marshall. Several taxa of mayflies, caddisflies, and stoneflies were found. Habitat scores at Albion and Marshall were both excellent with more gravel substrate and more heterogeneous channel morphology at Marshall (MDNR 1994). The lower N.B. Kalamazoo River had an excellent macroinvertebrate community as well as excellent habitat in the form of cobble, gravel, and woody structure. The upper north branch has lower gradient with more sandy substrates and had a variable invertebrate community ranging from acceptable to excellent (MDEQ 2000a). Rice Creek had an excellent invertebrate community while Wilder, Talmadge, Bear, S.B. Rice, and N.B. Rice creeks had acceptable populations due to impaired habitats. The only federally threatened species in this segment is the silphium borer moth.

Middle

The Kalamazoo River mainstem had an invertebrate community that ranged from acceptable to an excellent rating. Habitat ratings were good to excellent. Mayfly and caddisfly were common with some stonefly present. There were 12 species of special concern, two endangered (American burying beetle and Mitchell's satyr), and one threatened (persius duskywing) within this segment according to the Michigan Natural Features Inventory (Table 20). B Avenue had the highest diversity of mussels within this segment at 11 species (Sherman-Mulcrone and Mehne 2001). Wanadoga, Wabascon, Seven Mile, Augusta, Gull Lake, Comstock, Davis, Portage, and Pine creeks and Battle Creek and Gun rivers all have macroinvertebrate ratings of acceptable (MDEQ 2000a, 2001a, and 2001b). Poor communities were observed in the upper Wanadoga Creek and Battle Creek River and were associated with channel modifications to facilitate agricultural land use. Spring Brook was the only stream surveyed with an excellent community rating. Its ratings are some of the highest in the state. Spring Brook is a water quality reference site because it has been minimally affected by anthropogenic activities (MDEQ 2000a).

Lower

No invertebrate surveys have been conducted on the mainstem except mussels. Sherman-Mulcrone and Mehne (2001) collected a total of 11 species of mussels in this segment. Dumont Creek has excellent habitat and an excellent invertebrate community (MDEQ 2000a). The threatened frosted elfin, karner blue butterfly, and ottoe skipper are also found in this segment (Table 20).

Mouth

Again only mussel information was available for the mainstem river. The highest diversity was observed at the town of Douglas with 14 different species of mussels (Sherman-Mulcrone and Mehne 2001). The threatened frosted elfin, karner blue butterfly, ottoe skipper, and persius duskywing have been known to occur in this segment as well as nine species of special concern (Table 20). Swan, Tannery, and Goshorn creeks and the Rabbit River were rated as having acceptable macroinvertebrate communities (MDEQ 1999a; MDEQ 2000a). Mann and Silver creeks had poor communities due to unstable substrates and channel modifications. There may also be water quality problems in Mann Creek based on the presence of biological slimes at the outfall of Curtice Burns Foods (MDEQ 2000b). Sand and Bear creeks had excellent invertebrate populations.

Amphibians and Reptiles

> Many amphibians and reptiles rely on the aquatic environment for habitat, reproduction, and food. Marsh areas of lakes and rivers are homes to many frogs and turtles. Vernal ponds in both woodland and open grasslands are important breeding places for other species of anurans and salamanders (Harding 1997). Amphibians and reptiles are an integral component of the watershed. They are valued consumers of a variety of plant and animal materials, and they are an important food source for other species including fish, mammals, and birds.
>
> The degradation, fragmentation, and destruction of natural habitats due to watershed development are undoubtedly the greatest threats to amphibian and reptile populations (Harding 1997). Populations have become restricted to smaller habitats making them more vulnerable to mortality and exploitation. Effects of watershed development have favored adaptable species with broad habitat tolerances. (Leonardi and Gruhn 2001).

Forty-four species of amphibians and reptiles have been found in the Kalamazoo watershed (Table 27). Little information, except for Michigan field guides, is available on the distribution and abundance of amphibians and reptiles in the basin (Holman 1989; Harding and Holman 1990; Harding and Holman 1992). Michigan Natural Features Inventory list five species of concern: eastern box turtle, Blanding's turtle, wood turtle, Massasauga rattlesnake, and black rat snake; two as threatened: marbled salamander and spotted turtle; and two as endangered: copperbelly water snake and Kirtland's snake (Table 20).

Birds

Many birds use rivers and river corridors in the Kalamazoo River basin as nesting, feeding, and resting areas. Some species are year-long residents, but many others migrate through during different times of the year. Birds are an integral component of the biodiversity of the watershed. They are important consumers and are a food source for other animal life. Many recreational birders appreciate the aesthetics of their sight and sound. Other bird species also provide hunting opportunities and table fare for humans. MDNR, Wildlife Division has reintroduced wild turkeys into several areas of the basin. These birds use river corridors and groundwater seeps and have been spreading to new locations.

As part of the Mississippi Flyway, Canada geese, many species of dabbling and diving ducks, and mute swans, use the Kalamazoo River watershed. Allegan and Kalamazoo counties are common sites for several species of warbler. This area encompasses both the northern and southern ranges of Michigan warblers. Hardwood stands in river lowland areas are crucial to many songbirds. Loons, herons, mergansers, cormorants, ospreys, and kingfishers feed primarily on fish. The extent of their effect on fish populations is not known, but several of these species are known to consume considerable quantities of fish in their lifetime (Peterson 1965; Alexander 1976).

There are over 218 different breeding bird and regular migrant species found in the watershed according to Brewer et al. (1991) (Table 28). Historically, Northern Goshawk, Short-eared Owl, Barn Owl, Common Raven, Black-throated Blue Warbler, and Pine Warbler also bred in the watershed but were not observed during the Brewer et al. (1991) survey from 1983 to 1988. The Trumpeter Swan is found at Kellogg Bird Sanctuary, which is participating in a population rehabilitation project. Endangered watershed species include the King Rail, Prairie Warbler, Short-eared Owl, and Loggerhead Shrike. Threatened species include the Bald Eagle, Common Loon, Osprey, Least Bittern, Trumpeter Swan, Red-shouldered Hawk, Caspian Tern, Common Tern, Long-eared Owl, Yellow-rumped Warbler, and Henslow's Sparrow (Tables 20 and 28).

Mammals

The Kalamazoo River basin is home to a diverse assemblage of mammals. Many species are highly valued by humans for aesthetics, hunting, and food. Habitat created by watershed plant communities provides essential cover for reproduction and survival. Aquatic environments are important sources of food and water. Watershed development has altered natural habitat, reducing, fragmenting, and degrading it, requiring mammals to adapt to coexistence with humans. Management of game species is necessary to avoid conflicts with humans and maintain balanced assemblages in limited habitat.

Although there have been no comprehensive studies of Kalamazoo River watershed mammals, there are at least 40 species known to use the area (Table 29). Beaver, otter, muskrat, mink, and raccoon are present. Beavers influence streams by altering channels and building dams. They are found in low numbers in this basin but populations are increasing. Muskrats are common and burrow in stream banks, which can lead to erosion problems and alter channel characteristics. Otter are rare but have been reported within the Allegan State Game Area in the mouth segment. Predation on fish by vertebrate predators can be significant in some areas (Alexander 1976) but is probably not significant in the Kalamazoo River basin (M. Bailey, MDNR, Wildlife Division, personal communication). The prairie vole is listed as endangered, and the least shrew is threatened (Table 20).

Other Natural Features of Concern

The Michigan Natural Features Inventory maintains a list of endangered, threatened, or otherwise significant plant and animal species, plant communities, and other natural features (Table 20). Vascular plants are the most commonly listed group of threatened and endangered species in the basin. Many are wetland plants or are found in floodplains and river corridors. Plant communities include southern swamps, prairie fens, coastal plain marshes, tall grass prairies, bogs, Great Lakes marshes, interdunal wetlands, open dunes, submergent and emergent marshes, wet and mesic prairies, hard-wood conifer swamps, and intermittent wetlands. Most of these natural features are found in the middle segment and in the Allegan State Game Area in the mouth segment.

Other unique features not listed include cold water tributaries to the mainstem that are spawning areas for coho and Chinook salmon, steelhead, and brown trout that ascend the river from Lake Michigan. Natural reproduction of these species has been documented in the Rabbit River and Mann, Bear, Sand Silver, and Swan creeks. It may be possible that there is natural reproduction in other tributaries. Some streams also have wild populations of resident brown and brook trout.

Large areas of grasslands or prairies historically existed in the Kalamazoo River basin. Prairies extended into southern Michigan from the Great Plains, where climatic conditions or periodic fires kept out invading woody plants. Some areas included oak barrens, in which a few large trees dotted the landscape. Prairies typically have rich topsoil and have been extensively cultivated. Prairies are important features because they contain a great diversity of grasses and forbs.

Pest Species

Pest species are defined as those species that have been intentionally or accidentally introduced and pose a significant threat to native species or their habitat. Most species do not pose any threat unless present in high densities.

Pest fish species in the Kalamazoo River basin include: sea lamprey, goldfish, round goby, and common carp. Goldfish and round goby are not present in pestilent densities. The recent introduction of round goby to the mouth segment from Lake Michigan is of concern. Should round goby reach high density, they could out compete native darters (Jude and Smith 1992). Common carp are found in high densities within impoundments, especially in the lower mainstem segment and Lake Allegan. Carp are notorious for stirring up the bottom and causing reduced water clarity. Some environmental groups have also accused the carp of re-suspending PCB contaminated sediment in the lake. These groups have requested that the carp be captured and removed or killed. Due to the scale of such a task, Fisheries Division has declined to participate in a carp removal program. Fisheries Division maintains the theory that if water quality was improved in the lower segment and Lake Allegan, then the fish community would become more balanced with a smaller carp population.

Sea lampreys are probably the deadliest aquatic pest (parasitic) species encountered by fish in the Kalamazoo River basin. The sea lamprey attaches to other fish with its sucking disk and horny teeth. Its sharp tongue rasps through scales and skin as it feeds on body fluids, often killing the prey fish. Adult sea lamprey prey on large fish in Lake Michigan until these adult lamprey migrate up streams to spawn. Lampreys spawn on gravel riffles in the lower Kalamazoo and Rabbit rivers and Bear, Sand, and Mann creeks (Klar and Schleen 2001). Eggs hatch into larvae (ammocete) that burrow in sand and silt areas. The larvae live there for 3 to 17 years. The United States Fish and Wildlife Service routinely surveys tributaries accessible to sea lampreys. Streams with viable juvenile populations are treated with the lampricide TFM (3-trifluoromethyl-4-nitrophenol) to eliminate or reduce sea lamprey populations. Treatments are scheduled every three to four years, or as often as necessary to ensure no sea lampreys older than age 3+ will be in a stream. The Rabbit River and Sand

and Bear creeks have populations of sea lampreys and receive regular treatments. Sea lampreys are limited to the mouth mainstem segment and tributaries because the Lake Allegan Dam prevents their movement further upstream.

The lampricide TFM can negatively affect local aquatic communities. Studies have found a temporary reduction of mayflies after treatments. Tadpoles and salamanders are susceptible, but most amphibians have left the water for terrestrial habitats during treatment time. Mud puppies are especially sensitive (Klar and Schleen 2001). Limited fish kills do happen on occasion. TFM may affect fish that are already stressed from pollutants, low dissolved oxygen levels, increased water temperatures, or spawning. Besides lampreys, channel catfish have the highest sensitivity to TFM followed by rainbow trout and lake sturgeon juveniles (Hay-Chmielewski and Whelan 1997; Klar and Schleen 2001). Most fish have low sensitivity to the lampricide.

A pest species of mollusk, the zebra mussel is established in Lake Michigan and found in the Kalamazoo River from Lake Allegan down to Lake Michigan. Several lakes within the basin have also been invaded including Duck, Mud, Twin, Gull, Payne, and Gun lakes in the middle segment (MSUE 2001). Veligers suspend in the water column and have the potential to move downstream of infested lakes via stream outlets. Through human activities such as boating, zebra mussels have the potential to spread throughout the basin. However, veligers can only settle in slow current areas, so high densities of zebra mussels will be limited to lakes and impoundments. Zebra mussels attach to any hard surface and can clog water intake pipes. They can become a nuisance on docks and piers, and may compete with resident aquatic species that filter algae and zooplankton for food. Zebra mussels also kill native mussel species through suffocation and starvation. They do, however, improve water clarity and may contribute to increases in rooted aquatic vegetation.

Rusty crayfish also pose a threat to the ecology of streams. These invasive crayfish often exclude native crayfish through competition for food and habitat, and can decimate aquatic plant communities by over grazing. The presence of rusty crayfish has been reported in all harbors along the eastern Lake Michigan shore, which would include the mouth segment of the Kalamazoo River (Lodge and Feder 2001). One rusty crayfish was also found during a fisheries survey of the Kalamazoo River near the town of Marshall in 2002 (Michigan Department of Natural Resources, Fisheries Division, unpublished data). “Rusty crayfish prefer areas that offer rocks, logs, or other debris as cover and inhabit both pools and fast water areas of streams. Juveniles feed heavily on benthic invertebrates and may directly compete with fish for food. Some fish will eat crayfish, but crayfish food quality is not as high as other invertebrates because of their thick exoskeleton. Fish growth in streams can be affected by less invertebrate food and lower food quality. Once established in an area, birds, anglers, and bait dealers can spread rusty crayfish. Environmentally sound ways to eradicate or control introduced populations of rusty crayfish have not been developed (Gunderson 1995).” (Wesley and Duffy 1999).

Purple loosestrife is a serious plant pest in the watershed. It can be found in most wetlands, and in some areas, it dominates wetland vegetation. Purple loosestrife spreads quickly. Due to its attractive purple flower, humans through transplantation to gardens and lakeshores have spread it. Wind, flowing water, and animals disperse seeds. Purple loosestrife will out compete more beneficial native plants for space. It provides little cover for wildlife, and is not used as a food source (Eggers and Reed 1987). It has the potential to destroy the wildlife value of wetlands. The United States Fish and Wildlife Service is attempting to control spread of loosestrife by spraying existing stands with a selective herbicide. Other means of control are also being researched, including biological control with a non-native beetle species that feeds exclusively on loosestrife. MDEQ, Geological and Land Management Division is proposing to add purple loosestrife to the state noxious plant list (D. Kenaga, MDEQ, GLMD, personal communication).

Eurasian milfoil and curly leaf pondweed are two widespread nuisance plants in lakes and impoundments throughout the watershed. Lakes with public access sites have a greater tendency to have problem densities of these aquatic plants, because boats and trailers transfer species. Nuisance plants form vast mats of vegetation in nutrient-rich lakes and in river mouths. In shallow areas, these plants can interfere with water recreation such as boating, fishing, and swimming. They can also crowd out important native aquatic vegetation. MDEQ issues aquatic vegetation control permits for lakes and impoundments but not for flowing waters. A treatment permit is needed on all lakes, except those less than 10 acres, with no outlet, and owned by one person. (Wesley and Duffy 1999)

Other pest species in the Kalamazoo River watershed include gypsy moth, Japanese beetle, forest tent caterpillar, mosquitoes, horse and deer flies, black flies, Asian clam, sometimes mute swan, Canada geese, deer, beaver, muskrat, raccoon, and mouse and mole species.

Fishery Management

MDNR, Fisheries Division management of the Kalamazoo River watershed dates back to the late 1800s. Management to improve the recreational fishery has been vigorous at times, generally concentrating on isolated areas or tributaries. The entire watershed is subject to fishing regulations, as contained in law. Laws and regulations are forms of fisheries management aimed at protecting, preserving, and enhancing a fishery resource. Below is discussed historical and current fisheries management of the watershed using mainstem segment boundaries identified in this report. Emphasis is placed on historical and current fisheries management, fisheries management limitations, and potential fisheries enhancement.

Headwaters

The South Branch of the Kalamazoo River has been popular with local anglers since the early 1900s when stocking began. Brook, brown, and rainbow trout have all been stocked at one time or another. The latest stocking phase, 1973 to 1993, has only included brown trout. Unlike the past management of other trout streams in the watershed, the south branch has never been chemically treated to remove competing species of fish. A fin clip experiment in 1993 determined that stocked brown trout were not contributing significantly to the overall population or fishery (Herman 1994). Therefore, stocking was discontinued in 1994. The stream section between Concord Road Bridge and Strait Bridge (Jackson and Hillsdale counties) is designated as a trout stream under Fisheries Order 210. In 2000, this same section was designated as a Type I trout stream under the new coldwater fishing regulations. The open and possession seasons are the last Saturday in April through September 30 with an 8-inch size limit. These regulations appear to be working well and fit local angler's expectations for the stream. Future management of this section will focus on maintaining the existing natural population of brown trout, which ranges from 126 per acre at Rowe Road to 536 per acre at Pope Road. An obstacle to this goal is a significant sand bedload that comes from nonpoint sources within this agricultural watershed. A buffer strip program could prevent such sediment from entering this stream and would ensure that this natural population of trout continues well into the future.

The only management within the lower half of the South Branch Kalamazoo River has been a comprehensive fish population survey in 1982 using rotenone (Towns 1984). This portion of the Kalamazoo River has limitations for sport fish management as indicated by the low standing crop (Towns 1984). This area is marginal in temperature for brown trout and too small a stream in terms of its size or catchment area to support high densities of smallmouth bass (Zorn et al. 1998). However, small populations of smallmouth bass, northern pike, bluegill, rock bass, and white sucker are available for anglers. Management of this section should consider agricultural BMPs to reduce sedimentation and projects to improve instream habitat and remove fish barriers. More specifically, consideration should be made to remove the Mosherville and Albion dams and to replace the stone wall through Albion with a more natural stream bank where feasible.

Upper

Fisheries management in this mainstem segment was limited until the 1980s because of poor water quality. Nonpoint source and wastewater treatment problems from the City of Albion degraded this section of river. Since water quality has improved, fisheries management has been limited to population estimates and fish stocking. Towns (1984) found a good population of smallmouth bass, which ranged from 32 to 61 fish per acre between Marshall and Battle Creek. Northern pike populations were good between Albion and Marshall at 9 fish per acre. Various stockings followed this survey and included northern pike, tiger musky, smallmouth bass, walleye, and channel catfish. This section was last stocked in 1992 with channel catfish and northern pike (Table 19). Current and future management of this section will focus on maintaining and enhancing the existing self-sustaining coolwater fishery with an emphasis on smallmouth bass. Enhancements can be accomplished by restoring high gradient habitat through the removal of Ceresco dam and the City of Marshall Dam once decommissioned.

The North Branch Kalamazoo River was managed as a trout stream in the 1930s. Managers soon realized that warm water temperatures were limiting trout survival and discontinued stocking. The North Branch begins as a warm water outlet from Farwell Lake. Temperatures do cool upstream of Horton, but the Horton impoundment warms the water again. This small section could be considered for trout management if the Horton Dam is removed resulting in cooler stream temperatures. Restricted by its small size and warm water temperatures, the North Branch has limited management potential. The lower section near Albion produces a small population of smallmouth bass and northern pike. Farwell Lake is stocked annually with rainbow trout and is the most expensive managed water in this segment at an average cost of $6,500 a year. This lake creates an excellent two-story fishery with rainbow trout, smallmouth and largemouth bass, and bluegill. Continued stocking is recommended with periodic assessment through creel census, limnological sampling, and fish surveys.

Rice Creek has been managed for trout through stocking efforts since 1934. Numerous surveys were conducted between 1952 and 2000. A large population of competing fish was observed in 1982. As a result, a rotenone treatment was conducted in 1983 to remove all fish species and restocked with brown trout. The trout grew well with little competition. Competing species populated the stream again, which resulted in another rotenone treatment in 1989. Conditions have remained constant since that time with a high number of competing species along with a moderate population of stocked brown trout, which is typical for a marginal trout stream. Since 1998, accelerated-growth brown trout have been stocked. Early indications show that survival of these fish is good. Continued evaluation is needed and stocking locations may need to be moved or discontinued based on competing fish and northern pike populations in the upper and middle portions. Lower Rice Creek near Marshall could be improved by removing the existing dam. This would expose a high gradient area and prevent thermal loading through the existing impoundment. Habitat improvement is necessary to improve the existing trout fishery; however, improvements are limited because Rice Creek has been channelized and is a designated drain.

Bear, Brickyard, Minges, and Dickenson creeks have been stocked with brook and brown trout since the 1930s. Stocking has been discontinued at all creeks due to limited public access or a sustainable wild population. This area is under tremendous urban development pressure, and the streams fate is uncertain at this time. Private or commercial property surrounds these creeks. Future management will focus on preserving these wild brown trout streams and promoting smart development to protect groundwater flows. Dickenson Creek has a county park at its mouth before it enters the Kalamazoo

River. This site was surveyed in 2001, and no trout were observed. Due to the access potential by anglers, re-establishing brown trout may be a management option.

Middle

The middle segment has areas with excellent fish habitat. However, fisheries management has been lacking due to historically poor water quality and current PCB contamination. Black crappie, bluegill, and rock bass were stocked in the river near Morrow Impoundment in the 1930s and 1940s. Walleye stocking of Morrow Lake began in 1972 and continues today. This stocking provides a good fishery in the impoundment, and since water quality has improved in this section, walleye have moved below the impoundment and have established a small population down to Lake Allegan. Channel catfish were stocked above Morrow Impoundment in the 1980s and have established a self-sustaining population throughout the segment. The smallmouth bass population has also significantly improved in this section with increased water quality. Future management should focus on continued water quality improvements, PCB contaminated sediment removal, and removal of unnecessary dams such as the state owned dams (Plainwell and Otsego). With the above habitat improvements, the middle Kalamazoo River has the potential to be one of the best smallmouth bass fisheries in the Midwest. Furthermore, there is high potential for lake sturgeon spawning rehabilitation through this mainstem segment. Habitat characteristics such as river size, temperature, substrate, and gradient are excellent based on a recent river classification (Seelbach et al. 1997). Fish passage would be a considerable part of this rehabilitation effort.

Fisheries management in the Battle Creek River proper has been limiting to some recent stocking and a 1986 rotenone survey by Towns (1987). Channel catfish have been stocked in Verona Impoundment since 1988 and have created a good fishery. Much of the upper and middle reaches of the Battle Creek River are channelized and designated as a drain. Future management should include working with the Eaton and Calhoun County drain commissions to ensure that fisheries habitat is protected during future drain maintenance. Battle Creek above Charlotte needs to be investigated for potential trout management. Water temperatures are cold enough for trout; however, downstream northern pike populations, poor habitat, and lack of public access would be potential limitations. Battle Creek from Charlotte downstream to Bellevue produces good numbers of northern pike. Instream habitat and riparian wetlands should be protected and restored to maintain this fishery. Lower Battle Creek River should continue to be managed for smallmouth bass. Habitat and access could be improved through the City of Battle Creek. Duck Lake is the largest lake in this subwatershed, and it has been managed through walleye stocking since the early 1930s (Towns 1992). Redear sunfish were introduced in 1984 and have become self-sustaining. Fisheries Division stocking of walleye was discontinued in 1988 due to the marginal survival of spring fingerling walleye. The lake association has since stocked larger fall fingerlings, which have had better survival.

Wabascon and Gull creeks are both small-sized warmwater streams that flow through several lakes and impoundments. Fisheries management in the creeks is limited by their size. Some northern pike, bluegill, largemouth bass, and sucker fishing opportunities exist. Management should focus on the lakes themselves and providing barrier-free movement of fish into the lakes. Gull Lake is a large heavily-managed waterbody found in the headwaters of Gull Creek. Averaging stocking costs between 1990 and 2000, Gull Lake is the most expensive inland stocking program in the watershed at $22,000 per year (Table 19). It is considered a mesotrophic lake and provides a two-story fishery. Stocking began in the 1920s and has included walleye, rainbow smelt, Atlantic salmon, brown trout, and rainbow trout (Dexter 1996b). Presently, only brown and rainbow trout are being stocked annually. Atlantic salmon were discontinued in 1992 due to consistent hatchery rearing problems. The last unsuccessful attempt to re-introduce rainbow smelt occurred in 2000. Gull Lake is a Type E trout lake with a 15-inch size limit and is open all year. Current management of the lake will focus on maintaining the health of the existing fishery and environment with continued stocking of coldwater fish. Obstacles to this management include the zebra mussel population, which could change zooplankton populations, and the increased recruitment of northern pike to the lake from tributary lakes (Dexter 1996b). Northern pike prey heavily on rainbow trout. It is unclear whether anglers would prefer a two-story rainbow trout fishery or a trophy northern pike fishery.

Augusta, Portage, and Pine creeks and Gun River are managed as stocked brown trout streams. Habitat conditions in each of these streams prevent self-sustaining populations from developing. Augusta Creek is a marginal trout stream with borderline stream temperatures for trout (Table14). However, public access is excellent and warrants the continuation of trout management. Management in Augusta Creek dates back to 1933 when brown, brook, and rainbow trout were stocked. In the 1950s, it was recognized that holdover trout were uncommon, so managers experimented with stocking legal sized trout. Several surveys, population estimates, and research projects have been conducted on Augusta Creek due to the amount of state-owned and Michigan State University land adjacent to the creek. With this good public access, this stream has high angler use. A section of stream was designated as catch and release between 1988 and 1993 to regulate and measure effects of angler harvest. The Kalamazoo Valley Chapter of Trout Unlimited has also conducted several habitat improvement projects. Currently, a sediment trap is being maintained in Kellogg Forest to capture non-point sources of sediments. Augusta Creek is stocked annually with accelerated-growth brown trout, and the current regulation is Type 4. Augusta Creek should continue to be managed as a marginal trout stream.

Portage Creek has good stream temperatures for being within an urbanized watershed. It has also been managed for trout since the early 1930s. The City of Portage, using Inland Fisheries Grant Funds, has conducted some habitat improvement in the upper section. Future management should focus on maintaining the existing fishery through stocking and protecting the cold water characteristics of the stream through proper land use planning and development. There is potential to expand the trout fishery up to Hampton Lake if water temperatures are cold and habitat is improved.

The lower two thirds of the Gun River is managed for trout through stocking. Habitat is limited due to channelization. The river supports a good fishery and stocking should be continued. Habitat could be improved by working with the drain commissioner to make sure clean outs are kept to a minimum. Gun Lake is the largest lake in southern Michigan at 2,680 acres. The lake is shallow and supports a good population of warmwater fish. Early records indicate there were native populations of both muskellunge and walleye (Duffy 1990). Walleye stocking began as early as 1921 and continues today. Muskellunge stocking occurred between 1970 and 1985. Due to significant northern pike populations, Gun Lake was used as a brood stock lake in 2001 and 2002 but was discontinued because of inconsistency in catch. Gun Lake should continue to be managed as a warmwater fishery with continued stocking of walleye.

Pine Creek has been managed for various species of trout and has been managed for brown trout since 1960s (Dexter 1991a). Stocking should continue in this stream because natural reproduction will not sustain the current fishing pressure. Habitat restoration activities are limiting for most of its length because Pine Creek is a designated drain and has been channelized.

The middle segment also contains several high quality coldwater streams that contain self-sustaining populations of brown trout and some brook trout. Some of these streams include Seven Mile, Travis, Silver, and Spring Brook creeks (Dexter 1992; Dexter 2000). These creeks typically have excellent water quality and should continue to be managed as wild trout streams. No fisheries management is needed other than continued monitoring stream conditions and working with local governments to push for protective land management to maintain the cold water and habitat of these streams.

Lower

There has virtually been no fisheries management conducted in the lower section of river due to historically poor water quality and existing PCB sediment contamination. Towns (1984) found a low total standing stock of fish that was dominated by carp and white suckers. The smallmouth bass population through the 1980s was the lowest of the entire river at only one per acre. With water quality improvements, smallmouth bass and walleye angling has increased especially below Trowbridge Dam, which has public access for shore fishing. Walleye have moved down into this segment from stockings in Morrow Lake. This segment of river has excellent gradient that could provide fish habitat in the form of pools and riffles, but the Trowbridge, City of Allegan, and Lake Allegan dams impound this high gradient habitat. Sediments behind these dams are also contaminated with PCBs. These dams also prevent fish movement and may be preventing a game fish recovery since water quality improvements have been made. Of the 24 miles of river, only eight miles are free flowing with high quality fish habitat. Trowbridge Dam is state-owned and scheduled for removal once PCB contaminated sediment is removed.

The lower Kalamazoo River including Lake Allegan is dominated by common carp. Past management plans called for a total fisheries reclamation of the Kalamazoo River from the city of Kalamazoo to Lake Allegan Dam using rotenone (Michigan Department of Natural Resources, Unpublished Management Plan). This would remove the large carp population and would allow newly stocked game fish to repopulate the river. More recently, Kalamazoo River Watershed groups and scientists have recommended reclamation again to remove PCB contaminated carp and to reduce the amount of carp that cause sediment re-suspension in Lake Allegan. Although this was a common management practice at one time, it is not recommended in more modern management plans. Current philosophy follows the concept that if habitat and water quality were suitable, more desirable game fish would move into these areas naturally. For example, the fish community of the Kalamazoo River between the City of Kalamazoo and Plainwell is diverse and dominated by smallmouth bass and was once over populated with carp. This transition occurred naturally after water quality improvements were made. Rotenone reclamation would also be very expensive (this would be one of the largest reclamations ever conducted in the United States), and it would be a short-lived solution to a much deeper problem, which is a need for better habitat and water quality. Carp would quickly repopulate this section as long as water quality problems continued to exist, especially in Lake Allegan. Furthermore, if carp are re-suspending PCB contaminants, a better solution would be to remove the PCB contaminated sediment.

Lake Allegan provides a limited fishery for largemouth bass, smallmouth bass, walleye, channel catfish, and some bluegills. It is shallow and very eutrophic. Fisheries management is limited by water quality problems associated with high phosphorous concentrations in the lake. Periods of low oxygen in summer and winter prevent multi-year class fisheries from developing, although some fish move in and out of the lake for refuge. The on-going phosphorous TMDL plan should help reduce phosphorous in the lake and provide better water quality for a more balanced fish community.

The City of Allegan (Imperial Carving) and Lake Allegan (Calkins) dams are privately owned and currently are being used to provide recreation, electricity, and town aesthetics. It is recommended that these dams be removed once they no longer serve a purpose; if removal is not possible, fish passage must be provided. Once the sills of Trowbridge and Otsego dams are removed the only remaining blockages to fish movement up to the City of Kalamazoo will be the City of Otsego, City of Allegan, and Lake Allegan dams. Considerable thought should go into the design of fish passage systems at these dams. A potamodromous fish passage plan could be developed for the Kalamazoo River mainstem. This plan should consider a sea lamprey barrier, lake sturgeon passage, warmwater fish passage, and the effects of salmon on native brown and brook trout populations. It should also consider the potential risk of contaminated fish migrating up to Battle Creek if passage is provided at Morrow Lake Dam.

Passing Great Lakes fishes above Lake Allegan into the upper portions of the Kalamazoo River has the potential to re-establish spawning runs of native (lake sturgeon, walleye, whitefish, and suckers) and naturalized (Chinook salmon, coho salmon, steelhead, and brown trout) fishes, and restore self-sustaining fish populations in the river and Lake Michigan. Substantial fishery, recreational, and economic benefits could result from these spawning runs. Some of these fishes, however, could contain elevated levels of chemical contaminants in their tissues that could be introduced into upstream reaches as fish spawned and died. These chemicals, especially dioxins, dieldrin, PCBs, and DDE, are absent in many tributaries and low to non-existent above Morrow Lake. The effect of these introduced chemicals on animals co-inhabiting upstream reaches may be a cause of concern. Bioaccumulation of these chemicals could lead to adverse effects on populations of fish-eating carnivores, such as Bald Eagle, cormorant, osprey, great blue heron, kingfisher, mink, and river otter. Great lakes nesting eagles have shown increased productivity in recent years, so the risk of population affects may be overstated.

Many social issues may dictate fish passage on the lower and middle mainstem. The primary social issue involves conflicts between riparian residents and anglers. A potamodromous fishery would attract more anglers. On private property, trespassing, littering, illegal angling, and other problems may occur. The state government owns land in the lower mainstem segment and could control some of these problems. The potential for riparian conflict would be greater in the middle mainstem segment where riparian ownership is primarily private. More public access would be required if fish passage occurs up through the middle segment.

A much better fishery would be expected if the dams were removed and water quality improved. Using Wiley and Seelbach’s (1997) Valley Segment Ecological Classification and Zorn et al. (1998) patterns of stream fishes, this segment is expected to support a fish assemblage dominated by smallmouth bass, channel catfish, and walleye as the primary game fish with northern hog sucker, black redhorse, shorthead redhorse, stonecat, sand shiner, and striped shiner as common non-game fish. Without the dams, this segment could be characterized as having fair base flow and moderate peak flow. A relatively narrow glacial fluvial valley confines its channel. Water temperature would be cool from medium groundwater inflows and substantial shading.

Schnable Brook and Dumont Creek are the primary tributaries. Fisheries management is limited in these systems because they are warm and relatively small. Dumont Creek was stocked with brown trout from 1933 to 1935 with no success. Dumont does receive some groundwater, but Dumont Lake discharges warm water to the creek making it marginal for trout. Dumont Lake was also stocked in the 1930s with various species of panfish. In the 1970s, Dumont Lake was used in a study to compare rearing methods with tiger muskellunge (Beyerle 1984). Tiger muskellunge stocking was discontinued in 1991. The lake is managed as a warm water fishery with a good natural population of northern pike, largemouth bass, and bluegill (Wesley 2000b).

Mouth

Only these 26 miles of the Kalamazoo River’s 175 miles are connected to Lake Michigan. Potamodromous fishing opportunities are numerous. Major stream fisheries exist for Chinook salmon, steelhead, walleye, smallmouth bass, and channel catfish. Towns (1984) found the highest standing crop and species diversity in this area. A 2004 creel survey from April through October below Allegan Dam to New Richmond estimated 21,265 angler trips (84,999 hrs) were made on the river with a catch of 2,241 Chinook salmon, 1,326 coho salmon, 3,447 steelhead, 266 brown trout, 7,333 smallmouth bass, 6,555 walleye, and 4,412 channel catfish (Z. Su, MDNR, Fisheries Division, personal communication). Angler trips and catch were lower in the 1988 creel survey that estimated 9,110 angler days (40,997 hrs) on the river in spring and fall with a catch of 833 Chinook salmon, 23 coho salmon, 963 steelhead, and 15 brown trout (Rakoczy and Rogers 1990). At a value of $54 per angler day or trip (United States Department of Interior, Fish and Wildlife Service and United States Department of Commerce, Bureau of Census, 1991), the value of the potamodromous fishery was worth $491,940 annually in 1988 and $1,148,310 in 2004. This estimate would be higher if the creel survey included other sites between New Richmond and Saugatuck, as well as some tributaries like Swan Creek and Rabbit River.

Management has focused on stocking salmonids to produce a fishery in Lake Michigan and the potamodromous fishery in the river. Annual walleye stockings began in 1971, which added to the existing fishery. Natural reproduction is limited to Chinook salmon, whose young leave the river before water temperatures become too warm in summer months, and walleye. Some natural reproduction of brown trout and steelhead does occur in small cold water tributaries. Chinook salmon, winter steelhead, brown trout, and walleye require continued stocking to maintain the existing fishery. Salmonid stockings occur at the mouth in Saugatuck and consist of annual plants of 54,600 Chinook salmon, 19,800 Seeforellen strain of brown trout, and 14,000 winter steelhead. Approximately 84,000 spring fingerling walleye are also stocked annually. The total annual cost of stocking is $30,645. This stocking cost is justifiable based on the angler hours produced on Lake Michigan and in the mouth segment of the river.

Any proposed changes to salmonid stocking in the Kalamazoo River must first be approved by the Fisheries Division, Lake Michigan Basin Team and then by the Great Lakes Fishery Commission, Lake Michigan Committee. Changes in stocking must result in no net increase in forage consumption to the Lake Michigan fish community. For example, if the number of Chinook salmon stocked is increased, then the number of brown trout or steelhead stocked would have to be reduced according to a predator and prey (i.e., CONNECT) or other ecological models as suggested by the Lake Michigan Committee.

Special stream regulations apply for the entire river from Lake Allegan to Kalamazoo Lake (U.S. 31) in Saugatuck. It is designated as a Type 3 stream, which is open all year with a 15-inch size limit on brook, brown, and rainbow trout, splake, and Atlantic salmon; a 24-inch limit on lake trout; and a 10-inch limit on coho, Chinook, and pink salmon. Kalamazoo Lake from U.S. 31 down to Lake Michigan is a Type F trout lake, and it is open all year for all trout species except lake trout, which is open from May 1 to Labor Day. The size limit is 10 inches for all trout and salmon.

Future management of the mouth segment should focus on continued stocking of salmonids and maintaining the existing potamodromous fishery. The summer fishery that includes northern pike, walleye, smallmouth bass, flathead catfish, and channel catfish should be promoted. Periodic assessments (fish population surveys or creel census) will be needed to track fish population changes and angler use over time.

The Rabbit River has been actively managed through stocking of brown trout in its upper section since 1939 (Dexter 1996a). Various strains of brown trout have been stocked annually. The current stocking rate is 225 Gilchrist Creek strain brown trout per acre. Steelhead stocking in the lower Rabbit River started in the mid-1970s and continues today. Even though there is a small dam in Hamilton, steelhead are able to migrate up into good trout water (above U.S. 131) and spawn. Some natural reproduction of steelhead has been noted in past surveys (Dexter 1996a). Limited habitat management has been conducted on the Rabbit River because it is a designated drain. Frequent drain maintenance and non-point agricultural pollution prevent good habitat from establishing. EPA, Section 319 projects have attempted to reduce non-point source pollution with limited success. Drain projects and non-compliance with BMPs continue to degrade the habitat of the Rabbit River. Future management activities should focus on promoting BMPs for agriculture and drains, removing Hamilton Dam, acquiring more public access in the upper river, and maintaining stocked and naturalized trout populations in the upper river and tributaries.

Swan Creek is a coldwater stream that has been heavily managed in the past. Trout stocking began as early as 1928 with various strains of brook, brown, and rainbow trout. A chemical reclamation was conducted in 1962. This treatment removed four tons of competing carp that were swimming upstream into trout water from Swan Creek Pond. Habitat improvement projects were initiated in 1963 and 1972. Improvement included the installation of deflectors, logjams, rock riprap, and spawning beds. These structures had a limited effect on improving fish habitat because the sand bedload was so high. Most of Swan Creek runs over and across a large sandy outwash and lake plain area that has sand for several feet up to a hundred feet under the stream surface. Swan Creek is currently being stocked with 3,000 seeforellen brown trout. This stocking is at a reduced rate (50 fish per acre) due to lack of habitat and macroinvertebrate production. Swan Creek also supports a spring and fall potamodromous salmon fishery below Swan Creek Pond.

Sand, Bear, and Mann creeks are small cold water tributaries that have been managed for trout since the 1930s. Mann and Sand creeks support naturalized populations of brook trout with some evidence of natural reproduction of steelhead (Dexter 1993b; Wesley 2001). Cold groundwater flows and instream habitat should be protected on these streams to maintain their natural populations of trout. Bear Creek is stocked annually with 1,400 brown trout (Gilchrist Creek strain), which should continue in order to support this small fishery.

Recreational Uses

The Kalamazoo River watershed offers a variety of water-based recreational uses. Opportunities for hunting, fishing, swimming, camping, picnicking, boating, and wildlife viewing exist at various locations. Limited public access and the public's awareness of polluted sediments hinder potential recreational use of the Kalamazoo River, especially in the middle and lower segments.

From 1928 to 1964, conservation officers recorded catch and effort data from anglers at several locations in the watershed (Appendix 2). Records indicate preferred fish species sought by anglers and gives some indication of species abundance. More carp were recorded in these surveys compared to all other species indicating their high abundance in the early to mid 1900s. Brook trout, suckers, brown trout, and rainbow trout followed in total numbers caught. Carp and suckers were generally caught in the Kalamazoo River proper and large tributaries while trout were caught in small streams. Brook trout were the most commonly stocked trout at that time, and conservation officers seemed to emphasize these streams during patrols and with creel surveys. Bluegill, northern pike, walleye, and channel catfish were commonly recorded as well, especially in the mouth segment.

Estimates of fishing pressure and angler harvest are limited to the 2004 and 1988 creel surveys below Lake Allegan Dam (Rakoczy and Rogers 1990). Traditional access or roving creel surveys have not been conducted elsewhere in the basin. Estimates of harvest and fishing pressure can also be made using tagged fish or angler-return post cards. These techniques should be attempted on all heavily-managed waters including the mouth mainstem segment, stocked trout streams, and Gull and Gun lakes. Any analyses of fishing pressure and success are limited to (biased by) perceptions derived from discussions with anglers, charter boat captains, conservation officers, and bait and tackle dealers.

There are 35 canoe and boat launches (Figure 31) advertised within the watershed. There are also numerous unmarked sites on lakes and streams that are commonly used for access. Only 17 access sites are on the Kalamazoo River mainstem, and most sites are limited to canoes. Boats are limited to Morrow Pond, Lake Allegan, and the mouth segment. More public access sites are needed, especially in the upper and middle segments. There is only one improved access site for every ten miles of river. Most river recreation plans call for at least one site every six miles of river. Informal or unimproved canoe launch sites are common throughout the basin and mainly consist of bridge crossings. The

Kalamazoo River is canoeable from Homer downstream. However, the South and North branches are subject to low flow, insufficient water depth, and logjams during certain times of the year.

Some conflicts between user groups are seen on Kalamazoo River impoundments, the mouth segment, and its connecting streams and lakes. These user conflicts are typically between pleasure boaters and anglers. Some large lakes like Gun and Gull are virtually unfishable on summer weekends because of heavy pleasure boat traffic. On smaller streams, conflicts arise among anglers, homeowners, and canoe enthusiasts. Anglers should be responsible and always ask permission before entering on private property to fish or only access streams at public sites. Excessive removal of woody structure to enhance canoeing can also be a problem. Canoeists should only remove the center of logjams to allow safe canoe passage and leave the remaining woody structure for fish habitat.

Waterfowl hunters use much of the mainstem and major tributaries, especially impoundments. Many of the stream floodplains are wooded wetlands, providing excellent habitat for deer and are hunted extensively. Deer hunters with permission from riparian land owners canoe the river during hunting season. There is a significant amount of public land open to hunting in the middle, lower, and mouth segments (Figure 32).

> Campsites, ranging from rustic tent sites to modern trailer/recreation vehicle sites, are found in private and public campgrounds. Private recreational facilities provide a variety of services, including golf courses, archery ranges, horseback riding, boat and canoe rentals, marinas, Great Lakes charter boat services, fishing ponds, skiing, snowmobiling, and sledding.
>
> Two state parks and a major state game area are located in the watershed. Fort Custer Recreation Area, a 2,960 acre state park, is located along the Kalamazoo River between Kalamazoo and Battle Creek. Yankee Springs Recreation Area, a 5,000 acre state park (of which about 1,000 acres are in the watershed along the Gun River tributary), is located northeast of Plainwell. The Allegan State Game Area, with 48,000 acres, is the largest state-owned area in the watershed and is traversed by the Kalamazoo River. Other state-owned recreational properties in the watershed include a portion of the Kal-Haven Trail Sesquicentennial State Park and several game areas. Fort Custer, Yankee Springs, and Allegan provide day-use and overnight facilities.
>
> There are several major city and county parks. Major ones include Markin Glen, River Oaks, Coldbrook, Milham, Verberg, and Kindleberger parks in Kalamazoo County and Littlejohn Lake, Dumont Lake, and Oval Beach in Allegan County. City/village parks and river walks proving access to the river are found in Albion, Marshall, Battle Creek, Kalamazoo, Parchment, Plainwell, Otsego, Allegan, and Saugatuck.
>
> In addition to the state parks and game areas described above, several privately owned nature areas/preserves are found in the watershed. Site with major visitor facilities include the W.K. Kellogg Biological Station, the Kalamazoo Nature Center, and Binder Park Zoo in Battle Creek. The Michigan Nature Conservancy sites include Jenny Woods. Southwest Michigan Land Conservancy also has preserves in the watershed. These sites, as well as the state, county, and municipal parks, walkways, and launch sites, provide opportunities to observe the plants, animals, and natural and manmade landscapes of the Kalamazoo River watershed. (KRWC 1998).

Recreational use of the river system is described more thoroughly by mainstem segment below. Fishing information was compiled from angler reports, fishery surveys, and miscellaneous creel reports (Appendix 2).

Headwaters

Canoeing is popular from Homer down to Albion. Brown trout fishing is available upstream of Mosherville. The fishery is limited to a small population of smallmouth bass, northern pike, and suckers from Homer to Albion. Shore fishing is available at Victory Park in Albion (Figure 32). Angler access needs to be improved upstream of Homer, especially in the brown trout section (Figure 31).

Upper

The Kalamazoo River between Albion and Battle Creek is large enough to provide recreational opportunities throughout the year. Canoeing is good through the entire section. Canoe launches are needed between Albion and Marshall and between Marshall and Battle Creek for there are more than 12 miles between launch sites (Figure 31). Most fishing pressure is for smallmouth bass and northern pike. Rice Creek is another popular stream for brown trout, especially in the lower third of the river. This section also has some canoeing potential. The North Branch Kalamazoo River has limited fish opportunity due to lack of public access. Where anglers do find access, the river is good for smallmouth bass fishing. Some impoundments also provide good panfish opportunities for both open water and ice fishing.

Middle

The middle segment offers more variety in recreational opportunities than the upper and headwater segments. Camping, hiking, mountain biking, skiing, hunting, and fishing are available on public lands at Fort Custer State Park, Gourdneck State Game Area, Barry State Game Area, or Yankee Springs Recreation Area (Figure 32). Information including maps of these parks and game areas can be found on the MDNR web site (www.michigan.gov/dnr). Canoeing is popular on the mainstem, lower Battle Creek River, Portage Creek, and Gun River. Pleasure boating and lake fishing opportunities are available on Gull, Morrow, and Gun lakes. Several other lakes over 10 acres in size also occur within this segment (Figure 3). Both Gull and Gun Lakes have public boat launch facilities, and Gun Lake has a fishing pier that is handicapped accessible (located in Yankee Springs State Park). Gull Lake, being deep and clear, also is popular for scuba diving. Fishing on the mainstem is mostly for smallmouth bass, channel catfish, northern pike, walleye (mainly in Morrow Lake), suckers, and carp. Public perception of the river from Kalamazoo downstream is poor due to the PCB sediment contamination. Although fish are not edible for the most part through this section, catch and release fishing as well as other recreational uses of the river should be encouraged. Several tributary streams offer great brown trout fishing with the best public access being on Augusta and Portage creeks. More public access is needed on the mainstem between Kalamazoo and Plainwell as well as on the Battle Creek River, Gun River, and Pine Creek.

Lower

Recreation in this segment is limited due to PCB contaminated sediments and river fragmentation. The Trowbridge Dam requires a canoe portage, and its former impoundment has poor habitat for fishing and limited recreational opportunities due to PCB contaminated sediments. There is another dam in the town of Allegan, and Lake Allegan is formed by a third dam. Removal of the state-owned dams and PCB sediment clean up in this and the middle segment would provide more recreational activities. Access is available at the Trowbridge Dam and Lake Allegan. Lake fishing and boating activities are available in Lake Allegan and Dumont Lake. Largemouth bass, smallmouth bass, walleye, and carp are commonly caught in the Kalamazoo River and Lake Allegan. Dumont Lake is good for largemouth bass, northern pike, and rock bass (Wesley 2000b). Severe eutrophication of

Lake Allegan limits aesthetic, fishing, boating, and swimming activities. Hunting, trapping, and hiking opportunities are available in the Allegan State Game Area.

Mouth

This mainstem segment is the most heavily used for recreation within the watershed. There are over 21,265 angler trips made below Lake Allegan Dam for salmon, smallmouth bass, channel catfish, and walleye (see **Fisheries Management**). Allegan State Game Area provides over 48,000 acres for outdoor activities such as hunting, nature watching, hiking, and skiing. Ely Lake and Pine Point campgrounds, over 20 miles of cross county and foot trails, Highbanks and Ottawa waterfowl areas, and special use areas for horseback riding and dog sledding are all available within the game area. There are full service boat launches on the mainstem below Lake Allegan Dam, at New Richmond, and on Kalamazoo Lake in Douglas. There is also a carry-in boat access site four miles downstream of Lake Allegan Dam. Maps of the game area and special use areas are available on the MDNR web site (www.michigan.gov/dnr).

Most fishing pressure is for salmonids in spring and fall (brown trout, lake trout, Chinook salmon, coho salmon, and steelhead). There is a growing interest in the walleye, channel catfish, and flathead catfish fisheries. The upper Rabbit River and Swan, Bear, Sand, and Mann creeks provide good trout fisheries. Public access is generally good on these streams as they meander within and through the game area with exception of the Upper Rabbit River, which could use a public access site.

Citizen Involvement

Citizen involvement in management of the Kalamazoo River occurs through interactions with government agencies that manage water flows, water quality, animal populations, land use, and recreation. Government agencies include: MDNR, MDEQ, United States Fish and Wildlife Service, United States Department of Agriculture, Natural Resource Conservation Service, soil conservation districts, county drain commissioners, and community governments.

The Kalamazoo River Protection Association is an active non-profit organization dedicated to improving water quality in the Kalamazoo River and tributaries. The association works to protect areas of the river system that provide valuable wildlife habitat, to improve outdoor recreation opportunities, and to educate citizens about environmental issues. Founded in the mid-1970s, the association has become an outspoken contributor to public policy discussions and is a major voice calling for the wise stewardship of natural resources within the basin. Successes include a major study in 1982 identifying areas of PCB-contaminated sediments throughout the middle and lower segments of the river, initiation of the natural rivers plan and designation of the lower river as wild and scenic, and receiving an EPA Technical Assistance grant to facilitate the superfund process.

The Kalamazoo River Public Advisory Council (PAC) is a group of local citizens representing a variety of stakeholders throughout the Area of Concern (AOC): business people, agricultural interests, land owners, hunting-fishing groups, local government units, public health agencies, educators, conservationists, and environmental activists. The PAC was established in 1993 to assist and advise the MDEQ Remedial Action Plan (RAP) team with the development of the RAP, a plan to restore and protect the Kalamazoo River. The PAC mission statement says the "Council is to work for the continued improvement and protection of the Kalamazoo River through the wise balance and management of human, economic, and ecological resources. To that end, we seek to work with parties in a committed, cooperative manner for the improvement of the quality of life within the Kalamazoo River Watershed."

In the summer of 1990, the Forum for Kalamazoo County created a River Partners Steering Committee to provide direction and leadership for building partnerships between government, and private and non-profit groups whose activities border, affect, or have a major interest in the rivers future. The first directive from the River Partners committee members was to recommend that staff support be used to interview and collect information from community leaders representing the interests of business, government, education, recreation, and citizens. The purpose of each interview was to inventory existing and proposed development along the river and to ask for each community leader's personal vision for the future of the river. Results of the interview were printed and distributed by the Forum for Kalamazoo County.

Another productive and hands-on organization in the watershed has been the Kalamazoo Valley Chapter of Trout Unlimited. Kalamazoo Valley Chapter was formed in 1965, making it one of the oldest in the nation. Currently there are over 400 members in Southwestern Michigan. The chapter has undertaken a host of trout habitat projects, ranging from its ongoing work on Augusta Creek in Kalamazoo County to protection and restoration projects on Swan, Silver, and Sand creeks in Allegan County. The chapter also assists and supports other projects outside the watershed in Southwest Michigan and throughout the state.

Local watershed projects, often receiving assistance from state or federal grants, are also an avenue for citizen involvement. Local watershed projects receiving federal grants from the Clean Water Act in the Kalamazoo River basin include: Battle Creek, Gun, Little Rabbit, Rabbit, and Kalamazoo rivers; Rice, Davis, Arcadia, and Portage creeks; and Lake Allegan (see **Water Quality**).

With the Kalamazoo River having so many diverse citizen groups, it is important that these groups make an effort to work together to accomplish their goals. Although working separately under different names and organizational structures, all the above groups and those listed in Table 30 generally have the same goal and that is to protect and restore the quality of natural resources in the Kalamazoo River watershed.

MANAGEMENT OPTIONS

The Kalamazoo River is fairly healthy and is predominately warm with some cold and cool water habitats. However, fish populations and habitat are degraded and in need of attention. The management options presented in this assessment are to address the most important problems that are now understood and to establish priorities for further investigation.

The options follow recommendations of Dewberry (1992), who outlined measures necessary to protect the health of river ecosystems. Dewberry stressed protection and rehabilitation of headwater streams, riparian areas, and floodplains. Streams and floodplains need to be reconnected where possible. A river system must be viewed as a whole, for many important elements of fish habitat are driven by whole system processes.

The identified options are consistent with the mission statement of Fisheries Division to protect and enhance public trust in populations and habitat of fishes and other forms of aquatic life, and promote optimum use of these resources for the benefit of the people of Michigan. In particular, the division seeks to: protect and maintain healthy aquatic environments and fish communities and rehabilitate those now degraded; provide diverse public fishing opportunities to maximize the value to anglers; and foster and contribute to public and scientific understandings of fish, fishing, and fishery management.

Four types of options for correcting problems in the watershed are presented: 1) options to protect and preserve existing resources; 2) options requiring additional surveys; 3) opportunities for rehabilitation of degraded resources; 4) opportunities to improve an area or resources, above and beyond the original condition, are listed last.

History

Archaeologists are interested in the recent past as well as more ancient times. Pioneer homesteads, mills, logging camps, trading posts and other nineteenth and early twentieth century sites can teach us much that was not recorded in written records.

Archaeological sites can be damaged or destroyed by any activity that disturbs the soil. Most sites lie in the upper foot of soil; a few are more deeply buried. The Office of the State Archaeologist maintains records on archaeological sites and can advise on management. Archaeological artifacts can not be removed without the permission of the land owner. Permits are required for investigation of sites on federal or state lands.

There are guidelines to follow while working near archaeological sites (Mead 1985), but the overriding principle is to avoid disturbing soil.

Option: Protect existing and future archaeological and historical sites by contacting the Office of the State Archaeologists before any major earth moving or river restoration projects.

Option: Survey for and identify animal artifacts at archaeological sites to further our understanding of the historical presence of animals within the watershed.

Geology and Hydrology

The Kalamazoo River has moderately stable flows due to a thick surficial layer of coarse-textured glacial deposits and pervious soils. Some reaches and tributaries have less-stable flows than expected based on their surrounding geology. Poor land use, channelization and extensive drainage, irrigation practices, and dams cause most of these flow problems.

Option: Protect all existing cold water, stable streams from effects of land use changes (increase in impervious surfaces from development practices), channelization, irrigation, and construction of dams and other activities that may disrupt the hydrologic cycle by educating and working with planners, zoning boards, developers, drain commissioners, and land owners.

Option: Protect critical groundwater recharge areas by identifying these and developing a strategy to protect them. Identify major removals of groundwater and analyze potential effects of existing groundwater removals (e.g., irrigation, industrial, and municipal withdrawals).

Option: Protect and rehabilitate the function of wetlands and floodplains as water retention structures for high flow conditions. Develop an inventory of existing and potential areas for creation or protection of wetlands, with emphasis on riparian areas.

Option: Protect remaining natural lake outlets by opposing construction of new lake-level control structures. This would allow for natural fluctuation of water levels needed for maintenance of lake-associated wetlands.

Option: Protect and rehabilitate (e.g., Battle Creek and Rabbit rivers) flow stability by developing a hydrologic routing model for the entire river system that describes both ground and surface water routes in response to changes on the landscape. Such a model would allow various alternatives to be examined and drive future planning processes by providing fundamental information critical for proactive landscape and storm water management planning. It could also be used to identify critical tributary watersheds.

Option: Protect nearshore habitats and floodplain connectivity by encouraging and requiring natural methods of bank stabilization (e.g., rock riprap, log or whole tree revetments, and vegetative plantings) rather than seawalls through permitting processes, zoning procedures, and education.

Option: Survey surface and groundwater withdrawals and establish minimum flow requirements for the mainstem and all tributaries. Support programs that promote conservation and regulate surface and groundwater withdrawals.

Option: Survey flows and water quality below mainstem and tributary dams and lake-level control structures to determine if minimum flow or run-of-river flow requirements are necessary.

Option: Survey daily and annual flows in the lower and mouth mainstem segments by installing and operating continuous gauges. This data will be important while making decisions on dam removals, fish passage, and PCB sediment removal.

Option: Rehabilitate mainstem and tributary run-of-river flows by operating dams and lake-level control structures as fixed-crest structures rather than by opening and closing gates.

Option: Rehabilitate mainstem and tributary run-of-river flows by removing dams and lake-level control structures where possible.

Option: Rehabilitate summer base flows on mainstem and tributaries by establishing minimum flow requirements downstream of all dams and lake-level control structures. These minimum flows could be established through administrative or legal processes. This could also be accomplished through maintenance of run-of-river conditions.

Option: Rehabilitate headwater and tributary flow stabilities by working with county drain commissioners to incorporate flow patterns into criteria for drain design and storm water management.

Option: Rehabilitate flow stability by removing or plugging agricultural drain tiles that are no longer critical for land drainage.

Option: Rehabilitate developed floodplains by supporting policies that regulate land use activities and reconstruction of roads, homes, and other structures in floodplains after large floods.

Soils and Land Use Patterns

Agricultural and urban land uses have altered portions of the Kalamazoo River system. Undeveloped land within the watershed has buffered some changes. Projected urban sprawl and intensive, high acreage farming threaten the integrity of the buffer and will alter the water budget, routing more water along a surface path. There are 2,755 known road and railway crossings in the watershed; adverse effects attributable to these sources are significant. In addition, pipelines and other submerged crossings affect streams during placement and can cause erosion and barrier problems when exposed in the streambed.

Option: Protect undeveloped landscapes through property tax incentives, transportation policies, integrated land use planning, conservation easements, and policies to encourage redevelopment of urban areas.

Option: Protect pervious open spaces by preserving agricultural landscapes through best management practices and agricultural zoning plans.

Option: Protect developed and undeveloped lands through land use planning and zoning guidelines that emphasize protection of critical areas, minimizing impervious surfaces, and improve storm water management for quality and quantity and maximize use of groundwater infiltration systems.

Option: Protect remaining wetlands, especially small “unregulated” wetlands, by working with local governments and planners, zoning boards, agricultural agencies, and groups.

Option: Protect riparian wetlands by encouraging off-river basins for new marinas, with single outlets to the river.

Option: Protect and rehabilitate forested corridors along the river and its tributaries. Encourage additional tree planting and reforestation throughout the watershed.

Option: Protect and rehabilitate critical areas through maintenance of current storm-water management systems and retrofitting areas that are in need of storm-water management systems.

Option: Protect existing streams from sedimentation and flow constrictions by routing new roads to avoid streams rather than crossing, where feasible. Review crossing reconstruction proposals to ensure adequate stream protection.

Option: Protect streams from degradation by promoting bore and jack or flume methods of pipeline stream crossings as an alternative to open trench construction.

Option: Protect the functionality of the watershed through legislation that preserves rural lands by controlling urban sprawl and "industrial development".

Option: Protect natural river functionality through the purchase of flooding rights within the flood plain (i.e., similar to conservation easements by public and private organizations).

Option: Survey watershed to locate crossings that are degrading streams through sedimentation, disruption of stream flow, or creation of barriers to fish passage. Start with Allegan, Calhoun, and Kalamazoo counties, which combined have over 80% of the crossings.

Option: Survey watershed and create map of all known submerged pipelines. Identify pipelines that are exposed and causing bank erosion or barriers to fish movement and notify the appropriate pipeline company for repairs.

Option: Survey, identify, prioritize, and draft options for abandoned railway crossings with degraded structures that could collapse causing stream flow redirection and damming.

Option: Rehabilitate any crossings identified above through erosion control measures, reconstruction of poorly placed crossings, and replacing perched and narrow culverts.

Channel Morphology

The channel of the Kalamazoo River ranges from normal to degraded for habitat diversity and natural form. Most high-gradient areas have been impounded, covering sections with good hydraulic diversity. Dredging, straightening, and high sediment loads causing channels to be simple, over wide, shallow, lacking diversity, and lacking woody structure have adversely affected several tributaries.

Option: Protect tributaries from further channelization by developing alternatives to current dredging practices for drainage improvements.

Option: Protect riparian greenbelts through adoption and enforcement of zoning standards.

Option: Survey channel cross-sections throughout the watershed and further investigate streams that deviate from an expected channel form.

Option: Rehabilitate rare high-gradient habitats by removing dams no longer used for their original purpose, for example, retired hydroelectric facilities (e.g., Ceresco, Plainwell, Otsego City, Otsego, Trowbridge, Allegan City, and Hamilton) and dams serving little purpose (Upper Plainwell Dam);. Failed dams should be thoroughly evaluated on the basis of environmental and social factors to determine whether reconstruction is appropriate. Existing Hydroelectric dams should evaluate options for removal or modification at the close of their license term (e.g., Lake Allegan (Caulkins) and Morrow Pond dams).

Option: Rehabilitate recruitment of woody structure by developing and managing wooded greenbelts on riparian lands and managing amounts of wood in a channel (e.g., river clean-ups should be carefully carried out to ensure that most structure remains).

Option: Rehabilitate natural channel morphology in streams with high resource potential to enhance existing habitat diversity (e.g., Battle Creek, Rabbit, and Gun rivers and Portage and Pine creeks).

Option: Rehabilitate stream banks by replacing artificial wall structures with more natural banks made of vegetation or field stone (e.g., cities of Battle Creek and Albion).

Dams and Barriers

There are 110 dams in the Kalamazoo River watershed, and many have significant negative effects on aquatic resources. Dams fragment habitat for resident fish, impede fish movements, impound high gradient areas, trap sediments and woody structure, cause flow fluctuations, cause fish mortalities (entrainment with hydroelectric dams), and block navigation. Lake-level control structures alter natural water regimes and can severely impair downstream aquatic habitat. Some dams, however, provide impoundments with existing and future potential for fisheries and other recreational uses not provided by flowing water.

Option: Protect and improve biological communities by providing upstream and downstream fish and large woody structure passage at dams to mitigate for habitat fragmentation.

Option: Protect fishery resources by recommending screened turbine intakes at operating hydroelectric dams (e.g., Marshall, Bellevue, Morrow, and Lake Allegan (Calkins)).

Option: Protect remaining connectivity of the river system by opposing construction of dams and within stream channel storm water detention basins.

Option: Protect and restore angler access rights to the Kalamazoo River by recommending to FERC that they require STS Hydropower to allow angler access below the Morrow Pond Facility.

Option: Protect fishery habitat and river functionality through active opposition of hydroelectric facilities development within the Kalamazoo River basin. If hydroelectric development cannot be avoided, the Department of Natural Resources should forcefully pursue mitigation of all project effects on the resource.

Option: Survey and develop an inventory of barriers to fish passage, such as culverts, and explore options to correct any problems.

Option: Survey and develop a watershed list of the most environmentally damaging dams and barriers to fish passage in the river, with recommendations to mitigate damage.

Option: Survey to determine the number of small unregistered dams in the basin.

Option: Rehabilitate free-flowing river conditions by encouraging dam owners to make appropriate financial provisions for future dam removal and seek legislation to require dam owners to establish such funds.

Option: Rehabilitate free-flowing river conditions by removing dams, requiring dam owners to operate at run-of- river (e.g., Morrow Dam), and modifying all possible dams to fixed-crest structures.

Option: Rehabilitate river navigability by constructing canoe portages and upstream and downstream access sites at dam locations on the mainstem and major tributaries.

Option: Rehabilitate natural water levels by requiring all lake-level control structures to be operated to maintain existing seasonal water level fluctuations. Lake-level control structures could be removed or converted to fixed crest to accomplish this.

Option: Rehabilitate the former productivity of the Kalamazoo River for Lake Michigan fishes by removing state-owned and private dams on the middle, lower, and mouth mainstem (e.g., Upper Plainwell, Plainwell, Otsego, and Trowbridge) and installing fish passage structures at the remaining dams (e.g., City of Otsego, Allegan City, and Lake Allegan (Calkins). A Lake Allegan fish passage proposal should consider limiting passage of non-native potamodromous fish.

Option: Rehabilitate river functionality through foundation support and appropriations to create a dam removal fund that local communities can use to help remove their unwanted dams.

Option: Rehabilitate river connectivity through alternative proposals that provide an attractive waterfront in the City of Allegan that would allow the dam to be removed.

Water Quality

Kalamazoo River water quality has improved since the establishment of the NPDES program pursuant to the Clean Water Act of 1973. Continued improvement is needed with storm-sewers and nonpoint sources, which have significant effects on bacteria, nutrient, and dissolved oxygen levels in the river. The many contaminated (Part 201) sites in the watershed raise concern about future and current loading of toxic materials to the river and groundwater. PCB contaminated sediments continue to be the main impediment to fisheries management in the middle and lower mainstem segments.

Option: Protect and rehabilitate water quality by implementing improved storm water and nonpoint source best management practices. These projects are needed throughout the entire watershed.

Option: Protect and rehabilitate water quality by promoting BMPs for agriculture fields and drains (e.g., Battle Creek, Gun, and Rabbit rivers and Rice Creek).

Option: Protect and rehabilitate water quality through effective use of regulatory tools (enforcement) by the Department of Environmental Quality and federal agencies (i.e., the United States Environmental Protection Agency and Army Corp of Engineers).

Option: Protect and rehabilitate water quality by supporting the existing phosphorous TMDL project and any future TMDL projects in the watershed.

Option: Protect water quality and fish habitat by ensuring enforcement and compliance of erosion control permits under Part 91 of the Michigan Natural Resources and Environmental Quality Protection Act (1994 PA 451).

Option: Protect water quality by conservation of existing wetlands and riparian corridors, rehabilitating former wetlands, and maximizing use of constructed wetlands as natural filters.

Option: Protect river quality by supporting educational programs for farmers, land developers, and other resource users that teach land and water management practices that prevent further degradation of aquatic resources.

Option: Protect and rehabilitate water quality by continuing to improve pollution prevention for storm water discharge or regulated industrial sources.

Option: Protect groundwater and stream flows by supporting laws that would require major water withdrawals from surface water or groundwater to register, report volumes used, and document that protected uses of the source of water will not be impaired to Department of Environmental Quality.

Option: Protect major aquifers in the watershed by promoting hydrogeologic studies to characterize groundwater and programs to protect groundwater from contamination in watershed.

Option: Survey the watershed with continued wide-scale sampling to determine areas with contaminated fish. Wide-scale sampling will provide baseline information on areas of the watershed with no or limited data.

Option: Survey loading of nutrients and sediments to the river and develop strategies to reduce nonpoint source pollution problems by working with MDEQ, MDA, and local Natural Resource Conservation Service offices.

Option: Survey groundwater use to determine resource availability and potential for overuse.

Option: Survey water quality to determine effects of water withdrawal.

Option: Survey temperature elevation effects of dams to determine where effects are greatest.

Option: Rehabilitate and protect water quality by supporting Part 201 site and Superfund cleanups concentrating on the cities of Kalamazoo and Battle Creek. Kalamazoo contains 45% and Battle Creek contains 20% of the contaminated sites.

Option: Rehabilitate ecosystem functions of the middle, lower, and mouth segments by removing PCB contaminated river sediments sufficient to: restore, protect, and if possible enhance populations of species adversely affected by PCBs, particularly Bald Eagles, river otters, and mink; relax fish consumption restrictions; allow for public trust resource management of the river environment, fisheries, and wildlife; allow for safe, high quality recreational use and access to the river; compensate for past injury and trust losses through river corridor restoration; substantially minimize discharge of PCBs to Lake Michigan from the Kalamazoo River; and allow for the removal of all state-owned dams along the river.

Option: Rehabilitate water quality (reduce nonpoint source pollution) by encouraging communities to implement street cleaning practices that reduce contributions of refuse, sediment, and pollutants to the river.

Special Jurisdictions

Natural resources and environmental quality are managed directly by the State of Michigan through the departments of Natural Resources and Environmental Quality. The Federal Energy Regulatory Commission licenses active hydro power facilities within this watershed. County drain commissioners have authority over designated drains and many lake-level control structures. Township and city officials control zoning and ordinances that can have an effect on the quality of the river system.

Option: Protect recreational access to streams by continuing to advocate and work toward legislative adoption of the recreational definition of navigability (e.g., a stream is legally navigable if it can be navigated by canoe or small boat).

Option: Protect and rehabilitate the river system by supporting cooperative planning and decision-making. Develop a Geographic Information System that could be used in these processes.

Option: Protect cold water tributaries by designating appropriate reaches as trout streams to ensure proper management and environmental protection.

Option: Protect the quality of wetlands, streams, and lakes through rigorous enforcement of Parts 31, 91, 301, and 303 of the NREPA Act of 1994.

Option: Survey and review management of land and dams owned by the State of Michigan.

Option: Survey and identify river reaches for natural river designation. The lower and middle mainstem segments could be considered for this designation.

Option: Rehabilitate designated drains by encouraging drain commissioners to use stream management approaches that protect and rehabilitate natural processes rather than traditional deepening, straightening, and widening practices that emphasize moving water away quickly with little consideration for the effect on the stream or biota.

Option: Rehabilitate designated drains to natural stream status where drain designation is no longer appropriate or where past drainage modifications have been excessive and permanently altered stream channels (e.g., Rice, Battle Creek, Gun, and Rabbit rivers).

Option: Rehabilitate designated drains by supporting efforts to re-write the drain code.

Option: Rehabilitate lake outlet streams by encouraging run-of-river management at lake-level control structures.

Biological Communities

The biological communities of the Kalamazoo River have improved significantly since the 1980s due to water quality improvements. Although 102 species of fish were identified in 2002 in the Kalamazoo River watershed, certain problems demand consideration. There has been a decline in species that require clean gravel substrates. This habitat has been lost to sediment deposition, impoundments of high gradient areas from dams, and channelization. There has also been a loss of potamodromous species that historically used the river for spawning (e.g., lake sturgeon). These species have been cut off from spawning habitats by dams on the mainstem and tributaries. Channelization and stream clearing has degraded channel morphology and removed woody structure used for habitat and raised stream temperature. Mussel and aquatic invertebrate species have declined from poor water quality, sedimentation, and loss of free-flowing river and gravel habitats due to impoundments. Amphibians and reptiles have been on the decline presumably from loss of wetlands.

Option: Protect remaining stream margin habitats, including floodplains and wetlands, by encouraging setbacks and vegetation buffer strips in zoning regulations, controlling development in the stream corridor, and acquiring additional greenbelts through agricultural set aside programs, conservation easements, or direct purchases from conservation organizations or government agencies.

Option: Protect remaining high gradient and naturally-graveled habitats, especially between the cities of Kalamazoo and Plainwell, which contains excellent lake sturgeon spawning habitat potential and smallmouth bass habitat. Other short stretches exist on the mainstem and tributaries that should also be protected.

Option: Protect native aquatic species from predation, competition, and habitat destruction from invasive species (e.g., sea lamprey, gobies, zebra mussels, rusty crayfish, and purple loosestrife), by suppressing the spread and population expansion of pest species through education and chemical or biological control (TFM, beetles, or species specific bacteria) when feasible.

Option: Protect native mussels by removing dams so less lentic habitat is available for zebra mussels.

Option: Protect and rehabilitate cold and cool water thermal habitat areas and their unique biological communities including the South Branch Kalamazoo, Battle Creek, Gun, and Rabbit rivers; and Rice, Seven Mile, Portage, Silver, Spring Brook, Pine, and Swan creeks.

Option: Protect and rehabilitate upland habitats for native plant and wildlife diversity.

Option: Survey and map biological community distributions in the watershed using advanced technology including global positioning and geographic information systems.

Option: Survey distribution and status of aquatic invertebrate (mussels and insects) and fish fauna (e.g., mainstem middle, lower, and mouth segments, Battle Creek and Rabbit rivers, and Wabascon Creek).

Option: Survey distribution and status of amphibians and reptiles within the watershed and protect critical habitats.

Option: Survey distribution and status of species of concern and develop protection and recovery strategies for those species and explore options to protect critical habitat.

Option: Survey distribution and status of lake sturgeon in the mouth mainstem segment.

Option: Survey smallmouth bass abundance and recruitment in the middle and lower mainstem segments.

Option: Rehabilitate rare, high-gradient areas and fragmented habitats by removal of unnecessary dams (e.g., Ceresco, Plainwell, City of Otsego, Otsego, Trowbridge, City of Allegan dams).

Option: Rehabilitate populations of potamodromous fish by removal of unnecessary dams and installing upstream and downstream passage at other dams and barriers in the watershed (e.g., Lake Allegan (Calkins) Dam). Passage facilities should consider the migration of salmonids as well as warmwater species (smallmouth bass, walleye, flathead catfish, lake sturgeon, redhorse, and suckers).

Option: Rehabilitate fish diversity by re-establishing the extirpated weed shiner to the watershed.

Fishery Management

Moderately stable, groundwater moderated flows and coarse substrates represent the key values of the Kalamazoo River. The river has the potential to support substantial populations of cool and warm water fishes along much of its length. Angling is good, especially in the mouth segment for potamodromous salmonids. Fish populations and fishing pressure are low, however, in the middle and lower segments. PCB contaminated sediments and fish consumption advisories reduce angler interest in this section despite the growing smallmouth bass and walleye populations. Angling opportunities could be expanded through more concerted management and careful review of existing management practices.

Option: Protect headwater habitats by promoting BMPs and buffer strips.

Option: Protect urban streams in the upper and middle segments by instituting ecologically smart development techniques.

Option: Protect tributary trout streams by evaluating the need for a Fisheries Division policy regarding the use of blocking weirs to prevent potamodromous fish (e.g., sea lampreys, Chinook salmon, coho salmon, or steelhead) from migrating up tributary trout streams.

Option: Protect the existing wetlands (e.g., northern pike spawning and nursery habitat) in the upper Battle Creek River.

Option: Protect and identify high quality trout streams through inclusion on beaver exclusion list within the Departments Beaver Management Policy.

Option: Protect the fishery in upper segment through habitat protection that maintains natural reproduction of smallmouth bass and northern pike.

Option: Survey fish populations and inventory habitat in waters lacking data (e.g., Wabascon Creek and Battle Creek and lower Rabbit rivers).

Option: Survey water temperatures and trout survival in managed waters to determine if trout stocking is prudent (e.g., summer temperatures too marginal, natural reproduction can sustain fishery, adjust strains, or discontinue stocking).

Option: Survey and evaluate the success of stocking larger-sized brown trout in Augusta Creek.

Option: Survey and evaluate existing lake sturgeon, walleye, channel catfish, and flathead catfish populations in the mouth segment.

Option: Survey and evaluate the need for special regulations (e.g., catch and release) near metropolitan areas if increased angling pressure begins to affect sport fish population structures.

Option: Survey trout management opportunities in the Battle Creek River above Charlotte and in Indian Creek near Olivet.

Option: Survey and evaluate trout management opportunities in the North Branch Kalamazoo River if the Horton Dam is removed.

Option: Survey angler fishery management preferences in Gull Lake (e.g., trout vs. trophy northern pike management).

Option: Rehabilitate habitat continuity by removing unnecessary dams (e.g., Mosherville, Albion, Ceresco, Plainwell, Otsego, Otsego City, Trowbridge, and City of Allegan dams). Require upstream and downstream fish passage as well as bottom-draw release on those dams that remain (e.g., Marshall, Morrow, and Lake Allegan dams).

Option: Rehabilitate lake sturgeon spawning activity in the middle mainstem segment by removing or providing adequate fish passage at Lake Allegan, City of Allegan, Trowbridge, Otsego, City of Otsego, Plainwell, and Morrow dams.

Option: Rehabilitate the brown trout fishery in Rice Creek, Gun River, and Upper Rabbit River by promoting trees, bank stabilization, and woody structure and by promoting alternatives to further dredging.

Option: Rehabilitate trout habitat on Augusta Creek by maintaining the existing sediment basin in Kellogg Forest to reduce sand bedload.

Option: Rehabilitate historical populations of Great Lakes muskellunge in the mouth, lower, and middle mainstem segments by initiating stocking programs and providing fish passage or removing dams.

Option: Rehabilitate the brown trout population in Dickenson Creek (Calhoun County), provided that habitat is still adequate, through stocking of fall fingerling brown trout.

Option: Rehabilitate angling opportunities by continued improvement and acquisition of public access property.

Option: Rehabilitate historical potamodromous runs through stocking if needed. The original species that are best suited are walleye and lake sturgeon.

Option: Rehabilitate potamodromous fish movements by developing a fish passage plan for the Kalamazoo River that considers a sea lamprey barrier, lake sturgeon passage, warmwater fish passage, and the effects of salmonids on naturalized brown and brook trout populations. It should also consider the potential risk of contaminated fish migrating up to Battle Creek if passage is provided at Morrow Lake Dam.

Option: Rehabilitate fishing opportunities through stocking programs. Stocked waters should continue to be surveyed to evaluate fish populations and angler use to justify future stocking (e.g., mouth mainstem segment, Gull Lake, Gun Lake, and several trout streams).

Recreational Use

The watershed provides great recreational opportunities in public-owned areas. The river and tributaries are used frequently for fishing, hunting, canoeing, and nature watching, especially through state recreation and game areas. These recreational opportunities would be enhanced by increased public access to the river, especially in the headwater and upper segments. Navigation is impeded by poorly designed and maintained portages around some mainstem and tributary dams. Recreational use would also significantly increase once the stigma of PCB contaminated sediments is removed after a clean-up project is complete.

Option: Protect and rehabilitate recreational values through a PCB clean-up strategy that removes state-owned dams and maintains a natural river corridor with continuous public access.

Option: Protect, encourage, and support existing parks and promote responsible management for riparian areas in public ownership.

Option: Protect recreational (fishing, canoeing, hunting, etc.) use of small tributaries by supporting establishment of a “recreational” definition of legal navigability as opposed to the “commercial” definition.

Option: Protect and expand access site opportunities through the development of a basin public access plan similar to the one developed by Parks and Recreation Division for the Grand River basin, with the goal of a public access site every six miles along the Kalamazoo River. For example, there are more than 12 miles between launch sites on the Kalamazoo between Albion and Marshall and between Marshall and Battle Creek.

Option: Protect angler access by considering development of a stream public right-of-way, by purchasing easements for angler access from private land owners.

Option: Survey and promote recreational areas through more efficient use of media outlets and publications – especially in the urbanized middle segment.

Option: Survey and quantify recreational user groups within the river system, and identify programs to enhance compatible use of resources (e.g., educate liveries of the importance of woody structure in streams; educate pleasure boaters and personal watercraft users of proper operational etiquette near wild shorelines, wildlife, swimmers, and anglers).

Option: Survey angler use of the mouth segment through periodic creel sampling.

Option: Rehabilitate canoe portages and boat launches at all dams along the mainstem. These sites can be maintained by hydro power facilities under FERC re-licensing agreements where applicable.

Option: Rehabilitate small-scale public access where lacking (e.g., headwaters within trout water and upper mainstem, North Branch Kalamazoo, Battle Creek, Gun, and Rabbit rivers, and Rice and Pine creeks) through MDNR, county, township, and other municipal recreation departments, as well as private organizations.

Option: Rehabilitate angler use on the Kalamazoo River by promoting the fishery while educating anglers of the Fish Consumption Advisories. An excellent smallmouth bass fishery exists that is under used.

Option: Rehabilitate access through funding support for fishing piers, river walkways, and other facilities to provide recreational use of the river. Allow these grant monies to be used for maintenance needs.

Citizen Involvement

Citizen involvement in the watershed is increasing. Several groups have developed with specific goals for the watershed. It is important that all interest groups communicate with each other as well as with other groups around the state to develop educated and effective management strategies toward watershed improvements.

Option: Protect and rehabilitate communication between interest groups in the Kalamazoo River watershed.

Option: Protect and expand Fisheries Division’s partnerships with continued involvement with special interest groups by attending meetings, reviewing project proposals, and providing information on watershed issues.

Option: Protect the natural landscape by supporting the Southwest Michigan Land Conservancy and other land conservancies (e.g., Michigan Nature Association, The Nature Conservancy) in identifying lands for conservation easements.

Option: Survey water quality conditions by encouraging and supporting further studies by elementary and secondary school students to monitor local water conditions within their portion of the watershed (e.g., "River Watch").

Option: Survey and evaluate the Kalamazoo River basin in terms of the issues-needs-concerns of the major subwatersheds (e.g., North Branch Kalamazoo, South Branch Kalamazoo, Battle Creek, Gun, and Rabbit river watersheds, and Rice, Augusta, Portage, and Pine creeks). Prioritize watersheds according to natural resource criteria and level of local public involvement. Encourage and develop watershed plans specific to each watershed.

Option: Rehabilitate and implement strategies to educate the community to the benefits of river ecosystems, wetlands, and floodplains by supporting local conservation organizations.

Option: Rehabilitate river habitat by encouraging and supporting habitat improvement projects conducted by sports groups.

Option: Rehabilitate citizen use of the river by supporting programs that encourage use and contact with the river.

PUBLIC COMMENT AND RESPONSE

The draft of the Kalamazoo River Assessment was distributed for public review in spring 2005. Both printed copies and an electronic copy from the State of Michigan, DNR Fisheries web site were available. Statewide MDNR Press Releases were issued in conjunction with release of this draft. Printed copies were available from the MDNR Plainwell Operation Service Center. In addition, printed copies were sent to: local libraries; numerous local and state-wide sports and fishing groups; local, state, and federal units of government; MDEQ; USGS; and any public that requested copies. A letter explaining the purpose of the assessment and requesting review comments was enclosed with all copies.

Four public meetings were held to receive comments concerning the river assessment draft. Allegan Community Center, June 6, 2005 (9 people attended); Battle Creek Department of Public Works, June 7, 2005 (6 people attended); Oshtemo Public Library, June 8, 2005 (16 people attended); and Albion City Hall, June 9, 2005 (9 people attended).

The public comment period for the river assessment draft ended July 15, 2005. However, comments received after this period were accepted until July 30, 2005 and included. Comments of similar subject were combined to avoid unnecessary duplication. All comments received were considered. Where Fisheries Division agreed with comments, changes were made. Where Fisheries Division disagreed with comments, reasons why are stated in our response.

Introduction

Comment: Various comments were made supporting the river assessment process and complimenting Fisheries Division on the effort. Reviewers often requested copies of the final assessment.

> Response: These comments are acknowledged and appreciated. The final assessment will be distributed similar to the draft. Copies will also be sent to all people who requested one.

Comment: The assessment concentrates on the mainstem but not on large tributaries like the Rabbit River. Will the Rabbit River have its own assessment?

> Response: No. The Rabbit River and other main tributaries are analyzed and discussed in the same way as the mainstem within the assessment. This is a river assessment and includes these tributaries. Management Options are developed for these tributaries along with the mainstem.

Comment: Can the assessment be used to apply for grant funding?

> Response: Absolutely! Although the assessment is not tied to any particular grant funding source, it should be useful when applying for grants. Most state and federal grants require or at least look more favorably on projects that are identified in river assessments.

Comment: Is the assessment on the internet?

Response: The draft was on the MDNR internet site under Fisheries until the public comment period ended on July 15, 2005. The final document will be placed on the internet on the MDNR, Fisheries site under Fisheries Library, Fisheries Management/Special Reports. Also, a limited number of hard copies will be available.

Comment: How will the report be used to set policy?

Response: Fisheries Division uses river assessments to guide long- and short-term work planning within a watershed. River assessments are long-term documents (40 to 50 years) that help build our understanding of an aquatic system, changes that have occurred, and opportunities to protect or rehabilitate habitats. We will use the assessment to develop work plans to address specific areas for protection or rehabilitation. From a policy standpoint, we anticipate that local units of government will also use the assessment in developing zoning management plans and groundwater protection programs. Watershed groups can use the assessment to identify projects and to help obtain funding.

Comment: The assessment should identify all other information sources and studies that are not included in the report.

Response: Many studies and information sources were used in the assessment and were referenced. A complete listing of studies on the Kalamazoo River can be found on the Kalamazoo River Clearing House at: http://www.wmich.edu/geology/gem/dataclearing/home.html.

Comment: The document should be based on science and not just facts to represent and bolster the MDNR viewpoint.

Response: Analyses and reports used to describe the Kalamazoo River system are science-based and well-documented. Management options stated for the river are based on our mission to protect and restore aquatic resources and habitats.

Comment: Sport Fish Restoration demonstrates agency preference for sport fish over other species, including native species. This indicates a bias.

Response: We have no authority over the name of the federal fund that helped support this document. The river assessment is a comprehensive report that discusses native species of fish, aquatic invertebrates, birds, mammals, reptiles, and amphibians, as well as sport fish.

History

Comment: Michael Higgins' Masters Thesis documents lake sturgeon bones at the Schwerdt site on the Kalamazoo River.

Response: Thank you, this reference has been added.

Geology and Hydrology

Comment: There are several USGS reports related to the dams and sediments between Plainwell and Allegan.

> Response: Some of these reports were not available when this section was drafted. These have been reviewed and cited in the final document.

Comment: Table 14: Within the "middle" watershed part of the table there is an entry, "Wanondoger Creek:" I believe the correct name is "Wanadoga Creek".

> Response: We have seen both spellings in documents. Most modern maps refer it to Wanadoga Creek; the change has been made.

Comment: Page 9, Annual Water Flow, 1st paragraph: I suggest changing the sentence that begins "Daily measurement of stream discharges…"to "Daily mean stream discharge, measured in cubic feet per second (cfs) are published by USGS". We do not make daily "physical" measurements (at the river), rather the discharge is determined using several tools including the physical measurements of discharge to quantify the stage-discharge relation and appropriate stage shifts at the site.

> Response: The wording change has been made.

Comment: Page 12, Daily Water Flow section, first and second paragraphs: There are a couple parts of this discussion that are somewhat misleading. Daily flows (daily mean discharge) tend to average out highs and lows that occur during the day. Change the wording to "flows tend …." Instead of "Daily flows tend". Daily flows that we publish have historically tended to not show the true picture of stream flow downstream from hydroelectric facilities. As you are aware, using instantaneous flow data (now 15-minute frequency at most our stations) gives a better picture of the regulation pattern.

> Response: The changes have been made.

Soils and Land Use Patterns

Comment: Land use changes are the most noticed change in natural ecology. This change seems to be forgotten as a factor when assessing reasons for fishery alterations.

> Response: We recognize the importance of land use changes and its affects on fishery habitat and fish populations (see **Geology and Hydrology**, **Soils and Land Use Patterns**, and *Factors Affecting Fish Communities*).

Channel Morphology

Comment: "High gradient areas critical" – no substantiation, editorializing.

> Response: The **Channel Morphology** section discusses gradient and its importance to fish habitat. Several papers are cited indicating the importance of gradient in characterizing fish habitat for various species.

Dams and Barriers

Comment: Caukins Dam (Lake Allegan) is scheduled to be re-licensed in 2010. What is MDNR's position?

> Response: With any hydroelectric facilities, Fisheries Division will request fish passage, true run-of-river operation, portage for recreational navigation, attainment of water quality standards (§401 certification) and information and education displays at the site. Other specific information would be likely included in the FERC negotiations.

Comment: The assessment should be more balanced. Along with resource protection, we all need power for our homes.

> Response: The assessment takes an ecosystem approach that recognizes ecological (biological), social, and economic values. We agree that we need power. The best available technology should always be used to limit or eliminate resource damages during the production of power.

Comment: The City of Allegan Dam and generating unit have undergone $2 million in upgrades and repairs. The draft should be modified to recognize this.

> Response: The assessment has been changed to reflect these upgrades.

Comment: Why would MDNR want lake sturgeon, a threatened species, to move into such a degraded area? We need to learn to manage for the current conditions, including the dams, and make the most of what we have.

> Response: Not all the dams on the Kalamazoo River provide a benefit. Many, including the three state owned dams, no longer generate power and serve no useful purpose. Removal of these dams will open up some of the most significant historical habitat in the watershed. Removal of these structures will allow us to manage for better recreational fisheries and aid in the restoration of lake sturgeon.

Comment: What about flood control? Will dam removals result in flooding in the downstream areas?

> Response: The MDNR dams are at sill level and have very little flood storage. The dams on the Kalamazoo River either provide power for electricity or were built to provide recreational opportunities. No dams were built for the purpose of flood control. Kalamazoo River impoundments are too small to provide flood storage.

Comment: Do you consider the structure near Dickman Road in Battle Creek a dam?

> Response: Yes. It is listed in Table 6 as Monroe Street Dam.

Comment: There is a sewer crossing upstream of the confluence of the Battle Creek River and Kalamazoo River that is like a dam and needs to be portaged around.

> <u>Response</u>: Yes. It is listed in Table 6 as Sewer Crossing.

Comment: What do you need from Albion to work on getting rid of the dam? We have to do costly repairs and maybe we should look at removal as on option.

> <u>Response</u>: Fisheries Division will offer advice to the city on how to go about dam removal, where to find funding, and the best procedures for removal. The amount of our involvement is determined by the commitment of the city to remove the dam. It is recommended that the city council discuss dam removal and pass a resolution showing their full commitment for removal. The removal process can take more than five years, so it is important to have this support before much effort is put into the process.

Comment: How would you get community support for dam removals?

> <u>Response</u>: This is no easy process due to a community's historical attachment to dams and their resistance to change. It is recommended to announce the intension to remove the dams and hold public meetings to discuss it. Invite speakers from other communities that have gone through a dam removal. Have experts on hand that can discuss the process and answer questions. A presentation that goes through case studies of dam removals showing pictures of before, during, and after the removal is very helpful.

Comment: No mention of the positive aspects of dams (i.e., green power generation, water quality improvement, public recreation, wetlands, flood retention, ground water recharge, habitat increase, invasive species exclusion, contaminant exclusion, aesthetics, etc). This is unbalanced and indicates bias.

> <u>Response</u>: We admit that the assessment is biased towards river and biological quality. Fisheries Division uses an ecosystem approach to management which considers biological, social, and economic values. Therefore, we have several concerns with dams and their operation. The assessment does mention the recreational and exotic species barrier benefits of dams.

Comment: "Mortality over dams and through turbines" – no substantiation or documentation. This needs to compare increased fish production due to enlarged habitat via pondage with actual mortality through low head turbines with appropriate screening.

> <u>Response</u>: Screening does prevent entrainment and mortality of fish through turbines. Even with screening mortality has been well documented at hydro-power facilities. Bohr and Liston (1987) estimated that 45,987 juvenile and adult fish passed through the STS Facility at Morrow Dam in a 6.5-month period.

Comment: "Peaking hydroelectric…" irrelevant grandstanding, as all hydro plants on the Kalamazoo River operate in run-of-river mode.

> <u>Response</u>: All facilities on the Kalamazoo River are obligated under FERC to run-of-river flow. However, we still document instances when there are several flow fluctuations below the dams at peak use times indicating some peaking operations (See Figure 20 in the assessment).

Comment: "Flow fluctuations" – no documentation as to occurrences or severity. Natural processes can also double flows in short time periods and strand aquatic organisms.

Response: We understand and recognize that natural flow fluctuations occur. We have also documented fluctuations below dams during periods of no precipitation. Figure 20 illustrates a day when fluctuations occurred with no precipitation.

Comment: "Sediment transport/bedload" – as long as there are excess sediments due to unnatural land use practices compounded with polluted sediments subject to transport, the partial disruption of bedload by dams is a water quality positive and needs consideration. Dam modification of floods can mitigate flood crests, another public health/safety/welfare.

Response: It is obvious that dams prevent the natural transport of sediment. Most impoundments on the Kalamazoo River are filled or filling quickly with sediments. Rivers are designed to transport water and sediment. When rates of water or sediment are changed or are out of equilibrium, the river must change to compensate. These changes create instability in the river system. We want to maintain this equilibrium and want to maintain natural rates of water and sediment transport. We agree that impoundments can act as temporary sediment basins that can be useful to contain contaminants. However, these contaminants need to eventually be removed to prevent their movement if these dams fail in the long-term. Kalamazoo River impoundments have little flood storage capacity. They are not effective at mitigating flood crests. If anything, they increase upstream flooding and do little to mitigate downstream flooding.

Comment: "Wetlands" – silt behind dams ultimately becomes wetlands. Under no net loss policy, these wetlands would have to be replaced if dams are removed.

Response: Typically, there is not a net loss of wetlands due to dam removals. Existing wetlands change their character and might convert from a marsh to scrub/shrub wetlands. Riparian wetlands are also formed in the former impoundment areas that were once open water.

Comment: "111 dams" – how many are owned by MDNR? Given that the dam itself causes most of the impacts, wise policy would be to install generating facilities on all 111 dams and reduce the CO2, SO@, Hg, pollutants and transport mining impacts caused by fossil fuel generation, especially as society makes a transition from gasoline to electrically produced hydrogen.

Response: MDNR owns 12 dams in the watershed. Only three are on the mainstem and were once hydro power facilities until they became unprofitable (generation revenue did not exceed maintenance of facility) and sold to the state. MDNR purchased them with intent of removal. Other dam owners within the watershed have the right to produce power provided that they receive the proper permits to do so.

Water Quality

Comment: The Michigan Department of Environmental Quality, Water Bureau, Waste and Hazardous Materials Division, and Remediation and Redevelopment Division had several comments and suggested changes within the water quality section.

Response: Thanks for your comments. They were incorporated into the final draft.

Comment: The (Kalamazoo) river is a Superfund Site and no PCB clean-up strategy has been identified so why would MDNR want fish passage and construction of fish ladders if fish are going to enter a contaminated environment and likely die?

Response: Most of the high quality habitat is outside of the contaminated area or has low concentrations. In areas where PCB contamination is found, the contamination must be addressed. This document provides an outline of our goals for the river for the future when contamination is no longer an issue.

Comment: What about sediments when sills are removed? How will MDNR make sure downstream areas are protected? The dams are protecting the Allegan State Game Area and downstream environment by trapping PCB sediments.

Response: PCBs are constantly moving downstream even with the dams in place. Rain and large snowmelts events mobilize PCBs in the river that are transported to Lake Michigan. Any plans to remediate the sediments and remove the dams will need to include measures to minimize sediment transport.

Comment: The Kalamazoo River Study Group report indicates keeping the dams in place is a good option and protective of the river.

Response: The dams are in very poor condition and could fail. Furthermore, PCBs continue to be mobilized downstream with the dams in place. It is more prudent to provide a stable final remedy that would remove PCBs from the erosive power of the river and eliminate exposure to humans and wildlife.

Comment: How will PCB sediments be removed?

Response: This will be site specific and has not been determined yet. In general, the PCB sediments are in the river bank and floodplain. These areas would need to be isolated from the river flow and then the PCB contaminated soils could be excavated. When the PCBs are removed, the river banks and floodplain would be restored.

Comment: We are concerned about releasing PCBs downstream if the Lake Allegan Dam is removed or if a fish ladder is installed?

Response: Lake Allegan (Caulkins) Dam continues to provide hydro power and recreation. There are no immediate intensions to remove this dam. If the dam were to be removed or if a ladder is installed, PCBs would have to be removed or safeguards would have to be in place to limit PCB mobilization.

Comment: Other than PCBs, what are the other contaminants that cause fish advisories in the watershed?

Response: Mercury, an airborne pollutant, is responsible for the general inland lake fish consumption advisory issued by Michigan Department of Community Health.

Comment: How do PCB advisories compare with mercury advisories?

Response: In general, the PCB advisories on the Kalamazoo River are more restrictive and include areas of no consumption for all species.

Comment: What are the action levels of PCBs in fish?

Response: Trigger levels are listed in Table 15. PCB advisories are placed when concentrations are above 2.0 ppm.

Comment: Are there fish with higher levels of PCBs (higher than 2.0 ppm)?

Response: Yes. Common carp range from non-detect to over 30 ppm.

Comment: You mentioned that the first dam on the Kalamazoo River is a barrier to exotics. From another aspect, doesn't it also help prevent contaminants from coming into the river system from Great Lakes fish? Isn't that good and important because of the negative effects these fish have on eagles and mink?

Response: The level of fledgling success of Bald Eagles nesting on rivers with heavy runs of Great Lakes fishes supports our position on fish passage. Bald Eagles along these reaches are now reproducing at what the U.S. Fish and Wildlife Service characterizes as "healthy" levels. Those nesting along Great Lakes shorelines are now reproducing at "stable" levels (USGS data). These data are especially significant because Great Lakes-nesting and inland-nesting Bald Eagles, by consuming fish and colonial water birds, feed at higher trophic levels and are thought to bioaccumulate contaminants more readily than mink or river otter. Such productivity has occurred despite risk assessment studies suggesting Bald Eagle reproduction in these areas should be severely impaired. Bald Eagle productivity data and field observations of mink and river otter in rivers with Great Lakes fish access suggest the findings of risk assessment (laboratory and modeling) studies of mink may be overstated. Still, we support further reduction in contaminant levels in the Great Lakes. We think however, that providing fish passage has the potential to restore lost production of native and naturalized Lake Michigan fishes. We also think that this can be done without causing significant harm to Michigan's Bald Eagle, mink, or river otter populations.

Comment: Should include guidelines as well as fish consumption advisories in the assessment.

Response: The assessment discusses the fish consumption advisories in the text as well as in Table 15 and Figure 29. For more details on consumption advisories and to learn more about the guidelines, review Michigan Fish Consumption Advisories or contact the Michigan Department of Community Health.

Comment: Mercury has been known for a long time to be a watershed pollutant. Will MDNR get on board with setting National policy issues regarding the control of mercury in the environment?

Response: Fisheries Division is concerned with the amount of mercury in our inland lakes. This mercury primarily comes from airborne sources. We will do what we can in our limited authority to bring the mercury issue to the forefront. MDEQ and the Environmental Protection Agency are the lead agencies for airborne pollutants and National policy for mercury.

Comment: Should include more information on sources of mercury in the watershed, such as identifying coal fired power plants and other air emissions.

Response: Atmospheric flows and deposition are outside the scope of this assessment. Information will be added on where this information can be found within the assessment.

Comment: What about dioxins in Kalamazoo River fish tissue?

Response: The concentration of dioxins in Kalamazoo River fish tissue has not been identified as a risk to human health and according to the MDCH does not warrant the issuance of a fish consumption advisory.

Comment: How will funds for the Natural Resources Damage Assessment (NRDA) be used?

Response: The United States Fish and Wildlife Service (USFWS) is the lead agency for the NRDA. The MDNR is a co-trustee and consults with the USFWS and other trustees on NRDA issues. This is a separate process from the Kalamazoo River Assessment and is more specific to damages as a result of the PCB contamination. The Kalamazoo River Assessment will be a great resource for the trustees to use when considering mitigation projects as part of the NRDA.

Comment: Lake Allegan is hypereutrophic and the subject of the MDEQ phosphorus TMDL. Why would you want to introduce more fish (via ladders) into Lake Allegan?

Response: As the total phosphorus concentrations in Lake Allegan are reduced through point source and nonpoint source controls, we expect the habitat to improve and support a more diverse community of fish, including those that are now blocked from some of the best quality habitat by dams.

Comment: If all the phosphorous inputs were eliminated from Lake Allegan, would the fish community improve quickly?

Response: Once the phosphorous inputs are address, internal cycling of phosphorous within the lake may continue for some time. Dissolved oxygen levels should improve during this time allowing for a more diverse fish community.

Comment: One of the remediation ideas listed on the EPA web site is perpetual maintenance of the dam by the PRPs. The universe of options is dam removal to perpetual maintenance. Given the lack of progress in PCB removal, Allegan has concluded that the dam will be there for a good long while. Tremendous work and expenditures have made the reservoir the focal point of the city. Snarky editorial comments by MDNR about off channel ponds and greenways replacing the pond do not increase enthusiasm for the Draft Kalamazoo River Plan.

Response: There are several options for addressing PCB contamination through the superfund site. Fisheries Division has and will continue to recommend an option that considers removal of the state owned dams and removal of contaminated sediments to provide barrier free movement, natural flows, and lateral movement of the river as necessary to maintain stability. Other dam owners may consider other options provided that it meets the cleanup criteria established by EPA. We recognize the structural improvements to Allegan City Dam and have made changes in the assessment to reflect that. Other communities in the state enjoy the green space and off channel ponds created after dam removal, so it was offered as an alternative option.

Comment: "Water quality in the basin is now considered good…" – With a no eat order applied to most of the river's fish, high turbidity, low DO, and unresolved Superfund designation, this must be more wishful thinking than fact. This needs substantiation.

Response: Water quality for most of the watershed is good. Water quality in the Kalamazoo River proper is also good in terms of dissolved oxygen, temperature, and turbidity. This will be made clearer in the assessment. Yes, we agree that there is still room for improvement with the superfund site, Lake Allegan, and with non-point source sedimentation in the tributaries. The Kalamazoo River was once considered dead. Water quality and species diversity has increased considerably and is considered good to excellent in some sections.

Comment: The USGS collected water quality samples, as part of the NASQAN program, between 1972-75 and 1987-93 at the M89 River crossing (downstream from Allegan Dam). This data can be accessed online at http://waterdata.usgs.gov.

Response: Thank you. This data was accessed and reviewed. Information was added to the Water Quality Section.

Comment: Several NPDES permits (Table 10) have changed since 2002 due to termination or facility name changes. .

Response: Table 10 has been updated.

Comment: Page 133, Part 31 of Act 451 Water Resources Protection should be on your list.

Response: This has been added to Table 16.

Special Jurisdictions

Comment: Have you considered nominating other parts of the river for Natural River status?

Response: Yes. Surveying and identifying river reaches for Natural Rivers designation is a Management Option in the assessment. The entire mainstem of the river should be considered as well as portions of major tributaries such as the North Branch Kalamazoo River, Rice Creek, Battle Creek River, Gun River, and Rabbit River.

Comment: What programs are you working on with the county drain commissioners?

Response: Fisheries Division staff serve on watershed steering committees along with drain commissioners and other local officials. We also work with drain commissioners on habitat improvement projects and comment on proposed drain projects through the MDEQ permit reviews.

Comment: I would like to see some training targeted at drain commissioners.

Response: Fisheries Division does training on specific projects, and we would support a stronger effort to train and communicate more with drain commissioners.

Comment: The public should not lose drainage that has been paid for. Everyone in the state benefits from the activities that have occurred as a result of the drain code. If habitat improvement is a goal, then state funds should assist with the costs.

Response: There are many benefits and costs to the existing drain code and with regards to specific drain projects. Drain maintenance should continue where it is necessary provided that best management practices are used. Drains that no longer serve a purpose or no longer need maintenance should be abandoned. Continuing to maintain these drains because of their historical benefits or costs is not a good long-term strategy. Funding currently is available through state and federal groups to protect and improve habitat in streams and will continue to be made available.

Comment: If drains are an issue, shouldn’t the assessment identify revision of the Drain Code as a management option?

Response: Yes. It is included as an option in the assessment.

Biological Communities

Comment: The assessment should address the nearshore (wetland) areas contaminated by the PCB paper waste.

Response: Other studies have documented these effects and are included by reference in the assessment.

Comment: It seems like we have experienced a loss of habitat and animals in the Rabbit River.

Response: The assessment points out that the Rabbit River is one of the flashiest streams in the watershed. These spikes in the hydrograph along with the predominately dredged channel and sandy banks have caused instability within the system that is affecting biological communities. The cities of Byron Center, Dorr, and Wayland continue to grow and will add more pressure on this disturbed system. It is recommended that wetlands be restored for flood storage and that the river be reconnected to its flood plain to lessen stream power during flood events. This along with encouraging woody structure within the river will help restore river function as well as habitat and biological community diversity.

Comment: If lake sturgeon have PCBs in their flesh of 20 ppm, the female's eggs will have to have a lot more. Are these eggs viable? Has this been tested?

Response: Concentrations in most lake sturgeon are probably lower than 20 ppm. The best data set for PCB concentration in lake sturgeon is from the Menominee River, and those levels are below 5 ppm. Lake sturgeon spend most of their life in the Lake Michigan where concentrations of PCBs are lower compared to specific rivers like the Kalamazoo. Studies have not been conducted on Kalamazoo River lake sturgeon to determine the relationship between egg viability and parent flesh PCB concentrations. Live lake sturgeon larvae have been recovered below the Lake Allegan dam suggesting that the eggs are viable. Other spawning rivers within the Great Lakes also have viable eggs and successful natural reproduction. Adult stocks and availability of spawning habitat are more of a limiting factor for lake sturgeon.

Comment: Is there a major come back of beavers?

Response: Beaver and beaver dam observations appear to be increasing in the Kalamazoo River watershed.

Comment: If the population in Lake Allegan is 96% carp, due to PCBs, does river segmentation really matter until PCB/mercury removal takes place?

Response: The Lake Allegan fish population is predominately carp by both number and weight. Lake Allegan is hyper-eutrophic and experiences low dissolved oxygen levels. The poor water quality has lowered the species diversity and has favored low dissolved oxygen tolerant species like common carp. The phosphorous TMDL is addressing this water quality issue in Lake Allegan. Species diversity in the entire lower segment is less than the rest of the Kalamazoo River mainstem. This section has a series of dams that fragment the system and that have covered good high gradient habitat under their impoundments. These impoundments have poor habitat and poor species diversity. Restoring a free flowing rivers system through this segment will increase habitat and species diversity.

Comment: Fish populations are tabulated on a fish per acre basis. Less acres (due to dam removal) results in less fish.

Response: Typically, species diversity and density increases in natural river channels compared to impoundments. We expect that a dam removal on the Kalamazoo River would increase the density of fish (more fish per acre).

Comment: "Dredging behind dams" – Wet dredging may impact mussels, but certainly not as much as dry dredging.

Response: If this comment is in regards to dam removal techniques, we would conduct a mussel survey before the project. If mussels are present, we will develop a plan to transplant them, so they are not affected by dredging activities. Most sediments behind the state owned dams are already dry.

Comment: “Birds” – no mention made of increase in waterfowl habitat due to pondage behind dams. MDNR has constructed dams specifically for waterfowl habitat. Unbalanced, indicates bias.

Response: Table 6 lists dams in the watershed. MDNR, Wildlife Division manages Swan Creek and Highbanks dams to promote marsh habitat for waterfowl.

Comment: Several specific comments were offered by Wildlife Division staff to improve the accuracy of the biological section and species lists.

Response: Thank you.

Comment: Badra and Goforth (2002) surveyed 8 sites on the Kalamazoo and found 19 species of mussels including Asian clam and slippershell not listed in Sherman-Mulcrone and Mehne (2001).

Response: These species have been added. Thank you.

Fishery Management

Comment: The river is a great potential resource. Unit the PCBs are gone, MDNR Fisheries Division should not spend any money or resources on the river.

Response: Regardless of the PCB contamination, the Kalamazoo River is an excellent resource that benefits from habitat protection and restoration as well as fishery and recreational management. Fisheries Division will continue to manage the river’s resources for present and future generations to use and enjoy.

Comment: You need to punch up the biological and recreational losses in the Plainwell to Trowbridge reaches. Also, you need more fisheries and other biological survey data for this area.

Response: The biological and recreational losses are being developed as part of the Natural Resource Damage Assessment. Michigan river data can be used to model the biological and fishery community with and without the dams. Creel data from the lower Kalamazoo River could be used to estimate angler use. Fisheries Division will work with the Fish and Wildlife Service to make sure all losses are accounted for. The best fisheries data set for this section of river was from a 1984 rotenone survey. Since then, several studies have been conducted by various consulting firms and government agencies. The fish community has improved in this area with better dissolved oxygen in the river. A drastic change in the community is not expected until the dams are removed. Fisheries Division will engage in monitoring studies to track biological community changes during and after dam removal.

Comment: In regards to dam removals and fish ladders, some anglers are not concerned with salmon or steelhead migrating up the river.

> Response: Fish passage is a complicated issue. Ideally, we would like to pass walleye, suckers, smallmouth bass, and lake sturgeon safely up and downstream of dams. Some species like sea lamprey will need to be restricted from passing. Passage of other species like Chinook salmon and steelhead may be limited, so naturalized populations of brook and brown trout are not affected.

Comment: Why isn't there a fish ladder like on the Grand and St. Joseph rivers to pass fish? Is it because of PCBs?

> Response: The St. Joseph and Grand River project have been very successful as passing salmonids up into urban areas. Before an extensive effort is pursued on the Kalamazoo River, a fish passage plan is necessary. This plan would address all the pros and cons of fish passage – especially at the Lake Allegan Dam. Issues include PCB contamination, existing dams and whether they will be removed in the near future, potential for exotic species migration upstream, whether the ladder design will pass cool water species (i.e., smallmouth bass, walleye, northern pike, suckers, lake sturgeon, etc.), how far upstream should salmon migration go, etc. The assessment supports fish passage and has a management option to develop this fish passage plan.

Comment: The Kalamazoo River channel in Battle Creek has been channelized. Can it be fixed?

> Response: The assessment has a management option to diversify habitat in this section of the river.

Comment: There is no law enforcement in the Battle Creek area (see lots of poaching)?

> Response: The message was passed to MDNR, Law Enforcement Division. If game regulations are violated, call the Report All Poaching Hotline at 800-292-7800. Law needs to be aware of problems before they can address them.

Comment: Where would you get money for river restoration?

> Response: Depending on the scale of the project, Fisheries Division could conduct some projects under its operating budget. Large scale projects may need capital outlay requests from the Game and Fish Protection Fund. Funding from grants, foundations, and sport groups could also be pursued.

Comment: Have you considered a slot limit for walleye in the Kalamazoo River?

> Response: The walleye fishery is primarily supported by stocking in the Kalamazoo River. River connectivity to spawning habitat appears to be the limiting factor. Adult spawning populations are adequate. Angler harvest on walleye is low, so there is no biological need for a slot limit regulation to protect the spawning stock.

Comment: "Certain species of fish have declined. Dams…" No mention of other reasons for decline (i.e., pollution, invasive species, increased silt load from farming and development, MDNR rotenone intentional fish kills, etc.). Always blaming dams without mention of other factors indicates bias.

Response: This quote is taken out of context. Within the **Dams and Barriers** section, we discuss how dams affect fish populations. Within the *Factors Affecting Fish Communities* section, we discuss all issues affecting fish and aquatic organism declines.

Comment: "Acknowledge role of stocked fish". Stocked fish have no role if they compete with native fish. Stocked "sport fish" are not wild fish. Non-native stocked fish are little different than carp or sea lamprey or round goby in their effects on native fish, except that unaware people seem to like them (and influence MDNR policy). Stocked natives (genetic monoculture) lack site specific genetic imprinting and adaptation and compete and interbreed with natives (to detriment of natives).

Response: We agree with some of your statements, such as natives in most cases are more important than exotics and that genetics are an important consideration. Fisheries Division stocks salmonids (naturalized species) and coolwater fish such as walleye, northern pike, and lake sturgeon, (native species). We stock to restore populations such as with lake sturgeon and to produce fisheries, such as walleye. In some cases, a niche may be available that can be filled by a predator, such as walleye, that can not naturally reproduce in the waterbody due to lack of habitat. Salmonids also fill a niche that was provided when sea lamprey, an aquatic nuisance species, lowered lake trout stocks causing numbers of alewife, a naturalized species, to explode in the absence of predation. These salmonids play an important role in maintaining balance in the Great Lakes and provide excellent sport fisheries. With the ever changing ecosystem that we call the Great Lakes, stocking will continue to play a role in maintaining a healthy balance. We will continue to be judicious with all stocking and consider native fish, genetic, disease, social, biological, and economic effects of stocking (see **Fishery Management** section for more details).

Comment: "Rotenone sampling" – This type of sampling kills invaders and natives alike.

Response: We agree. Rotenone and other fish toxicants are fishery management tools used to measure species presence and abundance and to remove high populations of competing or predatory fish (native and exotic).

Recreational Uses

Comment: What are you doing about providing assistance for keeping the river cleared of trees? There are no resources for small towns – is there no one responsible for this?

Response: Fisheries Division gives advice to drain commissioners, communities, sport groups, and boaters on the best way to clear a path for navigation. Trees or woody structure provide excellent habitat for fish and other aquatic organisms. It is recommended that as much of the tree as possible remains in the river. Drain commissioners will typically remove some log jams if there is a flooding concern. Sport groups may move trees within a stream to prevent bank erosion or to move them to a place with more habitat potential.

Comment: MDNR needs to increase access for boating and non-boating public. Dwindling fishing license sales are linked to opportunities.

> Response: One of the management options is to increase public access within the watershed. We will continue to seek opportunities to purchase more and develop existing parcels where appropriate.

Comment: Are you familiar with Albion's five-year recreation plan for the dam?

> Response: No. Fisheries Division would be interested in working with the City of Albion on developing the plan. The assessment offers recommendations to improve habitat and recreation in this area.

Comment: If we considered a white water canoe race by the Albion dam, would Fisheries Division support this?

> Response: In concept, yes. Fisheries Division would like to be sure that the design passes fish and that the operation of the canoe race continues as run-of-river flow. The flow rates in the South Branch of the Kalamazoo River are not conducive to support year a round white water, but it still might provide recreational diversity to the area. The city should consider whether liability for the dam will change with this construction. Will it still be considered a dam and require inspections and maintenance?

Comment: Allegan certainly hopes there will be some fish to catch someday. The high carp populations and no eat orders dissuade most fish activities near Allegan. The City has provided some of the best access to the Kalamazoo. Ideas are being considered for an additional boat launch in the Mill District, River Walk extensions, a canoe portage, and a possible whitewater park and fish passage facility at City dam.

> Response: It is unfortunate that the lower section of river has poor habitat and contaminated sediments. This is why we are promoting management options for PCB clean up and dam removals, so that the habitat and fish quality increase. We support the work that the City of Allegan has done to promote the river. The recreational activities mentioned above would provide excellent opportunities for that section of the river.

Comment: The recommendations on improving the trout fishery in parts of Rice Creek and investigating the upper part of the Battle Creek River for trout management are sensible if the public receives the practical stream access discussed on pages 37 and 38. These small streams do not have many access points and many of us are unsure about our legal right to wade or canoe along them. There is not going to be much interest in trout fisheries or stream habitat improvement projects while this uncertainty exists.

> Response: Before we expand our trout fishery management in streams, we will evaluate public access of the stream. Streams with no public access or with no property-owner support for public fishing will not be stocked or actively managed for trout. We recognize the lack of public access in southern Michigan and continue to seek opportunities to obtain more. The **Special Jurisdictions**, *Navigability* section describes navigability and riparian rights, which are used in determining the legal right to wade and canoe.

Comment: Page 46 of the report cites the 1992 survey report on Duck Lake prepared by Gary Towns as evidence that the lake contains spotted garpike. I have a copy of this report and do not find any reference to spotted garpike in it. I have seen many gar of all sizes in Duck Lake over the years and they have all been longnose gar.

> Response: You are right. The Towns (1999) report only reports longnose gar in Duck Lake. University of Michigan Museum vouchers indicate that a spotted gar was found in Duck Lake in 1863. The wording in the assessment has been changed.

Citizen Involvement

Comment: All these perspectives are great for creating a watershed approach. Would it be possible to establish one group to integrate all the different issues in the watershed?

> Response: There is a management option to increase communications among all the Kalamazoo River groups. It would be possible to establish one group or council for the watershed. Right now there are several groups competing for funds and volunteers for their own special interest or for their section of the river. The watershed would benefit if one comprehensive group existed that could organize and unite efforts throughout the watershed.

Management Options

Comment: Add an option about the well head protection areas in the watershed. These areas should be considered when reviewing oil and mineral leases.

> Response: This option has been added in the **Geology and Hydrology** section of the **Management Options**.

Comment: Basically the options are for the anti dam movement. No counter options proposed (fish passage, etc.). Unbalanced, indicates bias.

> Response: We have supplied management options that will protect and promote rehabilitation of riverine habitat and aquatic populations. There are several other management options listed besides dam removal such as fish ladders, run-of-river flow, screens for turbines, and portages.

GLOSSARY

acre-feet - volume of water required to cover 1 acre of land to a depth of 1 foot; equivalent to 325,851 gallons

aggradation - the accumulation of bed materials

ammocete - juvenile lampreys that burrow in the substrate of streams for 3 to 6 years before smolting to Lake Michigan

anadromous - migrating from salt water to a fresh water river to spawn

anuran - a frog or toad

base flow - the groundwater discharge to the system

basin - a complete drainage including both land and water from which water flows to a central collector such as a stream or lake at the lower level elevation, synonymous with watershed

benthic - plants and animals living on, or associated with, the bottom of a waterbody

benthos - plants and animals living on the bottom of streams, rivers, and lakes

bioaccumulation - the accumulation of substances, such as pesticides, PCB, methylmercury, or other organic chemicals in an organism or part of an organism.

biodiversity - the number and type of biological organisms in a system

biological oxygen demand - the measure of the consumption (usually by aerobic bacteria) of oxygen in an ecosystem within a fixed period of time

biological slime - a colony or colonies of micro-organisms that form on the surface of objects

biota - animal and plant life

BMPs - best management practices

carbonaceous biochemical oxygen demand – is the result of the breakdown of organic molecules such as cellulose and sugars into carbon dioxide and water.

catchment - see watershed

centrarchid - species of fish in the Centrarchidae family, generally the sunfishes, crappies, and basses

cfs - cubic feet per second

channelize - to straighten and clean a streambed or waterway to enhance land drainage

channel morphology - the study of the structure and form of stream and river channels including width, depth, and bottom type

cobble - naturally rounded stones larger than pebbles and smaller than boulders arbitrarily limited to a size of two to ten inches in diameter

conservation easement - an agreement where a land owner receives financial benefits or tax abatements for conducting conservation practices or agreeing not to farm or develop environmentally sensitive portions of the property

detritus - debris broken away by the action of water (e.g., small pieces of wood or leaves)

DDT – Dichloridiphenyltrichloroethane

DO - Dissolved Oxygen

drought flow - water flow during a prolonged period of dry weather

ecological - the relations between living organisms and their environment

ecosystem - a biological community considered together with the non-living factors of its environment as a unit

effluent - the outflow of a sewer, septic tank, municipality, industry, etc.

end moraine - an arch-shaped ridge of moraine found near the end of a glacier.

entrainment - to trap an object during a given mechanical process (e.g., fish in hydro power turbine)

embeddedness - to fill or the degree of fill between interstitial spaces and beneath large substrate particles such as gravel or cobble with small particles such as sand or silt

erosion - the process of moving soil particles by wind or water

eutrophication - a process of becoming increasingly rich in nutrients either as a natural phase in the maturation of a body of water or artificially enhanced by human use such as agriculture run-off or waster disposal

evapotranspiration - the loss of water from plant material to the atmosphere

exceedence curves - the probability of a discharge exceeding a given value

exotic species – see "invasive species"

fauna - the animals of a specific region or time

FCMP - Fish Contaminant Monitoring Program

FD – Fisheries Division

FERC - Federal Energy Regulatory Commission

flashy - streams and rivers characterized by rapid and substantial fluctuations in stream flow

fixed-crest - a dam that is fixed at an elevation and has no ability to change from that elevation

floodplain - a relatively flat valley floor formed by floods which extends to the valley walls

forage fish community - a group of fish that provide food for piscivorous fish

glacial fluvial valley - a river valley formed by glacial melt waters cutting through deposits left by a glacier

glacial moraine - a mass of rocks, gravel, sand, clay, etc. carried and deposited directly by a glacier

glacial outwash - gravel and sand carried by running water from the melting ice of a glacier and laid down in stratified deposits

GLEAS - Great Lakes Environmental and Assessment Section

GLFC - Great Lakes Fishery Commission

gradient class - an index of hydraulic diversity in streams

ground moraine - continuous layer of till near the edge or underneath a steadily retreating glacier.

groundwater - the water beneath the surface of the ground that is the source of spring and well water

heterogeneity - having composition of dissimilar parts

hydraulic diversity - the variability of water depths and velocities in a stream or river channel

hydrology - the science of water

hydrograph - a graph of the water level or rate of flow of a stream as a function of time, showing seasonal change

hydrogeologic - pertaining to groundwater and the type geological material (clay, gravel, and bedrock) that influences groundwater flows

ice contact - pervious glacial material (gravel) found in moraines that is associated with groundwater recharge

impervious - not permitting penetration or passage

impingement - a process of physically capturing juvenile and adult fishes on screens designed to prevent debris from entering a power plant along with process cooling water

impoundment - water of a river system that has been held up by a dam, creating an artificial lake

indigenous - a species that is native to particular area

infiltration - a process of water moving through soil particles

interlobate – between lobes of a glacial moraine formation

inundate - to flood or cover with water

invasive species - successfully reproducing organisms transported by humans into regions where they did not previously exist

invertebrate - an animal having no backbone or internal skeleton

KRWC - Kalamazoo River Watershed Council

lacustrine - pertaining to lakes

lake plain - land once covered by a lake that is now elevated above the water table

lake-level control structure - a low head dam placed at the outlet of a lake to control the lake level

laminar flow - the smooth pattern in which water flows in a uniform rate

land cover - primary character or use of an area of land (i.e., forest, wetland, agriculture, urban, etc.)

large woody structure - trees, logs, and logjams that are in a stream or lake

lentic - pertaining to or living in still water

GLMD – Geological and Land Management Division

macroinvertebrates - animals without a backbone that are visible by the human eye

mainstem - the primary branch of a river or stream

mainstem segment - reaches of a river with similar ecological characteristics

MDCH - Michigan Department of Community Health

MDEQ - Michigan Department of Environmental Quality

MDNR - Michigan Department of Natural Resources

MGD - Million gallons per day

MNFI - Michigan Natural Features Inventory

mitigation - action required to be taken to compensate for adverse effects of an activity

moraine - a mass of rocks, gravel, sand, clay, etc. carried and deposited directly by a glacier

morphology - pertaining to form or structure of a river or organism

moss animals - taxa belonging to the Bryozoa phylum

naturalized - animals or plants previously introduced into a region that have become permanently established, as if native

niche - the position or function of an organism in a community of plants and animals

NPDES - National Pollution Discharge Elimination System

nonpoint source pollution - pollution to a water course that is not attributable to a single, well-defined source, e.g., sediment resulting from poor agricultural practices

oligotrophic - a lake characterized by a low accumulation of dissolved nutrients and having a high oxygen content

outwash – area of glacial meltwater that carried away fine silts and clays leaving coarser sand and gravels behind

panfish community - a group of fish in the centrarchid family commonly harvested by anglers to eat. Species include bluegill, black crappie, pumpkinseed sunfish, and rock bass

Parabolic cross section – a stream cross section that resembles a parabola (geometric shape consisting of the cross section of a right circular cone).

P.A. - Public Act

PCB - Polychlorinated biphenyl

peaking mode - operational mode for a hydroelectric project that maximizes economic return by operating at maximum possible capacity during peak demand periods (generally 8 am to 8 pm) and reducing operations and discharge during non-peak periods

perched culvert - an improperly placed culvert that fragments habitat by creating a significant drop between the culvert outlet and stream surface

percolate - to pass a liquid through small spaces or a porous substance

pestilent – noxious species that out compete native or more socially valuable species

physiography - the science of physical geography (landform and texture)

plankton - floating or drifting organisms in a body of water

point source pollution - pollution to a water course that is attributable to a single, well-defined source, e.g., outfall of a wastewater treatment plant

potamodromous - fish that migrate from fresh water lakes up fresh water rivers to spawn; in the context of this report it refers to fish that migrate into the Kalamazoo River from Lake Michigan

reach - a section of river

riffle - a shallow area extending across the bed of a stream where water flows swiftly so that the surface is broken in waves

riparian - adjacent to or living on the bank of a river; also refers to the owner of stream or lakefront property

riverine - of or pertaining to a river

rotenone - a natural substance found in roots of plants in the pea family; it is used as a toxicant to all gill breathing animals; it is not toxic to air breathing animals

run habitat - fast non-turbulent water

run-of-river - instantaneous inflow of water equals instantaneous outflow of water; this flow regime mimics the natural flow regime of a river on impounded systems

salmonids - collective group of all trout and salmon in the family Salmonidae

savanna - a treeless plain or grassland with scattered trees

sedimentation - a process of depositing silt, sand, and gravel on a stream or river bed

sessile - to be attached or associated with the substrate of a lake or stream

Shannon-Weiner diversity index - a probability statistic that measures the number of groups of information in all the information

sport fish - fish valued by anglers

standing crop - abundance of organisms at a site, expressed in terms of number or biomass per unit area

surficial - referring to something on or at the surface

TFM - 3-trifluoromethyl-4-nitrophenol

thermocline - a layer of water between the warmer surface zone and the colder deep-water zone in a thermally stratified body of water (such as a lake), in which the temperature decreases rapidly with depth

throughflow - the act of water moving within soil (but not as part of an aquifer or groundwater)

tile - an underground enclosed drainage system generally installed for draining farmland

till - a mix of glacial clay, sand, boulders, and gravel

TMDL – total maximum daily loading

topography - the configuration of the earth's surface including its relief and the position of its natural features

tributary - a smaller stream feeding into a larger stream, river, or lake

turbidity - the measure of suspended sediments in the water column

USDA - United States Department of Agriculture

USFWS - United States Fish and Wildlife Service

USGS - United States Geological Survey

vascular - plants having a xylem and phloem

veliger - the free-swimming larval stage of zebra mussels

vernal - relating to, or occurring in, spring

viability – the capability of living, growing, and developing as a species.

WD - Water Division

watershed - a drainage area or basin, both land and water, that flow toward a central collector such as a stream, river, or lake at a lower elevation

wastewater treatment - the treatment of sewage

wetland - those areas inundated or saturated by surface or groundwater at a frequency and duration enough to support types of vegetation typically adapted for life in saturated soil; includes swamps, marshes, and bogs

xylem - woody tissue of a plant