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Muskegon River Watershed Assessment

Richard P. O'Neal

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EXECUTIVE SUMMARY

This assessment for the Muskegon River watershed is one of a series being prepared by Michigan Department of Natural Resources, Fisheries Division, for river basins in Michigan. This assessment describes fisheries and related resources, identifies issues that are of concern to fishery managers, and outlines management options to address those issues. The assessment provides an organized approach to identifying opportunities and solving problems. It provides a mechanism for public involvement in management decisions; allowing citizens to learn, participate, and help determine decisions. It also provides an organized reference for Fisheries Division personnel, other agencies, and citizens who need information about a particular aspect of the river system.

The document consists of four principal sections: introduction, watershed assessment, management options, and public comment and response. The watershed assessment is the nucleus of the document. Physical, biological, and cultural characteristics of the watershed are described under twelve sections: geography, history, biological communities, geology and hydrology, channel morphology, soils and land use patterns, special jurisdictions, recreational use, dams and barriers, water quality, fisheries management, and citizen involvement.

Seventy-seven management options are provided. The options are consistent with the mission statement of the Michigan Department of Natural Resources, Fisheries Division and convey four approaches to correcting problems in the watershed. These include options to protect and preserve existing resources, options requiring additional surveys, opportunities for rehabilitation of degraded resources, and opportunities to improve areas or resources beyond existing conditions. Options are related primarily to aquatic communities; but wildlife, botanical, and social factors are noted where they are important and directly affect aquatic communities. Some options are simple but most are complex, sometimes involving management of the entire watershed which may take many years to accomplish. Management options listed are not necessarily recommended by Fisheries Division, but are intended to provide a foundation for public discussion and comment, eventually resulting in the selection of acceptable management objectives for the Muskegon River and tributaries.

The first draft of the assessment was available for public comment from March through August 1995. Comment from two public meetings and written comments were incorporated into the final assessment. A fisheries management plan will be completed based on the assessment and public comment received. The assessment process is continuous and updates can be completed when needed and new information becomes available.

The Muskegon River is located in north-central Michigan and incorporates over 2,350 square miles of land. The river is 212 miles long, with a 575 ft drop in elevation between the source and the mouth at Lake Michigan. Most of the watershed is contained within eight counties: Roscommon, Missaukee, Clare, Osceola, Mecosta, Montcalm, Newaygo, and Muskegon. Approximately 94 tributaries flow directly into the mainstem and primary tributaries include West Branch of the Muskegon River, Clam River, Middle Branch River, Hersey River, Little Muskegon River, Bigelow Creek, Brooks Creek, and Cedar Creek.

Numerous agencies have regulatory responsibilities that affect the river system. These range from small local governments to large federal bureaucracies. The Federal Energy Regulatory Commission has authority over hydroelectric dams. The US Fish and Wildlife Service, US Forest Service, US Department of Agriculture Natural Resources Conservation Service, and US Environmental Protection Agency have responsibilities for land and natural resources management. The Michigan

Departments of Natural Resources and Environmental Quality manage many natural resources and regulatory activities. Local agencies conduct zoning and other land management activities. County drain commissioners have responsibility for legally designated drains and some lake-level control structures.

There are numerous local government interests including counties, villages, towns, and cities within this watershed. Interest from organized recreational groups is widespread and includes many local hunting and fishing groups in the basin. The river also draws interest from Lake Michigan fishing groups because of migratory fish species using the river. A few environmental groups are locally active in the Muskegon area, focusing on local contamination problems.

Human settlement in this watershed occurred throughout the early to late 1800s and was influenced by exploitation for copper and white pine throughout the state. Lumbering had significant affects on river habitat through log transport down the river and deforestation of the uplands. The development of large hydroelectric dams began in the late 1800s and many smaller dams have been established on the tributaries. Agricultural and urban development has been moderate. Nutrient and chemical pollution peaked in the mid 1900s and had significant effects, especially in Muskegon Lake. The introduction or invasion of pest animals also had notable effects on aquatic communities in the river.

Today, agricultural and urban developments are moderate. Erosion of sediment into streams from uplands is significant. Drainage systems are established on many tributary streams. Irrigation is not widespread in the mainstem but is sometimes a significant withdrawal from tributaries. Use of floodplains for development and agriculture is substantial in many areas. Virgin timber was logged from the entire watershed but secondary timber growth is extensive.

The channel of the Muskegon River has been adversely altered. Most of the moderate and high gradient reaches have been impounded. High gradients produce high diversity stream channels favorable to aquatic communities. Removal of riparian vegetation, especially old growth forest, has reduced important wood habitat in the channel. Many tributaries have been dredged and straightened.

Numerous dams and impoundments exist in the watershed. Five major impoundments are on the mainstem. Three of these are created by operating hydroelectric dams located midway in the river. One is a retired and partially-removed hydroelectric dam at Big Rapids. The last mainstem dam is a wildlife flooding located at the headwaters. Most of the tributary dams are non-hydropower used for aesthetics, swimming, or wildfowl habitat. These dams are detrimental to the river because they impound most high gradient habitat, reduce river habitat, create water flow fluctuations, trap wood habitat and sediments, kill fish, fragment habitat that reduces the genetic integrity fish populations, and block potamodromous fishes from much of the river. As part of federal hydroelectric dam relicensing procedures, a settlement agreement was negotiated in 1994 between the resource agencies and Consumers Power Company. This settlement agreement provides mitigation for some effects the hydroelectric dams have on the river.

Water quality is good in most parts of the watershed. The mainstem is affected by moderate nutrient enrichment and excessive sediment bedload. Localized water quality problems exist near metropolitan sites and below dams. Chemical contaminants causing public health advisories on eating fish in the watershed include mercury, PCBs, chlordane, and PAHs. DDT, DDE, and dioxins are other chlorinated organic chemical contaminants in fish that can affect the health of wildlife species. Organic contaminants in fish have been reduced significantly since the 1970s and are primarily fond in species using Lake Michigan for part of their life history. Mercury is a concern for inland species and levels do not appear to be decreasing. Atmospheric emissions appear to be the largest source of mercury in and near the watershed. Sources for most contaminants are still present in the watershed but discharges appear to be low.

Stable flows generally produce good conditions for fish reproduction and survival. Stable discharge is supported by permeable geology's that provide groundwater to streams. Geologic landforms in the watershed are moderate to high in permeability, which is reflected by intermediate stability in mainstem discharge. The upper river (upstream of Big Rapids) appears to have the most unstable high flows. Hardy Dam is moderating high flows below Croton. Before 1994, hydroelectric dams destabilized low flows and significantly reduced habitat below Croton. The settlement agreement establishes provisions for near normal flows and habitat conditions should improve in the future. Flows in some tributary streams are less stable because of improper operation of lake-level control structures and many are affected by increased surface runoff from agricultural and urban development.

The native fish community in the Muskegon River watershed was composed of 97 species. An additional 12 species colonized through constructed channels or were directly introduced. Current survey records verify the presence of 77 (79%) native species. Of the twenty native species not currently verified, five are most likely extirpated. These include Arctic grayling, lake herring, muskellunge, sauger, and white bass. Three unverified native species may still be present but are not recorded because of limited sampling. These include bloater, lake whitefish, and round whitefish that are currently present in Lake Michigan and seasonally use Muskegon Lake and the lower river for spawning or feeding. The status of the remaining 12 native species not verified in current surveys is uncertain. Additional sampling will be needed to verify their presence or absence. These include spotted gar, mooneye, striped shiner, weed shiner, mimic shiner, pugnose shiner, pearl dace, black buffalo, ninespine stickleback, fantail darter, least darter, and slimy sculpin.

Limited information is readily available on the original aquatic communities in the Muskegon River watershed. However, changes in the fish community of the river are indicated by the disappearance of two species. Arctic grayling had a known riverine stock and the muskellunge most likely had a riverine stock. Grayling have been extirpated from the river system since 1905. Factors contributing to extirpation included overfishing, use of the river for logging, dam (barrier) construction, and habitat changes resulting from settlement. Grayling were very abundant in the Hersey River but the distribution of this species throughout the watershed is not known. The form of muskellunge originally present in the Muskegon River system was the Great Lakes muskellunge. The original distribution of this species in the watershed is not known.

Distributions of other extirpated fish species were not limited to the river. Factors outside the watershed contributed to their demise. Lake herring and sauger were predominantly Lake Michigan species that used the river for part of their life history, and their demise was associated with catastrophic changes that occurred in Lake Michigan fisheries. White bass were an extremely abundant species that primarily used Muskegon Lake and the lower Muskegon River, but the demise of this species may also have been related to changes in Lake Michigan fish species (predators and competitors), along with changes in Muskegon Lake and the Muskegon River. Severe declines in potamodromous stocks have also occurred for walleye, lake sturgeon, and probably lake trout, round whitefish, and lake whitefish. Declines of these stocks were influenced by changes in Lake Michigan and Muskegon Lake, as well as the Muskegon River watershed.

Recent fish community information is not sufficient to accurately document the distribution of most species within the watershed. Fish diversity and biomass are similar to many other large Michigan rivers. The fish community of the mainstem is intermediate in composition between Michigan warmwater and coldwater streams. Warmwater-coolwater species dominate the fish community but coldwater-coolwater fish are present throughout the mainstem. Populations of some species exhibit low recruitment. Hydroelectric dams are negatively affecting aquatic communities below Croton. A number of important pest species are present.

Five species of fish found in this watershed are listed as threatened species in Michigan: sauger, lake herring, lake sturgeon, river redhorse, and mooneye. Sauger and lake herring have been extirpated from the Muskegon River watershed. Lake sturgeon and river redhorse are found below Croton Dam, the distribution limited to the lower river by hydroelectric dam barriers. The presence of mooneye in the watershed is unlikely. There have been no recent reports from anglers nor have they been collected in fisheries surveys.

Two species of fish in the watershed are listed as Michigan species of concern. These are pugnose shiner and spotted gar. Pugnose shiner have been identified in lakes from within the watershed and spotted gar are found in Muskegon Lake. The weed shiner is an endangered species in Michigan and its presence in the watershed is uncertain.

Comprehensive studies of invertebrates, amphibians and reptiles in the watershed are not available. There are 15 invertebrate species listed on the Michigan Natural Features Inventory, including eleven terrestrial insects, two mussels, one aquatic snail, and one terrestrial snail. Five reptiles are listed on the Natural Features Inventory including three snakes and two turtles. Two mammals and five birds are listed on the Natural Features Inventory.

Outdoor recreation is extensive in the watershed. Fishing is limited over most of the mainstem because of fish blockage by hydroelectric dams. The impoundments cover most of the high gradient river sections and limit river boating recreation and fishing. Access is limited in several areas of the mainstem and tributaries, along with handicap accessible fishing locations.

The type of game fish present at specific locations vary with the character of the river. Fishing from the headwaters to Croton Dam is moderate to poor. From the headwaters to the confluence with the Middle Branch River, there are 85 miles of low gradient mainstem and the primary game fish is northern pike. There are approximately 40 river miles between the confluence with the Middle Branch River and Big Rapids, with 24 miles of moderate gradient and the rest low gradient. Smallmouth bass and walleye are the primary game species, along with stocked trout. Rogers, Hardy, and Croton dams impound approximately 40 miles of moderate and high gradient stream. Fishing in the impoundments is moderate to poor for yellow perch, walleye, smallmouth bass and crappie. Fishing from Croton Dam to Muskegon Lake is good to excellent. There are approximately 45 river miles in this section with 14 miles of moderate gradient and the rest low gradient. Fishing for walleye, smallmouth bass, and northern pike is good. Fishing for stocked resident trout, steelhead, and chinook salmon is excellent. Muskegon Lake is 4,150 acres and supports a variety of fisheries. Fishing is good to excellent for northern pike, walleye, smallmouth bass, largemouth bass, yellow perch, bluegill, pumpkinseed, black crappie, channel catfish, flathead catfish, steelhead, and chinook salmon.

There is considerable potential for protection and enhancement of fisheries in the river. All biological communities would benefit from stabilization of stream discharge, maintaining natural water temperatures, protection and rehabilitation of wetlands, reducing upland and streambank sediment erosion, protection and rehabilitation of instream and lake vegetation habitat, and dam removal or mitigation of various dam issues. Reintroduction of white bass would benefit Muskegon Lake and the lower river. Reintroduction of Great Lakes muskellunge may be possible. Improvement of native lake sturgeon numbers may be possible. Stocking rainbow trout in Croton and Hardy impoundments may be possible. Stocking resident trout and walleye may be possible in the Big Rapids to Osceola County river section. Fish passage at the hydroelectric dams would benefit the entire river. Species that could benefit include steelhead, chinook salmon, brown trout, walleye, lake sturgeon, river redhorse, and lake trout. Fish passage could significantly increase natural reproduction and angler catch.

INTRODUCTION

This assessment for the Muskegon River Watershed is one of a series being prepared by Michigan Department of Natural Resources (MDNR), Fisheries Division, for river basins in Michigan. This assessment describes fisheries and related resources, identifies issues that are of concern to fishery managers, and outlines management options to address those issues. This is the final assessment. However, comments will still be accepted and incorporated into any revisions. A fisheries management plan is being developed that will recommend management strategies to be implemented.

Anyone who reviews this assessment and wishes to comment should do so in writing to:

Fisheries Division
Michigan Department of Natural Resources
350 Ottawa Street, N.W.
Grand Rapids, Michigan 49503

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. These documents provide an organized reference for Fisheries Division personnel, other agencies, and citizens who need information about a particular aspect of the river system.

These watershed assessments are intended only to develop and document goals, problems, and objectives for management of river resources. They do not provide detailed data except as needed to describe a problem or support evaluation of management options. They do not incorporate or replace related plans developed by other agencies; when such plans are available, our assessment refers to those plans and identifies common elements.

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 change. All of Michigan's rivers have lost some complexity due to human alterations in the channel and on the surrounding landscape. Therefore, each assessment focuses on ecosystem maintenance and rehabilitation.

River assessments are based on ten principles guiding Fisheries Division activities. These are: 1) recognize the limits on productivity in the ecosystem; 2) preserve and rehabilitate habitat; 3) preserve native species; 4) recognize naturalized species; 5) enhance natural reproduction of native and naturalized species; 6) prevent unintentional introductions of exotic species; 7) protect and enhance threatened and endangered species; 8) acknowledge the role of stocked fish; 9) protect the genetic integrity of fish stocks; 10) recognize that fisheries are an important cultural heritage.

The nucleus of each assessment is a description of the river and its watershed using a standard format. This includes:

Geography - A brief description of the location of the river and its watershed; a general survey of the river from its headwaters to its mouth is provided.

History - A brief history of human uses and modifications of the river and watershed.

Biological Communities - Species present, both in the past and today, in and near the river, with emphasis on aquatic species, especially fish. Associated mammals and birds, key invertebrate animals, threatened and endangered species, and pest species are also briefly discussed. This section is the foundation of the rest of the plan. Maintenance of biodiversity is an important goal of natural resource management and essential to many goals of fishery management. Species occurrence, extirpation, and distribution are also important clues to the character and location of habitat problems affecting the watershed.

Geology and Hydrology - Patterns of water flow over and through the landscape. This is the principal feature determining the character of a watershed. Water flows reflect watershed conditions that influence temperature regimes, habitat, and perturbations.

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

Soils and Land Use Patterns - In combination with climate, soils and land use determine much of the hydrology and channel form in the river. Changes in land use are often drive changes in river habitats.

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

Recreational Use - Types and patterns of use. A healthy river system provides abundant opportunities for diverse recreational activities.

Dams and Barriers - Affect almost all river functions and ecosystem 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 uses of the river. Degraded water quality may be reflected in simplified biological communities, restrictions on river use, or reduced fishery productivity. Water quality problems may be due to discharges (permitted or illegal) or to non-point source runoff.

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

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

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

Comments received by the Fisheries Division are summarized in Public Comment and Response. A draft of this Assessment was distributed for public comment beginning in March, 1995. Two public meetings were held, on July 12, 1995 in Big Rapids and July 15, 1995 in Muskegon. Written comments received through August 15, 1995 were included in the Public Comment and Response section. Comments were either incorporated in the document or responded to in this section.

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

During development of this assessment, representatives of various management agencies discussed the major management issues within the watershed. Agencies involved in these discussions included: Michigan Department of Natural Resources, Fisheries and Wildlife divisions; Michigan Department of Environmental Quality, Land & Water Management and Surface Water Quality divisions, US Fish & Wildlife Service, and US Forest Service. The major management issues cited by the various agencies are addressed in this assessment.

WATERSHED ASSESSMENT

Geography

The Muskegon River begins in north-central lower Michigan, flowing from Higgins and Houghton Lakes, southwesterly to the City of Muskegon and discharging into central Lake Michigan. The river is 212 miles long and drops 575 ft in elevation between its source and river mouth. Most of the watershed is contained within eight counties: Roscommon, Missaukee, Clare, Osceola, Mecosta, Montcalm, Newaygo, and Muskegon. The watershed incorporates over 2,350 square miles of land. Approximately 94 tributaries flow directly into the mainstem (Figure 1). Major tributaries and landmarks include Higgins Lake, Houghton Lake, Reedsburg Dam, West Branch of the Muskegon River, Clam River, Middle Branch River, Evart, Hersey River, City of Hersey, City of Big Rapids, Rogers Dam, Hardy Dam, Croton Dam, Little Muskegon River, Bigelow Creek, City of Newaygo, Cedar Creek, Muskegon Lake, and the City of Muskegon (Figure 2).

History

Michigan's human population expanded from 4,800 people in 1810 to 212,000 by 1840. Further expansions throughout the state during the middle to late 1800s were influenced by extensive exploitation for copper and white pine. Lumbering throughout this watershed caused extensive damage to the Muskegon River. Logs transported down the river scoured the river channel and destroyed existing habitat for fish and other aquatic life. Watershed drainage and riparian vegetation were decimated by logging and the forest fires that followed. These extensive changes in native forests affected the river system by destabilizing water flow patterns, increasing water temperatures, increasing soil erosion, and decreasing natural woody habitat in the stream. The resulting changes in aquatic habitat had significant negative affects on native fish populations. These negative factors are still present, largely due to dam construction, deforestation for agriculture, and drainage for agriculture and urban development.

Construction of dams began during the late 1800s. The first documented logging dam was constructed at Big Rapids during 1866 and a hydroelectric dam at Newaygo in 1900. Newaygo dam blocked upstream movement of fish to the most productive habitat and all prime spawning habitat in the river. Four additional power dams were constructed between 1905 and 1931. Four of these hydropower dams and numerous small non-hydropower dams are currently present in the watershed. These dams have numerous and significant effects on habitat and aquatic life in the watershed.

Other important human developments during the 1900s were expansion of urban and agricultural land use. Along with factors noted before; nutrient, sediment, and chemical pollution from these sources peaked in the 1950s and 1960s. Nutrient and sediment pollution occurred throughout the watershed, whereas chemical problems were more local, especially in the lower river near Muskegon. Extensive wetland areas were dredged or filled throughout the development period, especially around Muskegon Lake and Muskegon marsh. Human introductions or invasions of exotic fish (alewife, sea lamprey, and common carp) also had significant negative effects on the biological community.

Changes in environmental conditions as a result of human settlement and development caused the demise of many native species. The Arctic grayling was extremely abundant in the Hersey River and present in other tributaries of the upper Muskegon River during the middle 1800s, but had disappeared by 1905 (Vincent 1962; Anonymous 1974). Some species that suffered severe declines in population numbers were lake sturgeon, walleye, elk, pine marten, and prairie chicken.

Many of the negative environmental factors affecting wildlife and fisheries in the watershed are still present. Large scale aquatic habitat problems include destabilized hydrologic conditions, water temperature changes, increased sediment erosion, and decreased instream habitat. These problems occur throughout the watershed and will probably become more severe as urban and agricultural development continues. Some chemical pollution problems have been corrected or have remedial action programs in place. Certain organic chemicals and mercury are still present in sufficient quantity to cause health advisory warnings for fish consumption. Sea lamprey and alewife populations have been controlled at low levels through management programs. However, sea lamprey populations are beginning to increase again and common carp present problems in many places. Little has been done to remedy non-point source pollution from agriculture, county drains, road crossings, and small dams. Hydroelectric dams and impoundments continue to cause many negative effects on the physical and biological features of the river. Limited public land prevents floodplain forest management practices necessary to maintain certain wildlife species.

Biological Communities

Maintaining the natural diversity of plant and animal species is very important to the health of a watershed. Biodiversity is dependent on habitat diversity, which is determined by physical features of the watershed. Changes in natural habitat, environmental quality, and species will cause changes in biodiversity. Examination of species occurrence and distribution in original and current communities provides important clues to the character and location of habitat problems affecting the river ecosystem. Assessment of biodiversity and habitat diversity provides valuable information for proper management of aquatic, wildlife, and forest communities. This discussion of biological features focuses primarily on aquatic resources, especially fisheries, but includes important wildlife and botanical features when they directly relate to management of aquatic resources.

Original Fish Communities

Bailey and Smith (1981) provide an account of native fish species in the Lake Michigan basin and tributaries to Lake Michigan. All species in the Lake Michigan basin and Muskegon River watershed colonized the area during the late Pleistocene Epoch, within the last 14,000 years. Original fish community data were compiled from Bailey and Smith (1981) and Dr. G. Smith (University of Michigan, personal communication; Table 1). Current fish community information was derived from Michigan Department of Natural Resources, Fisheries Division records (1965 - 1993), and Lawler, Matusky, & Skelly Engineers (1991a, 1991b, 1991c, 1991d). Distribution maps for each species are presented in Appendix 1.

The native fish community in the Muskegon River watershed was composed of 97 species (Table 1). An additional 12 species colonized through constructed channels or were directly introduced. Current survey records verify the presence of 77 (79% of original total) native species. Of the twenty native species not currently verified, five are most likely extirpated. These include Arctic grayling, lake herring, muskellunge, sauger, and white bass. Lake herring and sauger were important commercial species in Lake Michigan, that used Muskegon Lake and Muskegon River for spawning. The other three species were all important inland sport fish. Three unverified native species may still be present but are not recorded because of limited sampling. These include bloater, lake whitefish, and round whitefish, that are currently present in Lake Michigan and seasonally use Muskegon Lake and the lower river for spawning or feeding. The status of the remaining 12 native species not verified in current surveys is uncertain. Additional sampling will be needed to verify their presence or absence. These include spotted gar, mooneye, striped shiner, weed shiner, mimic shiner, pugnose shiner, pearl dace, black buffalo, ninespine stickleback, fantail darter, least darter, and slimy sculpin.

Changes in the fish community are indicated by the disappearance of two river species. Arctic grayling had a known riverine stock and muskellunge most likely had a riverine stock. Grayling were extirpated from the river system in 1905 (Anonymous 1974). Contributing factors for extirpation include overfishing, use of the river for logging, dam (barrier) construction and resulting habitat changes. Grayling were very abundant in the Hersey River (Vincent 1962; Anonymous 1974) but the distribution of this species in the watershed is not known. The form of muskellunge originally present in the Muskegon River system would have been Great Lakes muskellunge (Seelbach 1988). The original distribution of this species in the watershed is not known.

Home ranges of other extirpated fish species were not limited to the river suggesting that factors outside the watershed contributed to their demise. Lake herring and sauger were predominantly Lake Michigan species that used the river for part of their life history and their demise was associated with catastrophic changes that occurred in Lake Michigan fisheries (Smith 1970). White bass were an extremely abundant species that primarily used Muskegon Lake and the lower Muskegon River, but the demise of this species may also have been related to changes in Lake Michigan fish species (predators and competitors), along with changes in Muskegon Lake and the Muskegon River.

Lake trout, lake whitefish, and round whitefish may have been extirpated from the river above Newaygo by dam construction. When these species were abundant in Lake Michigan, they often had river spawning stocks. For example, a population of round whitefish still persists in the upper Au Sable River, isolated from Lake Huron by several dams (MDNR, Fisheries Division records). Dams have blocked access to nearly all spawning areas since the year 1900, which may have eliminated these stocks. Croton Dam currently limits access to the upper river.

Five species of fish found in the watershed are listed as threatened species in Michigan: sauger, lake herring, lake sturgeon, river redhorse, and mooneye. Sauger and lake herring have been extirpated from the watershed. Presently lake sturgeon and river redhorse are found in the mainstem up to Croton Dam (Table 2). The distribution of these species appears to be limited to the lower river by hydroelectric dam barriers. The presence of mooneye in the watershed is unlikely.

Bailey and Smith (1981) list this species in tributaries of Lake Michigan, but in the Muskegon basin no fossil records are known, nor have any been captured in surveys; however, neither have there been surveys targeting this species, so a slight possibility exists that they may be present.

Two species of fish in the watershed are listed as Michigan species of concern. These are pugnose shiner and spotted gar (Table 2). Pugnose shiner have been collected in lakes within the watershed and spotted gar are found in Muskegon Lake. Latta (1996) indicated the pugnose shiner should be considered threatened in Michigan. The weed shiner is an endangered species in Michigan and its presence in the watershed is uncertain. Latta (1995) indicated the weed shiner should be considered extirpated in Michigan

The best historical information for a fish species in the Muskegon River is on walleye (Schneider and Leach 1979; Schneider et al. 1991; Day 1991). Schneider and Leach (1979) noted that information on the original stock was lacking due to early development of the logging industry, around 1838.

Commercial fisheries were not established until about 1880 due to lack of a channel between Muskegon Lake and Lake Michigan that could support commercial fishing boat traffic. By this time, logging was most likely affecting the walleye population. This is indicated by commercial catch records, that show low catches of walleye until about 1907, followed by significantly higher catches. The increase in population numbers was attributed to construction of the Newaygo Dam (in 1900), that may have improved spawning habitat and recruitment by trapping excessive river bed sediment caused by deforestation and logging activities. Population levels remained relatively high until the late 1950s. Spawning runs were estimated at 114,000 fish in 1953 and 139,000 fish in 1954 (Crowe 1955). These levels were near the high end of the range for this period. A severe decline in the population occurred during the 1960s and the spawning run was estimated at about 2,000 fish in 1975. A stocking program was initiated in 1978, which increased the spawning run to about 43,000 fish in 1986 (Day 1991). Although more recent population data are not available, the current spawning run is believed to be near the 1986 level based on observations by Fisheries Division personnel during annual walleye egg-take.

Schneider and Leach (1979) attributed the severe population decline in the 1960s to lack of recruitment. Recruitment problems were not attributed to spawning or water quality conditions in the river, but to dramatic changes that were occurring in fish communities of Muskegon Lake and Lake Michigan. Severe declines in native yellow perch and white bass, and large increases in gizzard shad and the introduced alewife in Muskegon Lake indicate these changes. Water quality problems with nutrients and chemical pollutants were significant in Muskegon Lake. Commercial fishing and sea lamprey predation also may have contributed to the decline in the walleye population, but these were not considered primary factors (Schneider and Leach 1979). Day (1991) provided some evidence that suggests predation and competition for food, by alewife and gizzard shad, may not have been severe enough to directly affect walleye recruitment in Muskegon Lake.

Lack of information on biological communities in Muskegon Lake during this period makes absolute determination of the cause of the recruitment problem difficult. Lack of recruitment may still be present today. Following initiation of a stocking program in 1978, the spawning run of walleye increased to about 43,000 fish. This was a dramatic increase but it is not probable the population has attained the higher levels measured historically of over 100,000 fish. It is unknown if natural recruitment of walleye is currently present in the Muskegon River. Day (1991) found significant numbers of natural walleye fry in the river during 1986, but was unable to find fingerlings in Muskegon Lake. Another change in the river that may be affecting natural recruitment was the removal of Newaygo Dam in 1969. This opened an additional 14.4 miles of good spawning habitat to walleye. However, the thermal character of the spawning grounds may have been changed. Schneider et al. (1991) reported water temperatures on spawning grounds below Croton Dam were less than laboratory optima for walleye egg incubation and fry feeding. The hydroelectric impoundments are delaying spring water temperatures increases below Croton (refer to **Water Quality**). Schneider et al. (1991) also found that strong year-classes of walleye were produced during years with exceptionally warm spring temperatures. However, strong year-classes also were related to low adult walleye population densities and occurred in about ten year cycles (Schneider and Leach 1979). Again, lack of information on population levels, recruitment, food and habitat of walleye in the Muskegon River makes management of this population difficult.

In summary, there is limited information available on the original fish communities of the Muskegon River. This makes evaluation of current biological conditions difficult. The information provided is limited to a list of original species, listings of extirpated species, and other species showing signs of problems. There is no information showing the original distribution of fish or any quantitative data to show which species were most abundant. The extirpation of the Arctic grayling, from the Hersey

River, is the one documented piece of information showing a severe decline in a riverine stock of fish. It is also probable that a riverine stock of Great Lakes muskellunge was extirpated. Severe declines in potamodromous stocks have also occurred for walleye, sauger, white bass, lake sturgeon, and probably lake trout, lake herring, round whitefish, and lake whitefish. Declines of these stocks were influenced by changes in Lake Michigan and Muskegon Lake, as well as the Muskegon River watershed. The discussion provided on the historical abundance of walleye in the Muskegon River clearly indicates the lack of information on original fish communities, the dramatic changes that have occurred in fish communities and the lack of information on causative factors contributing to these changes. It is probable that more than one factor contributed to the dramatic population fluctuations of walleye in the river.

Present Fish Communities

Fish community samples were collected at several mainstem sites during 1990 through 1993 (Table 3). Some physical factors important in determining fish diversity in specific river sections include total stream discharge, water velocities, temperature, and composition of bottom materials. Water discharge increased from the most upstream site to the most downstream site. Discharge and water velocities were very similar at Croton and Newaygo. Water velocities were similar between Hersey and Clare County, but these sites had lower water velocities than downstream sites because they were located in lower gradient portions of the river. Temperature changes with the size of the stream and the amount of groundwater entering. Bottom material components were similar at all sites. The composition of rocky (gravel, cobble, boulder) substrate ranged from 34% to 65% among sites. The percentage of sand was similar at Croton, Hersey, and Clare sites. The Hersey site had a relatively low component of coarse organic materials (logs and branches) and silt.

A current list of species and biomass figures for the mainstem sites is provided in Table 4. Species were grouped into five broad categories represented by similar habitat requirements. These categories include coldwater-coolwater river species (species typically found in coldwater or coolwater streams with high concentrations of dissolved oxygen); coolwater-warmwater river species (species tolerant of both cool and warmwater streams); bayou and impoundment species (species that typically require or prefer lentic (non-moving) water as part of their habitat); sand tolerant forage species (species that can tolerate more general habitat requirements including sand sediment); and miscellaneous species (species relatively low in abundance, and those identified only to genus). Species within these broad habitat groups also have more specific habitat requirements that will be included in the discussion as needed.

Species diversity was highest at Hersey and Clare County. Both sample sites were furthest upstream and above the hydroelectric dams. Species diversity was slightly lower at Newaygo and substantially lower at Croton. The Croton site was located immediately below the discharge of Croton Dam. Total number of fish per acre followed a pattern similar to species diversity. Biomass of fish per acre was similar at Hersey and Newaygo, and lowest at Clare County.

Native (burbot, mottled sculpin, and longnose dace) coldwater-coolwater river species were common and relatively abundant at the Clare, Hersey, and Newaygo sites. The biomass of burbot was higher at the Clare site and the biomass of stocked trout was higher at the Newaygo site. Large numbers of young burbot were present at Hersey and this was likely a function of favorable habitat (moderate water velocities and sufficient cobble substrate) at this site. The coldwater-coolwater group was lower in abundance at the Croton site.

Coolwater-warmwater river species dominated the fish community at all four sites. In particular, redhorse and sucker species represented the largest portion of fish biomass. Biomass and number of northern pike were higher at the Clare site. Number of northern pike was high at the Hersey site. Biomass of walleye was higher at Newaygo. Forage species and juveniles of many species in the coolwater-warmwater group were numerically important at all four sites.

Species that prefer bayou and impoundment habitat were lower in abundance at all sites. However, common carp were an important component of the fish community at the Croton site, located just below Croton Impoundment. Carp were not present at upstream sample sites. Somewhat higher numbers of bayou and impoundment species at the Clare site was probably the result of associated wetlands in this river section.

Sand-tolerant forage species were most abundant at the Clare and Hersey sites, which reflects predominantly sand substrate at these locations.

The Croton site was very similar in habitat and river location to the Newaygo site, yet the fish community showed distinct differences. Total biomass, total abundance and species diversity were all substantially lower at Croton than at Newaygo. Coldwater-coolwater species were much lower in abundance. Common carp, an impoundment associated species in this river, was the largest single biomass component at Croton, whereas native river species dominated biomass at all other stations. Carp can thrive in rivers where water quality has been degraded (Nelson and Smith 1981). Stream discharge regulation and water quality degradation by hydroelectric dams, are affecting the fish communities in the river below Croton (refer to **Geology and Hydrology** and **Water Quality**).

The hydrologic characteristics of the Muskegon River system are intermediate between Michigan coldwater streams and warmwater streams (refer to **Geology and Hydrology**). Fish community characteristics reflect this. Average fish biomass and percentage of game fish in the Muskegon River fish community are intermediate among larger southern Michigan rivers (Table 5). Combined composition of redhorses, suckers, and carp is similar to other rivers. However, the composition of carp in the Muskegon River fish community is low, indicating good water quality. Carp are more tolerant of warm water and polluted stream conditions than native redhorses and suckers, and typically will form a large component of the bottom feeding fish community at degraded river sites. Muskegon River data (Table 5) do not include data from the sample site affected by Croton dam, where the largest biomass component of the fish community was carp. Croton impoundment is affecting water quality in the down stream river section (refer to **Water Quality**).

The native burbot is an important indicator species found in Michigan streams needing stable hydrology and moderately stable coolwater. Burbot are found throughout the Muskegon River system and are also found in other large Michigan rivers with moderately stable hydrology, including the Paw Paw River (Dexter 1991) and Thunder Bay River (Paul Seelbach, MDNR, Fisheries Division, personal communication). Typical Michigan warmwater streams that do not contain burbot include the St. Joseph (Towns 1988), Raisin (Towns 1985), Battle Creek (Towns 1987), and Grand (Nelson and Smith 1981) rivers. The coldwater-coolwater nature of the Muskegon River is very important when considering fishery management objectives for the mainstem. Management for trout species can be considered along with more typical coolwater-warmwater species such as smallmouth bass, walleye, and northern pike. This intermediate or marginal coldwater feature is very important when considering watershed protection. Many tributaries are coldwater, supporting trout and other coldwater biota (refer to *Designated Trout Streams*). These tributaries discharge cold water into the mainstem and provide a broad network of interconnecting habitats for coldwater species in the system. Changes in watershed land uses, drainage patterns, and dams, that disrupt system hydrology, can readily alter the thermal characteristics of the river (refer to **Soils and Land Use Patterns**).

The importance of maintaining the marginal coldwater nature of the mainstem can be shown by comparing its fisheries to Michigan warmwater streams. The primary river-game fish species in the Muskegon River are walleye, northern pike, smallmouth bass, brown trout, and rainbow trout. Resident walleye, northern pike, and smallmouth bass numbers are comparable to other Michigan rivers supporting moderate sport fisheries (Table 6). Smallmouth bass (>12") numbers in the Hersey area are comparable to numbers in the Huron River, one of the better smallmouth bass streams in southern Michigan (Merna 1990). The number of larger bass present in the Hersey area is most likely the result of low fishing pressure. Number of total catchable fish present at Newaygo on the Muskegon River is significantly higher than at any other site on the Muskegon River, or other large Michigan rivers supporting only warmwater fish (Table 6). This is the result of stocking rainbow and brown trout in this river section. Coldwater-coolwater fisheries management in the mainstem provides larger numbers of fish to anglers and improved recreation.

Tables 7 and 8 provide length frequency distributions of rainbow trout, brown trout, walleye, northern, pike, and smallmouth bass. Healthy fish populations contain large numbers of young fish. Rainbow trout, brown trout, smallmouth bass, and northern pike all have very low numbers of young fish. This information indicates reproduction or recruitment is a problem. Low recruitment can be caused by many factors, including limited spawning areas, blockage of spawning areas by barriers, covering spawning areas by siltation, excessively low or high water flows, unstable water temperatures, and poor water quality. The nursery area for walleye is Muskegon Lake (MDNR, Fisheries Division, survey records; refer to **Biological Communities**). The adult walleye population found at Hersey is most likely supported by the stocking program.

Some additional electrofishing samples were collected in the upper river, between Hersey and Reedsburg Dam, during 1992. This sampling provided information regarding distribution of smallmouth bass in the river. The upper distribution of smallmouth bass is limited to the mainstem at the confluence with the Middle Branch River. This also appears to be the lower limit of adult northern pike populations in the upper river, based on length frequency data (Table 8). This information will be discussed in more detail in **Fishery Management**.

Recent fish community surveys did not capture all species known to be present in the fish community. Some important additions include a smallmouth bass population below Newaygo. This river section was not sampled but a moderate sport fishery for smallmouth bass is present. Important seasonal species present below Croton include steelhead, chinook salmon, and walleye. Muskegon Lake has numerous species of fish including smallmouth bass, largemouth bass, northern pike, walleye, bluegill, crappie, yellow perch, and flathead catfish.

Aquatic Invertebrates

Comprehensive studies of invertebrates in the watershed are not available. Michigan Department of Environmental Quality (MDEQ), Surface Water Quality Division conducted surveys on 19 tributaries and various mainstem locations between 1954 and 1994 (Appendix 2). Many of these surveys were related to evaluating point source discharges on an affected water body.

Currently, there are 15 invertebrate species, found at 18 locations, listed in the Michigan Natural Features Inventory (Table 2). Eleven species are terrestrial insects and 7 of these are butterflies. The other four species are mollusks including two mussels, one aquatic snail, and one terrestrial snail. Five species are threatened, four are proposed threatened, and nine are special concern species.

Amphibians and Reptiles

Comprehensive studies of amphibians and reptiles in the watershed are not available. There are no amphibians listed on the Michigan Natural Features Inventory for the Muskegon River watershed.

Five reptiles, at 12 locations, are listed on the Michigan Natural Features Inventory for the watershed (Table 2). The Kirtlands snake is endangered, and the spotted turtle, wood turtle, black rat snake, and massasauga are special concern species. Wetlands and suitable nesting habitat are factors important for protection.

Wood turtles require sandy banks, along with other habitat requirements, for successful nesting. Habitat requirements for this species need to be considered in projects targeted at controlling sediment to the river.

Significant turtle mortalities occur annually along highway US 31 in Muskegon County. This highway crosses the river and this extensive marsh system that is the principal route for turtle migrations. Turtles migrating across this highway are killed by cars in substantial numbers, especially during spring egg-laying season.

Mammals and Birds

Principal game animals currently present in the watershed include white-tailed deer, black bear, fox and gray squirrels, cottontail rabbit, snowshoe hare, ruffed grouse, woodcock, raccoon, fox, coyote, beaver, mink, muskrat, turkey, and pheasant.

Extirpated species include eastern timber wolf, mountain lion, lynx, marten, fisher, moose, elk, prairie chicken, sharptail grouse, spruce grouse, and passenger pigeon (MDNR, Wildlife Division, personal communication). Some reasons contributing to extirpation of these species include loss of habitat, fragmentation of habitat (especially old growth forest), extermination by humans, unregulated harvest, brain worm disease, and forest fire suppression.

Two mammals are listed on the Michigan Natural Features Inventory (Table 2). Marten are threatened and woodland vole are of special concern. Maintaining suitable old growth forest is important to the woodland vole. Marten have been reintroduced into some areas of Michigan, but not in the Muskegon River watershed.

Eight birds are listed on the Michigan Natural Features Inventory (Table 2). Piping plover, Kirtland’s warbler, loggerhead shrike, and king rail are endangered. Common loon, osprey, and bald eagle are threatened. Black-crowned night-heron are of special concern. Problem factors include habitat loss, loss of nest sites, human interference (lack of buffer zones), contamination from chemicals, egg predators, and commercial fish nets.

Other Natural Features

Other natural features found in the watershed include great blue heron rookeries at six sites and a champion tree at one site (Table 2). Special plant communities are found at 17 sites. Special geologic features are found at 3 sites. There are 53 plant species, at 67 locations listed on the Michigan Natural Features Inventory for the watershed. Two are endangered, 25 are threatened, and 26 are special concern species.

Ground water seeps are not listed on the inventory, but are an important natural feature because male turkeys use these areas for wintering grounds.

Pest Species

Important pest species include sea lamprey, rusty crayfish, and common carp. Sea lamprey use the river below Croton for spawning and as a nursery. Selective chemical poisons are currently used for killing larval lamprey. Common carp are distributed throughout the river system and are a naturalized species. Non-native rusty crayfish often exclude native crayfish through competition. This is a southern species that apparently was introduced by bait dealers and anglers. Rusty crayfish now appear to be the dominant crayfish species in the mainstem of the Muskegon River in and near the hydroelectric impoundments (Lawler, Matusky, & Skelly Engineers 1991c) and is present in Tamarack Creek, a tributary stream.

The alewife is an introduced species that migrates into the lower river in massive numbers for spawning. This species became so abundant in Lake Michigan during the 1950s and 1960s, that swimming beaches could not be used due to large numbers of rotting alewife from natural mortalities. The abundance of this species also affected many native species through competition and predation. Coho and chinook salmon were introduced into Lake Michigan in the late 1960s, by the Michigan Department of Natural Resources, Fisheries Division, to control the alewife population. Alewife populations are currently controlled through predation by salmon and steelhead. Alewife are considered a pest species in the Muskegon River watershed because they are suspected to affect native species, for example walleye, through competition and predation.

White perch recently were found in Muskegon Lake. White perch compete with white bass and may inhibit the rehabilitation of this species.

Native chestnut lamprey are a parasite on fish and sometimes can be a pest, especially when lamprey numbers are high in combination with trout populations. Chestnut lamprey are abundant above Rogers Impoundment.

The zebra mussel has recently been found in Muskegon Lake. It is expected to colonize all Michigan waters. The effects this species will have are unknown.

Other pest species include purple loosestrife, Eurasian water milfoil, curly leaf pondweed, gypsy moth, jack-pine and spruce budworms, forest tent caterpillars, mute swans, and sometimes deer, beaver, and muskrat.

Geology and Hydrology

One critical physical factor to aquatic life is the hydrology, or water flow patterns, of a river. In Michigan, stable flows generally produce good conditions for fish reproduction and survival. Soils and geology in the watershed determines hydrology. In streams where groundwater is the principal water source, stable flow patterns occur. These patterns are characterized by low seasonal and daily fluctuations in discharge. Stable flows promote stable habitat in the form of diverse bottom substrates, stable instream cover, moderate water velocities, and moderate water temperatures. Unstable water flow patterns occur in streams with high contributions of surface water runoff, and are characterized by high seasonal and daily fluctuations in discharge. During periods of rain or snow melt, flows increase quickly and to high levels that cause increased water velocities, increased sediment erosion, removal of instream cover, and decreased bottom substrate diversity. During drought conditions, excessively low flows occur that cause extremes in water temperatures, and expose and reduce instream cover and bottom substrates. Factors that destabilize river hydrology, by increasing surface water runoff or directly regulating flows, include urban and agricultural land development, logging, drains, irrigation, water discharges, hydroelectric dams, and lake level control structures.

Along with stream discharge, other physical features that determine types of habitat and biological communities in a river include water quality (temperature, oxygen, nutrients, pollutants), channel characteristics and gradient, composition of bottom materials, and stream velocities. Many of these physical features are interrelated and a myriad of factors, some natural but mostly human induced, affects habitat in river systems.

Geology and Soils

The entire Muskegon River watershed is supported by glacial aquifers composed of lacustrine sand, outwash and glaciofluvial deposits, and till. Hydrologic soil types providing good rainwater infiltration are deep formations of sand, gravel, and coarse-textured till materials. Geologic or glacial landforms supporting these types of soils include glacial outwash and moraines of coarse textured till. Soil types with low infiltration rates are clays and fine textured tills, or other soils with high water tables or shallow clay layers near the surface.

Glacial landforms (permeable geology) supporting groundwater inputs are relatively constant, at about 88% of the watershed acreage, from the headwaters to the mouth (Table 9). The basin contains moderately high levels of permeable soils. Based on Soil Conservation Service soil texture classifications, soils in the watershed range from 42% to 78% permeable (permeable classification including high and moderate permeability soils combined). The percentage of permeable soils increases from Houghton Lake to Croton, then remains stable to the mouth (Table 9). The amounts of permeable glacial landforms and soils of the Clam River are moderately high. The amounts of permeable glacial landforms and soils of the Little Muskegon River and Tamarack Creek are high.

Stream Discharge

Mean annual discharge for the Muskegon River at Newaygo is 1969 cubic feet per second (cfs). Flows have not been recorded below Newaygo. Flows reported at USGS gauging stations at Merritt and Evart are not under the influence of regulation by Rogers, Hardy, or Croton hydroelectric dams (Table 10). The Newaygo gauge is located below the hydroelectric dams so seasonal and daily flows, at this gauge, are affected by regulation of flows at hydroelectric dams. The highest daily flow recorded at Newaygo since 1910, occurred during September 1986, when peak discharge was 23,200 cfs and the river was near a 100 year flood event (Blumer et al. 1992). The lowest daily flow occurring at Newaygo was in 1965, at 52 cfs. This occurred as a result of flow regulation for repair of a pipeline, and probably had severe effects on the aquatic communities in the river.

Flow stability is critical to support balanced and diverse fish communities in cold water (Richards 1990). Flow stability is known to be important to habitat suitability for pink salmon (Raliegh and Nelson 1985), largemouth bass (Stuber et al. 1982c), smallmouth bass (Edwards et al. 1983), walleye (McMahon and Nelson 1984a), brook trout (Raliegh 1982), brown trout (Raliegh et al. 1986b), and chinook salmon (Raliegh et al. 1986a).

Rivers with stable flows have high summer drought flows (baseflows) and low flood flows. As discussed earlier, stable flows are promoted by permeable soils and low surface runoff of rainwater. Baseflow yield is a measure of the amount of water that comes into the system as groundwater. Baseflow yield is determined by dividing mean summer (August) drought flow by drainage area, and is generally expressed as stream discharge per square mile. Dividing by drainage area standardizes data for comparison among different sites. USGS data on late summer flows for Michigan streams estimates the Muskegon River watershed has a baseflow yield of 0.20 to 0.40 cfs per square mile (Anonymous 1987b). This value is moderately high for Michigan (range = <0.03 to >0.60) and indicates moderately high levels of groundwater.

Baseflow yield for several sites on the Muskegon River and tributaries is compared to other southern Michigan streams (Figure 3). Baseflows for the Manistee and Au Sable rivers are high and indicate stable groundwater flows and cold summer water temperatures. These two streams exhibit baseflow conditions typical of our better cold water trout streams. Baseflows for the Shiawassee, Cass, and Kawkawlin rivers are low and indicate little groundwater and unstable surface runoff with high water temperatures. These streams support warm water fish communities. Baseflows for the Muskegon River and tributaries indicate intermediate flow stability. These data are consistent with the soil permeability data.

In natural streams, daily flow changes are generally gradual. However, some lake-level control structures and hydroelectric dam operations cause substantial daily flow fluctuations. There are many lake-level control structures on the Muskegon River system. At least some of these structures are operated to strictly meet legally established lake levels and are often operated as on or off structures. When a lake reaches a specific level, the control structure is opened releasing large volumes of water creating flood conditions in downstream areas. When lake levels are below the target level, water flow to the stream is shut off. Lake-level control structures often discharge into small streams where high water flows have significant affects on aquatic communities. Investigation is needed to document the operation of these facilities on the Muskegon River system. The lake-level control structure from Lake Cadillac is operated in a mode that is detrimental to the Clam River (L. Mrozinski, MDNR, Fisheries Division, personal communication). It should be noted that water quality problems are often associated with flow problems below dams and lake-level control structures (refer to **Water Quality**).

Hydroelectric facilities that operate in a "peaking" mode, reduce stream flows by retaining water in reservoirs until specific levels are reached. Then stream flows are rapidly increased as high volumes of water are released for generating electricity. This causes substantial daily fluctuations in stream flows below hydroelectric facilities. These daily fluctuations can destabilize banks, create moving sediment bed loads, disrupt habitat, strand aquatic organisms, and interfere with recreational uses of the river. Aquatic production and diversity are profoundly reduced by such daily fluctuations (Cushman 1985; Bain et al. 1988).

A comparison of 1984 daily flows was made between Rogers Hydroelectric Dam and the Evart gauging station (Figure 4). The Evart gauge is located above Rogers Dam and is unaffected by dam regulation. Erratic daily flow fluctuations present at the Rogers site are typical of peaking operations. Severity of daily fluctuations will vary at different facilities, but generally they create unstable flows conditions. Aquatic organisms may be subjected to alternating drought and flood flow conditions on a daily basis. Negative effects of daily flow fluctuations decreases with increasing distance downstream of a facility. Sometimes, all flow is stopped below dams. This generally would happen if a mechanical failure occurred at the dam. One of these events apparently occurred at Rogers Dam during March of 1984 (Figure 4). This type of event can have drastic effects on aquatic communities below dams.

The daily regulation of stream discharge by hydropower dams is affecting fish communities below Croton Dam. Instream flow-habitat modeling studies (Lawler, Matuskey, & Skelly Engineers 1991c) predicted significant reductions in habitat for aquatic organisms in the river (Table 11). These analysis indicate significant effects on fishery habitat have been occurring between Croton Dam and Newaygo. The 1994 Settlement Agreement (Appendix 2) between resource agencies and Consumers Power Company provides for improved flow regulation at Rogers, Croton, and Hardy hydroelectric facilities. Flows from Croton Dam are to be regulated more near natural conditions, and re-regulation of Hardy dam peaking flows at Croton Dam is expected to improve habitat conditions downstream.

Flow patterns were analyzed by examination of flow duration curves at various gauging stations. Flow duration curves display the proportion of days, during a period of record, when mean daily flows exceed specific discharges. Since different gauging stations on a river, or different rivers, represent different drainage areas, total flow volume may vary considerably between stations. A comparative index for flow duration curves can be developed by dividing each curve by the median value (or 50% exceedence). Flows at each station are then a direct proportion of the median value for that site. Typically graphs of these proportions are evaluated separately for high flows (greater than the median value) and low flows. The most stable streams in Michigan (Au Sable, Manistee, and Jordan rivers) have high flows (5% exceedence values) that are less than twice their median flows, and low flows (95% exceedence value) that are over 80% of their median flows.

Standardized index curves (discharge divided by 50% discharge), for three sites on the mainstem and two tributaries are presented in Figures 5 and 6. On the mainstem, high flows at Merritt and Evart are more unstable than at Newaygo (Figure 5). At Evart, high flows are about 3.5 times higher, and Merritt 3.1 times higher, than median flow, whereas at Newaygo high flows are about 2.5 times higher than median flow. This trend is consistent throughout the range of high flows. The Little Muskegon and Clam rivers have high flow patterns somewhat higher but similar to the mainstem at Newaygo.

The Little Muskegon and Clam rivers have more stable low flow patterns than the mainstem (Figure 6). Low flows in the mainstem are most unstable at Merritt (Figure 6). The reason for flow instability at Merritt is unknown and needs to be determined. The lowest flows at the Evart and Newaygo sites are identical, with low flows about 50% of median flow level. Over the range of low flows, the Evart site is more stable than the Newaygo site. Differences in flow patterns at these two sites is the result of flow regulation at hydroelectric dams. These low flow patterns may also be partly the result of soil characteristics in the basin. Soil permeability generally increases from headwaters to mouth along the mainstem. Although soil permeability would explain lower variability in the high flow ranges, it is not consistent with the greater variability in low flows at the downstream site. Regulation of flows at dams can affect both high and low flows.

Operation of hydroelectric dams on the Muskegon River is complex, because all three dams are located adjacent one another. Water discharge in the river is normally low during winter and high during spring. During winter, water from Hardy Reservoir is used to supplement normal discharge to Hardy Dam and increase electric power production. This creates a draw-down or lowering of the water level in Hardy Reservoir. During spring, water levels in the reservoir are returned to normal by reducing natural river discharge from Hardy Dam. This reduction in natural spring discharge can have the secondary benefit of easing downstream flooding in some residential locations during years with average precipitation. Alterations in flows resulting from winter power production at Hardy Dam generally increases natural winter flows and reduces natural spring flows in the river below Croton Dam. Croton Dam is the last dam in the series and was operated in a peaking mode. This affected flow stability in downstream sections during some portions of the year, and resulted in more unstable annual low flow patterns.

The 1994 Settlement Agreement (Appendix 2) between resource agencies and Consumers Power Company provides for improved flow regulation at the three hydroelectric facilities. Flows from Croton Dam are to be regulated more near natural river conditions so discharge patterns will be different in the future. These can be analyzed when data become available. The Settlement Agreement does provide for drawdown of Hardy Impoundment for winter power generation, so natural winter and spring flows will continue to be altered by this dam.

Stream Velocity

Water velocity data are available for the low gradient upper section of the river system, and for the moderate gradient portion of river between Croton and Newaygo. Flows measured at two sites in the low gradient upper river section average from 1.0 to 1.4 ft/s, ranging to a high of 1.8 ft/s (MDNR Fisheries Division data, Table 3). Flows measured at two sites in the moderate gradient section average 2.0 to 2.3 ft/s, ranging as high as 4.0 ft/s (Ichthyological Associates, Inc. 1991a). These values represent water velocities between drought and mean annual flows.

Channel Morphology

River gradient, together with flow volumes, are the main controlling influences on river habitat structure. Steeper gradients allow faster water velocities with concomitant changes in depth, width, channel meandering, and bottom sediment transport (Knighton 1984). Consequently, gradient has been used to describe habitat requirements of smallmouth bass (Trautman 1942; Edwards et al. 1983), flathead catfish (Lee and Terrell 1987), green sunfish (Stuber et al. 1982b), northern pike (Inskip 1982), warmouth (McMahon et al. 1984b), white sucker (Twomey et al. 1984), bluegill (Stuber et al. 1982a), black crappie (Edwards et al. 1982), blacknose dace (Trial et al. 1983), and creek chub (McMahon 1982).

Gradient is typically measured as elevation change in feet per mile. The average gradient of the Muskegon River is 2.6 ft/mi and average gradient for the Little Muskegon River is 6.2 ft/mi. Gradient varies in different sections of the river with some sections falling very rapidly and others falling gradually. These different gradient areas create different types of channel, resulting in different types of habitat for fish and other aquatic life. Typical channel patterns in relation to gradient are (G. Whelan, MDNR Fisheries Division, personal communication):

Gradient class	Channel characteristics
0-2.9 ft/mi	mostly run habitat with low hydraulic diversity.
3.0-5.9 ft/mi	some riffles with modest hydraulic diversity.
6.0-10.9 ft/mi	riffle-pool sequences with good hydraulic diversity.
11.0-70.9 ft/mi	well established, regular riffle-pool sequences with excellent hydraulic diversity.
71.0-150.9 ft/mi	chute and pool habitats with fair hydraulic diversity.
> 150 ft/mi	falls and rapids with poor hydraulic diversity.

In these descriptions, hydraulic diversity refers to the variety of water velocities and depths found in the river. The best river habitat offers enough variety to support various life stages for multiple species. Fish and other aquatic life are typically most diverse and productive in sections of the river with gradient between 11 and 70 ft/mi. Unfortunately, these gradients are rare in Michigan because of our low relief landscape. Areas of high gradient are most likely to be dammed or channeled.

Highest gradient mainstem sections occur between Hersey and Newaygo (Table 12), a distance of about 63 miles (Figure 7). However, these sections are almost completely impounded by hydroelectric dams. The small portions of moderate gradient water currently not impounded, were once impounded by dams located at Big Rapids and Newaygo (refer to **Dams and Barriers**). The Little Muskegon River has about the same drop in elevation as the Muskegon River, over a distance of only 44 miles, producing a much steeper average gradient than the Muskegon River (Figure 8). Dams (Morley and Croton) on this tributary also impound the highest-gradient sections.

Gradient is important when evaluating fisheries habitat potential for potamodromous and riverine species. Gradient class was categorized as open to Lake Michigan fish migrations, closed to Lake Michigan fish migrations, and impounded (Table 12; Figures 9 and 10). The Muskegon River is 211.8 miles long, with 72% of this in low gradient class (<3 ft/mi), 27% moderate gradient class (includes 3 -5 ft/mi and 6-10 ft/mi) and 1% high gradient class (>10 ft/mi) water. All high gradient class water and 25 miles (43%) of moderate gradient class water are currently impounded. Nine miles (16%) of moderate gradient water is riverine and not blocked from Lake Michigan fish migrations by dams. Another 23 miles (41%) of moderate gradient riverine water is located above the hydroelectric dams. Overall, 88% or 165 miles of the river is blocked from Lake Michigan fish migrations by dams or impounded. Twenty-two percent or 45.7 miles of the river are impounded.

The Little Muskegon River has 3 miles of high gradient and 36 miles of moderate gradient water class (Figure 10; Table 12). Most high gradient water is currently impounded, but most moderate gradient water is riverine. All the Little Muskegon River is blocked from Lake Michigan by hydroelectric dams. It should be noted that all but a few of the many tributary streams are located upstream of the hydroelectric dams.

Characterization of habitat by gradient assumes normal channel cross sections for such gradients. However, channel cross sections can deviate from normal. Unstable flows will create flood channels that are wide and shallow during normal flows. Abnormal sediment loads (either too much or too little) will modify habitat. Bridges, culverts, bank erosion, and other channel modifications will also cause deviations from expected channel form. Detailed observations of the channel cross-section throughout the river are needed to check for these modifying factors.

One quantitative measure of channel form can be determined for a few locations on the Muskegon River and tributaries. Channel width can be compared to average width of rivers with the same discharge volume using data from Leopold and Maddock (1953) and Leopold and Wolman (1957). Overly wide channels are likely to be produced by fluctuating flows or excessive sediment bed load. Overly narrow channels are likely to be produced by bulkheads along the bank, by channel dredging, or by natural constraints (i.e., coarse materials or deeply incised valley with coarse materials).

At the few locations with available data, measured width was within calculated theoretical range (95% confidence range; Table 13). Theoretical width, including 95% confidence interval were calculated from the relationship: log (width) = 0.741436 + 0.498473 log (mean daily discharge), where width is measured in feet and discharge is measured in cubic feet per second. This relationship was derived from the authors cited above (G. Whelan, MDNR Fisheries Division, personal communication).

Diversity indices and qualitative observations can also be used to evaluate channel characteristics. However, specific site data needed for this type of evaluation is very limited in the Muskegon River basin, particularly quantitative data. The largest portion of quantitative data is available for a small section of river below Croton Dam. More physical data will be necessary to complete an evaluation of channel form problems in the Muskegon River basin.

Classification of bottom materials from the mainstem below Croton Dam was completed by Ichthyological Associates, Inc. (1991b). Gradient in this river section is moderate (3-10 ft/mi). Bottom materials in this river section showed good diversity, with mixtures of organic silt, sand, gravel, cobble, and boulders. Gravel, cobble, and sand are the primary bottom materials. General observation in other moderate gradient river sections (Big Rapids area) show similar bottom materials present (unpublished data, MDNR Fisheries Division, survey records). Observation of lower gradient river sections, above Evart and below Newaygo, indicate predominant bottom materials are sand, with small areas of gravel or cobble.

Channel dredging severely reduces aquatic habitat. River and tributaries have been ditched or straightened in the following known locations: mainstem channel-below Mill Iron Road in the Muskegon State Game Area, Mosquito Creek-headwater area (Muskegon County), and numerous miles of ditching in designated drains. Severe effects on fisheries has occurred in many tributary streams as a result of changes in water flows, water temperatures, and stream cover, from ditching (refer to **Soils and Land Use Patterns**).

Soils and Land Use Patterns

Land Development

Land development can significantly affect watershed hydrology. Both urban and agricultural development increases surface runoff and decreases groundwater infiltration of rainwater. This causes unstable hydrologic conditions in a river. Land development in the Muskegon River watershed is moderate, ranging from 16.7% to 34.0% along the mainstem. The percentage of developed land generally increases from Houghton Lake to Croton, then remains stable downstream to Muskegon (Table 9). Some tributary streams such as the Little Muskegon River and Tamarack Creek have substantial land portions developed for agriculture. Currently, agriculture accounts for most land development (33.4% agriculture, 0.6% urban) in the watershed.

Land development can significantly affect water quality. Agricultural land development especially affects water temperatures, sediment inputs, and levels of nutrients, herbicides, and pesticides in the water (Alexander et al. 1995). Nutrients and water temperatures in the Muskegon River will be addressed in **Water Quality**.

Tillage of soils increases erosion of sediment into streams. Elevated sediment levels in streams causes significant habitat degradation for example, natural bottom materials are covered with sand and silt. Sediment inputs are difficult to quantify on large river systems. The United States Department of Agriculture, Natural Resources Conservation Service, estimates soil erosion is occurring on 4.8 million acres of cropland in Michigan, at a rate of 42 million tons annually (Anonymous 1987a). The Muskegon River Basin lies in two Major Land Resource Area classifications of the Natural Resource Conservation Service. These are the Northern Lower Michigan Sandy Drift and Southern Lower Michigan Drift Plain. Estimated average annual sheet and rill erosion, on non-federal rural lands, in the Muskegon River basin Resource Areas is 0.84 tons/acre for cropland-pasture land and 0.04 tons/acre for forest land in the Northern Lower Michigan Sandy Drift; and 2.09 tons/acre for cropland-pasture land and 0.15 tons/acre for forest land in the Southern Lower Michigan Drift Plain. Soil erosion rates from crop and pasture land are occurring at rates 14 to 21 times higher than erosion rates on forest land. Even with moderate land development (about 25%), the river may be receiving a sediment load of a watershed five times as large as the actual basin. This does not include additional, substantial sediment load from bank erosion that is the result of past deforestation practices and destabilization of flows. Road crossings also increase erosion of sediment into the stream through improper construction and direct runoff from roads (Alexander et al. 1995).

The Natural Resources Conservation Service has determined that major conservation treatment needs on crop and pasture land are erosion control, drainage, and forage and brush improvement (Table 14). Major conservation treatments on forest lands are related to timber stand establishment and improvements. It is interesting that drainage is considered a conservation treatment for cropland. Drainage is detrimental to the natural resources of aquatic systems because it has negative affects on water flows, temperature, and sediment bed load. Frequently land is drained for use through deepening and straightening of existing streams, digging new drain channels, and constructing underground drainage systems. Channelization destroys natural channel diversity (depths, velocities, substrates) of existing stream systems, eliminating many habitats critical to reproduction and survival of aquatic organisms. The resulting shallow, uniform channel causes increased and more variable water temperatures. Woody habitat is removed from the channel and riparian vegetation is often discouraged, limiting instream cover for organisms and again contributing to increased water temperatures. Drainage destroys wetlands important as spawning and living areas for aquatic organisms and important to the water quality of the system. The whole process destabilizes water flow in the river system by increasing overland flow and decreasing groundwater recharge. Destabilizing water flows also increases the frequency and magnitude of flood flows and increases water temperature (Dunne and Leopold 1978).

Land development for urban use areas has dramatic affects on the aquatic environment (Toffaleti and Bobrin 1991). Temporary sediment erosion from unprotected construction sites is about 500 times greater than erosion from undisturbed land. Sediment erosion from improperly placed or maintained road crossings can also be a major input to the stream. Sediments that reach stream channels clog and bury gravel, cobble, and woody habitat that is critical to many aquatic organisms. Urban development noticeably increases the percentage of impervious land area. As urban areas are developed, there is a concurrent increase in the transportation network. Urban and suburban areas typically have 50-100% and 25-45% impervious land surface areas (Toffaleti and Bobrin 1991). Impervious surfaces include paved surfaces (roads, parking lots) and roofs of buildings. These have runoff coefficients 6-14 times greater than undisturbed lands (Toffaleti and Bobrin 1991). Engineered stormwater runoff systems also speed surface runoff. Increased surface runoff causes greater peak river flows, that are harmful to reproduction and survival of many aquatic organisms, increased bank and bed erosion, decreased groundwater recharge, increased summer water temperatures, and decreased available stream habitat (Leopold 1968; Booth 1991). Runoff from impervious surfaces carries pollutants including nutrients, bacteria, metals, oil and grease, herbicides and pesticides, and salts. Osborn and Wiley (1992) have shown that urbanization has the primary effect of increasing the summer nutrient concentrations in rivers.

Development that promotes the construction of wells reduces groundwater tables and summer baseflows in streams, with a resulting increase in water temperatures and decrease in stream habitat. Following use, this water returns to the system as heated surface water, causing increased and more variable water temperatures. This trend is noticed most in suburban developed areas.

Guidelines for the protection and rehabilitation of Michigan streams are summarized by Alexander et al. (1995). Recommendations for improved management of uplands are included. Anonymous (1994) provides guidelines for water quality management practices on forest lands. This document provides guidelines for timber harvest, equipment operation, buffer strips, road construction and drainage, culvert placement, sediment control, prescribed burning and fire control, and pesticide use. Forest planning for portions of the watershed included in the Pere Marquette State Forest are incorporated in the resource management plan for the Pere Marquette State Forest (Anonymous 1993b).

Designated Drains

Drains are constructed to increase groundwater and surface water drainage from land. Drains promote instability in the hydrology of the watershed by reducing groundwater reserves and increasing surface water runoff (refer to **Geology and Hydrology**). The total mileage of established designated drains for each county within the watershed is: Roscommon-information not available, Missaukee-information not available, Clare-10.5 miles, Osceola-55.1 miles (51.5 open ditch, 3.6 tile), Mecosta-34.7 miles (23.1 open ditch, 4.4 tile, 7.2 combined), Montcalm-42.5 miles, Newaygo-79.5 miles, Muskegon-information not available.

Irrigation

Irrigation is not significantly affecting basin hydrology. Some of the largest water withdrawals for irrigation are occurring on Tamarack Creek, Little Muskegon River, Middle Branch River, and Brooks Creek. Irrigation may become a problem in the future, particularly on smaller tributaries because of their low flow rates. Irrigation causes flow instability and sometimes can severely deplete water flows in stream beds. Irrigation also saturates soils, increasing overland flows during periods of rain fall, which leads to higher peak flows in streams.

Logging

The entire watershed was extensively logged during the late 1800s and early 1900s, and all virgin timber stands were removed. A large portion of the watershed is forested with new growths of timber. The mainstem and nearly all tributaries were used for transporting timber. This use caused extensive damage to stream channels that continues to contribute to sediment erosion problems.

A portion of ongoing stream bank erosion is suspected to be a result of past logging activities. Past and present effects of logging on the Muskegon River system have not been thoroughly studied or documented. Anonymous (1994) provides guidelines for timber harvest and water quality management practices on forest lands in Michigan.

Floodplain Use

Extensive use of the floodplain occurs throughout the river. These uses include: urban, agriculture, recreational, and residential. Residential buildings are often affected by flooding, especially below Croton.

Gas and Oil Storage

Gas and oil fields are located in Clare County (Winterfield Township), Reed City Field, Austin Field, and in Muskegon State Game Area. Operations of this type have the potential for introducing contaminants into the system. Associated road and stream crossings can be problems with these types of developments. No current problems are noted in the Muskegon watershed. The watershed has low to very low potential for natural gas resource development (Anonymous 1993a).

Special Jurisdictions

Michigan Natural Resources and Environmental Code, Public Act 451, 1994

Federal Regulation Over Dredged and Fill

The federal government has authority to regulate discharges of dredged or fill materials under the Clean Water Act, Section 404(b)(1). These guidelines are published in the Federal Register, Volume 45, Number 249, Part 230. The State of Michigan administers Section 404 regulation for the federal government in Michigan, except for waters regulated under Section 10 federal rules. The federal government also has authority to regulate dredge and fill activities under Section 10 of the Federal Rivers and Harbors Law. Section 10 regulation in the Muskegon River system includes Muskegon Lake and approximately 33 miles of river above Muskegon Lake to M-37 in Newaygo.

Michigan administers the Section 404 program using the Michigan Natural Resources and Environmental Code, Public Act 451, Parts 31, 301, and 303, 1994. Any dredging or filling of material within the floodplain or associated wetland, in the Muskegon River watershed, requires a permit. Permits for dredge and fill activities in regulated areas are administered by the State of Michigan. Permits are also required from the federal government from M-37, in Newaygo, downstream to the mouth. Agencies responsible for permits are the Michigan Department of Environmental Quality (MDEQ), Land and Water Management Division for the state, and the Corps of Engineers for the federal government.

Michigan Coastal Zone Management Program

Michigan Department of Environmental Quality administers a Coastal Zone Management Program associated with the Federal Coastal Zone Management Act of 1972. The purpose of this program is to preserve, protect, develop, and where possible, to rehabilitate or enhance, the resources of Michigan's coastal zone for this and succeeding generations. The Michigan program uses the Michigan Natural Resources and Environmental Code, Public Act 451, Part 325, 1994, incentive authorities and state-local partnerships to focus technical and financial assistance for protecting valuable resources in coastal areas. The program generally focuses on coastal lakes, river mouths and bays, sand dunes, flood plains, wetlands, public recreation and natural areas, and highly developed or urbanized areas. Areas of particular concern include areas of natural hazard to development, areas sensitive to alteration or disturbance, areas fulfilling recreational or cultural needs, areas of intensive or conflicting use and areas of natural economic potential. The program also examines federal government activities that affect the coastal zone area, from outside the designated area, and includes operation of Federal Energy Regulatory Commission regulated dams. The coastal zone designation for the Muskegon River Watershed includes Muskegon Lake and the river floodplain to approximately 6 miles above Muskegon Lake.

Michigan Natural River Designation

The entire mainstem of the Muskegon River and the Little Muskegon River are proposed for designation as Natural Rivers under the Michigan Natural Resources and Environmental Code, Public Act 451, Part 305, 1994. The goal of this act is to establish a system of natural rivers meeting certain criteria and to protect the natural character of the rivers from unwise use and development. The act provides guidelines for management practices for state owned lands along the river, as well as guidelines for local zoning which would guide new developments along the river to protect inherent natural values of the river, its tributaries, and adjacent lands. The Natural Rivers Program is administered by Michigan Department of Natural Resources, Forest Management Division, 5th Floor Mason Building, PO Box 30452, Lansing, MI 48909-7952. Natural Rivers are afforded additional water quality protection under the antidegradation section (Rule 98) of the Michigan Natural Resources and Environmental Code, Public Act 451, Part 31, 1994.

Michigan Water Quality Standards

The Michigan Natural Resources and Environmental Code, Public Act 451, Part 31, 1994, establishes water quality standards for the Great Lakes, connecting waters, and all other surface waters of the state. These standards are designed to protect the public health and welfare, to enhance and maintain the quality of water, and to protect the state's natural resources. Under this law, standards are set for dissolved solids, hydrogen ion concentration, taste or odor-producing substances, toxic substances, radioactive substances, plant nutrients, microorganisms, dissolved oxygen, temperature, mixing zones, and construction activities. The rules also provide standards for the following designated uses; agriculture, navigation, industrial water supply, public water supply at the point of water intake, warmwater fish, coldwater fish, potamodromous fish, other indigenous aquatic life and wildlife, partial body contact recreation, and total body contact recreation from May 1 to October 31.

The entire Muskegon River watershed is protected for all designated uses except the coldwater fish designation. The river is protected for coldwater fish in the same sections designated as trout stream (Figure 11).

Identification of Land and Water Contamination Sites

In 1982, the Michigan Legislature enacted the Michigan Environmental Response Act, Act 307, to identify and clean up sites of environmental contamination. The Act was recodified into the

Michigan Natural Resources and Environmental Code, Public Act 451, Part 201, 1994. The 1992 listing includes the following number of sites in each county of the Muskegon River watershed: Roscommon-28, Missaukee-13, Clare-25, Osceola-28, Mecosta-24, Montcalm-18, Newaygo-19 and Muskegon-70 (Anonymous 1991b). Most of these sites are known or expected to have adverse effects on groundwater quality. Typical sources include manufacturing, commercial operations, mining and oil drilling, oil and gasoline storage tanks, and highway maintenance and salt storage. Nine of the Muskegon County sites and one Clare County site are listed on the national priorities list for remedial action under the Federal Comprehensive Environmental Response Compensation and Liability Act 1980 (known as CERCLA or Superfund).

Designated Trout Streams

A large portion of the watershed is designated trout stream under the Michigan Natural Resources and Environmental Code, Public Act 451, Part 487, 1994. A designated trout stream is any stream or portion of a stream that contains a significant population of any species of trout or salmon, as determined by the Department (of Natural Resources). Sections of the mainstem that are designated trout streams include Muskegon Lake to Croton Dam and Paris to Hersey (Figure 11).

Blue Ribbon Trout Streams

Portions of fifty-one Michigan streams are classified Blue Ribbon Trout Streams. These streams meet specific criteria for this classification: they are Michigan’s best trout streams, they support excellent stocks of wild resident trout, they are large enough to permit fly casting but shallow enough to wade, they have diverse insect life and good fly “hatches”, they have earned a reputation for excellent trout fishing, and they are clear and clean. The following streams are classified Blue Ribbon Trout Streams in the Muskegon River watershed: Clam River from the Missaukee County-Wexford County line downstream to Turnerville Road; and the Middle Branch River in Osceola County, from T20N, R7W, Section 19, downstream to Marion Pond.

Designated Drains

County Drain Commissioners are given authority to establish designated drain systems under the Drain Code of 1956, Act 40. This law allows for the construction or maintenance of drains, creeks, rivers, and watercourses and their branches, for flood control and water management. "A designated drain may be cleaned out, straightened, widened, deepened, extended, consolidated, relocated, tiled, and connected to properly purify or improve the flow of the drain." The total mileage of established designated drains, for each county, is reported in **Soils and Land Use Patterns**.

Navigable Waters

Anonymous (1993c) discusses the issues associated with navigable, or public, waters in Michigan. People have the common right of fishing in a navigable stream, subject only to the restraints and regulations imposed by the State. All the mainstem and all tributaries of the Muskegon River are considered navigable, but only a few have been adjudicated navigable or non-navigable by the Michigan Supreme Court. The following waters, in the Muskegon River watershed, are listed in specific classifications cited by Anonymous (1993c):

1) Navigable waters of the United States in US Army Engineering District, Detroit, 1981. (It should be understood that this merely represents the views of the Department since the jurisdiction of the United States can be conclusively determined only through judicial proceedings).
   Muskegon Lake, navigable throughout.
   Muskegon River, M-37 highway bridge, 39.25 mile above mouth (33 miles from the head of Muskegon Lake).

2) Waters adjudicated navigable by the Michigan Supreme Court:
   Muskegon River, Roscommon County, downstream from Houghton Lake.
   Muskegon Lake, Muskegon County.

3) Waters indicated (by judicial notice or direct reference in court opinions) navigable by the Michigan Supreme Court:
   Backus Creek, Roscommon County, Mud Lake to Houghton Lake.
   Cedar Creek, Muskegon County.
   Clam River, Missaukee County, 6 miles above Falmouth to Muskegon River.
   Little Muskegon River, Mecosta County, to mouth from SE 1/4 of the SE 1/4, of Section 25, T13N
   R10W.
   Muskegon River, Roscommon County, downstream to mouth from Houghton Lake.
   Townline Creek, Clare and Roscommon County.
   Mud Lake, Roscommon County.

4) Waters adjudicated non-navigable by the Michigan Supreme Court:
   Conover Lake, Newaygo County.

Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC) is authorized under the Federal Power Act of 1920, as amended, to license and regulate hydroelectric facilities that meet one or more of the following criteria pursuant to Section 23 (b) (1) of the Act: 1) the project is located on a navigable water of the United States; 2) the project occupies lands of the United States; 3) the project utilizes surplus water or water power from a government dam; or 4) the project is located on a body of water over which Congress has Commerce Clause jurisdiction, project construction occurred on or after August 26, 1935, and the project affects the interests of interstate or foreign commerce. Presently when a project is being licensed or relicensed, power and non-power aspects of a project are balanced by FERC and the resulting license issued for the project contains specific articles to protect natural resources in the project area. Licenses are administered and enforced by FERC with MDNR Fisheries Division having a consultation role in both the licensing and enforcement proceedings.

FERC currently licenses the operation of Croton, Hardy, and Rogers projects on the Muskegon River, and the Morley project on the Little Muskegon River. Croton, Hardy, and Rogers hydroelectric operations were relicensed for 40 years, beginning July, 1994.

The Morley Project was issued an Exemption Order for relicensing by FERC on December 30, 1985. Article 2 of this Order made provisions for resource considerations at this project. On April 14, 1995, FERC issued a Compliance Order for Article 2 violations concerning stream discharge regulation, fish mortality studies, and water quality monitoring. On October 4, 1995, the generator at the Morley Project was destroyed in a fire and at this time (1996) the project is not generating electricity.

International Joint Commission Areas of Concern

The International Joint Commission, a United States-Canadian commission created by the Boundary Waters Treaty of 1909, monitors water quality of the Great Lakes under terms of the Great Lakes Water Quality Agreements of 1972 and 1978. These international agreements foster intergovernmental cooperation to solve pollution problems. The 1987 amendments to the Great Lakes Water Quality Agreement established the Area of Concern program. Remedial Action Plans are prepared for sites in the Great Lakes basin designated as Areas of Concern by the federal government. Muskegon Lake was established as an Area of Concern due to conventional pollutants, toxic organic substances, and contaminated sediments. The MDEQ, Surface Water Quality Division has prepared and is implementing a Remedial Action Plan for Muskegon Lake. Three potential major sources of pollution to Muskegon Lake which could cause impairment of the beneficial uses or inhibit further improvement of the water quality of the lake are urban stormwater runoff, contaminated groundwater, and contaminated sediments. Implementation of the remedial action plan is currently underway. Information regarding the remedial action plan can be obtained by writing to Michigan Department of Environmental Quality, Surface Water Quality Division, 2nd Floor, Knapps Center, Box 30273, Lansing, MI 48909.

Public Lands

Both the State of Michigan and the US Forest Service have extensive land ownership in the Muskegon River watershed. Acreage figures on this ownership are not available. Forest planning for portions of the watershed included in the Pere Marquette State Forest are incorporated in the resource management plan for the Pere Marquette State Forest (Anonymous 1993b). There are numerous state, federal, and local government campgrounds and parks in the watershed (for boat access sites to the river, refer to **Recreational Use**).

The United States Forest Service has riparian ownership along: Cedar Creek-3 miles, Little Henna Creek-1.5 miles, Penoyer Creek-3/4 mile, Bigelow Creek-1.5 miles, Cold Creek-1 mile, Little Muskegon River-4 miles, South Mitchell Creek-0.25 mile, Hodgers Creek-.25 miles, Betts Creek-0.5 miles. The Huron-Manistee National Forest Land and Resources Plan provides general guidelines for water quality protection on these lands. For information regarding this plan contact the US Forest Service, 1755 S. Mitchell Road, Cadillac, MI 49601.

Public Health Advisories on Eating Fish

The Michigan Department of Community Health, Division of Environmental Epidemiology issues general fish consumption advisories for Michigan waters. These are published in the Michigan Fishing Guide. The Department of Community Health has issued a special advisory concerning all inland lakes and reservoirs in Michigan due to widespread mercury contamination throughout the north central United States and Canada. These mercury advisories apply to rock bass, yellow perch or crappie over 9 inches in length, bass, walleye, and northern pike or muskellunge of any size. A general advisory for mercury contamination in large Lake Michigan walleye also applies to the Muskegon River downstream of Croton Dam. In 1997, the Michigan Department of Community Health issued a public health advisory for organic contaminants throughout Michigan in relation to consumption of large muskellunge, pike, bass, and walleye; fatty fish such as carp, catfish, large salmon and lake trout; and larger and older fish of any kind. This advisory was for pregnant women, women who intend to have children, and children under the age of 15.

Specific health advisories for contaminants in the Muskegon River watershed are as follows:

Bear Lake, Muskegon County - carp, polychlorinated biphenyls.
Hersey River, Osceola County - northern pike, bullhead, and brown trout, polycyclic aromatic hydrocarbons.
Muskegon Lake and river up to Croton Dam - lake trout, brown trout, carp, catfish, and whitefish from Lake Michigan, organic contamination.

The Department of Community Health or MDNR Fishing Guide should be consulted for specific advisories. Refer to **Water Quality** for additional information on chemical contaminants.

Recreational Use

The entire river from Houghton Lake to Lake Michigan is accessible by boat and canoe. Canoe use is moderate in the mainstem below M-55 and in the Little Muskegon River. High canoe and boat use occurs below Croton Dam to Muskegon. High use by tube rafters occurs in the Big Rapids area and from Croton to Newaygo. Rogers Impoundment receives low use by boaters, Hardy Impoundment has high boater use, and Croton Impoundment receives moderate boater use. On Hardy Impoundment, boat crowding and water skiing is a problem on holiday weekends. Preliminary surveys conducted on Rogers, Hardy, and Croton Facilities identified 34 land and water recreation activities occurring on these properties (Insight Marketing, Inc. 1993). Water related activities included boating and water skiing, fishing in reservoirs and downstream of Croton Dam, swimming and beach use, canoeing and tubing, jet skiing, and ice boating.

All riverine sections of the river are shallow enough to accommodate wading anglers, except for the lowest most portion. Use of the river for fishing upstream of the hydroelectric dams is very low. Use of the river for fishing is low to moderate on the impoundments. The lower section of the river, below Croton Dam, receives high to moderate fishing pressure (refer to **Fisheries Management**).

Access is best between Croton Dam and Newaygo (Figure 12). High fishing and canoe use in this river section is the result of good gradient and water velocities, which makes this area good for fishing and very scenic. State and federal land ownership along the river is adequate only in the upper and lower sections of the river. Public access is especially limited in the following areas: between Evart and Paris, upstream of the City of Newaygo to Thornapple street access, in Croton and Little Croton impoundments, and in lower Cedar Creek in Muskegon County. Access is often a problem in tributary streams where private ownership is extensive.

All public lands in the watershed are used extensively for hunting deer, small game, upland birds, waterfowl, and trapping for fur bearing animals. Recreation use in the watershed has not been evaluated and suitable studies need to be conducted.

Dams and Barriers

There are numerous dams and impoundments in the Muskegon River watershed (Figure 11). Many dams are not registered with the State of Michigan and are established on tributary streams. Impoundments of these small dams are usually for swimming, fishing, wildlife, and aesthetics. Many small impoundments are often created by improper placement of culverts for road crossings over streams. Some of the registered dams are lake-level control structures on the outlets of lakes.

There are 32 dams registered with the State (Table 15). Four dams are currently located on the mainstem and include Reedsburg Dam (constructed in 1940), Rogers Dam (constructed in 1906), Hardy Dam (constructed in 1931), and Croton Dam (constructed in 1907). Reedsburg Dam is a wildlife flooding located at the headwaters of the river, just below Houghton Lake. The other three are large hydroelectric dams with large impoundments, located in the middle portion of the river (Figure 2). Two other dams were located on the mainstem but have been dismantled. Newaygo Dam was constructed in 1900 and dismantled in 1969 and Big Rapids Dam was constructed in 1866 and dismantled in 1966 (hydropower starting in 1906). Remnants of the Big Rapids Dam (the sill) are still present.

Dams and impoundments affect river ecosystems in many ways. Some effects are obvious and can be measured directly using relatively short studies. Other effects are more subtle, occurring over long periods of time, and requiring long, expensive studies to evaluate. Most dams on the Muskegon River were built before any information on river habitat and biological communities was collected, and this makes assessments more difficult. A number of studies have recently been conducted on the major hydroelectric dams as a requirement of the Federal Energy Regulatory Commission relicensing process.

Dams directly and indirectly affect aquatic communities in various ways. Direct effects include entrainment and fish mortalities in hydroelectric turbines, and blockage of movement of aquatic organisms. Fish mortalities occur in all types of hydroelectric turbines and spillways across dams, and they often occur in significant quantities. Fish entrainment and mortality has been found to be a problem at the three hydroelectric dams on the Muskegon River. Total annual entrainment at the three dams is currently estimated at 301,583 fish and 79% of these are game fish. Total annual mortality is 44,042 fish, with 31,055 (70%) game fish and 12,987 (30%) non-game fish killed (Table 16). The estimated economic value of fish mortalities ranges from $52,256 to $328,570, annually. Overall, Croton Dam has the largest entrainment rates and fish mortalities, followed by Rogers Dam, then Hardy Dam (Table 16). Economic values of fish losses provided in Table 16 are calculated using two methods. The two methods provide a range of monetary values that indicate the extent of economic loss from direct fish mortalities. Mitigation for these losses is provided for in the 1994 Settlement Agreement (Appendix 3). Monetary losses in the Settlement Agreement for these three dams were negotiated at $62,000 annually (1992 dollars). Monetary retribution will decrease as fish protection devices are installed and fish mortalities decrease.

Blockage of movement produces fragmentation of the river system and occurs for both fish and aquatic invertebrates. Aquatic insects drift downstream as larvae until suitable habitats are found. After maturation, adults fly upstream to reproduce. Downstream movements of these insects can be inhibited when encountering reservoirs and upstream movement of adults can be inhibited by the dam structure and reservoir size. Many potamodromous (walleye, salmon, steelhead, lake trout) fish migrate long distances within rivers as part of their life histories. Generally these movements are for reproduction. Additionally, many river fish (brown trout, rainbow trout, northern pike, channel catfish, smallmouth bass, brook trout, Arctic grayling) also migrate within the river system as part of their life histories (Schlosser 1991). These movements are associated with reproduction, foraging, different summer and winter habitat requirements for cover, water temperature, velocities, and depth. Genetic viability of resident and non-resident river species can be decreased by barriers in a river (Kapuscinski and Jacobson 1987).

Mussels are affected by dams and impoundments in various ways (Fuller 1974). Low oxygen, water pressure, parasitism and siltation limit adult mussels in impoundments. Mussel reproduction is affected by changes in glochidial hosts (primarily fish), delays in maturation from cold water, siltation, and changes in drift patterns of young.

The affect of dams on habitat include: changes in water quality for temperature and dissolved oxygen; changes in river flows for "peaking" operations with resulting losses in downstream fish habitat due to high water velocities or uncovering and drying of the stream bottom during low flows; changing channel cross sections; increasing sediment erosion and lowering habitat diversity, increasing water evaporation in the reservoir with resulting loss of water flow in downstream sections; disrupting normal downstream movement of woody materials that is important habitat for aquatic life; covering and blocking the highest gradient and most productive habitats; and creating lake environments within the river system resulting in lower fish productivity and shifts in fish communities favoring lake species, that in turn affect upriver and down river fisheries. The 1994 Settlement Agreement provides mitigation of some problems at the hydroelectric dams. Marion Dam on the Middle Branch River, and Miller Dam on the Hersey River are causing substantial water temperature increases (refer to **Water Quality**).

Sometimes, dams offset current problems in a river system. When development increases water temperatures or sediment erosion, reservoirs can act as sediment and cold water traps, which can reduce downstream effects on the aquatic system. Pest species, such as sea lamprey, can be blocked from upstream river sections used for spawning, by dams. Some dams on the Muskegon River are currently producing some of these benefits for sediment removal and lamprey blockage. It must be pointed out that these dams were not built for these purposes and better alternatives are available to remedy the sediment and lamprey problems. Lamprey can be blocked by low head or electric barriers that do not have other negative effects of hydroelectric dams. Excessive sediment erosion needs to be dealt with using proper agricultural practices and non-point source control methods. Use of dams for sediment removal is only a temporary solution, because a reservoir will eventually fill with sediment or the dam will be retired from use. When this happens, the volume of stored sediment can be so large there may be no solution to remove it.

Numerous bridges and culverts are creating barriers to fish passage due to excessive water velocity or elevation of the culvert over the streambed. Poor design of bridges and culverts create excessive water velocities. Culvert elevation results from improper installation in conjunction with continuing natural streambed erosion. Some of the known problem sites include Little Henna Creek (Muskegon County), Rosy Run Creek (Mecosta County), Sand Creek (Newaygo County), and many Mecosta County culverts. A road crossing inventory needs to be completed for the watershed.

The old Big Rapids Dam sill is still in place in the mainstem and is a barrier to fish passage. Efforts are currently underway to remove this structure.

Offer of Settlement for Hydroelectric Dam Issues

Three hydroelectric dams on the main segment of the Muskegon River were relicensed for operation, by the Federal Energy Regulatory Commission (FERC), for a 40 year period beginning in 1994. FERC provided for review and consideration of natural resources issues as part of the relicensing procedure. Resource agencies (Michigan Department of Natural Resources, United States Department of Agriculture Forest Service, United States Department of Interior Fish and Wildlife Service, United States Department of Interior National Park Service, and Michigan State Historic

Preservation Officer) and Consumers Power Company worked for several years to study and evaluate environmental effects of these dams on the Muskegon River system. Negotiations between Consumers Power Company and resource agencies resulted in a proposed Settlement Agreement designed to provide mitigation for many hydroelectric dam effects on the river system. The Offer of Settlement was submitted to the FERC along with the new license applications and licenses were issued in July 1994. Most components of the proposed Settlement Agreement were incorporated as provisions of the new licenses.

The final Settlement Agreement for Rogers, Hardy, and Croton projects on the Muskegon River is included in Appendix 3. The Settlement concerns the resolution of issues on: land management including recreational facilities and leases; protection for movement of fish from the impoundments into turbines or downstream areas; water quality (water temperatures, dissolved oxygen, contaminants, sediment); historical and archeological resources; stream gauging and water quality monitoring; fish passage structures; project boundaries; dam retirement studies and trust fund; project coordination; resource agencies review and consultation; disputes; liquidated damages; soil erosion control; and stream flows through Rogers, Hardy, and Croton dams.

Water Quality

Water quality throughout the Muskegon River system is generally good. Historical problems caused by municipal and industrial discharge, especially in Muskegon Lake, have been resolved by more restrictive water quality standards and better treatment facilities. Wastewater treatment facilities, on the mainstem, are all currently operating within water quality standards.

Tables 17 and 18 show water quality data for several sites on the mainstem. Most parameters are near water quality values considered normal for Michigan streams by MDEQ, Surface Water Quality Division (Table 19). Phosphorus levels are somewhat elevated and are probably the result of extensive agricultural inputs. Levels of some metals are elevated in stream sections near municipalities (Table 17 and 18). This is probably the result of stormwater and industrial inputs. Dissolved oxygen levels are below water quality standards at times, although mean levels are adequate. Alkalinity, pH, and hardness are considered moderate or normal for this river.

Localized water quality problems on the mainstem and tributaries are present. Some of these are discussed under *Public Health Advisories on Eating Fish*. Some water quality and fish advisory problems result from contaminated sediments accumulated from past discharge practices. Fish contaminant problems are often related to air transport of contaminants, especially for mercury and some organic contaminants.

Water discharged from Hardy Dam and impoundment into Croton Impoundment is below Michigan Water Quality Standards for warmwater fish (Rule 64). The standards designate a minimum of 5 mg/l dissolved oxygen will be maintained in inland lakes. During 1990, water discharged from Hardy Dam was continually below water quality standards during most of July through August (Figure 13). Low dissolved oxygen effects both fish and food organisms in the impoundment.

Water discharged from Croton Dam and impoundment into the river is below Michigan Water Quality Standards for coldwater fish (Rule 64). Standards designate a minimum of 7 mg/l dissolved oxygen will be maintained in coldwater streams. During 1990, 17% of dissolved oxygen samples collected were below 7 mg/l (Table 20). All water quality violations occurred from June through

September. During summer, the water quality standard for oxygen was violated in 50% of the samples.

Water temperature (and discharge) problems occur on the Clam River as a result of the water control structure at Lake Cadillac (L. Mrozinski, MDNR, Fisheries Division, personal communication). Water quality evaluations need to be conducted on Falmouth Dam on the Clam River. The Clam River is classified Blue Ribbon Trout Stream upstream of Falmouth Dam, but conditions are considered marginal for trout below the dam. Marion Dam is significantly increasing water temperatures in the Middle Branch River. A temperature evaluation conducted on June 25, 1971 showed a water temperature increase of 9° F resulting from the dam (MDNR, Fisheries Division survey records). The Middle Branch River is classified Blue Ribbon Trout Stream Upstream of Marion Dam, but conditions are marginal for trout below the dam. Miller Dam is significantly increasing water temperatures in the Hersey River. A temperature survey conducted on June 28, 1971 showed a water temperature increase of 10° F resulting from the dam (MDNR, Fisheries Division survey records). The Hersey River is a designated trout stream. Michigan water quality standards (Rule 64) do not allow water temperature increases of more than 2° F in streams capable of supporting coldwater fish. Nearly all small dams and connected off-stream ponds in tributaries cause temperature and dissolved oxygen problems for fish. Some small, private fish hatcheries located on tributaries are believed to contribute excessive nutrients and increase water temperatures.

Information on water temperature is limited. Some water temperature data were recently collected by MDNR, Fisheries Division personnel and Lawler, Matuskey, & Skelly Engineers (1991a, 1991b, 1991c). MDNR data were collected from January 1991 to October 1992, five miles above Big Rapids and four miles below Croton Dam. Consumers Power Company collected data during 1990 and 1991 near their hydroelectric dams.

Water temperatures below Croton Dam are cooler than at Big Rapids, from about late March through the end of June. The rest of the year water temperatures are warmer below Croton Dam than at Big Rapids (Figures 14-16).

Differences in water temperatures between the two sites can be attributed to Rogers, Hardy, and Croton hydroelectric dams and impoundments. Effects of hydroelectric facilities on water temperature are complex because Rogers and Croton dams draw water from the top of the impoundment, where Hardy Dam discharges mostly bottom waters. Overall, Hardy Dam is the major factor altering temperatures between the upper and lower river (Figures 17 and 18). Hardy impoundment is a very large, deep reservoir, that dampens heat input into the lower river, and produces a delay in river water temperature warming below the dams.

The impoundments also reduce the variation in daily temperature in the lower river. Figures 19-21 demonstrate this trend and show August temperatures fluctuating less below the impoundments than above them.

During the summers of 1990 and 1991, water temperatures higher than 70 °F were more prevalent below Croton than at Big Rapids (Figures 22-24). The reverse was true during the summer of 1992. This was probably the result of an unusually cool summer during 1992 caused by volcanic eruptions (J. Schneider, MDNR, Fisheries Division, personal communication). Water temperatures higher than 70 °F were also less prevalent during 1992, at Big Rapids, when compared to 1990 and 1991. This data indicates during average climatic conditions, water temperatures above 70°F will be greater below Croton Dam than at Big Rapids.

Low water temperature extremes (<32 °F) were more prevalent at Big Rapids than below Croton (Figures 22-24). Extended periods of water temperatures between 31.0-31.9 °F, were recorded at Big Rapids during the winters of 1990, 1991, and 1992. Extended periods of low water temperature extremes were not found below Croton during the winters of 1991 and 1992. Elevated water temperatures during winter below Croton are the result of delayed river-water-temperature warming caused by hydroelectric impoundments. Water temperatures below 32 °F, occurring over extended periods, indicate potential formation of anchor and frazil ice, which can be detrimental to fish and other aquatic organisms.

The water temperature regime above Rogers Impoundment may be affected by numerous non-hydroelectric impoundments and upland development. Soil permeability is lowest in this portion of the watershed, which indicates cool groundwater supporting baseflows are more limited (refer to **Geology and Hydrology**). Instability in high stream discharge is greatest in this portion of the watershed, but interpretation of this factor is confounded by hydroelectric dam effects (refer to *Stream Discharge*). In stream sections with limited groundwater inputs, dams and upland development can readily affect water temperatures. Dams and impoundments especially may be affecting temperatures in the Muskegon River watershed, because many of the major coldwater tributaries are impounded, along with the mainstem at Reedsburg Dam (Table 21).

The upstream temperature site, near Big Rapids, was located above Paris Creek (Table 21). A minimum of 39% of the drainage basin area above this site is affected by dams and impoundments. This figure includes only drainage basin areas for Reedsburg Dam, Hersey River, and about half of the Clam River. These are the only dam-impoundment affected tributaries with available drainage basin data. Besides known drainage basin areas, 46% (13 of 28) of the remaining major tributaries in this river section are impounded or suspected to be impounded (based on examination of topographic maps). Approximately 27% of the watershed in this river section is developed into agriculture or metropolitan areas, along with over 66 miles of county drains and numerous sediment erosion sites (Table 21). Below Big Rapids, the percentage of tributaries affected by dams decreases, but the three major hydroelectric dams impound the mainstem (Table 21).

Erosion of sand, silt, and clay sediment into streams occurs from upland areas and from the banks or margins of stream channels. A certain level of sediment erosion is natural from both sources, but increases in sediment erosion from development is detrimental to aquatic communities (Alexander and Hansen 1988). Sediment erosion from upland areas has been previously discussed in **Soils and Land Use Patterns**. Excessive erosion of sediment from stream banks has the same detrimental effects including reduction in habitat diversity and aquatic production by clogging and covering of gravel, rocky, and woody habitat; channel widening; and water temperature changes. Stream bank erosion is increased by: removing or changing stream bank vegetation; changes in hydrology from upland agricultural and urban development; deforestation; improper operation of lake-level control structures; and operation of hydroelectric dams in a mode that changes the normal flow patterns of the river (peaking mode). Vegetation stabilizes stream banks by developing entangling root systems that promote cohesion of soils and provide a protective surface layer of leaves and branches. These protective barriers are destroyed when bank vegetation is removed. Improper operation of dams and development increase the magnitude and frequency of high stream discharge. Much higher levels of energy are dissipated on stream banks during periods of high water flow and this increases sediment erosion rates.

A streambank erosion inventory was conducted on 249 miles of the Muskegon River and tributaries in Osceola and Mecosta counties (Anonymous 1991a; Table 22). A total of 1,208 bank erosion sites were identified. This information clearly indicates potential sediment effects in the watershed, especially considering this is only one source. Significant increases in sediment erosion are also coming from upland development (refer to **Soils and Land Use Patterns**). A complete inventory of sediment erosion in the watershed has not been completed, but there is enough data to indicate sediment erosion is a significant problem.

The Director of the Michigan Department of Environmental Quality has authority to issue National Pollution Discharge Elimination System (NPDES) permits. Discharges are regulated to protect minimum water quality standards and the designated uses of the receiving water body according to the Michigan Natural Resources and Environmental Code, Public Act 451, Part 31, 1994. There are 57 NPDES discharge permits in the Muskegon River watershed (Table 23). In general, these discharges are not large enough to influence the hydrology of the mainstem and large tributaries. Hydrology's of small tributaries can be adversely affected. NPDES discharges contain trace amounts of chemical or nutrient contaminants.

Chemical contaminants causing public health advisories on eating fish in the watershed include mercury, polychlorinated biphenyls (PCBs), chlordane, and polycyclic aromatic hydrocarbons (PAHs). DDT (dichloro-diphenyl-trichloroethane), DDE (p, p'-dichloro-diphenyl-trichloroethylene) and dioxins are other chlorinated organic chemical contaminants in fish that can affect the health of wildlife species. Refer to *Public Health Advisories on Eating Fish* for more information. A Remedial Action Plan has been developed in relation to chemical contamination in Muskegon Lake. Refer to *International Joint Commission Areas of Concern* for more information. A full treatment of sources and effects of these chemicals is beyond the scope of this document. Some sources of mercury, PCBs, and DDT(DDE) are discussed below. General references on these contaminants include: the Michigan Critical Materials and Wastewater Register, MDEQ, Surface Water Quality Division; the Michigan Air Emission Inventory, MDEQ, Air Quality Division; the report on Mercury Pollution Prevention in Michigan, MDEQ, Michigan Office of the Great Lakes (Anonymous 1996); the Michigan Fish Contaminant Monitoring Program, 1995 Annual Report, MDEQ, Surface Water Quality Division (Wood et al. 1995); and the Michigan Lakewide Management Plan for Toxic Pollutants submitted to the US Environmental Protection Agency (Science Applications International Corporation 1993).

Mercury consumption advisories have been issued for eight species of fish, in all inland lakes and reservoirs in the watershed, and for large Lake Michigan walleye in the river below Croton (refer to *Public Health Advisories on Eating Fish)*. Mercury can enter water bodies through direct discharge, non-point source run-off, or from atmospheric deposition. Atmospheric deposition is the most significant source. The 1991 Michigan Critical Materials and Wastewater Report listed four industrial users of mercury in the watershed, and one of these had wastewater discharges of less than one pound of mercury annually (C. Hull, MDEQ, Surface Water Quality Division, personal communication; Table 24). Total mercury discharge to Michigan surface or ground waters in 1991 was 200 to 1800 pounds (Anonymous 1996). Atmospheric emissions of mercury in Michigan were estimated at 8,400 to 10,400 pounds annually (Anonymous 1996). Most atmospheric mercury emissions are deposited within 622 miles of the source. Principal air emission sources in Michigan include electric utility coal combustion (41%), industrial and commercial coal combustion (6.5%), municipal waste incineration (28%), and hospital waste incineration (9.4%). Consumers Power Company and Detroit Edison Company estimate emissions from their coal fired utilities at approximately five pounds of mercury per trillion BTUs. Coal combustion is related to sulfur dioxide emissions. Considering the 1995 sulfur dioxide Air Emissions Inventory, the largest source of coal combustion in the watershed was Consumer's Power B.C. Cobb Plant in Muskegon (personal communication, Jim Lax, MDEQ Air Quality Division; Table 25). There are three additional substantial sources of coal combustion located in Ottawa County, immediately adjacent the watershed. These include Consumers Power Company Campbell Plant, Holland Public Works, and the Grand Haven Board of Light and Power (Table 25). Disposal of mercury in the municipal and commercial solid waste stream were estimated at 3,750 to 3,800 pounds for 1985 (Anonymous 1996). Sources of mercury in the solid waste stream include lamp manufacturing and breakage, electrical switches, batteries, thermostats, laboratory use, and dental amalgam preparation.

Mercury is highly toxic to fish and other aquatic organisms and is highly persistent in the environment. Most mercury in fish is in the methyl form and bioconcentration factors, from water to fish, range from 1,800 to 85,000. Both organic and inorganic forms are toxic to developing fetuses. Symptoms such as numbness of the extremities, tremors, spasms, personality and behavior changes, difficulty in walking, deafness, blindness, and death have been associated with the long term ingestion of mercury contaminated fish. Mercury levels in Michigan fish are higher in inland lakes and reservoirs than in streams or the Great Lakes (Wood et al. 1995).

PAH advisories are listed for northern pike, bullheads, and brown trout below Reed City in the Hersey River. Contamination is the result of an old industrial process at this location. PAHs are composed of carbon and hydrogen arranged in the form of two or more fused aromatic rings. PAHs are components of crude and refined petroleum and coal. Most PAHs are formed during incomplete combustion of organic matter at high temperature. Oil is also a major source of PAHs in the environment. Industrial and domestic sewage often contain high concentrations of particulate and soluble PAHs. Storm water runoff contains PAHs from wear and leaching of asphalt road surfaces and from wear of vehicle tires. Most of the PAHs emitted to the atmosphere are in particulate form. Long range transport of PAHs has been demonstrated. PAHs are highly persistent in soils as indicated by their half-lives ranging from 50 days to 1.9 years. PAHs have high potential for dietary bioaccumulation in aquatic species. PAHs administered by various routes have been found to be carcinogenic in several animal species and to have both local and systemic carcinogenic effects (Science Applications International Corporation 1993).

Advisories on eating fish related to polychlorinated biphenyls (PCBs) have been issued for brown trout, carp, channel catfish, lake trout, and lake sturgeon in Lake Michigan and in the river below Croton. Advisories for carp have also been issued for Bear Lake. PCBs are industrial compounds once widely used in a variety of products, including electrical transformers and capacitors, carbonless copy paper, plasticizers in plastic and rubber products, and hydraulic fluids (Science Applications International Corporation 1993). Their high stability contributed to both commercial usefulness and long term detrimental environmental and health effects. In May 1979, the Environmental Protection Agency banned use of PCBs except in totally enclosed systems. In 1982, these regulations were revised to restrict uses of PCBs in electrical equipment. PCB transformers posing a risk to food were banned in 1985. In limited access areas, PCB transformers and large capacitors can be used until the equipment is worn out. Small PCB capacitors can continue to be used. Based on the 1991 Michigan Critical Materials Register, there are 171,718 pounds of PCBs in use at 15 sites in the watershed (C. Hull, MDEQ, Surface Water Quality Division, personal communication; Table 26). There are no discharges to surface waters and disposal of residual materials from production sources are by incineration, hazardous waste treatment or shipping out of state.

PCBs are relatively insoluble, persistent, sorb strongly to organic matter and have high potential for bioaccumulation. PCBs are highly toxic to aquatic life. They have been linked to deformities in wildlife and are commonly detected in the tissue and eggs of fish eating birds (Science Applications International Corporation 1993). PCBs administered orally have been shown to cause liver tumors in rats and mice. Liver damage is the major toxic effect in animals. Other effects in animals include stomach, thyroid, kidney damage, and immunosuppressive effects.

PCB levels in lake trout, coho salmon and chinook salmon have decreased significantly since the early 1970s (Wood et al. 1995; Figures 25 and 26). The decline in PCB levels appears to be leveling off. Studies using caged fish to monitor uptake of PCBs in various Michigan rivers indicate PCB uptake is very low in the Muskegon River system (Figure 27). In general, PCBs are higher in Lake Michigan fish than inland fish (B. Day, MDEQ, Surface Water Quality Division, personal communication).

Advisories on eating fish related to chlordane contamination have been issued for lake trout and lake whitefish in Lake Michigan and in the river below Croton. Chlordane is a chlorinated hydrocarbon originally registered as a pesticide in 1948. Chlordane has been released into the environment primarily from its application as an insecticide. It is estimated that before 1983, 3.6 million pounds were used annually in the United States. All commercial use of chlordane has been banned from use by the Environmental Protection Agency since 1988. Chlordane has a mean half-life of 3.3 years in soil and is highly persistent in aquatic environments. Dietary bioaccumulation factors range from 7,240 to 20,000. Chlordane is readily transported through the atmosphere. It has been linked to bird sickness and mortalities (Science Applications International Corporation 1993). Chlordane administered orally has been shown to cause liver carcinomas in mice and rats. Chronic exposure causes liver disease in rats, mice, and dogs. It also can cause blood disorders such as anemia. Chlordane levels in Lake Michigan fish display no clear trends between 1986 and 1992 (Figure 28).

DDT related fish consumption advisories are not present in the watershed, however, potential effects on wildlife warrants discussion. Michigan’s fish consumption advisories are based on total DDT, and includes DDT, DDD, and DDE. DDT is a polychlorinated pesticide first used in 1939 (Science Applications International Corporation 1993). In 1963, DDT production reached a peak of 180 million pounds. DDE and DDD are metabolic breakdown products of DDT. DDT was banned in 1972 and is no longer produced commercially in the United States. DDD was used as a pesticide (not nearly as much as DDT) and is still used in some cancer chemotherapy. DDT is a non-degradable pesticide and half-lives of up to 31 years have been reported for DDT, and up to 15.6 years for DDE. The volatilization and sorption in biota tissues and sediments are major processes for transfer of DDT and DDE in the aquatic environment. It is estimated that 98% of the load to Lake Michigan is attributable to atmospheric deposition. There are no reported uses of DDT in the 1991 Michigan Critical Materials Register (C. Hull, MDEQ, Surface Water Quality Division, personal communication).

DDT is very persistent and highly toxic to aquatic organisms. Dietary bioaccumulation factors range from 12,000 to 363,000 (Science Applications International Corporation 1993). DDT is a confirmed carcinogen, with experimental carcinogenic, tumorigenic and teratogenic data. DDE has caused liver tumors in mice and is classified by the Environmental Protection Agency as a probable human carcinogen. DDT and DDE are present in the tissue and eggs of many fish eating birds, and has been linked to egg shell thinning and reduced reproductive success in various birds.

DDT levels in Lake Michigan fish have decreased significantly since the early 1970s. Concentrations in fish appear to have leveled off in recent years (Figure 26).

Dioxin related fish consumption advisories are not present in the watershed, however, potential effects on wildlife warrants discussion. Dioxins are formed as unwanted impurities during the manufacturing of other organic compounds. They can be generated as a by-product of paper and pulp mill processes that use chlorine. Dioxins can be released to aquatic systems in various wastewater streams and sludges generated by these industries. Incineration of municipal and industrial waste can also produce dioxins. TCDD (2,3,7,8 tetrachlorodibenzo-p-dioxin) is the most toxic and best understood of all the types of dioxins. Furans are a group of 135 halogenated tricyclic aromatic hydrocarbons with many structural and toxicity similarities to the dioxins. There are two companies listed in the 1991 Michigan Critical Materials Register that generated dioxins and furans (personal communication, Chris Hull, MDEQ Surface Water Quality Division). NOR-AM Chemical, in Muskegon, generates less than two pounds of these byproducts and disposes of them by shipping out-of-state or incineration. Scott Paper Company, in Muskegon, generates less than two pounds of these materials and discharges them to the municipal wastewater treatment system. Dioxin and furans have not been evaluated in Muskegon River fish although these contaminants have been found in fish from other Great Lakes locations.

The Environmental Protection Agency classifies TCDD as a probable human carcinogen. TCDD causes adverse reproductive effects in a variety of animals including reduced fertility and spontaneous abortion in monkeys, and birth defects in mice. Toxicological studies of furans indicate the effects of this group of compounds are similar to the dioxins (Science Applications International Corporation 1993).

Fisheries Management

This section includes discussion of historical and current programs, interactions of fish with avian and mammal species, and potential programs for improvement or expansion of sport fisheries. Discussion of historical and current programs is divided into four sections: the river located upstream of the hydroelectric dams (*Higgins Lake to Big Rapids*), the river impounded by the hydroelectric dams (*Big Rapids to Croton*), the river located downstream of the hydroelectric dams (*Croton to Muskegon Lake*), and *Muskegon Lake*. Since habitat is a critical factor in fisheries management, a summary of important habitat features and related problems is included for each river section.

Fisheries and Management Programs

Higgins Lake to Big Rapids

Stream discharge is intermediate in stability in this river section, which is a function of soil characteristics of the watershed and land development. Agricultural, urban, and residential development and floodplain use are moderate. Significant sediment from bank erosion have been documented on the mainstem and tributaries in Osceola and Mecosta counties, and flow instability may be contributing to this problem. Sediment erosion from developed land is much higher than natural erosion rates. Problems with fish recruitment, especially northern pike and smallmouth bass, may be a result of high sediment inputs.

A significant portion of tributaries are affected by small impoundments. This presents a threat, and may already be affecting the marginal coldwater-coolwater nature of the river. Water temperatures range into the upper 70s but extremes in the high range are short in duration. Extended periods of water temperatures occur between 31°F and 32°F during winter months. The extent of anchor and frazil ice formation, from these low temperatures, is unknown. Current fisheries production and species diversity data do not indicate low water temperatures are significantly affecting fish populations. Native coldwater-coolwater species such as burbot, longnose dace, and mottled sculpin are present in the fish community but survival of stocked trout may be low. The documented disappearance of Arctic grayling, from the Hersey River, indicates significant habitat and fish community changes have occurred in this river section.

Higgins Lake is 9,600 acres in size with a maximum depth of 135 ft. The fish community is composed of predominantly coldwater species. Primary sport fish include rainbow smelt, yellow perch, rainbow trout, brown trout, and lake trout. Moderate fisheries also exist for northern pike, smallmouth bass, lake whitefish, and lake herring. Rainbow trout are the only species currently stocked. In recent years oxygen depletion has occurred in some areas of the hypolimnion. Elevated nutrient from shoreline development is suspected to be the cause. Eurasian milfoil is present and is affecting native vegetation.

Houghton Lake is 20,044 acres in size and the largest inland lake in Michigan. Maximum depth is 22 feet, but the largest portion of the lake is shallow with an average depth of 8 feet. There are extensive sand and gravel shoals, and submergent and emergent vegetation. Legal lake level elevation is maintained by a dam at 1138.1 feet. Two large marshes, each approximately 400 acres in size, are located on the west shore. Shoreline development for permanent and recreational homes is extensive. Several wastewater treatment systems help to control nutrient inputs from surrounding homes. Fisheries have been managed since 1921. The fish community appears stable, with no major changes occurring since 1962. Primary game species include bluegill, walleye, northern pike, crappie, largemouth bass, smallmouth bass, and yellow perch.. Walleye are the only species currently stocked.

Just below Houghton Lake the river is impounded by Reedsburg Dam into a large wildlife flooding. Reedsburg flooding is predominantly shallow with many stumps and snags. The flooding provides a small amount of fish habitat for warmwater fish. Between Houghton Lake and Hersey, river gradient is low, bottom materials are predominantly sand, water velocities are moderate, and pool development is good but riffle areas are limited. Between Hersey and Big Rapids, river gradient is moderate, bottom materials are intermittent sand with extensive areas of gravel and cobble, and water velocities are moderate to high with good riffle, run and pool development.

Fish community data indicate the downstream distribution limit of adult northern pike in the mainstem is at the confluence with the Middle Branch River. This also appears to be the upstream limit for smallmouth bass. This distribution pattern may be influenced by river gradient. There are approximately 85 miles of low gradient river upstream of the Middle Branch River confluence. Low gradient favors northern pike habitat that includes wetlands, bayous, and low water velocities. Below the confluence with the Middle Branch River, gradient is moderate (Figure 7). Moderate gradient provides suitable smallmouth bass habitat.

Current use of the upper river for sport fishing is low to moderate. The moderate populations of northern pike, smallmouth bass, walleye, and stocked trout support small local sport fisheries. Angler use and other recreational use need to be evaluated.

Fisheries management in the 85 miles of mainstem, upstream of the Middle Branch River confluence, should be targeted at northern pike. The introduction or reintroduction of Great Lakes muskellunge may also be feasible. Muskellunge were native to the river and the Great Lakes strain historically had riverine stocks. It is unknown if muskellunge originally inhabited this river section and more review will be needed to determine potential stocking locations. Bayous, wetlands, gradient and water velocities found in this section of river are typical habitat for muskellunge (Scott and Crossman 1973). However, river habitat preferences for muskellunge may be different than for northern pike (Harrison and Hadley 1978), and northern pike can suppress muskellunge populations (Crossman

1978). The northern pike population may deter introduction of muskellunge. Management for walleye may also be possible but stocking would be required to establish a population and possibly to maintain a fishable population. All three species tend to occur at relatively low densities in river systems and there appears to be abundant forage to support additional predators. Instream cover, especially large logs, may be a limiting factor and more complete evaluations for this type of habitat need to be conducted. Protecting and enhancing wetlands and bayous associated with the mainstem is critical to maintaining the naturally reproducing stock of northern pike. Northern pike and muskellunge use wetland areas for spawning, rearing, and for food and cover. Low numbers of young northern pike may indicate recruitment is currently a problem. Trout stocking would not be successful because trout typically exhibit poor survival in combination with northern pike. Reintroduction of Arctic grayling is not recommended since reintroduction of this species into Michigan rivers has not been successful (Nuhfer 1992).

There are 39.5 miles of river between the confluence with the Middle Branch River and Big Rapids. The 15.4 miles of mainstem from the Middle Branch River Confluence to Hersey is mostly low gradient, and the 24.1 miles of stream below Hersey has moderate river gradient. All 39.5 miles could be managed for smallmouth bass and walleye. Moderate populations of both species currently exist. The walleye population is supported by a moderate stocking program. The smallmouth bass population is self sustaining. Low numbers of young bass indicate recruitment may be a problem. Controlling excessive sediment inputs or stocking smallmouth bass may improve recruitment. The introduction of muskellunge may be possible. Suitable habitat and forage for muskellunge are present and the abundance of competing northern pike is low. Instream cover may be a limiting factor and needs to be evaluated. The 19 miles of moderate gradient stream below Hersey may support resident rainbow or brown trout management. The mainstem is currently classified designated trout stream between Paris and Hersey (Figure 11). This section is currently stocked with brown trout but the fishery appears to be limited because survival is low, at about 5.3% from spring stocking to the first fall. The trout fishery seems to have declined in recent years due to unknown reasons (L. Mrozinski, MDNR Fisheries Division, personal communication). However, current stocking rates for trout are relatively low at 38 per acre. Typical stocking rates for trout in southern Michigan streams are 200 to 300 per acre. Stocking the Hersey to Big Rapids section of river at these rates would require 87,600 to 131,400 fish, annually. Similar stocking rates in the Muskegon River at Newaygo have produced a very good fishery.

All the upper river would benefit from passage of potamodromous fish. In the mainstem, these benefits would be primarily from angler use above Hersey and from angler use and natural reproduction of fish below Hersey. Primary potamodromous species that would benefit angler use would be walleye, chinook salmon and steelhead. Potamodromous species that would benefit from reproduction are chinook salmon, steelhead, walleye and possibly lake sturgeon and river redhorse. Potential annual natural reproduction is estimated at 585,268 chinook smolts and 116,716 steelhead smolts. The potential annual economic benefits of reproduction and angler use, for the Hersey to Big Rapids river section, are estimated at over $3,000,000 (Table 26). Potential potamodromous use and reproduction are based on values from the Muskegon River between Croton and Newaygo. Riverine trout angler-days values are based on estimates from another southern Michigan trout stream.

The following large tributaries in this section have good to excellent brown and brook trout fisheries: Hersey River-above Miller Dam in Reed City; Clam River-Falmouth Dam up to the Missaukee-Wexford County line (classified Blue Ribbon Trout Stream); Middle Branch River-above Marion Dam (classified Blue Ribbon Trout Stream); and West Branch of the Muskegon River-entire stream. Dams in these tributaries are blocking migrations of trout within the tributary and to the main channel. This may have negative effects on recruitment. The lake-level control structure at Lake

Cadillac is degrading water quality (water temperatures and discharge) in the Clam River (refer to Water Quality). The effects of Falmouth Dam on the Clam River need to be evaluated. Marion and Miller dams are degrading water quality in the Middle Branch and Hersey rivers.

Big Rapids to Croton

Below Big Rapids the river becomes semi-riverine grading into a 610 acre impoundment created by Rogers dam. This impoundment is largely sand bottom and there is very limited development of aquatic vegetation. The upper part of the impoundment is filling in with sand. This may be limiting development of stable beds of aquatic vegetation, that also limits fish production. During summer, temperature and oxygen stratification occur, with oxygen limited for fish below 25 feet deep (Lawler, Matusky, & Skelly Engineers 1991a; MDNR, Fisheries Division survey records). This is typical of many Michigan lakes. The underlying river gradient is moderate to high in this river section.

The fishery of Rogers Impoundment, both historic and current, is classified as moderate to poor. A good population of black crappie is present along with small populations of northern pike, and smallmouth bass. Some walleye are present but the majority of the fish population is composed of carp, suckers, and redhorse. A chemical reclamation project was conducted on the impoundment in 1967 in an attempt to reduce carp numbers and improve game fish populations. Stocking of various species of game fish has occurred since 1937. Species stocked at various times include walleye, brook trout, rainbow trout, brown trout, northern pike, yellow perch, smallmouth bass, largemouth bass, bluegill, hybrid sunfish, tiger muskellunge, and channel catfish. Fish entrainment and mortality through Rogers Dam is detrimental to fish populations in the impoundment (refer to **Dams and Barriers**). Approximately 55,875 fish are annually entrained and 8,527 are killed. If the dam and impoundment were not present, this 7.5 mile section of river could support substantial riverine trout, walleye, smallmouth bass, lake sturgeon, and potamodromous fisheries. Moderate and high river gradients would produce good hydraulic diversity and regular riffle-pool sequences that are ideal habitat for river species. Potential annual potamodromous angler use is estimated at 17,925 days, and along with potential natural reproduction and riverine trout fishing, the potential annual economic benefit is $1,019,841 (Table 27). These figures do not represent fisheries benefits to walleye, smallmouth bass, and lake sturgeon that also live in these river habitats.

Between Rogers and Hardy Dam, the river is semi-riverine for about two miles with extensive gravel-cobble substrate. This grades into Hardy Impoundment, which is 3,971 acres in size, with bottom materials consisting largely of sand. There is a narrow littoral shelf with very little development of aquatic vegetation. This shelf is largely exposed to winter freezing conditions as a result of winter impoundment drawdown. This causes limited development of stable beds of aquatic vegetation and is affecting fish production. Many fish species require aquatic vegetation for reproduction or as part of their habitat needs, and fish production is directly related to submersed macrophytes (Schneider 1975; Schneider 1978; Schneider 1981; Durocher et al. 1984; Wiley et al. 1984; Janecek 1988; Kilgore et al. 1989; Bettoli et al. 1993; Hinch and Collins 1993). Reservoir fluctuations or motor boat use appears to be causing sandy bank erosion in many locations. During summer, temperature and oxygen stratification occur, with oxygen limited for fish below 25 feet deep (Lawler, Matusky, & Skelly Engineers 1991b). The underlying river gradient is moderate to high.

The fishery of Hardy Impoundment is moderate for yellow perch and moderate to low for walleye, black crappie, and smallmouth bass. The majority of the fish population is composed of suckers, redhorse, and carp. Species of fish that have been stocked since 1931 include bluegill, smallmouth bass, yellow perch, walleye, brown trout, rainbow trout, northern pike, and channel catfish. There is no current fish stocking in Hardy Impoundment. Natural reproduction of walleye in Hardy

Impoundment is substantial (unpublished data, MDNR Fisheries Division). Entrainment and mortality of fish through Hardy Dam are affecting fish populations in Hardy Impoundment (refer to **Dams and Barriers**). Approximately 25,947 fish are annually entrained and 3,801 are killed. Hardy impoundment may have the potential to support stocking of rainbow trout, if protection from entrainment through Hardy Dam can be provided. Temperature and dissolved oxygen may be suitable for trout management, however, additional information would be needed to determine if this is feasible. An estimated 198,000 to 397,100 trout would be needed annually to stock this impoundment adequately. If Hardy impoundment was not present, this 25.1 mile river section has the potential to provide $3,458,211 in benefits, annually, from riverine trout fishing and potamodromous fishing and natural reproduction (Table 27). Moderate and high river gradients would produce good hydraulic diversity and regular riffle-pool sequences that are ideal habitat for river species. These figures do not represent fisheries benefits to walleye, smallmouth bass, and lake sturgeon that also live in these river habitats.

Between Hardy and Croton dams, there is a very short semi-riverine section that grades into Croton Impoundment. Croton Impoundment is 1,380 acres in size and has a narrow littoral shelf with moderate development of aquatic vegetation. Reservoir fluctuations or water craft appear to be causing sandy bank erosion in some places. Limited establishment of stable beds of aquatic vegetation may be limiting fish production. The upper portion of Croton Impoundment is affected by low dissolved oxygen discharges from Hardy Dam (refer to **Water Quality**). Croton dam also impounds a portion of the Little Muskegon River, which is called Little Croton Impoundment. This part of the impoundment is shallower and has some larger areas of established vegetation and many old stumps. The bottom materials of Little Croton have more organic debris. During summer, temperature and oxygen stratification occur, with oxygen limited for fish below 25 feet deep (Lawler, Matusky, & Skelly Engineers 1991c). The underlying river gradient is moderate to high in both impoundments.

The fishery in Croton Impoundment is moderate for yellow perch, and moderate to low for black crappie and walleye. The majority of the fish population is composed of suckers, redhorse, and carp. A rough fish removal project was conducted in 1985, but only 5,000 pounds of the targeted 75,000 pounds of fish were removed due to unfavorable netting conditions. Species of fish that have been stocked in Croton Impoundment include bluegill, walleye, and brown trout. Small numbers of walleye are currently stocked in Croton each year. Entrainment and turbine mortalities are affecting the fisheries in Croton Impoundment (refer to **Dams and Barriers**). Approximately 219,761 fish are entrained and 31,714 are killed (Lawler, Matusky, & Skelly Engineers 1991c). Croton impoundment may have the potential to support rainbow trout, if protection from entrainment through Croton Dam can be provided. Temperature and dissolved oxygen may be suitable for trout management, however, additional information would be needed to determine if this is feasible. An estimated 69,000 to 138,000 trout would be needed annually to adequately stock this impoundment. If Croton impoundment was not present, this 7.5 mile river section has the potential to provide $1,019,841 in benefits, annually, from riverine trout fishing, and potamodromous fishing and natural reproduction (Table 27). Moderate and high river gradients would produce good hydraulic diversity and regular riffle-pool sequences that are ideal habitat for river species. These figures do not represent fisheries benefits to walleye, smallmouth bass, and lake sturgeon that also live in these river habitats.

The upper portion of the Little Muskegon River is stocked with trout to maintain a fishery. The Little Muskegon River has a substantial amount of moderate gradient habitat and there is extensive agricultural development in the watershed. Water temperature and habitat evaluations are needed on this stream.

After hydroelectric dams were built, migrating walleye were unable to return to upstream areas for spawning and feeding. The general downstream migration pattern of mature walleye resulted in a walleye population consisting largely of small fish in the impoundments. When the Newaygo Dam was still in operation, large numbers of walleye congregated below the dam during the spring spawning run. From 1923 through the 1960s, spawning walleye captured below Newaygo Dam were transferred into the three upper impoundments. This operation was called the Newaygo Transfer. The purpose of this program was to supplement poor walleye fisheries in the impoundments (Eschmeyer 1947). Results of tagging studies associated with the fish transfer showed benefits lasted only one year (Eschmeyer 1948). Some fish were caught by anglers and the remaining fish migrated downstream through the dams. After removal of Newaygo Dam in the late 1960s, walleye were able to migrate up to Croton Dam allowing more access to river spawning habitats. The impoundments continue to have poor to moderate walleye fisheries due to blockage of fish movements by the dams.

In summary, none of the management procedures conducted on any of the three hydroelectric impoundments have been successful in producing lasting fishery improvements. Reasons for this include fish entrainment-mortality problems at the dams, water quality problems with dissolved oxygen and temperature, habitat limitations in the littoral zone, and blockage of fish migrations by dams. Angler use and other recreational use need to be evaluated on these impoundments.

Croton to Muskegon Lake

Agricultural, urban, and floodplain development is moderate. Bank erosion of sediment is substantial between Croton and Newaygo. Bottom materials between Croton and Newaygo are intermittent sand with large areas of gravel and cobble stone. Water velocities are moderate to high and there is some good riffle and pool development. River gradient is moderate. Water velocities and bottom substrate conditions are favorable for spawning and this is currently a primary spawning area for walleye, steelhead, chinook salmon, and lake sturgeon. This section of river produces the highest number of natural chinook salmon smolts in the State of Michigan, with annual production at about 350,000 (Carl 1980). The prime section of river used for fish spawning, between Newaygo and Croton (14.4 river miles), was blocked from fish migrations by the Newaygo Dam from 1900 through 1969. Below Newaygo the bottom materials again are largely sand and water velocities are moderate. Some good pool areas are present but riffle areas are limited. River gradient is low.

Stream discharge is intermediate in stability and is a function of soil characteristics and land development. Daily and annual flow stability have been affected by water regulation at hydroelectric dams. Spring flood-water storage in Hardy Impoundment reduces the severity of high spring flows so annual high flows are reduced in duration and amount. Annual low flows were less stable and this was attributable to dam regulation. Daily flows below Croton were more extreme at both high and low flows. The regulation of stream discharge by the hydroelectric dams caused significant reductions in fishery habitat below Croton Dam. Croton Impoundment is also affecting water quality by decreasing dissolved oxygen concentrations below the dam. These affects are most severe immediately below the dam and decrease downstream towards Newaygo. Hardy Impoundment is altering water temperature fluctuations in this river section. Water temperatures range into the 70s and occur for longer periods of time, but are less extreme than above the dams. Water temperatures below 32 °F do not occur between Croton and Newaygo. Hydroelectric impoundments are causing a delay in water temperature increases during spring months and this may be detrimental to walleye egg survival and hatching in the river (Schneider et al. 1991). Fish community data also indicate effects on biological communities below Croton Dam. Fish biomass, diversity, game fish composition, and coldwater-coolwater fish numbers are lower at Croton than at Newaygo. Native coldwater-coolwater fish and stocked trout are relatively abundant in the fish community at Newaygo, indicating good water quality conditions. Biological communities below Croton Dam will be enhanced by the re-regulated discharges required in the new FERC license. Reduction of water quality problems caused by the hydroelectric dams will also improve biological communities. The 1994 Settlement Agreement (refer to *Offer of Settlement for Hydroelectric Dam Issues*) has provisions to mitigate many hydroelectric dam effects noted above.

All the mainstem is designated trout stream between Croton and Lake Michigan (Figure 11). The purpose of this designation is to protect the populations of riverine rainbow and brown trout, chinook salmon, steelhead, and coho salmon.

The current sport fisheries for walleye, chinook salmon, steelhead, brown trout, and rainbow trout from Croton to Muskegon are very good by today's standards. The fisheries and programs for these and other important species are summarized below. Tributary streams having good trout fisheries include Bigelow Creek, Cedar Creek, and Mosquito Creek.

Moderate numbers of large walleye are present all year. During spring, large numbers of spawning fish from the river, Muskegon Lake, and Lake Michigan congregate in the area of river between Croton Dam and Newaygo. This spawning run is used to supply eggs for a large portion of the MDNR, Fisheries Division’s walleye stocking program. The nursery area for walleye is Muskegon Lake. The number of fish in the spawning run is currently estimated at 43,000 (Day 1991), which is lower than the near maximum level of 130,000 occurring during the 1950's (refer to **Original Fish Communities**). Currently, this population is supported by a stocking program that is expected to continue supplementing natural reproduction until historic population levels are reached (Figure 29). More study is needed to determine current population characteristics and problems affecting the walleye population in this system. The Muskegon River population of walleye is genetically pure which is unique in the Great Lakes Basin (Hebert 1988). Very little stocking of other genetic strains has occurred in the Muskegon system. The MDNR, Fisheries Division is attempting to protect the integrity of this strain.

Chinook salmon have been stocked since 1967, with annual stocking rates ranging from 210,000 to 530,000 (Figure 29). The current stocking rate is 250,000 annually. The Muskegon River produces the largest number of natural chinook salmon smolts in Michigan (Carl 1980). Smolt production averages about 350,000 annually, although recent MDNR, Fisheries Division data indicate production may be as much as four times this value. High smolt production is the result of optimal spawning habitat (water velocity and cobble sized stone) for this species. Current stocking levels and natural reproduction are supporting an excellent river fishery, and also support an excellent fishery in Lake Michigan. The Muskegon River is large and may support increased levels of stocking. Current levels of natural reproduction should be evaluated for chinook salmon. Natural reproduction in the river is suspected to have decreased in recent years as the result of low numbers of adult spawning fish. A basin wide decrease in the number of chinook salmon has occurred in Lake Michigan during the past 8 years, resulting from bacterial kidney disease infections.

Steelhead have been stocked since 1966, with annual stocking rates ranging from 14,000 to 60,000 fish (Figure 29). The current stocking rate is 50,000 annually. This stocking rate produces an excellent river fishery and contributes to an increasing Lake Michigan fishery. About 50% of adult steelhead returning to the river are naturally reproduced fish, so natural reproduction is an essential part of the fishery (Seelbach and Whelan 1988). Higher stocking levels of steelhead could be supported by this large river system. In 1984, about one half of the winter steelhead stocking was diverted to stocking summer run strains of steelhead. This program was discontinued in 1990 due to poor returns of summer run fish. Current levels of natural reproduction should be evaluated for steelhead in this system.

Coho salmon were stocked from 1968 to 1979 (Figure 29). Stocking was discontinued due to poor returns of fish to the river. A very small amount of natural reproduction currently occurs in the river.

Riverine rainbow trout have been stocked since 1966, at rates ranging from 5,000 to 75,000 annually (Figure 30). Currently, 75,000 fish are annually stocked between Croton and Bridgeton. This stocking rate produces an excellent river fishery that is extensively used for bait and fly fishing. This fishery is supported primarily by stocking, although some natural reproduction may be occurring.

Riverine brown trout have been stocked since 1966, at rates ranging from 4,000 to 50,000 annually (Figure 30). Currently, 50,000 are annually stocked between Croton and Bridgeton. This stocking rate produces an excellent river fishery that is extensively used and is supported by some natural reproduction.

A moderate smallmouth bass fishery exists. The smallmouth bass population is self sustaining and more information is needed on this population in the lower river.

Both lake sturgeon and river redhorse are classified threatened species in Michigan. Both species are present in low abundance in the Muskegon River. Thorough evaluations should be conducted to determine proper management programs for protection and enhancement of these species. A substantial spring spawning run of white sucker, longnose sucker, and various redhorses occurs. This spawning run produces a good fishery.

The introduction of Great Lakes muskellunge may be possible. More review will be necessary to determine if suitable habitat is present.

Little current or historical information is available on use of the river system by lake trout, lake whitefish, round whitefish, and sauger. In recent years, lake trout have been using Muskegon Lake and the lower river more frequently, based on sport catch information. More information will be needed to determine if management programs can enhance these populations in Muskegon Lake and the lower river.

Sea lamprey use this river section for spawning. Currently, larval lamprey are controlled using selective poisons. Generally, treatments occur every three years at a cost of $620,000 (1993 dollars). Croton Dam blocks movement of lamprey to upstream areas. Alternative controls need to be considered. Use of electric or low-head barriers near the mouth of the river need to be investigated. The current cost of installing an electric barrier on the Pere Marquette River was $200,000. The cost would be at least twice as much for the Muskegon River because of its larger size. Allowing lamprey access to river sections above Croton would substantially increase chemical control costs, to approximately $1,800,000 (E. Coon, US Fish & Wildlife Service, personal communication).

Bigelow Creek supports a good brown and brook trout fishery that is supported by natural reproduction. Cedar Creek supports a good brook trout fishery that is supported by natural reproduction. Cooperative habitat protection and rehabilitation programs are ongoing in both of these streams. Water temperature evaluations have been collected on both streams but analyses have not been completed. Fish population estimates were conducted at two sites on Cedar Creek in August 1995 (MDNR, Fisheries Division survey records). Average estimated brook trout numbers and weight were 1,962/mile, and 56.8 lbs/acre. Average estimated steelhead parr numbers and weight were 910/mile, and 10.6 lbs/acre. Other species collected included white sucker, sculpins, central mudminnow, yellow perch, burbot, bullhead, and blacknose dace. Fish population estimates were conducted at four sites in Bigelow Creek in August 1994 (MDNR, Fisheries Division survey records). Average estimated numbers and weight of individual species were: brook trout - 29/mile, 5.8 lbs/acre; brown trout - 340/mile, 65.1 lbs/acre; steelhead parr - 104/mile, 6.2 lbs/acre; and chinook salmon - 22/mile, 0.4 lbs/acre. Chinook salmon were juveniles that had not smolted during spring. This stream produces much greater numbers of chinook salmon smolts than is indicated by this summer collection (Carl 1980). Other species collected included sculpin, central mudminnow, blacknose dace, white sucker, creek chub, green sunfish, johnny darter, yellow perch, bullhead, and burbot.

Brooks Creek was stocked with brown trout but stocking was discontinued due to poor survival. This stream is marginal and there is substantial development in the watershed. Habitat is limited and there is excessive bedload sediment in the stream. Additional habitat and water temperature evaluations are needed. Some work to improve conditions in Brooks Creek has been conducted through the non-point source program sponsored by MDEQ, Surface Water Quality Division.

Muskegon Lake

Muskegon Lake is 4,150 acres in size and supports extensive fisheries. Associated systems include Bear Lake, a shallow lake connected by a channel to Muskegon Lake; a marsh system 10 to 15 square miles in size encompassing the river immediately above the lake; and Lake Michigan, connected to Muskegon Lake by a shipping channel. The association of the river, marsh, and Lake Michigan produces a large variety of sport fishing in Muskegon Lake. Important fisheries include resident black crappie, bluegill, yellow perch, walleye, smallmouth bass, largemouth bass, northern pike, and flathead catfish. Walleye are the only species currently stocked. Largemouth bass are most abundant at the east end of the lake where smallmouth bass are more abundant near the west end. The west end receives cool water influxes from Lake Michigan that are favorable to smallmouth bass. The extensive marsh system supports a large northern pike population. The fisheries for bass and northern pike are excellent. Sometimes during fall and winter months, large numbers of yellow perch migrate from Lake Michigan to Muskegon Lake, and these fish support a large winter fishery. Spawning runs of chinook salmon and steelhead provide fall and spring fisheries.

Two species of native fish should be considered for reintroduction into Muskegon Lake. These are white bass and Great Lakes muskellunge. Both are important sport fish and reintroduction may be favorable due to improvements in water quality. The presence of a large northern pike population may deter introduction of muskellunge. Recently, both white bass and white perch were collected from Muskegon Lake. White perch compete with white bass and this may interfere with rehabilitation.

Probably the most significant problem affecting the fish communities in Muskegon Lake is the loss of shallow, littoral zone fishery habitat from dredging and development. This has been occurring since the early 1800s and continues today. Almost the entire littoral zone of the south shore of the lake has been dredged or filled. Significant filling of wetlands has also occurred in the primary northern pike spawning areas located above the lake. Other concerns include the recent introduction of zebra mussel and existing polluted sediments in the lake.

Avian, Mammal and Fish Interactions

Several birds and mammals use fish as a food source or directly affect fisheries habitat in the river. These include bald eagle, river otter (*Lutra canadensis*), mink (*Mustela vison*) and beaver (*Castor canadensis*). Only the bald eagle is classified a threatened species in Michigan. All four species are present throughout the Muskegon River watershed. Both wildlife and fisheries management programs should consider affects on species that interact. Integrating the needs of all species in individual programs should prevent major conflicts in management goals, and this will produce a more diverse and balanced ecosystem. This approach also should prevent management of one species to the complete exclusion of another, and allow consideration of economic, recreational, and other social needs.

Beaver, Wildlife Floodings, and Coldwater Fish

Management for coldwater fisheries sometimes conflicts with beaver and wildlife flooding management. Beaver and wildlife impoundments have the same affects as other dams (refer to **Dams and Barriers**). They are generally detrimental to coldwater fisheries because of effects of increased water temperatures, decreased dissolved oxygen, and as barriers to seasonal spawning and wintering habitat. As a result of decreases in coldwater fishery habitat in Michigan, MDNR policy favors beaver removal when in conflict with coldwater fisheries. Beaver populations currently are adequate in the Muskegon River watershed, except for the Muskegon State Game Area, where population numbers could be increased (N. Kalejs, Michigan Department of Natural Resources, Wildlife Division, personal communication). Numerous impoundments constructed for wildfowl are present in the watershed and decreasing natural wetlands will probably increase the demand for wildlife floodings in the future. Currently, many small dams and wildlife floodings in the watershed, primarily on tributary streams, are limiting coldwater fish management.

Bald Eagle, Mink, River Otter and Potamodromous Fish

Reproduction and other health aspects of bald eagle, mink and river otter can be affected by high concentrations of specific contaminants in fish and other prey such as gulls and water birds. Ludwig et al. (1993), summarized studies indicating human and wildlife populations are exhibiting subtle, chronic health effects due to PCBs and other polychlorinated hydrocarbons. Levels of contaminants responsible for health effects on these species are generally higher in potamodromous species of fish (refer to **Water Quality**). Potamodromous species are those fish that use Lake Michigan or Muskegon Lake for part of their life cycle.

A potential fishery management goal is the re-establishment of native (walleye, lake sturgeon, river redhorse, lake trout) and establishment of naturalized (chinook salmon, steelhead, brown trout,) fish spawning runs above Croton Dam, and improvement of the genetic viability of native river species, by providing fish passage or removal of dams in the river. There are substantial potential fishery, economic, and recreational benefits that would result from expansion of these spawning runs.

There is some concern that allowing passage of fish upstream of Croton Dam will affect, or partially reduce, the reproduction of inland nesting eagles, mink and river otter. Primary contaminants that affect bird reproduction include DDE, PCBs, dioxins and dieldrin. PCBs are the primary contaminant affecting mink and river otter. Concentrations of these contaminants have declined significantly in Lake Michigan fish since the early 1970s (Jackson and Carpenter 1995; Wood et al. 1995; Figures 25 and 26). Concentrations of these contaminants have also been declining in fish eating birds and their populations have been increasing (Ewins 1994, Wesoloh and Bishop 1995). Ewins (1994) describes the dramatic increases in double-crested cormorant (*Phalacrocorax auritus*) populations on the Great Lakes over the past 20 years, averaging a staggering 29% per annum. Michigan eagle populations have also increased substantially over the past 15 years. There were 88 breeding pairs of eagles in Michigan in 1977. The Northern States Bald Eagle Recovery Plan documented 102 occupied breeding areas in Michigan in 1981, and set a recovery goal of 140 nesting pairs and an annual average productivity of at least 1.0 fledgling per occupied nest (Grier et al. 1983). Considering 1981 through 1990 data, the breeding pair goal of 140 was achieved and the average productivity goal was nearly achieved (mean = .95; Kubiak and Best 1991). Kubiak and Best (1991) also stated eagles inhabiting Great Lakes shoreline breeding areas had lower productivity values (0.71 young per nest) than inland nesting eagles (1.05 young per nest). Bowerman et al. (1995) documented nesting areas for Great Lakes eagles increased at a faster rate than inland nesting areas from 1977 to 1993. They also showed Great Lakes eagle productivity increased substantially during this period, whereas inland eagle productivity remained unchanged. Eagle populations have continued to increase and there were at least 276 breeding pairs in Michigan in 1995, well above the recovery goal of 140 breeding pairs (G. Alexander, MDNR Fisheries Division, personnel communication). Average production of eaglets from 1989 through 1995, was 0.97 for inland nests, 0.74 for Great Lakes nests (within 5 miles of the shoreline), and 1.00 for nests located on streams overlapping with migrations of Great Lakes fish. In 1995, Great Lakes nest production was 0.97 young per nest (G. Alexander, MDNR Fisheries Division, personal communication). Stable eagle populations require a productivity rate of 0.70 fledged young per occupied nest and healthy populations require a productivity rate of 1.00 (Kubiak and Best 1991). This information indicates passage of fish at the hydroelectric dams would not affect inland eagle productivity.

A causal link between the status of mink and river otter populations and exposure to organochlorine chemicals from the Great Lakes has not been established, and there is a need for a large amount of research (Wren 1991). Diet studies on ranch mink indicate contaminants in Lake Huron carp can cause effects on reproduction (Heaton et al. 1995a) and hematology and liver integrity (Heaton et al. 1995b). Information on mink and river otter populations in Michigan are lacking and there are no ongoing population studies. Harvest regulations for mink have not changed for many years and there is no bag limit. River otter cannot be harvested in the southern lower peninsula, one can be harvested in the northern lower peninsula, and three can be harvested in the upper peninsula. The overall season bag limit for river otter in Michigan increased from 2 to 3 for the 1996 season. Special regulations to protect river otter populations are designated for some areas of the state, but none are designated for the Muskegon River watershed (except a 1/4 mile portion of Ryan Creek in Mecosta County). Before 1994, river otter harvest was closed in Muskegon County, but was opened as a result of increasing population levels in the lower White River. Currently, the White River is open for river otter harvest in the sections of stream overlapping with migrations of potamodromous fish (Muskegon & Oceana Counties), but is closed in a large section that is blocked from migrations of Lake Michigan fish. The White River is located just north of the Muskegon River and discharges into Lake Michigan. Reporting of harvested river otters are required by the MDNR Wildlife Division. A sub-sample of river otter is collected annually for biological information, that is used as documentation to verify the stability of populations and to allow continued harvest and exploitation's of pelts (Cooley et al. 1995). From 1985 through 1995, river otter harvest in Michigan has ranged from 654 to 1551 annually, with no clear trends. River otter harvest is not a good indicator of population abundance because harvest is dependent on fur prices and is correlated with beaver trapping. There are no Michigan regulations on mink and river otter directed at protecting populations that overlap with Great Lakes fish migrations.

Despite the significant decreases in organochlorine contaminants, significant increases in eagle and other avian populations, and apparent increases in river otter populations in Michigan, there is still concern contaminant levels in Great Lakes fish may be affecting wildlife populations. Kubiak and Best (1991) summarized 1981 through 1990 eagle population data and contaminant hazard-assessment information, and concluded contaminants were impairing eagle reproduction on the Great Lakes and along streams open to Great Lakes fish migrations. Contaminant hazard assessment studies were sponsored by Consumers Power Company during hydroelectric dam relicensing procedures, and were summarized by Ecological Research Services, Inc. (1991), Bowerman et al. (1991), Giesy et al. (1994a), Giesy et al. (1994b), and Geisy et al. (1995). The hazard assessments used estimated contaminant levels in surrogate birds and ranch mink to predict impairment when compared to a no observable adverse effect concentration predicted from controlled laboratory studies with surrogate birds or ranch mink. Wood duck (*Aix sponsa*), herring gull (*Larus argentatus*) and chickens were used as surrogate species for the bald eagle. Predicted contaminant levels in eagles and mink were based on contaminant levels in certain species of fish, along with numerous assumptions related to biomagnification, bioassay (cormorant blood plasma and cultured rat cellular enzymes) and estimated mercury, PCBs, DDT, DDE, and dieldrin chemical equivalence factors (dioxins or dioxin equivalents). Statistical uncertainty factors were not incorporated in the hazard assessment.

Several investigations have evaluated the transport and dispersal of organic contaminants, by fish, from lake or lower river sections to upper river sections. These studies indicate organic chemicals acquired in resident biota from transport by migrating fish occurs primarily by direct ingestion of eggs, or by direct ingestion of flesh. Elevated levels of chemicals were not found in water, sediments, or other biota not directly feeding on the flesh or eggs of migratory fish. Scrudato and McDowell (1989) evaluated mirex transport from Lake Ontario to tributary streams. Brown trout and blowfly larvae (Diptera: Calliphoridae) accumulated greater concentrations of mirex as a result of ingestion of salmon eggs or feeding on decaying salmon flesh. Elevated concentrations of mirex were not found in crayfish, stoneflies or sediments from the same locations. Lewis and Makarewicz (1988) also evaluated mirex transport from Lake Ontario into a tributary stream. Elevated levels of mirex were found in creek chubs, bluntnose minnow, and smallmouth bass, but not in white sucker from the tributary stream. Migrating salmonids were suspected as the source of contaminants but the exact route of contaminant uptake was not evaluated. Merna (1986) evaluated the transport of DDT, PCBs, and dieldrin from Lake Michigan salmonids into Muskegon and Manistee river tributaries. Elevated concentrations of DDT and PCBs were found in brown trout and levels were related to the number of salmon eggs ingested by trout. Sculpins (*Cottus spp*.) had somewhat elevated concentrations of DDT and PCBs, also related to egg ingestion. Elevated concentrations of DDT and PCBs were not found in crayfish, sand sediments or organic sediments from the tributary stream. Elevated concentrations of dieldrin were not found in any sediment or biota samples. Johnson et al. (1996) evaluated the dispersal of dioxin from a contaminated site in the Bayou Meto River in Arkansas. He found somewhat elevated concentrations of dioxin in fish from the river section upstream of the contamination site and attributed it to fish migration. However, sediment concentrations of dioxin in the upstream river section had not increased. Elevated concentrations of dioxin were found in fish and sediment at the contaminated site and fish contamination was related to direct uptake from adjacent sediments or through the food chain. They also found biomagnification of dioxins in predatory fish did not occur, even though laboratory studies document biomagnification of dioxins in fish. Natural systems may not produce the same level of biomagnification as laboratory studies due to the complexities of lipid metabolism, transport, and trophic dynamics (Johnson et al. 1996).

The issue of contaminant transport needs to be considered in fish passage decisions at the hydroelectric dams on the Muskegon River. Hazard assessment models and pre-1990 Great Lakes shoreline eagle population data have been used to suggest transport of contaminants by Lake Michigan fish may affect eagle, mink and river otter reproduction in upstream river sections. However, recent population data do not support this conclusion. There are no special regulations on mink and river otter harvest in stream sections overlapping with migrations of Lake Michigan fish. In the White River, stream sections open to Lake Michigan fish migrations have more river otter than some inland sections. Allowable river otter harvest in Michigan was increased in 1996, indicating an increasing population. Eagle population numbers have dramatically increased during the past seven years. There were at least 276 breeding pairs of eagles in Michigan in 1995, well above the Northern States Bald Eagle Recovery Plan goal of 140 breeding pairs. Great Lakes shoreline eagle productivity, although lagging somewhat, is stable (seven year average of 0.74) and is increasing

(0.95 in 1995). Great Lakes shoreline eagle productivity levels may be lower because highly contaminated avian prey form a larger part of their diet than fish, and this factor has not been considered, by the US Fish & Wildlife Service when making recommendations on fish passage (Kubiak and Best 1991). Kozie and Anderson (1991) found that herring gulls contained higher concentrations of DDE and PCBs, and were the major source of elevated contaminant levels in bald eagles nesting near Lake Superior on the Wisconsin shoreline. Eagle productivity on streams open to Great Lakes fish migrations is actually higher (1.00) than inland productivity (0.97). The nesting eagle pair located in the Muskegon State Game Area (a Lake Michigan shoreline nest), just above Muskegon Lake, have produced one fledgling during 1995 and one in 1996.

Transport by migrating Lake Michigan fish may result in somewhat elevated levels of chemical contaminants in birds and mammals that feed directly on eggs or decaying carcasses. Contamination of sediment, water and other biota does not appear to occur as a result of the presence of migrating Lake Michigan fish. This information appears consistent with the high productivity rates of eagles on stream sections overlapping with migrations of Lake Michigan fish.

Many factors other than contaminants in fish are important in maintaining eagle populations. Mortality and injury to non-nestling eagles are dominated by trauma (affects with vehicles, buildings, etc.), lead and dieldrin poisoning. Trapping and shooting are secondary causes of injury to eagles (Kubiak and Best 1991). Land development is one of the primary factors in determining the size of eagle populations (Buehler et al. 1991). In the Great Lakes, habitat availability and the degree of human disturbance to nesting eagles are also important to the success of productivity (Bowerman et al. 1991). Weather severity and food supply can also be factors affecting productivity. Another factor important to eagle populations on the Muskegon River is the development of dams and associated impoundments. Impoundments promote power boat use and this type of activity is intensive on the large hydroelectric impoundments. Shoreline development is also extensive on these impoundments. Boat usage, shoreline development and other intensive human activities are detrimental to eagles (Knight and Knight 1984, Buehler et al. 1991, Bowerman et al. 1991). The hydroelectric impoundments on the Muskegon River also cover approximately 40 miles of high gradient stream that would provide prime winter feeding habitat. During winter, these impoundments are covered by ice and prevent eagles from feeding over this extensive river section (Bowerman et al. 1991). Under natural conditions, this high gradient segment would remain free of ice during winter, providing foraging habitat for eagles.

The greatest numbers of eagles are found in the watershed during the winter period (Bowerman et al. 1991). Nesting eagles are well distributed throughout the watershed, occurring on lakes, impoundments, and streams with and without Lake Michigan fish migrations. There are 14 pairs of nesting eagles in the watershed (J. Weinrich, MDNR, Wildlife Division, personal communication). Five pair are located on the mainstem: two pair nest below Croton, one pair nest on a large private land tract on Croton Impoundment, and two pair nest in the headwaters. Nine pair nest along tributaries or lakes: four pair nest in Roscommon County, two pair nest in Clare County, one pair nest in Osceola County, one pair nest in Missaukee County, and one pair nest in Wexford County.

In summary, a potential fishery management goal for the Muskegon River is the re-establishment of native fish and establishment of naturalized fish spawning runs above Croton Dam, and improvement of the genetic viability of native river species, by providing fish passage or removal of dams in the river. There are substantial potential fishery, economic, and recreational benefits that would result from expansion of these spawning runs. The affects of allowing passage of fish upstream of Croton Dam on inland nesting eagles, mink and river otter need to be considered. Reproduction and other health aspects of bald eagle, mink, and river otter can be affected by high concentrations of specific contaminants in their food. Lake Michigan fish generally contain higher concentrations of organic contaminants in their bodies than inland fish. Hazard assessment models and pre-1990 Great Lakes shoreline eagle population data have been used to suggest transport of contaminants by Lake Michigan fish may affect eagle, mink and river otter reproduction in upstream river sections. However, harvest regulations for mink and river otter, and recent bald eagle population information does not indicate significant reproductive effects would occur. Population data are limited, but river otter populations appear to be increasing and allowable harvest of river otter in Michigan was increased in 1996. Population information is not available for mink. However, mink harvest regulations are unrestricted and have remained unchanged for many years. Mink and river otter are not classified threatened or endangered, and there are no special regulations directed at protecting these species in stream sections overlapping with migrations of Lake Michigan fish. The bald eagle is a threatened species in Michigan, but the nesting eagle population in Michigan is well above the federal recovery goal set in 1983. Reproductive rates of Michigan eagles located on stream sections overlapping with migrating Great Lakes fish are similar or higher than nesting eagles in inland locations. Reproductive rates of Great Lakes shoreline nesting eagles have improved significantly since the 1970s, consistent with decreasing concentrations of chemical contaminants in Great Lakes fish. Significant increases in the populations of other fish eating birds have also occurred during the past two decades. Furthermore, all life history aspects of bald eagle, mink, and river otter are important considerations in management of the Muskegon River watershed populations. Suitable habitat, food supplies, and weather severity are primary factors controlling animal populations. Trapping and poaching affect mink and river otter populations. Eagles are susceptible to trauma, lead poisoning, human nest disturbance, human land development, and disturbance by intensive human activities on water and land. Specific management plans have not been formulated for mink, river otter, or bald eagles in the Muskegon River watershed. Management plans using current information and addressing all life history aspects need to be developed. Fisheries management goals for the river should be considered in management plans developed for avian species. Integrating the needs of interacting species in management plans should prevent major conflicts in management goals, and this will produce a more diverse and balanced ecosystem. Obstruction of fish movements by the hydroelectric dams has impaired fisheries over most of the river for nearly 100 years. Fish passage or dam removal would provide significant fisheries benefits to over 78% (165 miles) of the river and impoundments that have had poor to moderate fisheries since 1900. The native, threatened lake sturgeon and river redhorse would benefit. Lake Michigan fisheries would benefit along with inland fisheries. The genetic viability of fish populations would be improved by restoring spawning habitat and allowing more natural fish movements for wintering and breeding. Considering available information, fish passage at the hydroelectric dams is a feasible management option.

Potential for Improvements and Expanded Sport Fisheries

All biological communities in the river system would benefit from protection and stabilization of stream discharge, water temperatures, wetlands, upland sediment erosion, and stream bank erosion. Fish recruitment problems appear to be occurring throughout the river and may be related to these factors. Water temperatures are marginal for coldwater-coolwater species in the mainstem and relatively small changes in flows or drainage patterns could destroy this natural feature. The removal of dams from small tributary streams would help preserve stable water temperatures and improve riverine trout migrations, natural reproduction, and genetic viability of the fish populations. Reduction of hydroelectric dam effects would benefit fisheries in all areas of the river. Improvements at the hydroelectric dams can be made in relation to flow regulation and reductions in habitat losses, water quality improvements for dissolved oxygen and water temperatures, reductions in fish entrainment and mortalities, and improvements to fish migrations and the genetic viability of fish populations by installation of fish ladders or dam removals. Evaluations and possible enhancement of instream fish habitat, especially log cover, may improve smallmouth bass populations. Protection of shallow, littoral zone habitat and wetlands is important to fisheries in Muskegon Lake.

Northern pike fisheries are moderate upstream of the confluence with the Middle Branch River, and high in Muskegon Lake. These are self sustaining populations that need to be protected and enhanced. Maintaining and improving wetland habitat is critical to this species.

Moderate smallmouth bass populations occur in the river below the confluence with the middle Branch River, and a good population occurs in Muskegon Lake. These are self sustaining populations that need to be protected and enhanced. Habitat improvements (stabilize stream discharge, reduce sediment, improve woody habitat) or stocking of smallmouth bass in the river may help alleviate recruitment problems and increase population numbers.

Walleye populations may be improved in the upper river by stocking or barrier removal. The population in the lower river needs to be increased by habitat protection or continued stocking. The recruitment problem in this population needs to be determined along with current population information.

Reintroduction of the white bass should be attempted in Muskegon Lake and the lower Muskegon River. Reintroduction of the Great Lakes muskellunge should be attempted in the river system. Additional review will be required to determine the most favorable location for reintroduction.

Assessment of lake sturgeon, river redhorse and lake trout use of the lower river needs to be conducted, along with assessment of potential use of the upper river. Alternatives to sea lamprey control in the river need to be investigated.

Chinook salmon and steelhead natural reproduction should be evaluated and stocking could be increased. Stocking rainbow trout in Hardy and Croton impoundments may have potential for improving the limited fisheries in these impoundments. However, additional dissolved oxygen and water temperature information is needed, and protection from turbine entrainment would be necessary (these are provisions in the Settlement Agreement). Trout stocking rates for Michigan lakes range from 50 to 100 per acre. Stocking Hardy impoundment would require 198,000 to 397,000 trout annually, at a cost of $144,540 to $289,810. Stocking Croton Impoundment would require 69,000 to 138,000 trout annually, at a cost of $50,370 to $100,740. Cost-benefit figures are difficult to produce for stocking lakes because angler use values are not available. However, fisheries on lakes stocked with trout are very popular in Michigan and fishing pressure is very high. Water quality improvements and protection from turbine entrainment will benefit warmwater fish populations in the impoundments. Stopping the winter draw down of Hardy Impoundment would benefit littoral zone fishery habitat, which is limited in this impoundment.

There is considerable potential for expansion of potamodromous fisheries and riverine trout fisheries into the sections of river above Croton Dam. Stocking riverine rainbow and brown trout in the river can significantly improve sport fisheries, which is evident from the fishery established below Croton on the Muskegon River (Table 6). Typical stocking rates for trout in southern Michigan rivers are 200 to 300 per acre. The Muskegon River is stocked at 148 fish per acre (846 acres, 29.1 river miles) and this produces a cost-benefit ratio of 22.2 (based on rearing costs of $0.73 per yearling fish and angler use benefit of $69,714 per mile from 1994 and 1995 MDNR, Fisheries Division, Rogue River creel survey). Similar fisheries may be achieved by stocking trout in the river between Hersey and Big Rapids, and in the river if impoundments were removed. The potential natural reproduction for two potamodromous species, angler use, and economic benefits are presented in Table 27. The values listed for the Newaygo to Croton Dam river section are currently existing. All other sections of the river are based on data extrapolated from the Croton to Newaygo river section. The values listed for Croton, Hardy and Rogers Impoundments would be realized only if the impoundments were removed and the river rehabilitated to its natural condition.

The potamodromous fish values for Rogers Impoundment to Hersey could be obtained by installing upstream and downstream fish passage at the three hydroelectric dams (Table 27). These values are substantial. Both species would more than double current natural reproduction in the river and the total economic value would be over 1 million dollars annually. Costs of fish passage devices would approximately range from $480,000 for trap and transfer to $1,600,000 for fish ladder construction, at each dam (based on estimates for Tippy Dam; Consumers Power Company 1991). Combined construction costs for the three dams would approximately be $1,440,000 to $4,800,000. These costs indicate a two to three year pay back for fish passage device construction on the Muskegon River. Annual maintenance and operations costs are substantially lower than construction costs, and annual maintenance costs are lower for fish ladders than trap and transfer operations. Downstream fish passage devices would increase pay back time, but would also benefit existing fisheries in the impoundments.

The total economic potential for expanding potamodromous and trout fisheries is over 8 million dollars annually (Table 27). The Muskegon River has the potential to supply 52% of total chinook salmon, and 70% of total steelhead the Michigan Department of Natural Resources stocks into Lake Michigan each year. Total 1990 Michigan stocking for these species was 3.64 million chinook salmon and 520,000 steelhead. The Muskegon River has the potential for producing 1.91 million chinook salmon and 362,000 steelhead smolts, annually.

There are undetermined values for other species not listed. These include walleye, lake trout, and the threatened lake sturgeon and river redhorse. Data also indicates estimated values for natural reproduction of chinook salmon and steelhead in the Muskegon River, below Croton, may be low due to effects of past operations of the hydropower dams. Carl (1980) estimated chinook salmon smolt production from the Muskegon River was 349,700 in 1979, and this estimate was used in Table 27. Similar smolt production was estimated using his methods in 1988 (MDNR, Fisheries Division, survey records). Using different methods in 1995, chinook salmon smolt production was estimated at 1,357,088 (MDNR, Fisheries Division, survey records), which is substantially higher than the 1979 and 1988 estimates. Differences between estimates may be the result of evaluation methods, changes in operation of hydroelectric facilities, or natural annual variation. These estimates indicate that values listed in Table 27 for chinook salmon are minimum values for potential natural reproduction. Estimates of angler use for potamodromous fish in Table 27 also should be considered minimum values. These estimates were made from 1985 through 1989 on the Muskegon River (Rakoczy and Rogers 1987, 1988, 1990, 1991; Rakoczy and Lockwood 1988). Poor adult returns of summer steelhead strains to the river were reducing adult spawning runs during this period, and this probably resulted in reduced angler effort (MDNR, Fisheries Division, survey records). In addition, the chinook salmon population in Lake Michigan declined significantly beginning in 1986-1987, which severely reduced spawning runs and reduced angler effort during the period angler use was evaluated.

The Michigan Department of Natural Resources, in conjunction with the US Forest Service and US Fish and Wildlife Service, is currently developing guidelines for determining the feasibility of fish passage on Michigan streams. These guidelines will include biological, social and economic factors that managers need to evaluate before installation of fish ladders. A more thorough review of fish passage on the Muskegon River will be conducted when these guidelines are completed. This review should consider affects on avian and mammal species that interact with potamodromous species.

Citizen Involvement

Most of the watershed is contained within an eight county area. There are numerous local government interests including counties, villages, towns, and cities. Interest from organized recreational groups is widespread. There are many local hunting and fishing groups in the basin. The river also draws interest from Lake Michigan fishing groups because of the migratory fish species using the river. Groups with interest in the Muskegon River watershed are listed in Table 28.

Community development in the watershed is moderate. Moderate sized metropolitan areas have developed at Muskegon and Big Rapids. Smaller villages and towns located along the mainstem include Houghton Lake, Evart, Hersey, and Newaygo. There are many small villages and towns along tributaries including Cadillac, Marion, Evart, Reed City, Fremont, Howard City, Lakeview, and Morley. Industrial development is not extensive except at Muskegon and Big Rapids, with light industrial development at most of the smaller communities. Farming interests are moderate throughout the basin but intensive on the Little Muskegon River watershed.

Most citizen involvement with management of the resources in the Muskegon River watershed is inter-mediated by government agencies including the Department of Natural Resources, US Forest Service, county drain commissioners, and local governments. These agencies are primarily involved with managing water flows, water quality, animal populations, land use, and recreational activities. All of these topics are addressed to some degree in this assessment.

MANAGEMENT OPTIONS

This section lists possible management options for various sections of the Muskegon River and primary tributaries. The management options listed below are related principally to aquatic communities, but wildlife, botanical, and social factors are noted where they directly affect aquatic community management. Some of the management options are simple, especially when related to smaller tributaries. Most options are complex, sometimes involving entire watershed management, and can take many years to accomplish. For example, preserving the hydrology of the watershed is critical to management of aquatic communities. To accomplish this option, all uplands, lowlands, and agricultural and urban drainage in the watershed needs to be managed properly. The social, political, and legal implications are very complex because of the size of the watershed and the many communities and special jurisdictions involved. Natural resource agencies often do not have the legal authority to accomplish the necessary changes. For example, the drain code gives direct authority for establishment of drains to county drain commissioners. Establishment of drains is usually in direct conflict with preserving watershed hydrology. There are many other problems, similar in nature, related to preserving watershed hydrology.

Regardless of the complexity, it is necessary to list important management options available to protect and manage aquatic communities in the Muskegon River watershed. This will provide a basis for discussion, public review, and proper choices of management options. Selection of options will provide management agencies with both long and short term management direction.

These options follow the recommendations of Dewberry (1992), who outlines measures necessary to protect the health of the nation's public riverine ecosystems. Dewberry stresses the protection and rehabilitation of headwater streams, riparian areas, and floodplains. Streams and floodplains need to be reconnected where possible. We must view the river system as a whole, for it is the entire system that must be managed, not fragmented pieces.

The identified options are consistent with the mission statement of the MDNR Fisheries Division. This mission is 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. 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 understanding of fish, fishing, and fishery management.

Options convey four approaches to correcting problems in the watershed. These include options to protect and preserve existing resources, options requiring additional information, opportunities for rehabilitation of degraded resources, and opportunities to improve an area or resources above and beyond the original condition.

Biological Communities

Limited information is readily available on the original aquatic communities in the Muskegon River watershed. The extirpation of the Arctic grayling, from the Hersey River, is the one documented piece of information showing a severe decline in a riverine stock of fish. It is also probable that a riverine stock of Great Lakes muskellunge was extirpated. Severe declines in potamodromous stocks have also occurred for walleye, sauger, white bass, lake sturgeon, and probably lake trout, lake herring, round whitefish, and lake whitefish. Declines of these stocks were influenced by changes in Lake Michigan and Muskegon Lake, as well as the Muskegon River watershed.

Recent fish community information is not sufficient to accurately document the distribution of most species within the watershed. Fish diversity and biomass are similar to other large Michigan rivers. The fish community of the mainstem is intermediate in composition between Michigan warmwater and coldwater streams. Warmwater-coolwater species dominate the fish community but coldwater-coolwater fish are present throughout the mainstem. Populations of some species exhibit lack of recruitment. Hydroelectric dams are negatively affecting aquatic communities below Croton. A number of important pest species are present.

Numerous animal and plant species are threatened or endangered and the watershed contains many game species used extensively for recreation.

Option: Protect and preserve adequate river corridor forest, especially sensitive plant and animal communities. River-corridor forest management includes maintenance of old growth forest corridors, prevention of wetland loss, protection of sensitive habitats, and protection from over-development and intensive recreational use.

Option: Survey the distribution and status of fish, aquatic invertebrates, reptiles, amphibians and mussels.

Option: Survey the historic record to determine the pre-settlement fauna in the watershed.

Option: Rehabilitate populations of potamodromous fish above Croton by dam removal or fish passage.

Option: Rehabilitate migrations of river fish by removing dams or installing fish passage devices.

Option: Rehabilitate aquatic communities by controlling pest species. Species included are sea lamprey, rusty crayfish, carp, alewife, chestnut lamprey, zebra mussels, purple loosestrife, Eurasian water milfoil, mute swans, gypsy moth, forest tent caterpillars, and jack pine and spruce budworms.

Geology and Hydrology

In Michigan, the most productive aquatic communities are found in streams with stable discharge patterns. Stable stream discharge is supported by permeable geology's. Geologic landforms in the watershed are moderate to high in permeability, which is reflected by intermediate stability in mainstem discharge. The upper river appears to have the most unstable high flows. Hardy Impoundment is moderating high flows below Croton. Hydroelectric dams were destabilizing low flows below Croton. Flow regulation by hydroelectric dams substantially reduced fishery habitat below Croton. Flows in some tributary streams are less stable because of improper operation of lake-level control structures and many are affected by increased surface runoff from agricultural and urban development.

Option: Protect existing wetlands, floodplains, and natural upland drainage to maintain natural hydrologic condition of all streams in the watershed. Prevent establishment of new lake-level control structures and new agricultural and urban surface drainage.

Option: Survey historical records to determine pre-settlement flow patterns.

Option: Evaluate flow stability by developing an operational discharge model for the entire river system.

Option: Rehabilitate natural hydrologic conditions of streams by requiring proper operation or modifications of existing lake-level control structures, improving flow patterns in established county drains, eliminating unneeded drainage and restoring wetlands and floodplains.

Option: Rehabilitate natural flow patterns at hydroelectric dams by removal or require operation in non-peaking mode. (Provisions for flow improvement at Rogers, Hardy, and Croton dams were made in the Settlement Agreement, Appendix 3.)

Channel Morphology

The channel of the Muskegon River has been adversely altered. Most of the moderate and high gradient reaches have been impounded. High gradients produce high diversity stream channels favorable to aquatic communities. Removal of riparian vegetation has reduced the introduction of important woody habitat in the channel. Many tributaries have been dredged and straightened.

Option: Protect tributaries from further ditching by allowing no new drains or developing suitable alternatives.

Option: Survey historical records to determine pre-settlement channel form.

Option: Survey the river to determine channel form.

Option: Rehabilitate moderate and high gradient stream sections by removing hydroelectric dams.

Option: Rehabilitate woody habitat by establishing natural woody buffer zones along the river and reducing high flood flows.

Land Use Patterns

Agricultural and urban development are moderate. Erosion of sediment into streams from uplands is significant. Drainage systems are established on many tributary streams. Irrigation is not significant in the mainstem but may be causing problems in the tributaries. Floodplain use is substantial in many areas. The entire watershed has been logged of virgin timber but secondary timber growth is extensive.

Option: Protect lands through land-use planning and zoning guidelines that emphasize protection of critical areas and improved stormwater management.

Option: Protect uplands by implementing USDA soil conservation practices to reduce erosion.

Special Jurisdictions

Numerous agencies have regulatory responsibilities that affect the river system. These range from small local governments to large federal bureaucracies. The Federal Energy Regulatory Commission has authority over hydroelectric dams. The US Fish and Wildlife Service, US Forest Service, US Natural Resources Conservation Service and US Environmental Protection Agency have responsibilities for land and natural resources management. The Michigan Department of Natural Resources manages many natural resource activities and the Michigan Department of Environmental Quality is responsible for regulatory protection of the environment. Local agencies conduct zoning and other land management activities. County drain commissioners have responsibility for legally designated drains and some lake-level control structures.

Option: Establish a watershed council to coordinate land and water management activities. This will protect and rehabilitate the natural river system by promoting coordinated management and planning for the future.

Option: Advocate all agencies incorporate recommended river protection measures in their land and water management programs.

Recreational Use

Outdoor recreation is extensive in the watershed. Fishing is limited over most of the mainstem because of fish blockage by hydroelectric dams. The impoundments cover most of the high gradient river sections and limit river boating recreation and fishing. Access is limited in several areas of the mainstem and tributaries, as are handicap accessible fishing locations.

Option: Survey recreational use in the watershed.

Option: Rehabilitate fish communities by establishing fish passage at hydroelectric dams.

Option: Rehabilitate and create more mainstem river fishing and boating recreation by removing the hydroelectric dams.

Option: Rehabilitate and create more river fishing by removing tributary dams.

Option: Improve existing sites and equip new sites for access for barrier-free access.

Option: Purchase or lease access sites where necessary.

Dams and Barriers

Numerous dams and impoundments exist in the watershed. Five major impoundments are on the mainstem. Three of these are operating hydroelectric dams located midway in the river. One is a retired and partially removed hydroelectric dam at Big Rapids. The last mainstem dam is a wildlife flooding located at the headwaters. Most of the tributary dams are non-hydropower used for aesthetics, swimming, or for wildfowl. These dams are detrimental to the river because they impound most high gradient habitat, reduce river habitat, create water flow fluctuations, trap wood habitat, kill fish, fragment habitat and reduce genetic viability of fish populations, and block potamodromous fishes from much of the river.

Option: Protect the biological communities of the river by providing fish passage at dams to mitigate for habitat fragmentation.

Option: Protect fishery resources by screening turbine intakes at hydroelectric dams.

Option: Protect natural water temperatures by removing problem dams in the mainstream and tributaries.

Option: Conduct a road stream crossing inventory to evaluate culverts, bridges, and associated problems.

Option: Evaluate the affect of Reedsburg dam on water temperatures, and other affects on the river.

Option: Rehabilitate free-flowing river conditions by removing dams that are no longer economically feasible such as Big Rapids.

Option: Rectify or mitigate the numerous problems associated with hydroelectric and non-power dams.

Water Quality

Water quality is good in most parts of the watershed. The mainstem is affected by moderate nutrient enrichment and excessive sediment bedload. Localized water quality problems exist near metropolitan sites and below dams.

Option: Control nutrient and sediment inputs using non-point source control measures.

Option: Control localized contaminant problems by cleaning up contaminated sites.

Option: Control oxygen and water temperature problems below dams.

Option: Survey water temperatures throughout the watershed.

Option: Survey sediment inputs to the river (agricultural and urban runoff, road crossings, stream banks).

Fishery Management

Fishing is good between Lake Michigan and Croton Dam. Fishing is moderate to poor in the mainstem upstream of Croton. The hydroelectric dams are affecting the fisheries downstream of Croton, are impounding most moderate and high gradient river reaches, and are blocking migrations of potamodromous species. Many small dams are reducing water quality for fisheries. Fisheries are affected by sediment erosion from improper land use and bank erosion.

Option: Protect the Clam River by operating the lake-level control structure from Lake Cadillac so water quality conditions in the river are not degraded.

Option: Conduct evaluations to determine if Falmouth Dam is affecting water quality conditions in the Clam River.

Option: Assess lake sturgeon, river redhorse and lake trout spawning.

Option: Evaluate habitat in the impoundments.

Option: Evaluate the effects of bank erosion in the impoundments on habitat.

Option: Evaluate current population and recruitment levels of walleye.

Option: Evaluate the potential for reintroduction of Great Lakes muskellunge.

Option: Evaluate fishery habitat in the mainstem and tributaries.

Option: Evaluate alternative control programs for sea lamprey.

Option: Evaluate effects of fish passage on interacting avian and mammal species.

Option: Evaluate angler use throughout the watershed.

Option: Inventory the entire river system to determine species abundance and fish distribution.

Option: Rehabilitate the Middle Branch River section by removing Marion Dam to improve water quality conditions in the downstream reaches.

Option: Rehabilitate the Hersey River by cleaning up the contaminated creosote site in Reed City, thereby reducing fish contamination.

Option: Rehabilitate the West Branch River by removing abandoned beaver dams in the headwaters which will improve water quality in the downstream river section.

Option: Rehabilitate Muskegon Lake fish community by reintroducing white bass.

Option: Rehabilitate potamodromous fish runs above the hydroelectric dams. Install fish passage devices at Rogers, Hardy, and Croton dams.

Option: Manage the river above the confluence with the Middle Branch River for northern pike. Protect and rehabilitate wetland and floodplain habitat for northern pike fisheries.

Option: Between the confluence with the Middle Branch River and Big Rapids, manage resident walleye, smallmouth bass, brown trout, and rainbow trout. Evaluate the potential for stocking these species.

Option: Manage the Hersey River for brook and brown trout.

Option: Manage the Clam River as a high quality trout fishery.

Option: Manage the Middle Branch River as a high quality trout fishery.

Option: Manage the West Branch of the Muskegon River as high quality trout stream.

Option: Manage the river fishery below Croton Dam for self-sustaining populations of the following species: walleye, smallmouth bass, river redhorse, chinook salmon, steelhead, brown trout, rainbow trout, and lake sturgeon.

Option: Manage Mosquito Creek, Muskegon County, for a self-sustaining brook trout fishery. Return ditched headwater sections to natural stream conditions to improve water quality.

Option: Manage Cedar Creek, Muskegon County, for a self-sustaining brook trout fishery. Reduce sediment erosion and agricultural drainage to improve water quality conditions. Acquire more access.

Option: Manage Bigelow Creek, Newaygo County, for a self-sustaining brook and brown trout fishery. Reduce sediment erosion to improve habitat quality. Acquire more access.

Option: Manage Brooks Creek, Newaygo County, for a brown trout fishery. Reduce sediment erosion and agricultural drainage to improve water quality conditions. Acquire more access.

Option: Manage Muskegon Lake for warmwater and coolwater fish. Primary species include walleye, northern pike, smallmouth bass, largemouth bass, panfish, yellow perch, flathead catfish; and seasonally chinook salmon, brown trout, steelhead, lake trout, and lake sturgeon. Protect wetlands and shallow water habitat required by these species.

Option: Retain Rogers, Hardy, and Croton Impoundments and manage for impoundment fisheries.

Option: Remove Rogers, Hardy, and Croton impoundments and manage this river section for walleye, smallmouth bass, lake sturgeon, rainbow trout, brown trout, and potamodromous fish.

Option: Install barrier screens at all three hydroelectric dams to reduce fish entrainment.

Option: Improve water quality conditions in the Hersey River by removing Miller Dam.

Option: Improve shallow littoral zone habitat in Hardy Impoundment by stopping winter drawdown.

Option: Improve water quality conditions in Croton Impoundment by maintaining proper dissolved oxygen concentrations in the discharge from Hardy Dam.

Option: Improve sport fisheries in Hardy and Croton impoundments by stocking rainbow trout.

Option: Improve fisheries below Croton by mitigating the negative effects caused by the hydroelectric dams. (Provisions for mitigation of negative effects at Croton Dam were made in the Settlement Agreement, Appendix 3.)

Citizen Involvement

There are numerous local government interests, from counties, villages, towns, and cities within this watershed. Interest from organized recreational groups is widespread. There are many local hunting and fishing groups in the basin. The river also draws interest from Lake Michigan fishing groups because of migratory fish species using the river. A few environmental groups are locally active in the Muskegon area because of local contamination problems.

Option: Improve and implement strategies to educate the community regarding river ecosystems.

Option: Establish a watershed council to increase citizen involvement in watershed planning and management.

PUBLIC COMMENT AND RESPONSE

Introduction

Comment: Various comments were made supporting the watershed assessment process.

Response: These supporting comments are acknowledged.

Comment: The assessment should have a second assessment prior to the writing of a final management plan, with the opportunity for public comment on selected or preferred management options.

Response: Assessment and planning are intended to be a continuing process. Comment on particular options or issues can be provided to the Department at any time.

Comment: The next step in the process should be the evolution of the assessment of existing conditions to a comprehensive management plan for the watershed, as spelled out in the Settlement Agreement.

Response: A management plan will be completed following completion of the final assessment.

Comment: This document would benefit from a broader ecosystem and landscape level approach.

Response: As discussed in the Introduction, these watershed assessments are intended only to develop and document goals, problems, and objectives for management of river resources. They do not provide detailed data except as needed to describe a problem or support evaluation of management options. General landscape information is used to document problems associated with this source. This is a fisheries oriented assessment and not an ecosystem report.

Comment: "The Department's Fisheries Division has produced an Assessment that provides substantial information about the existing fisheries conditions on the Muskegon River, particularly as they relate to coldwater fisheries management. However, this Assessment falls well short of the goals for an overall river management assessment even as a preliminary document. In summary, Consumers views this draft Assessment as containing valuable information regarding the historical development and current condition of the Muskegon River. It does not, however, provide adequate analysis of the impacts and issues associated with the management options presented. We believe this is absolutely essential to meet the objectives that the Department itself outlined for the Assessment. We do not believe that this Assessment should stand as a basis for completing a final river management plan. The Department agreed to develop a comprehensive River Management Plan for the Muskegon as well as the Au Sable and Manistee Rivers as part of the Settlement Agreement that was filed with FERC in the relicensing case involving eleven Consumers hydroelectric projects, including the three Muskegon River projects, including the three Muskegon River projects. Reference can be made to the Offer of Settlement (paragraph 9.1) and the Offer of Settlement Explanatory and Support Statement (paragraph 9.1, appendix A attached).

"We recommend that the Department revise the draft Assessment to address the issues we have outlined in this letter and the attached detailed comments and issue a revised Assessment to a much wider public audience. After obtaining public comment on the revised Assessment, the Department would be better able to develop a management plan on which the Michigan Natural Resources Commission could receive public input and take appropriate action."

Response: All the issues outlined by Consumers Power Company are addressed in the Public Comment section. The bulk of comments received from Consumers Power Company were not requesting additional information, but statements of disagreement regarding effects of hydroelectric dams that are outlined in the assessment. Considerable public comment was received on the Assessment and changes were made to the assessment as needed. The assessment and planning process will continue and additional comment can be submitted to the Department at any time. A comprehensive management plan will be developed based on this assessment and public comment.

Comment: "The appearance that the Fisheries Division did not obtain appropriate input from the US Fish & Wildlife Service, US Forest Service or even MDNR Divisions other than Fisheries. For example, we are aware that these agencies/divisions participated in scoping meetings in 1991 to assist the Department's Fisheries Division in developing the issues that it raised are not discussed in the Assessment. Based upon a recent meeting, we now understand the Fisheries Division will obtain this important input from other agencies and MDNR divisions."

Response: The consultation meetings were discussed in Agency River Management Consultation. As discussed, issues cited at these meetings were included in the assessment. This section has been moved from the Management Option section to the Introduction section. Agencies participating in the consultation meetings also provided written comment. None of the agencies involved in the consultation process indicated any of the issues discussed in the consultation meetings were left out of the assessment.

Watershed Assessment

Comment: It is important that all data be up to date and properly referenced.

Response: The most recent information is included in this assessment and new information can be added to future revisions.

Geography

Comment: The location of the West Branch of the Muskegon River which is listed as a major tributary is not identified on Figure 1. Consumers' is also interested in how the major tributaries were defined and chosen. In addition, other than the brief listing made here, many of the resources associated with these tributaries are not discussed elsewhere in this Muskegon River Watershed Assessment.

Response: Identification of the West Branch of the Muskegon River is now included in Figure 1. The key tributaries in Figure 1 were chosen based on size, location, and fishery aspects. All of these tributaries have coldwater fisheries that are discussed in Fisheries Management. Additional information on tributaries is now included in the assessment.

History

Comment: "It is suggested that the Department review the book entitled "Future Builders, The Story of Michigan's Consumers Power Company" by George Bush (New York: McGraw-Hill Book Company, 1973) for additional information on the development of hydroelectric power along the Muskegon River (see also Thornton, 1989; Randall, 1979). In addition, a greater discussion of recent history would also lend toward a better understanding of the current setting. The discussion here also talks about the extensive de-forestation but not the extensive re-forestation efforts that followed the logging era. The discussion presented in the first paragraph of this section talks about the destruction of existing fishery habitat by the extensive lumbering activities on the river in the middle to late 1800s. The discussion in the second paragraph goes on to talk about the construction of the Newaygo Dam and states that this dam blocked fish from the most productive habitat and all of the prime spawning habitat in the river. This discussion seems highly speculative in light of the recognition of the destruction of the productive and spawning habitat by lumbering activities that were still ongoing at the time the dams were constructed. In addition, as noted elsewhere in this Assessment, the dams are having beneficial impacts by moderating high spring flows (page 28) and providing colder water temperatures (pages 43 and 44) in the river below Croton Dam in support of the existing cold water fishery found in this reach of the Muskegon River. The last paragraph of this section states that the dams are limiting recreational fishing and resulting economic benefits and fails to recognize the many recreational and resulting economic benefits provided by the hydroelectric impoundments on the Muskegon River. These are discussed more fully in the reports titled "Socioeconomic Study: Muskegon River Projects" (Harza 1991) and "Recreation Use Study, Final Study Results, Recreation Use Associated with Consumers Power Hydroelectric Projects on the Muskegon River" (Insight Marketing 1993)."

Response: As noted in the Introduction, this is a historical review describing physical characteristics of the watershed and affects of past human use and alteration. The intent is to provide some insight into major human alterations of the system that have occurred historically. The intent is not to provide a full historical review of hydropower development, or any of the other many environmental factors noted. Currently, thorough historical reviews of the watershed are not available.

It is not speculation that the Newaygo Dam blocked movement of fish to prime spawning habitat in the river, even if this habitat was impaired by other factors noted. Despite impaired spawning areas, the habitat was used and this is apparent by the many species of native fish that are still present in the watershed. The Newaygo Dam blocked upstream movement of fish to 85% (179 miles) of mainstem and a much greater length of tributary streams. Croton Dam presently blocks upstream fish migration over 165 miles of the mainstem. These barriers have been in existence for 90 years, including the reforestation period noted above.

High spring flows are currently moderated by the hydroelectric dams because Hardy Impoundment is drawn down to augment winter power generation, and refilling does not begin until spring. High spring discharge is moderated by reservoir filling during some years. These moderated flows may or may not be beneficial to the river. Also, this drawdown has severe effects on aquatic habitat in Hardy Impoundment and there are numerous other environmental effects.

At this time, the hydroelectric dams and impoundments alter temperature patterns in the river causing cooler temperatures from late March to the end of June, and warmer temperatures the rest of the year. Overall, the thermal regime of the river is probably increased by these dams, because impoundments provide a greater surface area for heat accumulation. Current temperature alterations may be harmful to walleye, as noted in Present Fish Communities. Temperature alterations are complex and whether current conditions benefit coldwater fish is uncertain. Riverine trout populations below the dams are supported by high stocking levels. Trout stocking also occurs at much lower levels above the dams and survival there is also documented. Conditions for riverine trout, both above and below the dams, are currently considered marginal.

Hydroelectric dams are limiting recreational fishing and resulting economic benefits to 165 miles of the river. There is recreation on the impoundments, but fishing is generally fair to poor, as documented in the text. Suitable recreation studies will need to be conducted to determine the full extent of recreation in the watershed. This is included as a management option.

Biological Communities

Comment: "The statements made here as to the extirpation of the lake trout, lake whitefish and round whitefish as a result of dam construction are highly speculative and totally ignore the impacts of the lumbering activities practiced in the watershed in the middle to late 1800's as discussed in the section on History. The speculative nature of much of the discussion presented in the section on Biological Communities is finally acknowledged in the final paragraph of this section."

Response: It is probable the lake trout, and possibly the lake whitefish and round whitefish were extirpated from the river above Newaygo by dam construction, as stated in History. Potamodromous stocks of fish are dependent on suitable spawning habitat to maintain their existence. Newaygo Dam blocked movement of fish to nearly all high gradient portions of the river. One of the functions of this document is to identify all possible fisheries problems and opportunities. By design, this assessment must address this issue and points to the need for additional study. Lake trout have been reported during fall as far upstream as Croton Dam during recent years. Clearly, the potential for a river spawning stock needs to be evaluated. Lumbering activities had significant effects on aquatic communities, but most native species were able to survive and rebuild populations following reforestation.

Comment: "The statement "stream discharge regulation and water quality degradation, by hydroelectric dams, are impacting the fish communities in the River below Croton" is not supported by the data presented elsewhere in the Assessment.

For example, Table 17 (now 18), historical water quality data for the Muskegon River downstream of Croton impoundment, is not indicative of degraded water quality with the exception of summer excursions below dissolved oxygen concentrations for coolwater fish (Table 20; now 21) and these excursions may not be related to the dams (see discussion on page 5, paragraph 5 of these comments). Water quality represented in Table 16 (now 17) should not preclude native river species. Table 3, fish community list and biomass figures for four sites on the Muskegon River, likewise does not support the notion of a degraded fishery. While Table 3 indicates fewer numbers and pounds of fish per acre at Croton compared to the other three sites, the Croton catch is composed of a higher percentage (over 67%) of less tolerant species (at Croton a greater percentage of the species collected are coolwater or coolwater-warmwater) than at any of the other locations."

Response: The statement "Stream discharge regulation and water quality degradation, by hydroelectric dams, are affecting the fish communities in the river below Croton", in Present Fish

Community, is supported in discussion and with data presented in Biological Communities, Geology and Hydrology, and Water Quality.

In Water Quality, Tables 17-19 are used to provide some general water quality information on the river and support the statement that water quality in the Muskegon River is generally good. Water quality parameters reported in Table 17 were collected at Bridgeton, located about 25 river miles below Croton Dam, and are not indicative of localized water quality problems caused by the dams. The section of river below Croton is protected for coldwater fish under Michigan's Natural Resource and Environmental Code, Public Act 451, Part 31, 1994. Table 20 documents surface water quality regulations for oxygen are not being met below Croton Dam and show localized problems.

Table 3, fish community list and biomass figures for four sites on the Muskegon River, does indicate hydroelectric dams are affecting the fish community, as discussed in Biological Communities. The percentage designation noted in the comment is not relevant since all species in the table can be categorized as coldwater-coolwater or coolwater-warmwater. As described in Biological Communities, the classifications Bayou and Impoundment Species, Sand Tolerant Forage Species, and Miscellaneous Species were used to designate habitat preference or species low in abundance. Species in these classifications have the same warm or coldwater requirements as species listed in the other two groups and are not "less tolerant" in their water quality requirements. Also discussed in the text, the one species in the river that is tolerant of lower water quality conditions is the carp, and this species is found in the impoundments and associated downstream river sections.

Comment: Reference is made to a comparison of game fish species among Michigan rivers in Table 6, but Table 6 only includes data specific to the Muskegon River. The reference is probably supposed to be to Table 5. The comparison of numbers of rainbow and brown trout in Table 5 is, however, not a fair one in that the other rivers listed here are all in the southern part of the state and are probably not managed for cold-or coolwater fisheries.

Response: The table reference was changed. There were two reasons for the comparisons of harvestable fish in this table. One was to compare warmwater fish numbers. The other was to show the importance of the natural coldwater-coolwater feature of the Muskegon River to fisheries management, in comparison to large rivers that can only be managed for warmwater fish. This was brought forward in the discussion. This paragraph was revised to clarify this point.

Comment: The discussions of length frequency distributions provided in Tables 6 and 7 are misleading and should be omitted. The discussion implies that young fish are not present due to low recruitment as a result of the hydroelectric facilities. On the contrary, for the species discussed, rainbow and brown trout were present at locations in numbers and sizes consistent with the Michigan stocking effort, young and adult smallmouth bass were represented well at all locations in which they were collected and northern pike were very well represented at Clare. Young northern pike were also collected at Hersey while virtually none of any size were collected at Newaygo and Croton. Concerning walleye, a few young were collected upstream at Clare which is consistent with the limited recruitment experienced elsewhere in Michigan for this species, while Muskegon Lake is a successful nursery area. Since walleye runs remained high until late into the 1950's, it is unlikely that the decline is related to the hydroelectric facilities.

Response: As discussed in Present Fish Communities, healthy fish populations contain large numbers of young fish. The data in tables 7 and 8 support the conclusion that reproduction may be limited in the river. As noted in the discussion, barriers (including hydroelectric and non-hydroelectric dams) and other factors may be affecting recruitment. Walleye runs only were high in the river below Newaygo Dam. Hydroelectric dams clearly limited passage of this potamodromous fish to all areas above the dams. Additional analysis of the affects of dams on fish is included in Dams and Barriers and Table 11.

Comment: At a minimum, a list of river-associated threatened, endangered and special concern plant species should be included in this document. Fisheries management can affect these species and some may serve as indicators of ecosystem health.

Response: A list of plant species from the Michigan Natural Features Inventory is now included.

Comment: River management should include greenways, zoning, and protection and enhancement of all threatened and endangered species.

Response: All of these issues are included as management options.

Comment: While this document is titled a “watershed” fisheries assessment, in most respects it deals only with the river itself. Although upland wildlife are briefly mentioned in several places, issues that link upland species and habitat with the river are not addressed. At the least, a summary of current and presettlement land cover in the watershed would provide more perspective for evaluating management decisions.

Response: Reports comparing presettlement and current land cover for this watershed are not available. However, the extensive early lumbering activities are discussed in History, and problems associated with land development are discussed in Land Development. Management options are included for upland management.

Comment: Mayfly hatches are now very good on the river below Croton. Significant improvement since run-of-river has been implemented.

Response: Quantitative pre and post re-regulated flow analyses on invertebrate populations is not yet available. However, the Department has received numerous reports of improved adult insect diversity and numbers, especially mayflies, from anglers in 1995.

Comment: There are several errors in the list of threatened and endangered species.

Response: These errors have been corrected.

Comment: Identification and analysis of issues and management options related to amphibian and reptile populations should be included in this document. In particular, analysis of the compatibility of fisheries management options with maintenance of habitat for amphibians and reptiles. Wood turtles are globally rare enough to be considered as candidates for federal listing. Wood turtles rely on sandy banks for nesting substrate. Analyses of the effects of stream bank stabilization on wood turtle should be included in this document. Massasaugas are globally rare enough to be considered as candidates for federal listing.

Response: Amphibians and reptiles listed in the Michigan Natural Features Inventory are now included in the assessment. Many of these species are associated with wetlands and generally fisheries management activities attempt to protect or rehabilitate natural wetlands. The need for sandy banks, by wood turtles, for nesting is recognized by Fisheries Division. This will be considered in any bank rehabilitation project. Inventories of reptiles and amphibians are lacking and are now included as management options.

Comment: The zebra mussel invasion is given very little treatment, although the species is known to be having drastic effects throughout the region’s waterways.

Response: The zebra mussel is mentioned in the Biological Communities section as a pest species. It has only been found in recent years in Muskegon Lake and is not known to be present in other locations in the watershed. Control of this species where needed is listed as one of the management options. Much has been written in the newspapers regarding possible effects of this species on aquatic environments, but scientific studies measuring effects of this species in the Great Lakes are lacking. Effective control programs are also unknown at this time. More information will be needed to manage this species, if management is even possible.

Comment: The interpretation in most of the document seems to be that the most important aquatic life is sport fishes, especially introduced, non-native species.

Response: This document is a fisheries assessment on a watershed scale. The intent of the document is to include the assessment of other resources where fisheries management will affect or conflict with management of these resources. The majority of information available on fish in the watershed is on fish sought after by anglers, so the bulk of data discussed on fisheries management relates to these species. However, considerable treatment is given to non-game fish and other aquatic life both in the text and in the management options. A large portion of this assessment addresses habitat requirements necessary for maintaining healthy aquatic communities. Maintaining habitat benefits all aquatic life in the river.

Comment: More fisheries abundance information is needed on the river.

Response: This is listed as one of the management options under Biological Communities.

Comment: The importance of the Muskegon River to Great Lakes fisheries needs to emphasized, and impacts on chinook salmon and steelhead need to be considered in regard to restoration of native species such as walleye and white bass.

Response: The importance of the Muskegon River to potamodromous fish is well documented in the Biological Communities and Fisheries Management sections. Rehabilitation of native fish stocks is part of Fisheries Division’s Strategic Management Plan. Rehabilitation of the walleye stock has been in progress since 1978. Some white bass are currently present in Muskegon Lake, but in very low numbers. Effects on other species are considered when rehabilitation programs are initiated.

Comment: Alewife should be looked at as a positive impact rather than pest species.

Response: Alewife are an introduced species that live in Lake Michigan and migrate in large numbers into Muskegon Lake and the lower river to spawn. They are a pest species in the river and are suspected to affect other species through predation and competition. They are used as a food source by salmonids in Lake Michigan. In fact, salmon were introduced into Lake Michigan to control overabundant alewife that were severely affecting other fish species, and having massive die-offs littering beaches with tons of decaying fish. The use of alewife by salmonids as a food source is now included in the Assessment. Alewife continue to affect native species in Lake Michigan, and these effects need to be considered in management strategies.

Comment: Reintroducing lake sturgeon, river redhorse and white bass is important.

Response: Rehabilitation of native fish stocks is important and is part of Fisheries Division's Strategic Plan. Rehabilitation of these species are included in management options under Fisheries Management.

Comment: Need consideration of issues associated with the protection of waterfowl, wetlands and other sensitive habitats. A more comprehensive treatment of species and management issues other than fisheries is needed. These other species and issues are essential components of the Muskegon River ecosystem and are probably to be affected by fisheries management decisions.

Response: This document is a fisheries assessment on a watershed scale. The intent of the document is to include the assessment of other resources where fisheries management will affect or conflict with management of these resources. The preservation and rehabilitation of natural wetlands is nearly always a management goal in fisheries, and this is an issue related to land use discussed in this assessment. Wildlife and upland issues that may be influenced by fisheries management were reviewed with other natural resource agencies and MDNR, Wildlife Division. Issues identified in these consultations were discussed in Avian, Mammal and Fish Interactions. Management options regarding these issues are included in the assessment. Protection and rehabilitation of natural habitat in the watershed is the primary goal in fisheries management, and this will generally benefit the rest of the wildlife community.

Geology and Hydrology

Comment: Given current conditions, particularly the distribution of toxic contaminants, introduced pest and sport species, highly altered landscapes, and dense human settlements, how much restoration of natural flows is feasible, and if we stop half-way what does that get us.

Response: The complexity of this particular issue is discussed in the first paragraph under the Management Options section. Preservation of the hydrology of a watershed is critical to the health of aquatic life. Preservation of hydrology is a formidable task, involving all lands within a watershed. This issue must be addressed regardless of the difficulty or magnitude. If it is not, the long term results could be similar to those we currently have in some of our urban streams, that have limited fish communities, and little other aquatic life. Regulations are not the only answer and we believe a watershed council is needed to properly address this issue. Watershed councils have been effective in other parts of Michigan in dealing with these types of broad scale issues.

Comment: "*Stream Discharge*: The entire discussion presented here ignores several important facts. First, under the Offer of Settlement and the new FERC operating licenses, the Rogers Plant will be operated as run-of-river and the Croton Plant will be operated in a re-regulation fashion. Second, the Rogers Plant releases its water directly into the downstream Hardy impoundment which controls water levels downstream of the Rogers Plant such that the drought and flood conditions mentioned here do not apply. The significant impacts on fishery habitat mentioned here are no longer occurring. Consumers suggests that this discussion be stricken from the revised Assessment and recognition be given to the plant operations negotiated with the Department and agreed to in the Offer of Settlement and accepted by FERC in the new operating licenses."

Response: The Settlement Agreement was not completed until after this draft of the assessment was written. The text now indicates changes made as a result of the Settlement Agreement. The discussion regarding effects of dams will be retained in the assessment. These dams have been affecting the river system for 90 years and documentation for historical purposes is important. One of the purposes of this assessment is to allow citizens to learn and participate in fishery management activities, and this information is important for that process. In addition, this information forms the basis for part of the Settlement Agreement that is now included in the assessment. We do not anticipate 90 years of environmental effects caused by the hydroelectric dams will be remedied in a short time. The Settlement Agreement sets provisions for lessening many of the major effects, but the time for improvements is expected to be long term.

The discussion of flow stoppage at Rogers Dam was used as an example of what sometimes occurs at hydroelectric facilities. Even though Rogers Dam discharges into Hardy Impoundment, this area is semi-riverine and drastic flow changes can have effects on certain habitats and species. Should this type of flow stoppage occur at Croton Dam, the affects on the downstream river segment would be more severe.

Channel Morphology

No comments were received on this section.

Soils and Land Use Patterns

No comments were received on this section.

Special Jurisdictions

Comment: "FERC licenses can be issued for a period of between 30 to 50 years, not just the 35-year period mentioned here. The language included in the Assessment relative to exemptions is also misleading, an exemption is not a "perpetual license." The following change is recommended beginning in the third line. "In general, most FERC licenses are issued for a 30, 40 or 50-year period. Certain projects can receive exemptions from FERC licensing requirements. A FERC exemption contains a mandatory..." It should also be noted that the Morley Project on the Little Muskegon River currently has a license exemption."

Response: The information in this section has been revised to more clearly identify current Federal Energy Regulatory Commission licenses and exemptions in the watershed.

Comment: "The Assessment indicates that the entire mainstream of the Muskegon River and Little Muskegon River are proposed for designation as natural rivers under the Michigan Natural Rivers Act 231 P.A. 1970,. Consumers was not aware that this proposal had been made and would like more information regarding this proposal."

Response: Information on natural river designations can be acquired by writing to the address listed in Michigan Natural River Designation.

Comment: The Muskegon River should be a Designated Natural River.

Response: The Muskegon River is proposed for designation but the necessary studies needed to determine suitability for designation have not been completed. Information on natural river designations can be acquired by writing to the address listed in Michigan Natural River Designation.

Comment: The extensive land ownership by the US Forest Service is recognized here. This would be a good opportunity to introduce the fact that there is a comprehensive land use management plan which includes measures to protect water quality and aquatic resources within that part of the watershed managed by the US Forest Service.

Response: Reference to the Huron-Manistee National Forest Land and Resources Management Plan is now included in Public Lands.

Comment: "Public Health Advisories on Eating Fish: Consumers Power Company would like to note that the contaminant threshold for listing fish that are unfit for human consumption is much higher in Michigan than in other Great Lakes states. The fact that a large number of species, including lake trout, brown trout, coho and chinook salmon, carp, whitefish and catfish are on the Public Health Advisory List for the river below Croton Dam indicates a significantly contaminated resource. We would also like to note that Department records (MDNR-SWQD 1990) show that walleye eggs below Croton Dam exceed the contamination threshold for chlordane and total PCB."

Response: The comment is included here as requested. Public health fish consumption advisories are determined by the Michigan Department of Community Health and printed in the Fishing Guide.
Trigger levels for contaminant advisories currently vary for individual fish species among the Great Lakes states and the US Federal Drug Administration. Coho salmon and chinook salmon were dropped from Michigan's advisory list in 1995 and 1996 because contaminant levels decreased below Michigan's advisory levels. In 1997, the Michigan Department of Community Health again issued a public advisory on eating large salmon in Michigan, for pregnant and nursing women, women who intend to have children, and children. This has been included in Public Health Advisories on Eating Fish. All other Great Lakes states currently retain some level of fish contaminant advisories on coho and chinook salmon. Michigan currently has contaminant advisories for walleye and lake whitefish, but the other states do not. Michigan's trigger level for contaminant advisories are more restrictive for mercury and dioxin than US Federal Drug Administration regulatory or advisory guidelines, for fish that are sold in grocery stores in Michigan.

The assessment lists the general fish contamination advisories for the Muskegon River watershed in Public Health Advisories on Eating Fish. Organic contamination advisories are present on various fish species below Croton Dam. There is also an organic contaminant advisory above the impoundments, in the Hersey River, for northern pike, bullhead and brown trout.

The contaminant levels of some organic compounds, in walleye eggs, may be above trigger levels for human consumption advisories. However, Muskegon River walleye eggs are used to supply the largest portion of fry and fingerling walleye for Michigan's stocking program in the lower peninsula. Hatching rates are similar to other populations and these fish supply many inland fisheries in the state. The Muskegon River population was rehabilitated from about 3000 spawning fish in 1977 to about 50,000 spawning fish in 1986, using Muskegon River walleye eggs. The viability of these eggs appears to be adequate.

Contaminant advisories for mercury are currently established for eight species of fish on all reservoirs and lakes in the watershed, but not rivers and streams. Hydroelectric dams impound approximately 40 miles of river and create a source of mercury contamination for human consumption in the Muskegon River watershed. This is an important fact that needs to be considered when discussing contaminant issues.

Comment: The total mileage of designated drains is reported in the Land Use Patterns section not the Physical Features section of the Assessment.

Response: The reference was changed to Land Use Patterns.

Recreational Use

Comment: There are many user conflicts in the system and the Department cannot solve all of the problems. Developing the best fisheries in the system will create more user conflicts.

Response: The mission of Fisheries Division is 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 the benefit of the people of Michigan. The Muskegon River supports numerous sport fisheries and some of these currently rate among the best in Michigan. The largest user conflicts currently are on the lower river where the best fisheries are located. This area also has heavy canoe and boat usage. The impoundments also have heavy boat usage. Currently, we are maintaining the existing fisheries in the lower river, and possible expansions would be for rehabilitation of native species like white bass and lake sturgeon. It is unlikely these additions would cause more user conflicts in areas where there are problems. The impoundment's have similar conflicts between boating and fishing that are common to other Michigan lakes. Generally, local ordinances (e.g., time limits on speed boats, no wake zones, motor restrictions) are used to resolve boater conflicts.

Comment: More cooperation is needed between fishing and other user groups in the watershed.

Response: Formation of a watershed council would be a good way to facilitate more cooperation between user groups. This is included as a management option.

Comment: There is recreational abuse of the user's of the river below Croton, including float tubes, canoes and power boats. Problems include littering, rowdiness, noise and boat wakes. There is a need to develop a coalition and educate users (videos).

Response: A coalition is a good way to deal with this issue and educational programs are helpful.

Comment: Support maximum speed limits and no-wake zones for power boats in stretches of the river used by wading anglers.

Response: This is a large river that supports both wading and boat fishing. Most of the land along the river is in private ownership and difficult to access from shore, but boat use allows access to all areas of the river. There is a long history of power boat usage for fishing on the river, and the Department and local governments maintain boat ramps. It is difficult to even maneuver in this river without creating a wake. This is another user issue that is best addressed by all parties affected.

Comments: More enforcement will help reduce user conflicts.

Response: Enforcement can help reduce user conflicts when laws are broken. For specific problems, local sheriff departments can be contacted or Department offices in Cadillac (616-775-9727) and Grand Rapids (616-456-5071).

Comment: Increase patrols and limit the size, speed and hours of boating on Hardy Impoundment because they interfere with fishing and cause bank erosion.

Response: Ordinances regulating boating on specific lakes are enacted by local units of government in cooperation with Department of Natural Resources, Law Division. Hardy Impoundment is large with private, public, and power company ownership. This issue is best worked out by a group of all parties affected.

Comment: The discussion presented in this section (five very brief paragraphs) does not do justice to the tremendous amount of recreational use provided by the Muskegon River. The Department is referred to the various studies conducted by Consumers as part of its relicensing efforts (see "Recreation Report, Muskegon River Hydroelectric Projects" dated June 1991 by Harza Engineering Company and "Final Study Results, Recreation Use Associated with Consumers Power Hydroelectric Projects on the Muskegon River" dated December 31, 1993 by Insight Marketing, Inc. in association with M.C. Smith & Associates, Inc.) which documented well over five million recreation user days being spent on the Muskegon River in the vicinity of the hydroelectric plants alone during the 1992/1993 study period. In addition, the Muskegon hydroelectric plants that are utilized extensively throughout the year. These use levels are projected to increase through time given population dynamics.

Response: There is significant recreational use in the watershed, but there is no reliable quantitative information on this subject. The studies cited above were incorporated as part of the pre-license studies by Consumers Power Company to the Federal Energy Regulatory Commission. These studies provide some preliminary information regarding the types of recreation found on and near the hydroelectric projects. The studies do not provide reasonable quantitative data based on scientific methods. As noted in the Assessment, proper evaluations of recreation are needed throughout the watershed and this is included as a management option.

Dams and Barriers

Comment: "In addition to the issues associated with the critical question of fish passage, in our judgment the Assessment also lacks content and analysis in other important areas. For example, although the Assessment was published in late 1994 it hardly recognizes the comprehensive Offer of Settlement that was negotiated in 1992 between Consumers and the resource agencies (including the MDNR) in the relicensing of Consumers' 11 hydroelectric plants including the Croton, Hardy and Rogers plants on the Muskegon River. Furthermore, the Assessment utterly fails to recognize the fact that this Offer of Settlement was largely adopted by the FERC in the new operating licenses that were issued for these 11 plants on July 15, 1994. The new licenses and the Offer of Settlement establish a set of requirements whereby many of the issues and areas of concern raised in the Assessment with respect to these hydroelectric dams will be dealt with during the term of the new licenses. These issues include plant operations (flow regimes downstream of the plants), fish passage, fish entrainment and mortality and protection, water quality, wildlife, recreation and land use/management. This Assessment should be revised to reflect the agreements that were reached in the negotiated Offer of Settlement and incorporated into the new operating licenses issued by FERC."

Response: The writing of the first draft of this assessment began in June, 1981 and was completed in February, 1994. Following formatting changes and printing, copies were distributed for public comment beginning in March, 1995. Public meetings were held on July 6 and July 12, 1995. The Offer of Settlement was in negotiation and not approved until July, 1994, after completion of the first draft. The first draft of the assessment recognized an Offer of Settlement was being negotiated for hydroelectric dam affects in Offer of Settlement for Hydroelectric Dam Issues. A copy of the finalized Settlement Agreement is now included in Appendix 3.

Comment: It should be pointed out, the Federal Energy Regulatory Commission Settlement Agreement is just part of the overall fisheries assessment and comprehensive management plan for the Muskegon Watershed. The actual plan goes beyond the provisions of the Settlement Agreement.

Response: This is a fisheries assessment for the watershed and we attempt to summarize all of the major issues related to fisheries in this large system. The Offer of Settlement deals only with the three hydroelectric dams present on the mainstem. However, it should be noted that these dams have affects on fisheries and other aquatic life throughout the system.

Comment: Consumer's Power Company needs to educate its employees on the environmental impacts of dams and the need to improve conditions for natural resource protection.

Response: Most people other than professional resource managers are not aware of the many environmental affects dams have on aquatic systems. One of the primary purposes of this document is to provide this information to people and involve them in management decisions.

Comment: Protect fishery resources by screening turbine intakes at hydroelectric dams.

Response: Measures to prevent the movement of fish through hydroelectric dams are specifically explained in the Settlement Agreement contained in Appendix 3. Pilot studies are currently underway to determine if proper screening methods can be developed.

Comment: Comments were received both supporting and opposing dam removal in the watershed.

Response: The three hydroelectric dams on the mainstem have been relicensed for the next 40 years. The Offer of Settlement provides for mitigation of many of the major environmental effects associated with these dams during that period. Dam removal at other locations will be dealt with individually. Potential sites will be determined based on clear objectives and all aspects of dam removal will be considered along with public involvement in the process.

Comment: The overall thrust of the management options suggested for the Muskegon River is that hydroelectric dams are the main problem and should be removed, or fish passage should be provided.

Response: The effect of the hydroelectric dams on the river is extensive and well documented in the assessment. There are more than 70 management options listed and about 10 of these deal with hydroelectric dam removal or fish passage.

Comment: Discussion of benefits and problems of removing dams could include not only increased cost of lamprey treatments, but increased conflicts with maintenance of native fish and mussel populations, as some lamprey treatment chemicals are toxic to a number of smaller fish and mussels.

Response: Allowing expansion of sea lamprey spawning runs in the river is not an option the Department considers feasible. This would be considered in any dam removal operation. The overall objective of sea lamprey management is to reduce access of this species to the river using newly developed barrier techniques. This is included as a management option.

Comment: Water temperatures below Croton are too high for trout. Request that changes be made to the dams so water temperatures are maintained in the 60s during summer months. Is Consumer’s Power required to meet specific temperature limits under the Settlement Agreement? Request Settlement Agreement Funds be used to accomplish modifications to the dams.

Response: The Settlement Agreement includes provisions to evaluate the feasibility of improving water quality (including dissolved oxygen and water temperatures) discharges from the dams when surface water quality standards are not achieved. Moneys are provided for design and construction of devices to achieve improved water quality when studies indicate improvements can be made.

Comment: The Department needs to make sure flow agreements are strictly adhered to by Consumers Power Company.

Response: The Settlement Agreement provides for installation of gauges, operational procedures, flows and reservoir elevations for natural river flow operation (Rogers Project), peaking operation (Hardy Project) or re-regulated (Croton Project) flow operation at each dam. The Hardy and Croton projects will require study to determine specific parameters for flow operations designed to benefit reservoir or downstream habitats.

Comment: "During its relicensing process, Consumers developed a substantial amount of information about the Muskegon River and some of the management issues outlined in the Assessment. It appears that the Department used very little of this information in developing the Assessment. We encourage the Department to make use of this information to aid in addressing some of these issues."

Response: A substantial amount of information from the recent studies is included in this assessment. As noted in the Introduction, these watershed assessments are intended only to develop and document goals, problems, and objectives for management. They do not provide detailed data except as needed to describe a problem or support evaluation of management options.

Comment: "Consumers' is again disappointed in the Departments' apparent disregard for the agreements reached in the Offer of Settlement as it relates to the negotiated value of the fish being lost due to the operation of the hydroelectric plants. The values stated in the text and shown in the tables referenced here should reflect the negotiated values agreed to in the Offer of Settlement. In addition, there are insufficient data to determine the impact of entrainment on fish populations at Hardy, Croton and Rogers Dams, let alone the impact to aquatic communities. There are no population data available to support the inference made in the Assessment. The dollar values presented here for the fish that are killed by passing through the three hydroelectric plants are merely extrapolations of fish for cash based on American Fisheries Society or MDNR methods. They are not a proper basis for assessing the impact of entrainment mortality on the aquatic communities for fish populations that are involved. Much of the discussion at the bottom of this page with respect to plant operations impact also disregards the agreements reached in the Offer of Settlement regarding this issue and is not applicable to the Consumers' dams."

Response: The Settlement Agreement was not completed until after this draft was written. The text now indicates provisions made in the agreement.

The discussion of affects on aquatic communities by dams, in Dams and Barriers, is concerning all dams, not just the hydroelectric dams. The hydroelectric dams entrain over 300,000 fish annually and kill over 44,000 fish annually. This represents a loss to the aquatic community. Hydroelectric dams have impounded 40 miles of the highest gradient portion of the river system. This change alone represents a significant affect on aquatic communities of the river.

The assessment documents many effects the dams have on aquatic communities of the river. There is a long history of fishery complaints, problems, and management attempts by the Department to improve conditions in the impoundments. This is documented in Fishery Management. Fish entrainment and mortality clearly affects the fish community. The resource agencies requested sufficient information from Consumers Power Company in pre-license studies to determine affects of the dams on aquatic communities. Consumers Power did not conduct fish population studies during the pre-license phase. It would be very helpful to management should Consumers Power Company decide to continue these studies and obtain the information they currently indicate is lacking.

Comment: The text discusses potamodromous species and gives walleye, salmon, steelhead and lake trout as examples and states that these species migrate long distances within rivers for reproduction and use as nurseries. Potamodromous species, by definition, are species which live their entire lives in rivers and pass from one part of a river to another to complete various stages of their life cycle. Walleye, salmon, steelhead and lake trout are lake species that ascend rivers to spawn or for other reasons at various times of the year and are not strictly potamodromous species by definition. While the word anadromous has been used extensively to describe fish such as salmon that live in salt water and run upriver to spawn, the term anadromous also refers to any species, from fresh water or salt water, that runs from an ocean or lake environment upstream to spawn. In fact, all of the species listed as potamodromous in this plan also spawn in the Great Lakes; there are no obligate river spawners among native Great Lakes fish.

Response: The terms potamodromous and anadromous describe types of fish migrations. The term anadromous has been commonly used to describe the migration of some naturalized species from Lake Michigan into the Muskegon River system, for example, chinook salmon and steelhead. The term anadromous is the correct description for these species in their native environment, the Pacific Ocean and tributaries. Potamodromous is the correct term to describe their migrations in Lake Michigan and the Muskegon River. The term potamodromous is defined in the Glossary of this assessment. Potamodromous is also the correct term to describe the migrations of other native species of fish in Lake Michigan and the Muskegon River. A discussion of the proper use of fish migration descriptions is provided by Meyers (1949).

Water Quality

Comment: Protection of water quality throughout the watershed should be a high priority.

Response: Maintenance and improvement of water quality is critical to healthy aquatic communities. Michigan's Surface Water Quality Regulations are administered by the Department of Environmental Quality, Surface Water Quality Division. The Settlement Agreement for the hydroelectric dams has provisions for attempting to maintain water quality standards at these locations. The most difficult water quality issues to address are non-point sources of pollution (e.g., sediment, surface water run-off) and problems at the many small dams in the watershed.

Comment: Proper dissolved oxygen concentrations should be maintained below dams.

Response: The Settlement Agreement provides funding for study and improvements, when feasible, in dissolved oxygen concentrations from the hydroelectric dam discharges. Other dams in the watershed need to be evaluated.

Comment: The river should be monitored for sediment input and efforts should be made to reduce sediment input.

Response: Controlling sediment erosion and transport at natural levels in the river is truly a watershed scale issue. Once sediment is in the system, it will remain there until it reaches Muskegon Lake. A sediment control program involves proper land management throughout the watershed. Techniques are available for sediment control and have been used effectively on smaller tributary streams. The Department attempts to control sediment through normal permitting and regulatory activities. Non-point sources of sediment and excessive water flows from agricultural lands are major contributors to excessive sediment in the system. A watershed council would be a good avenue to plan and implement a control program for the Muskegon River. Sediment control and establishment of a watershed council are included as management options.

Comment: “The discussion in the second full paragraph regarding the release of water low in dissolved oxygen (DO) from the Hardy Project should be qualified in that the implication is made that the entire Croton impoundment is impacted. In fact, there is likely a relatively small area in the Hardy tailrace where mixing occurs and beyond that area the minimum acceptable DO levels are re-established. This is evidenced by the existing sport fishery for yellow perch, black crappie and walleye that is found in the Croton impoundment (see Assessment discussion at page 51). The discussion in the third full paragraph states that Croton Dam is degrading water quality (specifically DO levels) downstream of the dam whereas a comparison of the DO levels shown in Figures 12 (Hardy tailwater) to those shown in Table 20 (Croton tailwater) demonstrates that DO levels were higher in the Croton tailwater during the summer months when compared to those in the upstream Hardy tailwater. Consequently, there is no apparent basis for the assertion that Croton Dam is degrading water quality in the Muskegon River downstream of the dam. The discussion in the fourth full paragraph begins with a statement that hydroelectric facilities contribute to additional water quality problems but then references problems at water control structures, small dams and off-stream ponds (which are not hydroelectric facilities) in support of this statement.”

Response: Hardy and Croton Dam discharges are below surface water quality standards for dissolved oxygen and the text has been changed to indicate this. Reference to other water quality problems at hydroelectric dams was removed from the following paragraph because they were discussed later in Water Quality.

Comment: The purpose of the discussion presented on water temperatures is not made clear to the reader.

Response: The purpose of this discussion is to provide insight on water temperatures in the river system, and what is known about hydroelectric dam effects on water temperatures.

Comment: It is not clear what is meant by the phrase “suspected to be impounded” in reference to tributaries. How is this defined?

Response: Sometimes road culverts, illegal dams, and beaver dams create impoundments on small tributaries. These cannot be identified without field inspection. Maps of the watershed indicated some tributaries may have small impoundments formed by these types of sources.

Comment: “The Department notes that fishing below Croton Dam to Lake Michigan is “very good by today’s standards” (page 53, paragraph 2); whereas fishing above the dams on the upper Muskegon is “low to moderate” (page 47, paragraph 5). Given the litany of complaints on the impacts of dams on downstream resources (pp 40-42) and water quality (pp 43-45), one is hard pressed to explain the paradox represented by these statements. The Department has focused on the perceived negative aspects of the dams and is not looking at the river as a functional system nor at the dams as a useful part of that system.

The Department has noted that dams cause a dissolved oxygen problem, (p 43, paragraph 4) but do not compare downstream DO with an upstream control. The DO problem thus may or may not be due to the influence of the dams. It is interesting to observe (Tables 16 and 17) that average DO is higher below Croton Dam than above Rogers Dam (10.5 vs 9.8, respectively). The MDNR needs to be more objective in assessing water quality data and other data related to dams and their impact on water quality. For example, the temperatures and timing of discharges from Consumers Power Company dams beneficially affect the high quality anadromous fishery and the high quality resident trout fishery found below Croton Dam which has steadily improved since the implementation of re-regulation operations at Croton Dam. The fact is that the dams on the Muskegon River serve an extremely useful purpose in providing the cold water necessary to sustain a potential world class cold water fishery downstream of Croton Dam and help maintain optimal temperatures for the growth of cold water fish over a much longer period of time that would ordinarily be possible in a river that the Assessment characterizes as having marginal water temperatures for coldwater species (page 57, Potential for improvements and Expanded Sport Fisheries)."

Response: There is no paradox in statements regarding the environmental effects of dams and fishing quality below and above hydroelectric dams. Statements regarding dams are directed at all dams in the system, not just the hydroelectric dams. The fishery below Croton Dam is described as very good by today's standards. This statement does not preclude the notion the fishery could be much better if hydroelectric dam effects are corrected, and indeed, that is part of the basis for the Settlement Agreement. The fisheries below Croton Dam are better than above Croton Dam, largely because of potamodromous species and stocked trout. This is well documented in Fisheries Management. Croton Dam blocks movement of potamodromous species to upper river sections, and the potential improvement in fisheries for passage of these species is also documented in Fisheries Management. Resident trout are stocked above Croton, but at much lower densities. Similar stocking levels above the dams may create a fishery similar to that below Croton Dam.

The notion that timing of discharges from Consumer's Power Company Dams benefits the fisheries below Croton Dam is a paradox. Discharges from Croton Dam before the Settlement Agreement changed normal flow conditions and had effects on fisheries as noted in Dams and Barriers. The Settlement Agreement attempts to bring flows back to near normal or run-of-river conditions. The only exception is control of high flows during spring and that is based on winter power augmentation at the hydroelectric facilities rather than biological principals. Improvements noted after implementation of near run-of-river conditions are visible principally in better insect populations as noted by angler reports. Significant improvement in the riverine trout fisheries are the result of increased stocking levels, as well as the return to near normal natural flow conditions. Consumers Power Company began adjusting flows below Croton dam near re-regulated conditions in 1988, and made more improvements in 1992 (Dave Battige, Consumers Power Company, personal communication). Stocking levels for riverine trout below Croton were increased substantially in 1993. The most significant increases in fishing began in 1993 (from angler reports), and greater numbers of trout were evident in MDNR electrofishing surveys during spring of 1994.

The notion that changes in temperatures resulting from Consumer's Power Dams benefits the cold water fishery below Croton Dam is misleading. The Settlement Agreement provides for evaluation and possible modifications to the dams to achieve Michigan surface water quality standards. However, current data do not lead to the conclusion that the dams create colder temperatures below the dams. Available data are fully discussed in Water Quality. Overall, the hydroelectric dams likely increase heat input to the system because of greater heat absorption on the large surface area of the impoundments. The dams currently modify the thermal regime below Croton Dam. Temperatures are cooler below Croton from late March through the end of June. The rest of the year temperatures are warmer below Croton Dam. The dams modify extreme high and low temperatures, but they also extend continuous temperature periods above 70 F, which may be more detrimental to coldwater-coolwater species. Some of these temperature modifications may be detrimental to other species like the walleye, as noted in Biological Communities. This issue needs much more study. The Department is being objective on this issue by including all aspects of this topic in the assessment, and by including provisions for evaluation and modification in the Settlement Agreement.

Comment: "If the dams on the Muskegon River were removed, one wonders just what benefit would be accrued. The coldwater input from impoundments would be lost, as would the buffering effect that maintains stream temperatures for trout in the optimal range for growth over a longer period. What one would have instead are a few high gradient stretches in a marginal cold water stream with a sediment problem due primarily to the historic land use regime. If the dams were to be removed, the sediment issue would have to be addressed. Spawning reaches downstream from Croton which are now so productive (after having the benefit of a sediment trap in place for close to a century) would likely be severely impacted. Page 19, paragraph 6, attributes increases in walleye reproduction early in the 1900's to improved spawning habitat and recruitment resulting from the construction of Newaygo dam, which served as a sediment trap. Consumers' dams serve the same purpose in providing habitat for cool- to coldwater fishes. More focus is warranted on the tailwater fishery downstream from Croton and on the potentially productive fisheries in the ponds themselves, rather than continuing to press for fish passage structures or dam removal which are of questionable benefits and are not justified if the body of data is examined holistically."

Response: Currently, the river is a marginal trout stream, supported by stocking both above and below Croton Dam. Stocking below Croton is currently at a much higher rate. Riverine smallmouth bass, northern pike, and walleye (non-spawning), all have greater numbers of adults above Croton (Table 6). So even with land use problems above the dams, fisheries for resident species appear similar (even better for adults of some game species than below the dams). The same benefits for potamodromous species would be achieved in upper river sections if the dams were removed.

There is excessive sediment input into the river both above and below the dams, from various sources. Downstream sediment movement is stopped by the dams, but bank erosion below Croton is evident and may be as bad as above the dams. Land use issues are similar below Croton. There are no data to support the notion that spawning reaches below Croton are better than above the dam.

The hydroelectric dams have not solved the sediment issues, and may actually be creating a larger problem. Operation of normal sediment traps requires periodic removal of trapped sediment. The dams are acting as sediment traps but removal of the sediment is not occurring. Rather, excessive accumulations of sediment will make management more difficult when it becomes necessary to remove the dams. Dams are not the best way to manage sediment, and three hydroelectric dams are not necessary for this purpose. One dam would serve the same purpose.

The purpose of this Assessment is to review fisheries issues for the entire watershed, not just the river below Croton Dam or the impoundments. The Assessment and included management options, by design, address both sides of the fish passage and dam removal issues. The Settlement Agreement was negotiated and approved by Consumer's Power Company, the Department, and other agencies, and provides for evaluation and possible implementation of fish passage, along with dam relicensing. The Department cannot dismiss the issue of fish passage without proper evaluation, and neither should the other parties involved in the Agreement.

Fishery Management

Comment: Habitat improvements that benefit cold water fish also benefit warm water fish.

Response: Habitat improvements discussed in this assessment generally will benefit the entire aquatic community of the river.

Comment: There is a concern that we should not attempt to restore historical fisheries and scientific models should be used to determine fish stocking.

Response: Two objectives of Fisheries Division's Strategic Plan are to preserve native species and develop self-sustaining fish populations. Scientific models are good tools for evaluating alternative stocking regimes, but models need to be developed for specific systems and none are currently available for the complex Muskegon River system.

Comment: The walleye fishery in the river needs to be maintained.

Response: The Department currently is trying to rehabilitate this population and maintain the quality of the fishery. This is included as a management option.

Comments: Protecting the genetically pure walleye in the river is important.

Response: The Department is trying to maintain the integrity of this stock by using only Muskegon River strain walleye for stocking in waters from Manistee southward.

Comment: There is a concern that there are too many walleye in the river and they are affecting chinook salmon.

Response: Walleye are a native species in the Muskegon River and the population suffered drastic declines during the 1950s and 1960s. In 1978, a rehabilitation program was initiated and the population was estimated at one-third historical levels in 1986. More recent data are not available and extensive studies are needed to determine the status of this fish in the system. There is currently no information to indicate this species is affecting the natural chinook salmon population in the river. Recent studies indicate native adult chinook salmon represent the largest portion of the spawning run. Planning for additional studies on chinook salmon is currently underway.

Comment: The river below Croton should be managed primarily as a cold water fishery and anadromous fishery.

Response: Resident trout and potamodromous fish are an important part of the management program below Croton. This section of river is capable of multi-species management and this is discussed in Biological Communities and Fishery Management. This section of river is also managed for other important species including walleye and smallmouth bass. Lake sturgeon and river redhorse management also are important considerations.

Comment: There is a poor return on summer steelhead from stocking in the river.

Response: Summer steelhead were stocked for six years during the 1980s as noted in Fishery Management. Returns to the river were poor so the program was discontinued. Generally, summer steelhead returns in Michigan streams are much poorer than returns for Michigan (winter) steelhead.

Comment: Should increase steelhead and chinook salmon stocking, and consider stocking Atlantic salmon, Skamania steelhead and other cold water species..

Response: The Muskegon River is large and may support increased stocking of some species. However, the issue of increased stocking of various species is complex and thorough evaluations will be necessary before this would occur. Chinook salmon and Michigan steelhead would be likely candidates for increases. There are serious concerns with summer steelhead stocking and returns have been poor in the past. Expansion of the Atlantic salmon program in Michigan is unlikely for some time. Increasing natural reproduction would be a better alternative.

Comment: Support the goal of developing self supporting trout and anadromous fisheries in the river, especially below Croton. Support studies toward achieving these goals.

Response: Currently resident rainbow and brown trout fisheries in the mainstem are maintained by stocking. Adult steelhead spawning runs are 50% natural fish and adult chinook salmon runs are 60% to 90% natural fish. Planning for studies on potamodromous fish are currently underway. It is questionable if self-supporting populations of resident trout can be established, but more study is needed. Studies are included as a management option.

Comment: Support stocking trout and anadromous trout until self supporting populations are established.

Response: These stocking programs are expected to continue.

Comment: Opposing comments were received on the issue of special regulations for trout below Croton.

Response: This section of river has supported multiple use, family oriented, fisheries for various species for many years. Evaluations of recreational use need to be conducted on this river section to determine more specific needs. Application of special regulations requires approval by a majority of anglers using the river.

Comment: Fishing in the river is slow in Osceola County.

Response: This section of river currently has moderate populations of smallmouth bass and walleye. Other species that may have potential are trout and muskellunge. Fisheries management should be directed at these species.

Comment: Comments were made both supporting and opposing fish passage at hydroelectric dams.

Response: Potential benefits of fish passage include rehabilitation of native and naturalized potamodromous fish runs, improved sport fishing, and improved natural reproduction. Concerns are possible user conflicts and effects of expanding the range of Lake Michigan fish on interacting wildlife species. Guidelines for evaluating fish passage are being developed by the Department.

Comment: A thorough assessment of the impacts and benefits of implementing fish passage is needed, including the species and approximate numbers to be passed, interactions between species, and potential user-group conflicts;

Response: Guidelines for evaluating fish passage are being developed by the Department.

Comment: Contaminants are a concern with fish passage.

Response: This issue will be considered in evaluating fish passage.

Comment: Bigelow and Penoyer creeks should be managed with quality regulations for trout.

Response: These are small streams that support good brook and brown trout populations under current regulations. Recent data for Bigelow Creek confirm this. A current survey of Penoyer Creek is needed. Special regulations are used to obtain defined management objectives and need the support of a majority of anglers.

Comment: The fisheries in Hardy Impoundment need to be improved.

Response: A review of fisheries management and problems in this impoundment is presented in the assessment. Habitat, winter draw-down, and entrainment are important issues that need to be addressed and are included in management options.

Comment: Hardy Impoundment should not be drawn down so fish habitat can be improved.

Response: Hardy Dam has been relicensed and an annual winter drawdown of 12 feet to augment winter power generation is allowed in the license. Larger drawdowns are allowed for maintenance of the facilities. A drawdown of 15 feet from January through May, 1996 was allowed for dam repairs. Annual drawdowns will make habitat management and improvements to aquatic communities difficult in this impoundment.

Comment: Stock walleye in Hardy and Croton Impoundments to improve sport fisheries.

Response: Fisheries surveys of these impoundments indicate natural reproduction of walleye is present and stocking is not needed. Some supplemental stocking of Croton Impoundment occurs from one locally operated rearing pond located next to the impoundment.

Comment: Fish stocking should be spread out over the entire river.

Response: Stocking of various fish species occurs in the river from Osceola County to Muskegon Lake. This is discussed in Fisheries Management.

Comment: Use of electrofishing equipment for walleye collections in the river is killing fish.

Response: Fisheries Division annually collects adult walleye below Croton to collect eggs for walleye rearing programs. Collections are made using electrofishing equipment. This equipment temporarily paralyzes most fish that come in full contact with the electric field. These fish often float in the river current and appear dead. They recover after a short time. This type of equipment is used for collecting fish throughout Michigan and the world.

Comment: Need the development of balanced management objectives for both resident fish, including warm water and cool water impoundment species and anadromous fish species. Currently the Assessment is heavily biased in favor of cold water fish.

Response: Management objectives for warm and coolwater fish are outlined for all sections of the river in this assessment. Coldwater-coolwater fisheries are also important in this system as outlined in the discussion, especially in view of the regional importance of cold water river fisheries to this part of Michigan, and to Lake Michigan potamodromous fish. The river has natural physical and biological coldwater-coolwater components that need to be protected and rehabilitated. Cold, warm and cool water resources are discussed in this assessment where appropriate.

Comment: Need a balanced examination of measures needed to protect and restore threatened and endangered species and their habitat, including any measures needed to minimize the potential impact to these species of passing contaminated Great Lakes fish.

Response: Two threatened river species of fish, lake sturgeon and river redhorse, are currently found only in the river below Croton Dam. This section of river is open to free movement of Great Lakes fish. This would indicate factors other than elevated contaminants in Great Lakes fish are limiting the distribution of these threatened species. This issue, along with effects on other species discussed in Avian, Mammal and Fish Interactions will be considered in fish passage evaluations. More information and discussion regarding contaminants in fish and management of interacting species are included in Water Quality and Avian, Mammal, and Fish Interactions.

Comment: "Recognition of the fact that Great Lakes fish not only transport contaminants from the Great Lakes inland, but also contaminate inland fauna and ecosystems. In fact, one MDNR study showed that filets from resident trout on the Muskegon River below Croton Dam may be contaminated above regulator thresholds as a result of feeding on salmon eggs. Failure to recognize the problem has resulted in failure to establish a process to develop protective contaminant criteria;"

Response: The contaminant transport issue is recognized in Avian, Mammal and Fish Interactions. Additional discussion of this issue has been included.

Comment: "This section (Fisheries Management) is very one-sided. It fails to recognize that the introduction of coho salmon, chinook salmon, rainbow trout, brown trout and brook trout, while desirable to many anglers, had significant negative effects on the native biological community. Nor does it recognize that while potential fish reproduction areas are blocked from Lake Michigan fishes (most of which are introduced exotics), they remain available to the resident fish populations."

Response: The description "one-sided" is ambiguous. This section attempts to list all the general existing habitat, problems, fisheries in the river, and opportunities for fisheries management in the river.

There is no information that indicates these naturalized species have had negative effects on native species in this watershed. Natural populations of fish in Muskegon River tributaries with naturalized species (steelhead, salmon) are as good as or better than those without them. Barriers in the river not only block upstream movement of potamodromous fish, but also block natural seasonal movements for spawning and wintering of riverine species, and reduce the genetic integrity of these populations.

Comment: "We disagree with the statement on page 48 that "All of the upper river would benefit from passage of potamodromous fish." Passage of fishes to reestablish the native fishery as recorded pre-1900 would be highly speculative and not warrant the economic commitment. For example, if current water quality proved supportive, the threatened nature (low density) of lake sturgeon and river redhorse and the poor likelihood of locating a suitable genetic strain of river-run lake trout would severely limit success. While walleye passage could provide successful, similar success could be accomplished by alternate means such as reservoir development or upstream stocking. In addition, the passage of exotic (anadromous) fish stocks would likely prove detrimental to native stocks. Removal of the hydroelectric barriers would destroy the genetic integrity of established resident fish populations, allow the upstream movement of undesirable aquatic organisms such as lamprey, and permit the upstream movement of chemical contaminants contained in many species of Great Lakes fish."

Response: There is indication that fish passage would be economically feasible and this is discussed in Potential for Improvements and Expanded Sport Fisheries. The distribution of threatened lake sturgeon and river redhorse appears to be limited by the hydroelectric dams. Rehabilitation of these species are a goal of Fisheries Division's Strategic Plan and lake sturgeon rehabilitation strategy.

A river spawning stock of lake trout will likely develop from the existing stock in Lake Michigan, just as native stocks originally developed. Indication of this has developed in the last two years, as lake trout have been reported using the river below Croton during the fall spawning season. There is an ongoing lake trout rehabilitation plan in Lake Michigan and populations have increased in recent years. River spawning stocks could be an important part of management of this species.

Rehabilitating and maintaining self reproducing populations of walleye (or any other fish) is another goal of Fisheries Division's Strategic Plan. Maintaining a fish population through stocking, as an alternative to natural reproduction, is not sound resource management, and supplies of walleye for stocking are limited and will likely decrease in the future.

Removal of the hydroelectric barriers would improve the genetic viability of riverine fish populations. Native fish populations were established in a barrier free environment. Barriers separate and isolate normal population functions that maintain genetic viability (Kapuscinski and Jacobson 1987). Establishing self reproducing populations of fish also improves genetic viability.

The Department does not consider expansion of lamprey populations above the hydroelectric dams a viable part of dam removal. Suitable provisions for lamprey barriers would be made in any dam removal process. Restricting the distribution of sea lamprey using alternative means is discussed in Fisheries Management.

The effects of increasing the distribution of fish from Lake Michigan carrying elevated contaminant levels will be considered in any dam removal proposal. This is discussed in Avian, Mammal and Fish Interactions.

Comment: The reference to reservoir fluctuations as the cause of sandy bank erosion on the Hardy impoundment in the first full paragraph on page 50 ignores the contribution that is made by recreational boating and other recreational uses on this and the other impoundments.

Response: Reference to the possible effect of recreational boating is now included.

Comment: "While some fish are lost as a result of turbine passage, there is no indication that this loss is detrimental to the fishery or excessive in itself or in combination with other losses. On the contrary, as discussed on page 23, the sport fisheries for several species are currently rated among the best in Michigan."

Response: Entrainment and mortality of fish through turbines represents a loss of fish to the impoundment. As discussed in Fisheries Management, Eschmeyer (1948) documented losses of walleye from the Muskegon River hydroelectric impoundments and resulting effects on the fishery. There has been a long history of fishery complaints, problems, and management attempts by the Department to improve conditions in the reservoirs.

The reference regarding good sport fisheries conditions, in Biological Communities, refers to the river segment below Croton Dam and Muskegon Lake, not the impoundments where entrainment effects are occurring.

Comment: "The section on Bald Eagle, Mink, River otter and Potamodromous Fish underestimates the impact of introducing Great Lakes contaminants via upstream fish passage to upstream ecosystems. The Department's own research (Merna, J.W. 1986, Contamination of stream fishes with chlorinated hydrocarbons from eggs of Great Lakes salmon Trans. Am. Fish Soc. 115:64-74) documents the contamination of nonmigratory salmonids through ingestion of salmon eggs in anadromous-accessible segments of the Muskegon and Manistee rivers. The contamination of the upstream ecosystems is not even considered in this assessment. One wonders just what happens to the contaminants in dying salmon and their eggs, or in the eggs of species that return to the Great Lakes. The USFWS recognizes the threat to both ecosystems and piscivorous species (e.g. Kubiak, T J and D A Best, 1991, "Wildlife Risks Associated with Passage of Contaminated Fish at Federal Energy Regulatory Commission Licensed Dams in Michigan" unpublished report. US Fish and Wildlife Service, East Lansing Field Office). The USFWS has indicated that it will not exercise its authority to require upstream fish passage until such time as the fish contaminant levels no longer pose a threat to upstream wildlife and ecosystems. The Department should refer to the contaminant section in Exhibit E of CPCo's licensing application, the Biological Assessment for Bald Eagles that accompanies the FERC licenses, and in the peer-reviewed literature, Giesy et al (1994a, 1994b, 1995) for an appropriate perspective.

This section ignores the long-standing anadromous fish contaminant problem associated with low Bald eagle productivity on the Muskegon River. This perspective can be obtained from the Department's own Wildlife Division records.

Eagles use the fish resource on the Muskegon River throughout the year and add to their contaminant burden as they do so. Whether or not the passage of chinooks or browns overlaps the nesting season is somewhat irrelevant. They still are a significant contaminant source available to both adults and fledglings. The depuration rate for contaminants such as PCB is slow; contaminants ingested in the non-nesting season are stored in fat and are mobilized during egg laying. Consumers' data demonstrate a high level of winter use on the Muskegon by immature eagles that would be affected by this process."

Response: The Assessment addresses the issue of contaminants as one of the many considerations in fish passage, in Avian, Mammal and Fish Interactions. The Department has reviewed the literature on eagles presented in Consumers Power Company's pre-license studies and has many concerns with the conclusions of these reports. There is important information not considered in the pre-license studies.

Avian, Mammal and Fish Interactions now includes a more thorough review of information available on bald eagle, mink, and river otter. Available information indicates fish passage is a feasible management objective.

The interpretation of data regarding effects of contaminants on eagles and other animal populations in Consumers Power Company's pre-license reports appears to be exaggerated. There is no indication fish or populations of other aquatic organisms are impaired by contaminants in river reaches open to Great Lakes fish migrations, when compared to inland river reaches. In fact, two other threatened species, lake sturgeon and river redhorse are currently found only below Croton dam in the Muskegon River, indicating barriers are more of a problem to these species than contaminants. Again, elevated concentrations of contaminants in Great Lakes fish is only one of many issues that must be considered in fish passage, and management of bald eagles, river otter, and mink populations.

Comment: "There is indeed prime eagle nesting habitat on the Little Muskegon at the present time as is noted here. At issue, however, is not the protection of this nesting habitat from the contaminants being carried by Great Lakes fish but the protection of the eagles themselves which already forage on these same fish in the Great Lakes accessible reach of the Muskegon River downstream of Croton Dam. These contaminated fish would become even more accessible to the eagles and other sensitive, fish eating wildlife by providing upstream passage at consumers' hydroelectric plants on the Muskegon River. Consumers' also questions whether the Fisheries Division has considered the impact that removal of the Muskegon River dams may have on eagle nesting habitat."

Response: It is not likely eagles that might nest in the Little Muskegon River area would be exposed to any greater degree by fish passage at the dams. This area is very close to Croton Dam, and eagles currently use the river below Croton Dam.

Removal of the hydroelectric dams would likely benefit eagle nesting in the Muskegon River Basin. Removing the dams would eventually create significant expanses of forest adjacent high gradient sections of river, ideal for eagle nesting and foraging. One of the primary problems with eagle nesting noted in the pre-license reports, was human interference. Currently, motor boat use and human development on the impoundments are high and may be impeding nesting activities.

Comment: "The comments presented here that characterize hydroelectric impoundments as a detriment to eagles because of recreation levels or winter ice ignore the following:

Hydroelectric plant impoundments provide essential habitats that rivers do not - still waters with good visibility and warm-water "rough fish" for eagle forage. The majority of eagle territories on Michigan rivers are found in association with hydroelectric impoundments and would likely cease to exist if the dams were removed."

Response: The majority of eagle nesting habitat on the Muskegon River is not found in association with hydroelectric facilities. Also, the association of eagles with hydroelectric facilities is likely the result of suitable habitat found in large isolated land tracts near the facilities. These land tracts could be retained for eagle use without the dams and impoundments.

In the Muskegon River, fish species used for eagle forage are more abundant in the river than in the impoundments. Clearly, the high winter use of the river below the impoundments, by eagles, demonstrates the river provides good foraging for eagles. In addition, on the Muskegon River, there are more nesting eagles on the river than on the impoundments. This is true even though there is nesting habitat currently unused on Croton Impoundment.

Comment: "In winter, hydroelectric plant tailwaters often provide the best eagle wintering habitat due to the concentration of fish in the open water below dams."

Response: Hydroelectric plant tailwaters do not provide the best eagle wintering habitat due to the concentration of fish in the open water below the dam. Consumers Power Company pre-license reports documents wintering eagle use of the Muskegon River. Eagles were not associated with the hydroelectric dams and all wintering eagles were found in river segments well below the tailwaters of Croton Dam. The majority were found in the Muskegon State Game Area, just above Muskegon Lake. No eagles were reported on the impoundments and it appears that the impoundments are severely limiting winter eagle habitat in the Muskegon River, as discussed in Avian, Mammal and Fish Interactions. Ice cover on the impoundments prevents use for foraging during winter. Also, the impoundments cover 40 miles of the highest gradient portions of the river that would be prime, ice-free winter foraging areas for eagles.

Comment: "The reference to high levels of recreational and residential impacts ignores the present eagle use at Croton on the Little Muskegon and the potential use of the area above Davis Bridge on the Hardy impoundment. While recreation levels may well impact eagle productivity, eagle habitat without the impoundments would be marginal at best."

Response: As noted above, it is likely eagle habitat would be improved by removing the impoundments.

The eagle nest on Croton Impoundment is located on a large private tract of land. Human use is restricted in the nesting area and supplemental feed (carrion) is also provided. Use of the impoundment for foraging is not documented (although it probably occurs) and recreational use may be affecting foraging. Fisheries Division personnel often see eagles and osprey foraging in the river segment below Croton Dam, during spring and summer, and eagle nest sites are located in these downstream areas as well as the Muskegon State Game Area.

Comment: "Has the Department assessed the costs associated with the impact to downstream residential and commercial development in the floodplain in connection with the cessation of the seasonal drawdown of the Hardy impoundment. (Also see management option presented at the bottom of page 68)."

Response: The Settlement Agreement allows for the winter drawdown of Hardy Impoundment to augment winter power generation at the hydroelectric facilities. Any change in this Agreement would necessarily require more study of the resulting affects. Studies addressing the benefits of spring flood moderation during normal years, should also include the effects of high flood events that occur less frequently. Moderation of flooding during normal years can provide false security and foster development in the floodplain. This can lead to devastating social and economic losses during years of excessive flooding when floodwaters cannot be controlled. The drawdown is affecting fishery habitat in Hardy Impoundment and it will be difficult to improve habitat and aquatic communities in the impoundment as a result.

Comment: "Consumers is very interested in reviewing the guidelines being developed by the Department and other resource agencies regarding the feasibility of fish passage on Michigan streams."

Response: Consumers Power Company will have opportunity to comment on fish passage issues.

Comment: "As mentioned in the cover letter to these detailed comments, Consumers is disappointed at the lack of recognition of the agreements reached on many of the issues presented in the Assessment related to hydroelectric facility impacts and feels the discussion presented here should be expanded upon to include those agreements and to correctly reflect the fact that the Offer of Settlement was largely adopted by FERC in the new operating licenses that were issued on July 15, 1994 for Consumers' three Muskegon River hydroelectric projects."

Response: The writing of the first draft of this assessment began in June, 1991 and was completed in February, 1994. Following formatting changes and printing, copies were distributed for public comment beginning in March, 1995. Public meetings were held on July 6 and July 12, 1995. The Offer of Settlement was in negotiation and not approved until July, 1994, after completion of the first draft. The first draft of the assessment recognized an Offer of Settlement was being negotiated for hydroelectric dam effects in Offer of Settlement for Hydroelectric Dam Issues. A copy of the finalized Settlement Agreement is now included in Appendix 3.

Citizen Involvement

Comment: The Muskegon Lake Remedial Action Plan should be included in the assessment.

Response: The Remedial Action Plan is directed at more than just fisheries issues in Muskegon Lake and will not be included in this fisheries assessment. A copy of the plan can be obtained by writing to the address given in International Joint Commission Areas of Concern.

Comment: A Watershed Council should be formed to insure citizen involvement and address the issues.

Response: This is listed as a management option.

Comment: Any long term management plan must include strategies to educate the public regarding the goals of the management plan and any revised regulations.

Response: These assessments and management plans are designed to be updated on a periodic basis. The purpose of the assessment is to provide information and stimulate public involvement in the planning process.

Management Options

Comment: It is very important for the DNR to convey the effects of each option (i.e., benefits, consequences, trade-offs, relationship to other options, etc.) to the public and other agencies so they in turn can provide the best input to the DNR. One suggested approach is to consider combining options into logical management alternatives.

The Assessment should also give adequate consideration to the economic impacts associated with the various management options presented. Options like dam removal, fish passage, and downstream fish protection devices have significant costs and long term socioeconomic impacts. These costs and impacts need to be examined and the public consulted in the process.

Response: The assessment is intended to provide the information base for selecting management options. Some options will require additional analyses before any action is taken. The assessment planning process is intended to continue public involvement in the issues.

Comment: Most of the issues and options listed in the assessment are important, but will not be able to accomplish all at once.

Response: Selected options likely will be based on long and short term goals, and funding to complete projects.

Comment: Should use (Settlement Agreement) moneys to first focus on habitat improvement issues for fish, and accomplish projects rather than conduct surveys.

Response: It is likely moneys will be spent on both projects and studies. Studies and planning are often necessary before projects are started. Moneys are often tied to specific options and cannot be used in other areas.

Comment: Specific enforcement options and recommendations should be incorporated in the assessment, relative to selected options.

Response: Objectives defined in the assessment will be implemented through normal agency program management procedures. If new regulatory functions are needed to accomplish an option, it will be noted.

Comment: "(1) it is interesting to note that several management options presented in this portion Management Options) of the Assessment, e.g. maintenance of riparian vegetation (page 63) and USDA Soil Conservation practices (page 65), are either not very well developed or not even mentioned elsewhere in this Assessment. (2) The implication made on page 66 that hydroelectric dams limit recreational fishing is simply erroneous and short-sighted. On the contrary, hydroelectric dams enhance recreational fishing by concentrating fish below the dams to improve angler access to fish and creating the opportunity for reservoir fishery development in the impoundments established above hydroelectric facilities. The Assessment and these management options again ignore the extensive agreements reached as part of the negotiated Offer of Settlement including provisions for extensive recreational access in connection with Consumers' hydroelectric plants that will be accessible to people of all ability levels. (3) It is not clear why several mutually exclusive options are presented in this section, e.g. retain the dam impoundments and manage them for impoundment fisheries (page 68) versus remove the dams and manage the restored river for walleye, rainbow trout, and brown trout (page 69). (4) It is also interesting to note that in many cases the only remedy that is apparent to the Department with respect to the many stated and assumed problems caused by dams is their complete removal."

Response: Riparian vegetation and USDA soil conservation practices are discussed in Land Development.

The effects of the hydroelectric dams on fisheries in the Muskegon River are discussed throughout this assessment. River recreation activities could be improved by removing the hydroelectric dams, and this option has been revised to better indicate the intent. There is recreation on the impoundments and provisions have been made in the Settlement Agreement to improve recreational access.

One of the purposes of this assessment is to provide an avenue for public involvement in fisheries management decisions. As discussed in the Introduction, the management options listed are not necessarily recommended by Fisheries Division, but are intended to provide a foundation for public comment and subsequent selection of options. Returning rivers to natural conditions and retaining dams are both viable management options.

Sometimes dam removal is the only reasonable option available to achieve an objective or remedy a problem created by a dam. For example, management for river recreation is not possible when a river is impounded by a dam.

Public Comment and Response

Comment: More time is needed for public comment on the assessment, and more public meetings should be conducted.

Response: A six month period was allowed for public comment, along with two public meetings in Big Rapids and Muskegon. Considerable public comment was received on this assessment. The assessment and planning process are intended to continue, along with public involvement. Public meetings will be scheduled as needed for any particular issue.

Comment: Request that two public hearings be conducted for any dam affected by the final plan for the Muskegon River Watershed in Missaukee County.

Response: Public notification by the Department of Environmental Quality, through newspapers and local townships, is part of any permitting process for dam removals. Public hearings are scheduled as needed and are dependent on the type of project and public interest. Besides public hearings, there is a two week period allowed for written comment on the permit application.

GLOSSARY

anchor ice - ice that forms on bottom substrate of a stream

baseflow - the groundwater discharge to the system

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

centrarchid - species of fish that are in the centrarchidae family, generally the sunfishes, crappies, and basses

electrofishing - the process of putting an electric current, either AC or DC, through water for the purpose of stunning and capturing fish

emergent vegetation - rooted aquatic plants that grow in shallow water, with most of the plant protruding above the water surface

entrainment - to draw in and transport by the flow of water; in this report entrainment refers to the transport of aquatic organisms through dam structures by water

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

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

extirpation - to make extinct, remove completely

fauna - the animals of a specific region or time

FERC - Federal Energy Regulatory Commission

frazil ice - ice that results from the formation of crystal in supercooled water or from the persistence of entrained snow-flakes

gradient - change in elevation from one point in a stream to another

half-life - the time required for half the amount of a substance to be eliminated by natural processes

hydrology - the science of water

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

insectivores - those animals that rely primarily on insects for food

MDEQ - Michigan Department of Environmental Quality

MDNR - Michigan Department of Natural Resources

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

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

pest species - species that are a nuisance or detrimental to the health of the aquatic community, or interfere with management objectives.

piscivores - fish that eat other fish

potamodromous - truly migratory fishes whose migrations occur wholly within fresh waters (Meyers 1949). In the context of this report the term refers to fish that migrate from Lake Michigan or Muskegon Lake into the Muskegon River to spawn.

riparian - adjacent to, or living on, the bank of a river

run habitat - fast non-turbulent water

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

Settlement Agreement - a 1994 agreement made between Consumers Power Company and the resource agencies regarding Muskegon River hydroelectric dam issues. This agreement was incorporated in Federal Energy Regulatory Commission licenses for the dams.

Shannon-Weiner information statistic - a probability statistic that measures the number of groups of information within all of the information

submergent vegetation - rooted aquatic plants with stems and leaves below the surface of the water (occasional exceptions have a few small floating or aerial leaves)

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

till - an unstratified, unsorted glacial drift of clay, sand, boulders, and gravel

turbidity - water that has large amounts of suspended sediments in the water column

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

young-of-the-year - the offspring of fish that were born this calendar year

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Table 1.–Native and introduced fish species in the Muskegon River basin. Presence in the original community was determined by Bailey and Smith (1981). Present distribution (1965 or later) was from Michigan Department of Natural Resources, Fisheries Division records and Lawler, Matusky & Skelly Engineers (1991a, b, c). Table codes: x=native species; i=introduced species; c=colonized via channel or introduction; l=presence only within lakes in the watershed; p=probable species in the original community, but fossil records absent.

Common name	Species	Original distribution	Present distribution
Lamprey	Petromyzontidae		
Northern brook lamprey	*Ichthyomyzon fossor*	x	x
Chestnut lamprey	*Ichthyomyzon castaneus*	x	x
American brook lamprey	*Lampetra appendix*	x	x
Sea lamprey	*Petromyzon marinus*	c	c
Sturgeon	Acipenseridae		
Lake sturgeon	*Acipenser fulvescens*	x	x
Gar	Lepisosteidae		
Longnose gar	*Lepisosteus osseus*	x	x
Shortnose gar	*Lepisosteus platostomus*	c	
Spotted gar	*Lepisosteus oculatus*	x	
Bowfin	Amiidae		
Bowfin	*Amia calva*	x	x
Mooneye	Hiodontidae		
Mooneye	*Hiodon tergisus*	x, p	
Freshwater eel	Anguillidae		
American eel	*Anguilla rostrata*	c, p	
Herring	Clupeidae		
Alewife	*Alosa pseudoharengus*	c	c
Gizzard shad	*Dorosoma cepedianum*	x	x
Minnow	Cyprinidae		
Central stoneroller	*Campostoma anomalum*	x	x
Goldfish	*Carassius auratus*	i	
Lake chub	*Couesius plumbeus*	x	x
Spotfin shiner	*Cyprinella spiloptera*	x	x
Carp	*Cyprinus carpio*	i	i
Brassy minnow	*Hybognathus hankinsoni*	x	x
Striped shiner	*Luxilus chrysocephalus*	x	
Common shiner	*Luxilus cornutus*	x	x
Pearl dace	*Margariscus margarita*	x	
Hornyhead chub	*Nocomis biguttatus*	x	x
River chub	*Nocomis micropogon*	x	x
Golden shiner	*Notemigonus crysoleucas*	x	x
Pugnose shiner	*Notropis anogenus*	x, l	
Emerald shiner	*Notropis atherinoides*	x	x
Bigmouth shiner	*Notropis dorsalis*	x	x

Table 1.–Continued.

Common name	Species	Original distribution	Present distribution
Minnows continued			
Blackchin shiner	*Notropis heterodon*	x	x
Blacknose shiner	*Notropis heterolepis*	x	x
Spottail shiner	*Notropis hudsonius*	x	x
Rosyface shiner	*Notropis rubellus*	x	x
Sand shiner	*Notropis stramineus*	x	x
Weed shiner	*Notropis texanus*	x	
Mimic shiner	*Notropis volucellus*	x	
Northern redbelly dace	*Phoxinus eos*	x	x
Finescale dace	*Phoxinus neogaeus*	x	x
Bluntnose minnow	*Pimephales notatus*	x	x
Fathead minnow	*Pimephales promelas*	x	x
Blacknose dace	*Rhinichthys atratulus*	x	x
Longnose dace	*Rhinichthys cataractae*	x	x
Creek chub	*Semotilus atromaculatus*	x	x
Sucker	Catostomidae		
Quillback	*Carpiodes cyprinus*	x	x
Longnose sucker	*Catostomus catostomus*	x	x
White sucker	*Catostomus commersoni*	x	x
Lake chubsucker	*Erimyzon sucetta*	x	x
Northern hog sucker	*Hypentelium nigricans*	x	x
Black buffalo	*Ictiobus niger*	x, p	
Spotted sucker	*Minytrema melanops*	x	x
Silver redhorse	*Moxostoma anisurum*	x	x
River redhorse	*Moxostoma carinatum*	x	x
Black redhorse	*Moxostoma duquesnei*	x	x
Golden redhorse	*Moxostoma erythrurum*	x	x
Shorthead redhorse	*Moxostoma macrolepidotum*	x	x
Greater redhorse	*Moxostoma valenciennesi*	x	x
Catfish	Ictaluridae		
Black bullhead	*Ameiurus melas*	x	x
Yellow bullhead	*Ameiurus natalis*	x	x
Brown bullhead	*Ameiurus nebulosus*	x	x
Channel catfish	*Ictalurus punctatus*	x	x
Stonecat	*Noturus flavus*	x	x
Tadpole madtom	*Noturus gyrinus*	x	x
Flathead catfish	*Pylodictis olivaris*	x	x
Pike	Esocidae		
Grass pickerel	*Esox americanus vermiculatus*	x	x
Northern Pike	*Esox lucius*	x	x
Muskellunge	*Esox masquinongy*	x	
Mudminnow	Umbridae		
Central mudminnow	*Umbra limi*	x	x

Table 1.–Continued.

Common name	Species	Original distribution	Present distribution
Salmon	Salmonidae		
Lake herring	*Coregonus artedi*	x	
Lake whitefish	*Coregonus clupeaformis*	x	
Bloater	*Coregonus hoyi*	x, p	
Coho salmon	*Oncorhynchus kisutch*	I	I
Rainbow trout	*Oncorhynchus mykiss*	I	I
Chinook salmon	*Oncorhynchus tshawytscha*	I	I
Round whitefish	*Prosopium cylindraceum*	x, p	
Brown trout	*Salmo trutta*	I	I
Brook trout	*Salvelinus fontinalis*	I	I
Lake trout	*Salvelinus namaycush*	x	x
Arctic grayling	*Thymallus arcticus*	x	
Trout-perch	Percopsidae		
Trout-perch	*Percopsis omiscomaycus*	x	x
Pirate perch	Aphredoderidae		
Pirate perch	*Aphredoderus sayanus*	x	x
Cod	Lotidae		
Burbot	*Lota lota*	x	x
Killifish	Fundulidae		
Banded killifish	*Fundulus diaphanus*	x	x
Silverside	Atherinidae		
Brook silverside	*Labidesthes sicculus*	x	x
Stickleback	Gasterosteidae		
Brook stickleback	*Culaea inconstans*	x	x
Ninespine stickleback	*Pungitius pungitius*	x	
Sculpin	Cottidae		
Mottled sculpin	*Cottus bairdi*	x	x
Slimy sculpin	*Cottus cognatus*	x	
Temperate Bass	Moronidae		
White perch	*Morone americana*		I
White bass	*Morone chrysops*	x	
Sunfish	Centrarchidae		
Rock bass	*Ambloplites rupestris*	x	x
Green sunfish	*Lepomis cyanellus*	x	x
Pumpkinseed	*Lepomis gibbosus*	x	x
Warmouth	*Lepomis gulosus*	x	x
Bluegill	*Lepomis macrochirus*	x	x
Longear sunfish	*Lepomis. Megalotis*	x	x
Smallmouth bass	*Micropterus dolomieu*	x	x
Largemouth bass	*Micropterus salmoides*	x	x
White crappie	*Pomoxis annularis*	x	x

Table 1.–Continued.

Common name	Species	Original distribution	Present distribution
Sunfish continued			
Black crappie	*Pomoxis nigromaculatus*	x	x
Perch	Percidae		
Rainbow darter	*Etheostoma caeruleum*	x	x
Iowa darter	*Etheostoma exile*	x	x
Fantail darter	*Etheostoma flabellare*	x	
Least darter	*Etheostoma microperca*	x, l	
Johnny darter	*Etheostoma nigrum*	x	x
Yellow perch	*Perca flavescens*	x	x
Logperch	*Percina caprodes*	x	x
Blackside darter	*Percina maculata*	x	x
Sauger	*Stizostedion canadense*	x	
Walleye	*Stizostedion vitreum*	x	x
Drum	Sciaenidae		
Freshwater drum	*Aplodinotus grunniens*	x	x
Species totals			
Native		97	77
Introduced		8	7
Colonized via channel or	introduction	4	2

Table 2.–Natural features of the Muskegon River corridor. Information from the Michigan Department of Natural Resources, Wildlife Division, Natural Features Inventory, July, 1990. Type codes: A=vertebrate animal, C=plant community, G=geological feature, I=invertebrate animal, N=non-vascular plant, O=other feature (champion tree, rookery), P=vascular plant. Status codes: E=endangered, T=threatened, P=proposed status, X=probably extirpated, SC=special concern (rare, may become E or T in future).

Common name	Scientific name	Type	Federal status	State status
Clare				
Secretive Locust	*Appalachia arcana*	I		SC
Wood Turtle	*Clemmys insculpta*	A		SC
Common Loon	*Gavia immer*	A		T
Bald Eagle	*Haliaeetus leucocephalus*	A	E/T	T
Woodland Vole	*Microtus pinetorum*	A		SC
Ginseng	*Panax quinquefolius*	P		T
Massasauga	*Sistrurus catenatus*	A		SC
Mecosta				
Arethusa or Dragons Blood	*Arethusa bulbosa*	P		SC
Bog		C		
Emergent marsh		C		
Common Loon	*Gavia immer*	A		T
Great Blue Heron Rockery		O		
Bald Eagle	*Haliaeetus leucocephalus*	A	E/T	T
Hardwood - Conifer Swamp		C		
Furrowed Flax	*Linum sulcatum*	P		SC
Mesic Northern Forest		C		
Wet Scrubland, Upper Midwest	Northern Shrub Thicket	C		
Pugnose Shiner	*Notropis anogenus*	A		SC
Osprey	*Pandion haliaetus*	A		T
Poor Conifer Swamp		C		
Slender Fragrant Goldenrod	*Solidago remota*	P		SC
Shining Ladies' Tresses	*Spiranthes lucida*	P		SC
Bastard Pennyroyal	*Trichostema dichotomum*	P		T
Missaukee				
Secretive Locust	*Appalachia arcana*	I		SC
Wood Turtle	*Clemmys insculpta*	A		SC
Common Loon	*Gavia immer*	A		T
Great Blue Heron Rookery		O		
Bald Eagle	*Haliaeetus leucocephalus*	A	E/T	T
Loggerhead Shrike	*Lanius ludovicianus migrans*	A		E
Marten	*Martes americana*	A		T
Eastern Flat-whorl	*Planogyra asteriscus*	I		SC
Hill's Pondweed	*Potamogeton hillii*	P		T

Table 2.–Continued.

Common name	Scientific name	Type	Federal status	State status
Muskegon				
Spindle Lymnaea	*Acella haldemani*	I		SC
Lake Sturgeon	*Acipenser fulvescens*	A		T
Lake Floater	*Anodonta subgibbosa*	I		T
Missouri Rock-cress	*Arabis missouriensis*	P		SC
Lake Cress	*Armoracia aquatica*	P		T
Tall Green Milkweed	*Asclepias hirtella*	P		T
Witch-Hazel, Champion Tree	*Hamamelis virginiana*	O		
Piping Plover	*Charadrius melodus*	A	E	E
Hill’s Thistle	*Cirsium hillii*	P		SC
Pitcher’s Thistle	*Cirsium pitcheri*	P	T	T
Spotted Turtle	*Clemmys guttata*	A		SC
Wood Turtle	*Clemmys insculpta*	A		SC
Kirtland’s Snake	*Clonophis kirtlandii*	A		E
Infertile Pond/Marsh, Gt. Lakes	Coastal Plain Marsh	C		
Beak Grass	*Diarrhena americana*	P		T
Dry-Mesic Northern Forest		C		
Dry-Mesic Southern Forest		C		
Dry Sand Prairie, Midwest Type	Dry Sand Prairie	C		
Black Rat Snake	*Elaphe obsoleta obsoleta*	A		SC
Purple Spike-rush	*Elecharis atropurpurea*	P		E
Black-fruited Spike-rush	*Eleocharis melanocarpa*	P		T
Umbrella-grass	*Fuirena squarrosa*	P		T
Prairie-smoke	*Geum triflorum*	P		T
Great Blue Heron Rookery		O		
Great Lakes Marsh		C		
Tubercled Orchid	*Habenaria flava*	P		SC
Bald Eagle	*Haliaeetus leucocephalus*	A	E/T	T
Hardwood-Conifer Swamp		C		
Dwarf-bulrush	*Hemicarpha micrantha*	P		SC
Alkaline Shoredunes Marsh,Gt Lk	Interdunal Wetland	C		
Two-flowered Rush	*Juncus biflorus*	P		SC
Scirpus-like Rush	*Juncus scirpoides*	P		T
Spotted Gar	*Lepisosteus oculatus*	A		SC
Furrowed Flax	*Linum sulcatum*	P		SC
Broad-leaved Puccoon	*Lithospermum latifolium*	P		SC
Karner Blue	*Lycaeides samuelis*	I		PT
Appressed Bog Clubmoss	*Lycopodium appressum*	P		T
Northern Appressed Clubmoss	*Lycopodium sp 1*	P		SC
Mesic Northern Forest		C		
Beach/shoredunes, Great Lakes	Open Dunes	C		
Osprey	*Pandion haliaetus*	A		T
Philadelphia Panic-grass	*Panicum philadelphicum*	P		SC
Panic Grass	*Panicum spretum*	P		T
Orange/Yellow Fringed Orchid	*Platanthera ciliaris*	P		T

Table 2.–Continued.

Common name	Scientific name	Type	Federal status	State status
Cross-leaved Milkwort	*Polygala cruciata*	P		SC
Alleghany or Sloe Plum	*Prunus alleghaniensis var davisii*	P		SC
Bald-rush	*Psilocarya scirpoides*	P		T
Whorled Mountain-mint	*Pycnanthemum verticillatum*	P		SC
Meadow-beauty	*Rhexia virginica*	P		SC
Tall Beak-rush	*Rhynchospora macrostachya*	P		SC
Tooth-cup	*Rotala ramosior*	P		SC
Hall's Bulrush	*Scirpus hallii*	P		E
Few-flowered Nut-rush	*Scleria pauciflora*	P		T/PE
Tall Nut-rush	*Scleria triglomerata*	P		SC
Massasauga	*Sistrurus catenatus*	A		SC
Atlantic Blue-eyed Grass	*Sisyrinchium atlanticum*	P		T
Slender Fragrant Goldenrod	*Solidago remota*	P		SC
Trailing Wild Bean	*Strophostyles helvula*	P		SC
Bastard Pennyroyal	*Trichostema dichotomum*	P		T
Nodding/3-birds Pogonia orchid	*Triphora trianthophora*	P		T
Sand Grass	*Triplasis purpurea*	P		SC
ZigZag Bladderwort	*Utricularia subulata*	P		SC/PT
Wild Rice	*Zizania aquatica var aquatica*	P		T
Newaygo				
Lake Sturgeon	*Acipenser fulvescens*	A		T
False Arrow Feather	*Aristida necopina*	P		T
Western Silvery Aster	*Aster sericeus*	P		T
Dusted Skipper	*Atrytonopsis hianna*	I		SC
Side-oats Grama	*Bouteloua curtipendula*	P		T
Wood Turtle	*Clemmys insculpta*	A		SC
Dry Sand Prairie, Midwest Type	Dry Sand Prairie	C		
Snuffbox	*Dysnomia triquetra*	I		T/PE
Black-fruited Spike-rush	*Eleocharis melanocarpa*	P		T
Common Loon	*Gavia immer*	A		T
Prairie-smoke	*Geum triflorum*	P		T
Great Blue Heron Rookery		O		
Bald Eagle	*Haliaeetus leucocephalus*	A	E/T	T
Dwarf-bulrush	*Hemicarpha micrantha*	P		SC
Ottoe Skipper	*Hesperia ottoe*	I		T
Henry's Elfin	*Incisalia henrici*	I		SC
Frosted Elfin	*Incisalia irus*	I		PT
Geographical Feature	Kettle	G		
Great Plains Spittlebug	*Lepyronia gibbosa*	I		PT
Furrowed Flax	*Linum sulcatum*	P		SC

Table 2.–Continued.

Common name	Scientific name	Type	Federal status	State status
Karner Blue	*Lycaeides samuelis*	I		PT
Geographical Feature	Moraine	G		
River Redhorse	*Moxostoma carinatum*	A		T
Pugnose Shiner	*Notropis anogenus*	A		SC
Black-crowned Night-heron	*Nycticorax nycticorax*	A		SC
Waterthread Pondweed	*Potamogeton bicupulatus`*	P		T
Alleghany or Sloe Plum	*Prunus alleghaniensis var davisii*	P		SC
Bald-rush	*Psilocarya scirpoides*	P		T
Meadow-beauty	*Rhexia virginica*	P		SC
Tall Beak-rush	*Rhynchospora macrostachya*	P		SC
Phlox moth	*Schinia indiana*	I		SC
Blue-eyed Grass	*Sisyrinchium strictum*	P		SC
Slender Fragrant Goldenrod	*Solidago remota*	P		SC
Regal Fritillary	*Speyeria idalia*	I		T/PE
Osceola				
Wood Turtle	*Clemmys insculpta*	A		SC
Common Loon	*Gavia immer*	A		T
Great Blue Heron Rookery		O		
Geographical Feature	Kettle	G		
Marten	*Martes americana*	A		T
Osprey	*Pandion haliaetus*	A		T
Roscommon				
Secretive Locust	*Appalachia arcana*	I		SC
Arethusa or Dragon’s Mouth	*Arethusa bulbosa*	P		SC
Calypso or Fairy-slipper	*Calypso bulbosa*	P		T
Fescue Sedge	*Carex festucacea*	P		SC
Hill’s Thistle	*Cirsium hillii*	P		SC
Spotted Turtle	*Clemmys guttata*	A		SC
Wood Turtle	*Clemmys insculpta*	A		SC
Ram’s Head Lady-slipper	*Cypripedium arietinum*	P		SC
Kirtland’s Warbler	*Dendroica Kirtlandii*	A	E	E
Dry Woodland, Upper Midwest	Dry Northern Forest	C		
Rough Fescue	*Festuca scabrella*	P		T
Common Loon	*Gavia immer*	A		T
Great Blue Heron Rookery		O		
Bald Eagle	*Haliaeetus leucocephalus*	A	E/T	T
Doll’s Merrolonche	*Merolonche dolli*	I		SC
Osprey	*Pandion haliaetus*	A		T
Alleghany or Sloe Plum	*Prunus alleghaniesis var davisii*	P		SC
King Rail	*Rallus elegans*	A		E
Deepwater Pondsnail	*Stagnicola contracta*	I		T

Table 3.–Information for fish collection sites on the Muskegon River. Data from Michigan Department of Natural Resources, Fisheries Division records, and Lawler, Matusky & Skelly Engineers (1991c). Flows at Croton from L-transect at 1128 cfs, flows at Newaygo from N-transect at 1108 cfs.

	Site			
	Newaygo	Croton	Hersey	Clare
River mile	33	41	115	165
Date of sample	7/24/90	6/19/91	8/5/93	8/20/92
Method	Rotenone	Electrofishing	Rotenone	Rotenone
Area sampled (acres)	5.5	5.9	3.5	2.0
River width (ft)	228	182	170	81
River gradient (ft/mi)	3.45	2.7	1.2	1.7
Water velocity (ft/s)				
Average	2.3	2.0	1.0	1.4
Range	0.2-3.5	0.2-4.0	0.5-1.4	0.9-1.8
Water discharge (cfs)				
Mean annual discharge USGS gauge	1,969-Newaygo	1,863-Croton	1,006-Evart	
Day of sample	1,000 approximately	1,000 approximately	600	214
Bottom material composition (%)				
Silt & fine organic	26	15	2	13
Sand	6	42	40	37
Gravel	12	28	11	23
Cobble	51	6	43	16
Boulder	2	0	4	11
Coarse organic	3	9	low	moderate

Table 4.–Fish community list and biomass for four sites on the Muskegon River. Blanks indicate zero's. Data from Michigan Department of Natural Resources, Fisheries Division records, and Lawler, Matusky & Skelley Engineers (1991c).

	Number/acre				Pounds/acre			
Species	Newaygo	Croton	Hersey	Clare	Newaygo	Croton	Hersey	Clare
Coldwater - coolwater river species								
Rainbow trout	31.1	0.5			7.7	0.1		
Brown trout	17.0	1.2	2.0		2.7	0.3	0.9	
Brook trout			0.3				0.1	
Burbot	3.8	0.3	148.6	66.4	1.0	<0.1	2.9	14.3
Mottled sculpin	21.8		5.4	23.0	0.1		0.1	0.4
Longnose dace	7.9		55.4	33.2	0.1		0.6	0.3
Coolwater - warmwater river species								
Shorthead redhorse	78.6	34.6	183.2	24.4	115.5	46.5	135.2	10.3
Golden redhorse	36.0	32.0	90.6	14.7	58.7	43.4	66.3	18.6
Black redhorse	18.1		1.1		26.8		0.7	
River redhorse	0.9				5.6			
Silver redhorse	0.4	4.6	15.6	7.3	1.7	12.2	25.9	19.5
Redhorses, juvenile				43.5				0.1
Catastomidae, juvenile		59.5				0.3		
White sucker	2.2	15.2	54.5	122.6	3.6	13.1	10.0	10.7
Northern hogsucker	30.3	3.5	14.8	24.4	26.1	1.9	14.7	10.0
Rock bass	11.7	5.6	1.4	102.6	1.3	0.9	0.2	8.6
Smallmouth bass	15.2	12.5	9.4		4.4	4.2	11.0	
Northern pike	0.2	0.2	16.5	11.2	0.3	<0.1	0.9	14.2
Walleye	2.0	1.5	2.3	0.5	7.2	3.0	5.6	
Logperch	7.7	1.2	4.8	0.5	0.1	<0.1	0.1	
Rainbow darter	157.0	0.5	77.6	17.1	0.6	<0.1	0.2	0.1
Common shiner	71.8	60.0	578.7	1416.2	0.8	0.9	5.6	8.4
Hornyhead chub	18.5	4.9	6.3	115.3	0.5	0.1	0.1	1.5
Rosyface shiner	16.6	0.7	161.9	245.7	0.1	<0.1	1.1	1.2
Creek chub			4.3	180.3			0.1	1.0
River chub	28.5		9.7	424.5	1.2		0.1	6.6
Warmwater - bayou & impoundment species								
Black crappie	7.9	9.4	0.9	2.4	0.2	0.4	0.1	0.2
Bluegill	3.5		1.4		0.4			
Pumpkinseed	2.4	2.7	1.7	3.4	0.1	0.1	0.1	0.2
Green sunfish	0.4		5.1	36.6	<0.1		0.1	1.3
Warmouth			0.6				<0.1	
Longear sunfish				0.5				<0.1
Largemouth sass	0.9	0.8	0.6	1.5	0.4	0.5	<0.1	<0.1
Yellow perch		2.4	0.6	8.8		<0.1	0.2	0.9
Carp	0.4	7.6			5.5	58.5		
Yellow bullhead	2.2	0.2			1.1	0.1		
Black bullhead	0.2				<0.1			

Table 4.–Continued.

Species	Number/acre				Pounds/acre			
	Newaygo	Croton	Hersey	Clare	Newaygo	Croton	Hersey	Clare
Sand tolerant forage species								
Johnny darter	5.3	12.6	61.6	100.1	<0.1	<0.1	0.2	0.4
Blackside darter	1.3		133.2	274.1	<0.1		0.6	1.0
Sand shiner	6.4		744.6	96.7	<0.1		1.3	0.3
Blacknose shiner				2.4				<0.1
Northern redbelly dace				0.5				<0.1
Central mudminnow			0.6	0.5			<0.1	<0.1
Miscellaneous species								
Stonecat			5.4				<0.1	
Noturus sp. (madtom)				0.5				<0.1
Iowa darter				1.0				<0.1
Bluntnose minnow	7.7		3.4	2.0	<0.1		<0.1	<0.1
Spotfin shiner			0.6				<0.1	
Golden shiner			0.3				<0.1	
Central stoneroller				2.9				<0.1
Quillback carpsucker		0.0				0.9		
Chinook salmon	1.3	0.5			<0.1	<0.1		
Salmonidae, juvenile		0.2				<0.1		
Cyprinidae		0.8				<0.1		
Chesnut lamprey			1.7	4.4			<0.1	0.1
Northern brook lamprey				0.5				<0.1
Petromyzontidae		0.8				<0.1		
Total	617.0	276.5	2406.5	3412.3	273.6	187.6	285.2	130.2
Number of species	35	27	38	36				

Table 5.–Comparison of fish community information for some southern Michigan rivers. Muskegon River data are from the sites at Hersey, and Newaygo and Clare counties. Data from Michigan Department of Natural Resources, Fisheries Division records.

River and survey year	Number of sampling sites	Number of species collected	Average standing crop (lbs/acre)	Percent by weight		
				Sport fish	Redhorses & suckers	Carp
Muskegon (1990-1993)	3	53	230	10.2	81.3	0.8
St. Joseph (1987)	9	49	365	10.6	56.6	31.0
Shiawassee (1987)	14	51	294	11.4	54.5	28.7
Cass (1985)	11	43	268	9.4	47.9	24.4
Grand (1978)	22	70	160	9.6	44.0	45.6
Paw Paw (1989)	7	55	246	19.4	24.5	42.8

Table 6.–Primary river sport fish of harvestable size, at four sites on the Muskegon River and in several other warmwater Michigan rivers. Reported as number of fish per acre. Data from Michigan Department of Natural Resources, Fisheries Division records. N=Newaygo; Cr=Croton; H=Hersey; Cl=Clare.

	Muskegon River				Paw Paw	Battle Cr.	St. Joseph	Raisin	Huron
Species	N	Cr	H	Cl	River	River	River	River	River
Rainbow Trout (>8")	23.4	0.5	0.0	0.0	0-6	0	0	0	-
Brown Trout (>8")	5.3	1.0	1.7	0.0	0	0	0	0	-
Smallmouth Bass (>12")*	0.9	1.5	7.1	0.0	0-3	0-11	0-3	0-8	7.9-18.8
Northern Pike (>20")	0.0	0.2	0.0	2.0	0-8	0-1	0-3	0-3	-
Walleye (>15")	2.0	1.2	2.2	0.0	0-3	0	0	0	-
Total of Harvestable Size	31.6	4.4	11.0	2.0	1-11	0-12	0-6	0-8	-

*A size of 12 inches was the limit for harvest of bass at the time samples were collected. The current size limit is 14 inches.

Table 7.–Length frequency distribution of rainbow and brown trout collected at four sites on the Muskegon River. Reported as number of fish per acre. Data from Michigan Department of Natural Resources, Fisheries Division records, and Lawler, Matusky & Skelley Engineers (1991c).

Inch	Rainbow trout				Brown trout			
group	Newaygo	Croton	Hersey	Clare	Newaygo	Croton	Hersey	Clare
1	0.7	0	0	0	0.4	0	0	0
2	2.6	0	0	0	0.9	0	0	0
3	0.2	0	0	0	0.4	0.2	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	1.3	0	0	0
6	0.2	0	0	0	3.3	0	0	0
7	1.8	0	0	0	4.4	0	0.3	0
8	10.2	0.2	0	0	4.4	0.5	0	0
9	11.5	0.2	0	0	0.4	0.2	0.3	0
10	1.6	0.2	0	0	0	0.2	1.4	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0.2	0.2	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0.4	0	0	0
Total	28.9	0.5	0.0	0.0	15.9	1.2	2.0	0.0

Table 8.–Length frequency distribution of smallmouth bass, northern pike, and walleye at four sites on the Muskegon River. Reported as number of fish per acre. Data from Michigan Department of Natural Resources, Fisheries Division records, and Lawler, Matusky & Skelley Engineers (1991c). N=Newaygo; Cr=Croton; H=Hersey; Cl=Clare.

Inch	Smallmouth bass				Northern pike				Walleye			
group	N	Cr	H	Cl	N	Cr	H	Cl	N	Cr	H	Cl
1	0.2	0	0.6	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0.5	1.0	0	0	0	0	0	0	0	0	0	0
4	3.8	0.7	0	0	0	0	1.1	0	0	0	0	0
5	0.2	0.8	0	0	0	0	7.7	0.5	0	0	0	0.5
6	1.5	1.5	0	0	0	0	3.7	0	0	0	0	0
7	4.0	1.0	0	0	0	0	3.1	0	0	0	0	0
8	1.8	0.5	0	0	0	0	0.9	0	0	0.2	0	0
9	0.7	1.5	0	0	0	0	0	0.5	0	0	0	0
10	0.4	0.5	0.3	0	0	0	0	0	0	0	0	0
11	0.9	1.3	1.4	0	0	0	0	1.5	0	0	0	0
12	0.2	0.7	0.3	0	0	0	0	0.5	0	0	0	0
13	0	0.5	4.5	0	0	0	0	1.0	0	0	0	0
14	0.7	0	1.4	0	0	0	0	1.0	0	0.2	0	0
15	0	0.3	0.9	0	0	0	0	1.0	0	0	0	0
16	0	0	0	0	0	0	0	2.0	0.2	0	0.3	0
17	0	0	0	0	0.2	0	0	1.5	0	0	0.9	0
18	0	0	0	0	0	0	0	0	0.4	0.3	0	0
19	0	0	0	0	0	0	0	0	0.2	0.2	0	0
20	0	0	0	0	0	0	0	0	0.2	0.3	0.3	0
21	0	0	0	0	0	0	0	0	0.5	0.2	0	0
22	0	0	0	0	0	0	0	0	0.4	0	0	0
23	0	0	0	0	0	0	0	0.5	0	0	0.3	0
24	0	0	0	0	0	0	0	0	0	0	0.3	0
25>	0	0	0	0	0	0.2	0	1.5	0.2	0.2	0.3	0
Total	15.0	10.5	9.4	0.0	0.2	0.2	16.5	11.2	2.0	1.5	2.3	0.5

Table 9.–Watershed acreage, land development, and soil permeability at various locations in the Muskegon River watershed. Data from Michigan Department of Environmental Quality, Land & Water Management Division. Geology, soils, and developed land category descriptions are provided below.

River location	Total upstream acreage	% upstream developed land	% permeable soils	% permeable geology
Mainstem				
Lower Missaukee Co.	329,717	20	43	84
Lower Roscommon Co.	428,261	16	47	88
Lower Clare Co.	743,653	23	54	87
City of Hersey	1,057,070	27	65	87
City of Big Rapids	1,156,849	30	66	88
Croton Dam	1,478,663	34	74	88
City of Newaygo	1,522,872	34	74	88
Upper Muskegon Co.	1,553,992	34	74	89
Tributaries				
Little Muskegon River	108,919	54	99	98
Tamarack Creek	36,058	74	95	85
Clam River	149,422	35	77	86

Developed land: Includes urban and agricultural land.

Soils: Permeable includes dry and wet sand and gravel soils. Impermeable includes dry clay soils, wet loamy, organic and clay soils; and inland waters.

Geology: Permeable includes good to intermediate permeable materials of lacustrine and glacial outwash and end moraine sand, gravel and coarse textured till; and dune sand. Impermeable includes lacustrine and glacial fine textured silt and clay, bedrock, peat, muck, and artificial fill.

Table 10.–Water discharge at various locations on the Muskegon River; period of record in parenthesis. Data from Blumer et al. (1991).

River location	Drainage area (square miles)	Mean annual discharge (cfs)
Mainstem		
Merritt	355	230 (1947 - 1973)
Evart	1450	1006 (1934 -1985)
Newaygo	2350	1969 (1910 - 1985)
Tributaries		
Little Muskegon River near Morley	138	126 (1967 - 1985)
Clam River near Vogel Center	243	124 (1967 - 1985)

Table 11.–Affect of flow regulation by hydroelectric dams, based on minimum - maximum flows, for several aquatic organisms in the Muskegon River below Croton Dam. Data from Lawler, Matusky & Skelly Engineers (1991c). Evaluation by Michigan Department of Natural Resources, Fisheries Division.

Organism	Mean habitat loss (%)	Range (%)
Brown trout- juvenile	34.5	16.5 to 74.9
Brown trout- spawning	42.7	40 to 46
Rainbow trout- adult	27.6	11.6 to 55.3
Rainbow trout- fry	96.2	-
Mayfly	32	8.8 to 80.1

Table 12.–River gradient information for Muskegon and Little Muskegon rivers. Data from Michigan Department of Natural Resources, Fisheries Division records.

	Gradient class (ft/mi)				
Location	0 - 2.9	3 -5	6 - 10	11 - 70	Total
Muskegon River					
Total miles	151.5	51.1	6.8	2.5	211.8
Open to Lake Michigan fish migrations	37.7	8.1	1.4	0.0	47.3
Impounded.	18.3	21.1	3.9	2.5	45.7
Closed to Lake Michigan fish migrations by dams	95.4	21.8	1.5	0.0	118.8
Little Muskegon River					
Total miles	4.7	23.5	12.8	2.9	43.9
Open to Lake Michigan fish migrations	0.0	0.0	0.0	0.0	0.0
Currently impounded.	0.0	0.0	2.52	2.03	4.55
Closed to Lake Michigan fish migrations by dams	4.7	23.5	10.3	0.9	39.4

Table 13.–Measured and theoretical channel widths for several Muskegon River and tributary locations. Theoretical widths were calculated using average width of rivers with the same discharge volume (data from Leopold and Maddock 1953).

Location/date/source	Discharge (cfs)	Measured width	Theoretical width Mean	Theoretical width Min	Theoretical width Max
Newaygo, USGS #04122000					
USGS, 1910 -1985, Mean annual discharge	1969	235	242	165	356
Lawler, Matusky, & Skelly Engineers (1991c), 7/20/90	2135	267			
Newaygo - Croton, site 1 Lawler, Matusky, & Skelly Engineers (1991c), 7/20/90	2180 approx.	243	242	165	356
Newaygo - Croton, site 2 Lawler, Matusky, & Skelly Engineers (1991c), 7/19/90	2310 approx.	220	242	165	356
Newaygo - Croton, site 3 Lawler, Matusky, & Skelly Engineers (1991c), 7/19/90	2213 approx.	206	242	165	356
Croton, .946 adjusted flow from USGS #04122000 Lawler, Matusky, & Skelly Engineers (1991c), 7/19/90	2228	267	235	160	345
Evart, USGS #04121500, 1934 - 1985, Mean annual discharge	1006	145	173	120	250
Merritt USGS #04121000, 1947 - 1973, Mean annual discharge	230	82	83	60	115
Clare County, T20N,R5W,S1 Michigan Department of Natural Resources, Fisheries Division, 8/20/92	214	81	80	58	111

Table 14.–Conservation treatment needs on non-federal rural lands in Michigan, in 1987, by land and cover use. Units = 1000 acres. Data from Anonymous (1987a).

Conservation treatment needed	Cropland	Pastureland	Grazed forestland	Ungrazed forestland	Minor land/ cover use	Total
Erosion control	4817.3	193.9	1.3	101.3	99.2	5213.0
Drainage	2193.2	115.8	0.0	0.0	28.9	2337.9
Irrigation management	131.1	0.0	0.0	0.0	0.0	131.1
Management for forage improvement	1.2	270.2	13.5	0.0	0.0	284.9
Mechanical soil treatment for forage improvement	0.0	16.4	0.0	0.0	0.0	16.4
Weed control or brush management for forage	0.0	138.0	0.4	0.0	0.0	138.4
Plant reestablishment for forage management	0.0	172.3	0.0	0.0	0.0	172.3
Forage reestablishment with brush management	0.0	266.6	1.3	0.0	0.0	267.9
Establishment and reinforcement of timber	0.0	0.0	20.4	679.5	0.0	699.9
Timber stand improvement	0.0	0.0	34.0	5268.5	0.0	5302.5
Conservation treatment to improve timber crops	0.0	0.0	78.0	85.6	0.0	163.6
Toxic salt reduction	0.0	0.0	0.0	0.0	0.0	13.1
Total areas with some conservation treatment needed	5967.8	934.8	121.0	5994.5	141.2	13159.3
Total areas without needs	3516.0	1799.8	148.1	9219.2	2287.6	16970.7

Table 15.–Muskegon River watershed dams registered with the Michigan Department of Environmental Quality.Blanks indicate no information available.

Stream	Dam	ID number	Impoundment
Roscommon			
The Cut	Higgins Lake LCS	MI02012	
Trib. to Higgins Lake		MI01421	
Muskegon River	Houghton Lake LCS	MI02119	
Unnamed trib. to Houghton Lk.	Houghton Lk Flats SV Dam	MI02014	
Unnamed trib. to Houghton Lk.	Houghton Lk Flats NU Dam	MI02013	
Osceola			
Middle Branch River	Marion Dam	MI00316	
Middle Branch River	Vomastele Dam	MI01648	
Clam River	Kelinski Dam	MI01588	
Clam River	Clam River Dam	MI01909	
Hersey River	Nartron Dam	MI00356	Nartron Lake
Hersey River	Miller Industries Dam	MI01899	
Hersey River	Village of Hersey Dam		
Muskegon River tributary	Lake Lure Dam	MI00320	Lake Lure
Cat Creek	Cat Creek Dam	MI01762	
Mitchell Creek		MI02011	
Clare			
Townline Creek	Townline Creek Dam	MI00796	T.C. Wildlife Flooding
Mecosta			
Trib. to W. Br. Little Muskegon River	Lower Canadian Lakes Golf Course	MI00797	
Trib. to W. Br. Little Muskegon River	Lower Canadian Lakes Golf Course	MI01223	
Muskegon River tributary		MI01544	
Macks Creek	Evels Dam	MI01548	
Ryan Creek		MI01568	
Muskegon River tributary		MI01570	
Ground and swamp water		MI01571	
Cedar Creek		MI01657	
Muskegon River tributary	Carnes Pond	MI01660	Carnes Pond
Muskegon River tributary	Johnsons Dam	MI01759	
Muskegon River	Rogers Dam	MI00222	Rogers Pond
Newaygo			
Brooks Creek	Peterson Dam	MI02171	Grandpa lakes
Brooks Creek	Barton Road Dam	MI02451	
Trib to Half Moon Lake	Parker Dairy Co. Cam	MI02458	
Muskegon River	Hardy Dam	MI00195	Hardy Pond
Muskegon River	Croton Dam		Croton Pond
Missaukee			
Muskegon River	Reedsburg Dam	MI00310	

Table 16.–Annual mortalities and associated economic values of fish at Muskegon River hydroelectric dams, 1990-91. Fish mortalities estimated from data provided by Lawler, Matusky, & Skelly Engineers (1991a, b, c). Economic values are from American Fisheries Society (AFS) replacement values of freshwater fish (Anonymous 1982), adjusted for inflation (1983-91, 1.38 times higher), and from Michigan Natural Resources and Environmental code, Public Act 451, Part 487, 1994, which contains codified values for damages to wildlife and fisheries. Blanks indicate no mortalities were estimated.

	RogersDam			HardyDam			CrotonDam			Total		
Species	#killed	AFS	PA451	#killed	AFS	PA451	#killed	AFS	PA451	#killed	AFS	PA451
Shorthead redhorse	544	$236	$1,270	12	$5	$28				556	$241	$1,298
Golden redhorse							62	$26	$114	62	$26	$114
Greater redhorse	8	$5	$38							8	$5	$38
Silver redhorse	29	$9	$25							29	$9	$25
Moxostoma spp.	178	$72	$399				52	$20	$184	230	$92	$583
Northern hogsucker	13	$5	$18				30	$9	$24	43	$14	$42
White sucker	419	$137	$541	1,297	$1,130	$10,167	784	$307	$2,000	2,500	$1,574	$12,708
Black crappie	1,097	$1,808	$10,967	238	$245	$2,378	2,605	$4,513	$26,050	3,940	$6,566	$39,395
White crappie							27	$74	$265	27	$74	$265
Bluegill	364	$541	$3,645	42	$73	$419	8,453	$11,904	$84,532	8,859	$12,518	$88,596
Green sunfish	16	$27	$156				134	$171	$1,339	150	$198	$1,495
Pumpkinseed	78	$78	$781				1,749	$1,880	$17,489	1,827	$1,958	$18,270
Rock bass	318	$541	$3,181	22	$30	$220	752	$1,409	$7,518	1,092	$1,980	$10,919
Smallmouth bass	617	$2,977	$6,322	86	$262	$864	943	$3,660	$10,371	1,646	$6,899	$17,557
Largemouth bass							199	$370	$1,986	199	$370	$1,986
Unidentified sunfish	39	$23	$394				27	$37	$265	66	$60	$659
Bluntnose minnow	13	$1	$0							13	$1	$0
Fathead minnow	510	$42	$13							510	$42	$13
Lake chub	7	$1	$1							7	$1	$1
Redside dace	7	$1	$0							7	$1	$0
Finescale dace	91	$8	$2							91	$8	$2
N.redbelly dace	41	$3	$0							41	$3	$0
Notropis spp.	13	$1	$0							13	$1	$0

Table16.–Continued.

	RogersDam			HardyDam			CrotonDam			Total		
Species	#killed	AFS	PA451	#killed	AFS	PA451	#killed	AFS	PA451	#killed	AFS	PA451
Common shiner	23	$2	$0	15	$1	$0	245	$21	$4	283	$24	$4
Golden shiner	83	$7	$4							83	$7	$4
Spottail shiner	807	$67	$47	395	$33	$11	4,014	$332	$200	5,216	$432	$258
Sand shiner	41	$3	$0							41	$3	$0
Brook stickleback	600	$50	$9							600	$50	$9
Troutperch	41	$3	$1							41	$3	$1
Logperch	19	$2	$1	18	$1	$0	567	$47	$91	604	$50	$92
Gizzard shad							1,397	$503	$5,329	1,397	$503	$5,329
Carp							88	$7	$1	88	$7	$1
Bowfin	28	$58	$722							28	$58	$722
Chesnut-brook lamprey	159	$13	$0							159	$13	$0
Black bullhead	55	$16	$550				44	$21	$438	99	$37	$988
Brown bullhead	239	$93	$2,389	10	$3	$102	349	$146	$3,492	598	$242	$5,983
Channel catfish	32	$15	$300							32	$15	$300
Ictalurus spp.	320	$122	$3,198				44	$21	$438	364	$143	$3,636
Burbot	9	$7	$90	10	$18	$128				19	$25	$218
Northern pike	69	$667	$1,161				20	$156	$257	89	$823	$1,418
Walleye	522	$2,038	$5,395	709	$4,700	$9,681	1,065	$2,037	$10,647	2,296	$8,775	$25,723
Yellow perch	330	$97	$3,298	777	$489	$7,777	6,288	$5,634	$62,941	7,395	$6,220	$74,016
Brook trout	29	$36	$291							29	$36	$291
Brown trout	226	$270	$2,255	33	$56	$327	82	$20	$824	341	$346	$3,406
Rainbow trout	60	$129	$596				865	$1,143	$8,838	925	$1,272	$9,434
Chinook salmon	274	$393	$2,737							274	$393	$2,737
Unidentified fish	159	$13	$8	137	$11	$4	829	$114	$22	1,125	$138	$34
Total	8,527	$10,617	$50,805	3,801	$7,057	$32,106	31,714	$34,582	$245,659	44,042	$52,256	$328,570

Table17.–Historic water quality data for the Muskegon River upstream of Rogers Impoundment (M-66) and downstream of Newaygo (Bridgeton). Data from STORET 1975-81.

	M-66			Bridgeton		
Parameter	# samples	Range	Mean	# samples	Range	Mean
pH	131	7.5-8.6	8.1	74	7.2-8.6	8.0
Temperature (degree C)	144	0-24	10	73	0-25	10
Dissolved oxygen(mg/l)	130	4.6-16.0	10.5	74	6.6-12.9	9.8
Conductivity (umhos/cm)	142	206-461	359	74	130-415	298
Fecal coliform (No./100ml)	19	2-340	75.1	41	10-600	101.8
Total chloride (mg/l)	95	2-27	17	74	5-36	12
Total sulfate (mg/l)	94	10-29	20	3	8-11	10
Total alkalinity (mg-CaCO3/l)	76	92-299	144	43	41-170	129
Total phosphorus (mg-P/l)	89	0.010-0.220	0.035	41	64-194	150
Total kjeldahl nitrogen (mg-N/l)	90	0.16-2.90	0.57	3	43-58	50
Total ammonia (mg-N/l)	52	0.01-0.17	0.05	74	0.010-0.100	0.031
Total nitate and nitrite (mg-N/l)	57	0.01-0.86	0.29	29	0.39-0.95	0.59
Total chromium (ug/l)	9	10-20	12	69	0.001-0.162	0.02
Total Iron (ug/l)	28	70-600	236	74	0.2-0.63	0.18
Total lead (ug/l)	23	0-130	19	4	2-4	3
Total manganese (ug/l)	27	10-70	31.9	5	170-500	324
Total mercury (ug/l)	10	0.1-0.5	0.3	4	2-11	7.5
Total nickel (ug/l)	9	0-7	4	5	24-84	48
Total zinc (ug/l)	21	4-170	32	3	12-24	17

Table 18.–Water quality parameters for stations along the Muskegon River near Hersey, Michigan, fall and winter, 1979-80. Dash in range column indicates all measurements were the same. Concentration of metals are total unless specified as dissolved (D). Data from STORET.

	Evart		Hersey ambient		Near Johnson Plant		Big Rapids	
Parameter	Range	Median	Range	Median	Range	Median	Range	Median
Conductivity (umhos/cm)	130-400	315	190-302	238	190-313	251	235-385	320
Total alkalinity (mg-CaCO3/l)	41-170	136	145-194	172	144-189	166	104-150	140
Hardness (mg-CaCO3)	64-194	155	140-271	199	145-286	215	120-188	162
pH	7.2-8.6	8.0	6.2-8.5	7.2	-	-	7.7-8.4	8.2
Turbidity (NTU)	1.2-14.0	2.8	1.3-2.2	1.7	2-2.4	2.2	1.1-5.9	4.4
Total suspended solids (mg/l)	<1-24	8	2-7	4	0.5-5	2.8	3-21	8
Total dissolved solids (mg/l)	84-260	205	201-215	204	206-209	208	153-250	213
Total ammonia (ug-N/l)	<1-95	8	-	<6	-	7	<1-60	7
Total nitrite (ug-N/l)	-	-	-	0.1	-	0.1	-	-
Total nitrate and nitrite (ug-N/l)	16-630	134	164-170	170	-	180	30-200	112
Total phosphorus (ug-P/l)	10-100	28	16-21	17	-	19	18-50	30
Orthophosphorus (ug/l)	-	-	5.7-7.2	6.9	-	5.9	-	-
Silicate (mg-SiO2/l)	1.1-5.8	3.2	3.5-3.6	3.6	-	3.7	1.3-3.0	2.4
Total sulfate (mg/l)	11-16	12	17.0-17.6	17.4	-	17.4	6.9-35	15
Fluoride (ug/l)	-	-	12-14	14	-	12	-	-
Calcium (mg/l,D)	-	-	82-114	83	96-100	98	36-40	36
Sodium (mg/l)	7.9-8.2	8	8.5-9.2	8.9	-	9.2	-	-
Magnesium (mg/l)	-	-	11.5-12.5	11.8	-	11.5	5-10	8.5
Arsenic (ug/l)	1.0-1.1	1.0	<18-30	29	-	<18	0.3-1.6	<1.0
Cadmium (ug/l)	0.3-1.9	1.1	0.4-3	0.8	2-12	7	<1.0-2.2	1.2
Total chromium (ug/l)	3-4	3	6-24	8	6-8	7	3-6	3
Copper (ug/l)	<1-5	2	21-88	45	9-88	41	30-85	41
Cyanide (ug/l)	0.4-0.8	0.6	-	<30	-	<30	<20	<10
Total lead (ug/l)	2-11	10	16-90	30	48-88	71	<1-14	10

Table 18.–Continued.

Parameter	Evart Range	Evart Median	Hersey ambient Range	Hersey ambient Median	Near Johnson Plant Range	Near Johnson Plant Median	Big Rapids Range	Big Rapids Median
Total mercury (ug/l)	<0.2-1.4	<0.2	-	<1	-	<1	-	<0.02
Total nickel (ug/l)	12-24	14	26-159	85	26-127	80	<5-18	5
Selenium (ug/l)	<2	<1	-	<30	-	<30	<1	<1
Silver (ug/l)	<1-3	<1	<0.6-2.6	1	<0.7-10	<1	<1	<1
Total zinc (ug/l)	5-9	6	50-280	181	100-123	112	4-27	10
Residual chlorine (mg/l)	-	-	-	<0.01	-	<0.01	-	-
BOD (mg/l)	<0.5-3.8	1.4	1.2-2.9	1.4	-	1.2	-	-
COD (mg/l)	-	-	<13-36	33	-	22	-	-
TOC (mg/l)	3.0-38.0	8.4	5.0-5.8	5.1	-	5.6	4.7-9.3	6.4
Dissolved oxygen (mg/l)	6.6-12.4	9.7	9.7-13.9	13.0	-	10.5	-	10.0

Table 19.–Water quality values considered normal for Michigan. Data from Michigan Department of Natural Resources (now Michigan Department of Environmental Quality), Surface Water Quality Division (Elwin Evans, personal communication).

Parameter	Level(mg/l)
Chloride-Lower Peninsula	< 10.0
Chloride-Upper Peninsula	< 2.0
Chlorophyll A	< 0.01
Flouride	< 0.2
Ammonia	< 2.0
Nitrate	< 0.2
Nitrite	< 0.01
Total Kjeldahl nitrogen	< 3.0
Sulfates	< 20.0
Total organic carbon-“Blackwater”	< 10.0
Total organic carbon-“Clearwater”	< 3.0
Total phosphorus	< 0.02
Barium	< 0.05
Cadmium	< 0.0005
Chromium	< 0.005
Iron	< 0.3
Mangenese	< 0.04
Nickel	< 0.003
Lead	< 0.005
Selenium	< 0.005
Zinc	< 0.04

Table 20.–Water quality measurements collected in Croton Dam tailwater during 1990 and 1991. Data from Lawler, Matusky, & Skelly Engineers (1991c).

Date	Temperature (°F)	Dissolved oxygen (mg/l)	Oxygen saturation (%)
May 1, 1990	52.2	10.3	93.1
May 21, 1990	52.2	7.1	64.2
June 12, 1990	60.6	6.2	61.6
June 29. 1990	64.6	7.6	78.6
July 12, 1990	71.4	8.3	91.4
July 23, 1990	69.4	6.9	74.7
August 9, 1990	68.5	7.7	82.7
August 23, 1990	68.0	6.6	70.5
September 5, 1990	72.1	7.0	77.6
September 19,1990	65.8	6.4	67.0
October 5, 1990	60.4	8.2	81.3
October 23, 1990	51.6	9.9	88.9
November 6, 1990	47.3	10.0	85.1
November 20, 1990	44.2	12.8	104.9
December 11, 1990	38.7	12.4	93.8
December 18, 1990	37.2	12.9	95.6
January 9, 1991	33.8	12.9	90.8
January 25, 1991	33.8	13.0	91.5
February 11, 1991	34.7	14.2	101.3
February 25, 1991	34.3	12.6	89.4
March 13, 1991	34.3	12.0	85.2
March 27, 1991	38.5	12.8	96.6
April 11, 1991	44.1	11.3	92.1
April 25, 1991	48.4	10.7	92.3

Table 21.–Locations and drainage areas of major tributaries affected by impoundments, development, and drains in the Muskegon River watershed. Locations are entered in order from headwaters to mouth. Drainage area (da) in square miles. Impounded waters are known dams. Possible impoundments are sites identified from base maps that have illegal dams or dams caused by improper culvert placement. Tributaries are indented; Imp. = impounded.

Mainstem location or tributary (indented)	River mile	Drainage area	Imp.	Possibly Imp.	Not Imp.	% da developed	Miles of drain
Higgins & Houghton lakes headwaters							
Reedsburg Dam	13	349	X				
W Br Muskegon River					X		
Nellesville Ditch			X				
Butterfield Creek					X		
Bear Creek			X				
Lower Missaukee County		515				20	?
Wolf Creek			X				
Townline Creek			X				
Lower Roscommon County		669				16	?
Floodwater Creek			X				
Cranberry Creek				X			
Clam River			X				
Green Creek					X		
Dishwash Creek					X		
Halford Creek					X		
Giss-Was Creek					X		
Lower Clare County		1162				23	11
Middle Branch River			X				
Norway Creek					X		
Kinney Creek					X		
Whetstone Creek					X		
Doc & Tom Creek					X		
Sandy Run Creek			X				
Hoffmeyer Creek					X		
Thorn Creek					X		
Chippewa Creek				X			
Twin Creek					X		
Big Stone Creek				X			
Cat Creek			X				
Polluck Creek					X		
Hersey River			X				
Lower Osceola County	106	1652				27	55
Pogy Creek			X				
Blodgett Creek				X			
Buckhorn Creek					X		
Paris Creek					X		
Dalziel Creek			X				

Table 21.–Continued.

Mainstem location or tributary (indented)	River mile	Drainage area	Imp.	Possibly Imp.	Not Imp.	% da developed	Miles of drain
City of Big Rapids	120	1808					
Mitchell Creek					X		
Ryan Creek				X			
Higginson Creek					X		
Winters Creek				X			
Byers Creek					X		
Cold Spring Creek					X		
Ladner Creek					X		
Macks Creek					X		
Betts Creek					X		
Bennet Creek					X		
Lower Mecosta County							35
S. Mitchell Creek					X		
Rosy Run Creek					X		
Little Muskegon River						54	
Tamarack Creek					X		
Croton Dam	165	2310				34	
Bigelow Creek					X		
Penoyer Creek			X				
Sand Creek				X			
Minnie Creek					X		
Lower Newaygo County	203					34	80
Brooks Creek					X		
Mosquito Creek					X		
Cedar Creek					X		
Muskegon Lake (river mouth)							

Table 22.–Bank erosion sites on the Muskegon River and tributaries in Osceola and Mecosta counties. Number of tributaries surveyed in Osceola County = 22, Mecosta County = 20. Data from Anonymous (1991).

Stream name	Stream miles	Erosion sites				Sites per mile
		Minor	Moderate	Severe	Total	
Middle Branch River, Osceola County	28.2	79	17	3	99	3.5
Hersey River & E. Br, Osceola County	20.5	47	5	2	54	2.6
Muskegon River, Osceola County	28.0	20	32	3	55	2.0
Tributaries, Osceola County	86.5	349	39	10	398	4.6
Muskegon River, Mecosta County	29.0	28	37	11	76	2.6
Tributaries, Mecosta County	56.5	409	87	30	526	9.3
Total	248.7	932	217	59	1208	4.9

Table 23.–National pollution discharge elimination permits in the Muskegon River watershed. Flows are in million gallons/day.

Discharger	Location	Flow
AAR Brooks and Perkins	Cadillac	0.6
American Coil Spring Co.	Muskegon	0.09
American Logging Tool Corp.	Evart	0.015
American Porcelain Enamel Co.	Muskegon	0.06
Amoco Oil Co.-Muskegon	Muskegon	0.144
Big Rapids WWTP	Big Rapids	2.4
Blarney Castle Oil Co.	Cadillac	0.072
Bolthouse Farms Inc.	Grant	0.192
Boven's Custom Butchering	Morley	NA
Brunswick Corp.	Muskegon	0.432
Cadillac WWTP	Cadillac	2.0
CPCo-B C Cobb Plant	Muskegon	NA
CPCo-Croton Hydro Plant	Croton	0.003
CPCo-Hardy Hydro Plant	Croton	0.0097
CPCo-Musk. River Gas Comp Power	Marion	8.3
CPCo-Rogers Hydro Plant	Rogers Heights	0.0072
Evart Products Co.	Evart	NA
Evart WWTP	Evart	NA
Ferris State University	Big Rapids	0.0864
Forest Fish Farm	Evart	NA
Houghton Lake WWTP	Houghton Lake	1.1
Indal Inc.- Tubelite	Reed City	0.275
Kaydon Corp.- Kaydon Bearing Div.	Muskegon	0.2
Lakeview WWSL	Lakeview	NA
Liberty Dairy Co.	Evart	0.08
Lift-Tech International Inc.	Muskegon Heights	NA
Lomac Inc.	Muskegon	0.35
Marathon Petro Co.-Cadillac	Findlay	0.045
Marathon Pipe Line Co.	Martinsville	0.030
Marion WWSL	Marion	NA
Morley WWSL	Morley	21.0
Muskegon Co. WWMS No.1 WWTP	Muskegon	87.5
Muskegon Heights WFP	Muskegon Heights	0.0005
Muskegon Piston Ring	Muskegon	NA
Muskegon WFP	Muskegon	2.0
Newaygo WWTP	Newaygo	NA
Nor-Am Chem. Co.	Muskegon	0.6
Paris Fish Hatchery	Paris	3.5
Reed City Tool and Dye Corp.	Reed City	0.01
Reed City WWTP	Reed City	NA
Rexaire Inc.- GWCU	Cadillac	2.16
S.D. Warren Co.	Muskegon	0.15
Sealed Power Corp.- HQTRS	Muskegon	0.05
Sealed Power-Harvey Street	Muskegon	0.219

Table 23.–Continued.

Discharger	Location	Flow
Sealed Power-Muskegon Plant	Muskegon	0.09
Sealed Power-Sanford Street	Muskegon	1.2
Shaw Walker Co.	Muskegon	0.165
Speas Co.	Fremont	NA
Standish Oil Co.	Bay City	0.03
Superior Oil Co.-Norton Shores	Norton Shores	0.072
Teledyne Continental Motors	Muskegon	NA
Textron CWC Castings-Henry Street	Muskegon	0.5
Weaver Oil Co.	Fremont	0.043
West Mich Dock & Market Corp.	Muskegon	0.085
Wolverine Power Supply-Hersey	Boyne City	2.0
Yoplait USA Inc.	Reed City	0.35
Zephyr-Muskegon	Muskegon	0.2

Table 24.–Critical materials and wastewater report for mercury (1991) in the Muskegon River watershed. Use, discharge, and residual units are pounds. Data from Michigan Department of Environmental Quality (Chris Hull, personal communication). Blanks indicate none.

Source	Use	Discharge	Residual	Disposal of residual	NPDES permit number
Hitachi Magnetics Corp., Edmore	< 1	< 1	< 1	Hazardous waste	0027812
Consumers Power Co., B.C. Cobb Facility, Muskegon	101-500	0	101-500	Hazardous waste	
Mercy Hospital, Muskegon	11-100	0	0		
Teledyne Continental Motors, Muskegon	11-100	0	0		

Table 25.–Air emissions inventory of sulfur dioxide (> 20 tons/year) in the Muskegon River watershed and adjacent Ottawa County (1995). Sulfur dioxide reported in tons/year. Data from Department of Environmental Quality, Air Quality Division (J. Lax, personal communication).

Source	County	Sulfur dioxide emissions
Consumers Power Company, B.C. Cobb Plant	Muskegon	11,588
Scott Paper Company	Muskegon	3,317
Consumers Power Co., J.H. Campbell Plant	Ottawa	38,261
Holland Public Works	Ottawa	2,014
Grand Haven Board of Light and Power	Ottawa	584

Table 26.–Critical materials and wastewater report (1991) for PCBs in the Muskegon River watershed. Use, discharge, and residual units are pounds. Data from Michigan Department of Environmental Quality, Surface Water Quality Division (Chris Hull, personal communication).

Source	Use	Discharge	Residual	Disposal of residual
American Coil Spring Co., Muskegon	101-500	0	0	
Brunswick Corporation, Muskegon	33,000	0	0	
CWC Castings Division of Textron, Muskegon	7,000	0	0	
Lorin Industries, Muskegon	101-500	0	0	
Nor-Am Chemical, Muskegon	11-100	0	11-100	Incineration or shipped out of state
Occidental Chemical Corporation, Muskegon	11-100	0	0	
Scott Paper Company, Muskegon	40,500	0	101-500	Incineration, hazardous waste or shipped out of state
Sealed Power Division, Muskegon	36,500	0	4,100	Incineration or shipped out of state
Sealed Power Division, Henry Street, Muskegon	13,000	0	0	
Standard Automotive Parts, Muskegon	11-100	0	0	
Teledyne Continental Motors, Terrace Street, Muskegon	3,900	0	0	
Teledyne Continental Motors, Getty Street, Muskegon	27,638	0	0	
American Logging Tool Company, Evart	8,370	0	0	
Indol Corporation, Reed City	1-10	0	0	
Wolverine Power and Supply Company, Hersey	101-500	0	0	

Table 27.–Estimated annual production (number) and economic values for chinook salmon, and steelhead reproduction, and angler days for various segments of the Muskegon River. Estimated production of chinook salmon smolts was 24,285/mile based on data from Carl (1980). Estimated production of steelhead smolts was 4,843/mile based on data from Seelbach and Whelan (1988) and MDNR, Fisheries Division stocking records (55% of adult run was wild fish and average annual stocking of 63,393). Spring and fall potamodromous angler days estimates of 1,141/mile (average for 1985-89) based on data from Rakoczy and Rogers (1987, 1988, 1990, 1991) and Rakoczy and Lockwood (1988). Resident trout angler days estimate of 1,291/mile based on estimates for Rogue River (1994 and 1995 MDNR, Fisheries Division angler trip estimates). Hatchery production costs for chinook salmon were $0.12/fish and for steelhead were $0.73/fish based on MDNR records. An angler day value of $54 was used based on the 1991 national survey of fishing, hunting, and wildlife-associated recreation (US Department of the Interior, Fish and Wildlife Service and US Department of Commerce, Bureau of the Census (1991).

	Chinook salmon		Steelhead		Potamodromous fish angler days		Resident trout angler days
River section and length	Number	Value	Number	Value	Number	Value	Value
Newaygo to Croton Dam, 14.4 miles	349,700	$41,964	69,732	$50,904	16,430	$887,220	$1,003,882
Croton Impoundment, 7.5 miles	182,137	$21,856	36,322	$26,515	8,557	$462,078	$522,855
Hardy Impoundment, 25.1 miles	609,553	$73,146	121,559	$88,738	28,639	$1,546,506	$1,749,821
Rogers Impoundment, 7.5 miles	182,137	$21,856	36,322	$26,515	8,557	$462,078	$522,855
Rogers Impoundment to Hersey, 24.1 miles	585,268	$70,232	116,716	$85,203	27,498	$1,484,892	$1,680,107
Estimated total value	1,908,795	$229,054	362,209	$264,412	89,681	$4,842,774	$5,479,520
Estimated unused value	1,559,095	$187,090	292,477	$213,508	73,251	$3,955,554	$4,475,638

Table 28.–Organizations with interest in the Muskegon River watershed.

Cedar Creek Watershed Partnership
Ducks Unlimited and affiliates
Houghton Lake Association
MCFISH (Fishing and walleye rearing group in Missaukee County)
Michigan Hydropower Coalition
Michigan Steelheaders and affiliates
Muskegon, Grand Haven, Grand Rapids, and White Lake chapters
Michigan Trout Unlimited and affiliates
Muskegon - White River, and West Michigan chapters
Michigan United Conservation Clubs and affiliates
Muskegon Conservation Club, Marion Sportsman club, and Newago County Sportsman Club
Muskegon Lake Public Advisory Council
Muskegon Sportfishing Association
Sierra Club
White Lake Sportfishing Association

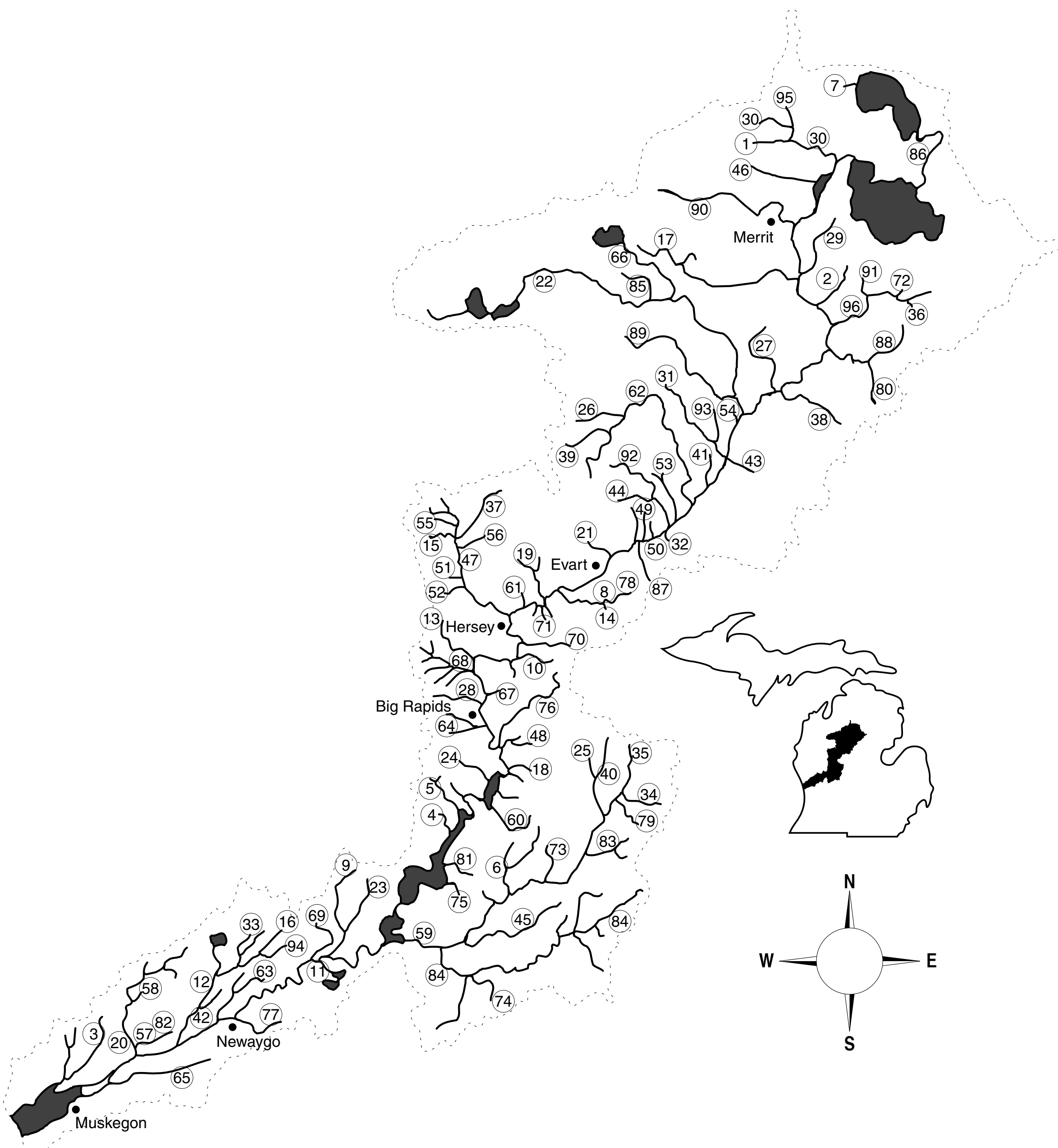

Figure 1.–Muskegon River watershed drainage.

1. Addis Creek
2. Bear Creek - Missaukee County
3. Bear Creek - Muskegon County
4. Bennet Creek
5. Betts Creek
6. Big Creek - Mecosta County
7. Big Creek - Roscommon County
8. Big Stone Creek
9. Bigelow Creek
10. Blodgett Creek
11. Brooks Creek - Newaygo County
12. Brooks Creek - Newaygo County
13. Buckhorn Creek
14. Bull Kill Creek
15. Burt Creek
16. Butler Creek
17. Butterfield Creek
18. Byers Creek
19. Cat Creek
20. Cedar Creek
21. Chippewa Creek
22. Clam River
23. Cold Creek
24. Cold Spring Creek
25. Cole Creek
26. Cracker Creek
27. Cranberry Creek
28. Dalziel Creek
29. Dead Horse
30. Dead Stream
31. Dishwash Creek
32. Doc and Tom Creek
33. Dry Run Creek
34. Dye Creek
35. East Branch Little Muskegon
36. East Branch Wolf Creek
37. East Branch Hersey Creek
38. Floodwood Creek
39. Franz Creek
40. Gilbert Creek
41. Giss-I-Was Creek
42. Graham Creek
43. Green Creek
44. Grindstone Creek
45. Handy Creek
46. Haymarsh Creek
47. Hersey River
48. Higginson Creek
49. Hoffmyer Creek
50. Hoffmyer Drain
51. Jewit Creek
52. Johnson Creek
53. Kinney Creek
54. Kinny Creek
55. Kissinger Creek
56. Lincoln Creek
57. Little Cedar Creek
58. Little Henna Creek
59. Little Muskegon River
60. Macks Creek
61. McKinstry Creek
62. Middle Branch River
63. Minnie Creek
64. Mitchel Creek
65. Mosquito Creek - Muskegon County
66. Mosquito Creek - Missaukee County
67. Palmer Creek
68. Paris Creek
69. Penoyer Creek
70. Pogy Creek
71. Polick Creek
72. Pup Creek
73. Quigley Creek
74. Rice Creek
75. Rosy Run Creek
76. Ryan Creek
77. Sand Creek
78. Sandy Run Creek
79. Schroder Creek
80. South Branch Townline
81. South Mitchel
82. Sweeter Creek
83. Sylvester Creek
84. Tamarack Creek
85. Taylor River
86. The Cut
87. Thorn Creek
88. Townline Creek
89. West Branch Clam River
90. West Branch Muskegon River
91. West Branch Wolf Creek
92. Whetstone Creek
93. Whisky Creek
94. Williams Creek
95. Willow Run
96. Wolf Creek

Figure 1.–Legend.

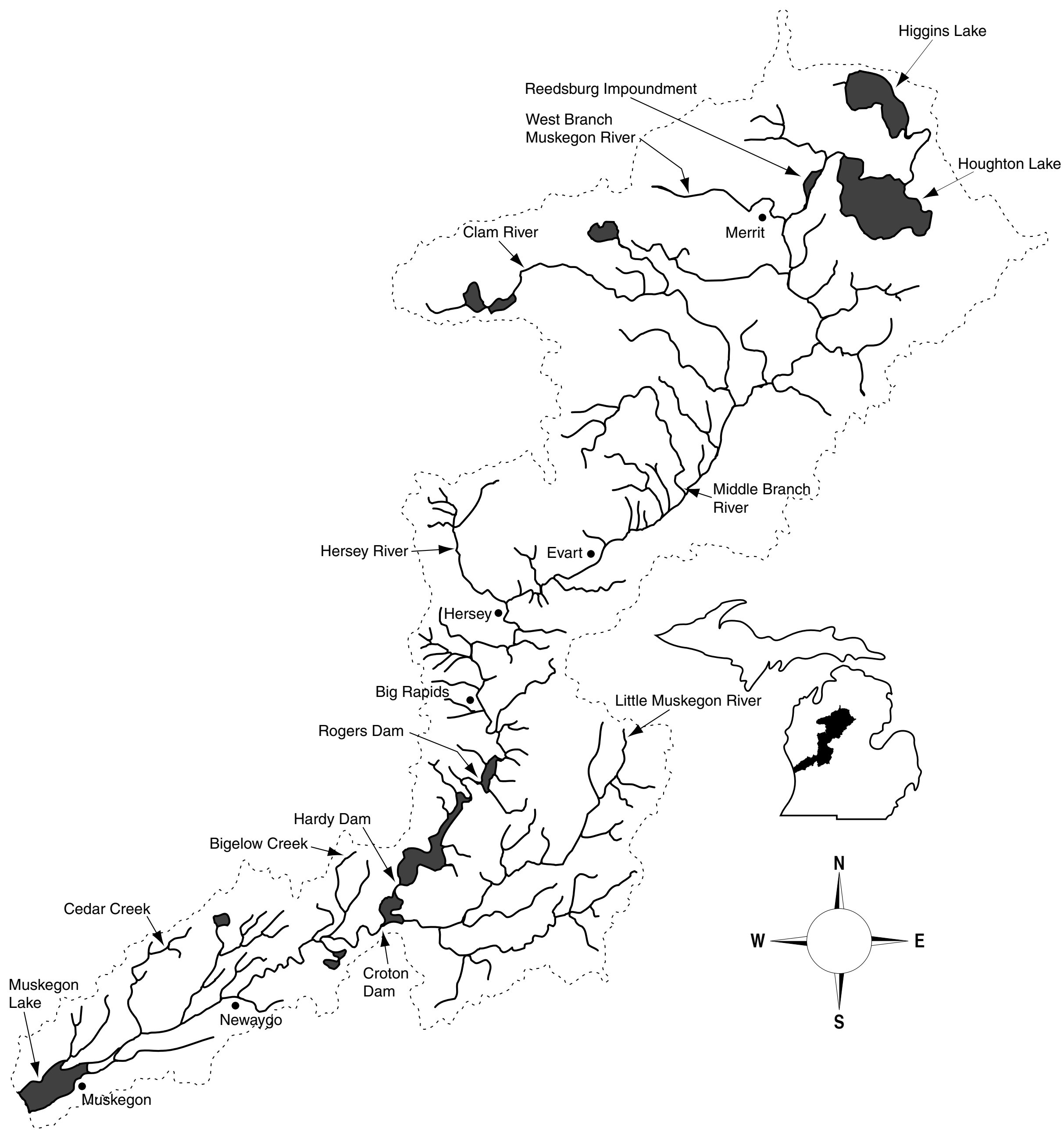

Figure 2.–Major tributaries and landmarks in the Muskegon River watershed.

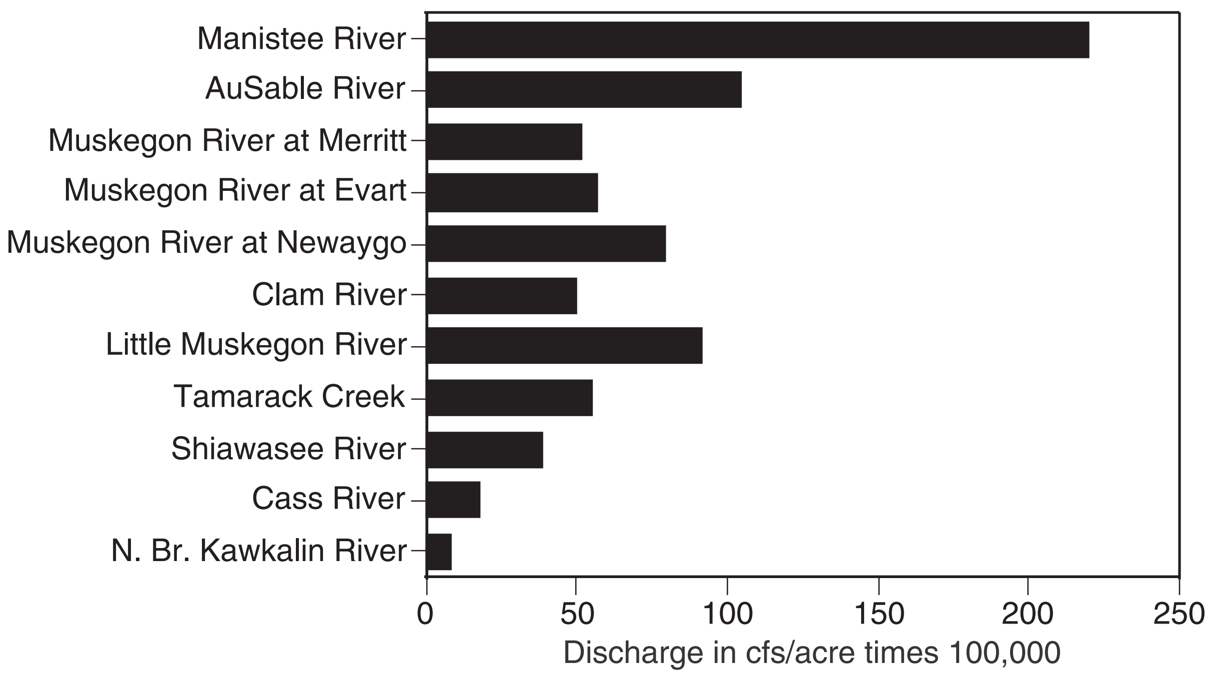

Figure 3.–Baseflow yield for some southern Michigan rivers. Data from Michigan Department of Natrual Resources, Fisheries Division records.

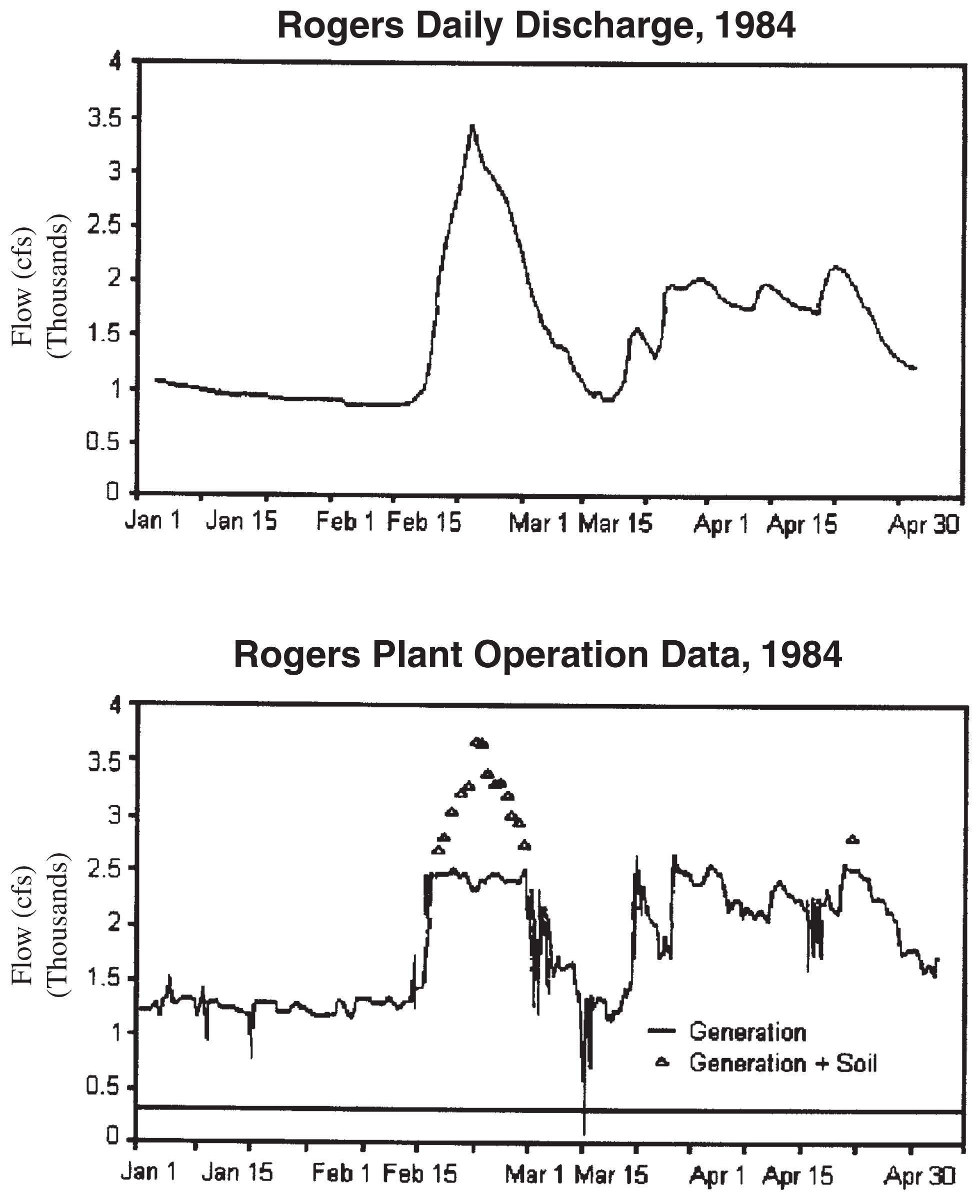

Figure 4.–Daily discharge at the USGS gauge at Evart (top figure), compared with total flow at the Rogers Project (bottom figure), 1984, Muskegon River, Michigan. Figure from Lawler, Matusky & Skelly Engineers (1991a).

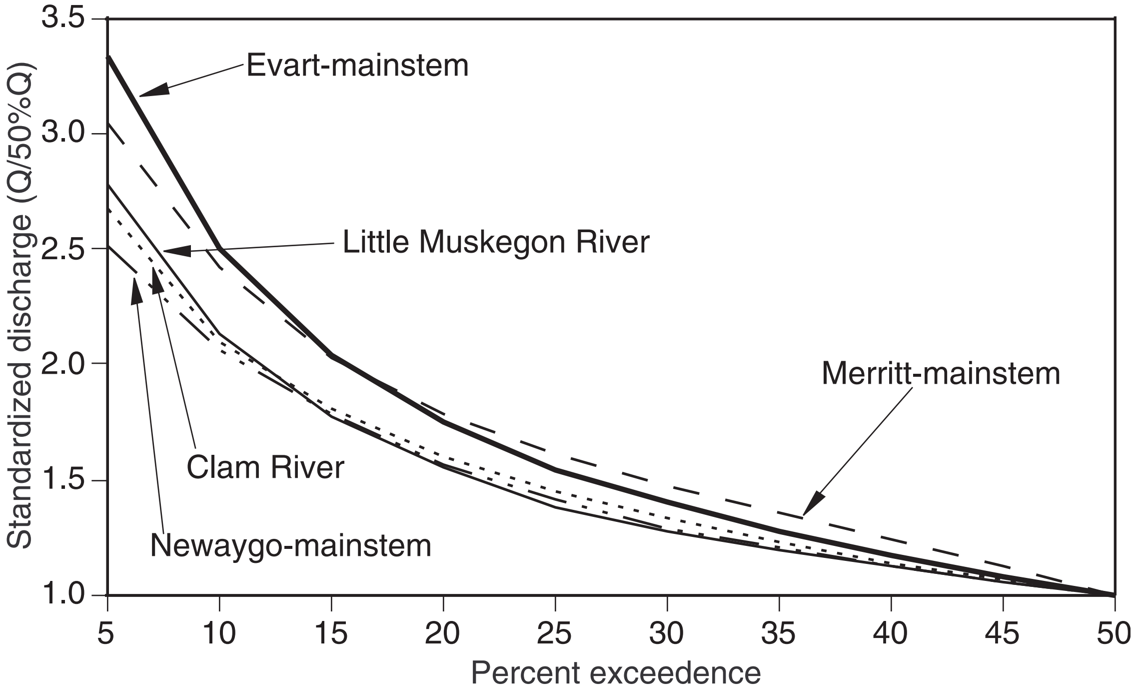

Figure 5.–Standardized high flow curves for the Muskegon River and two tributaries. Data from Blumer et al. (1991).

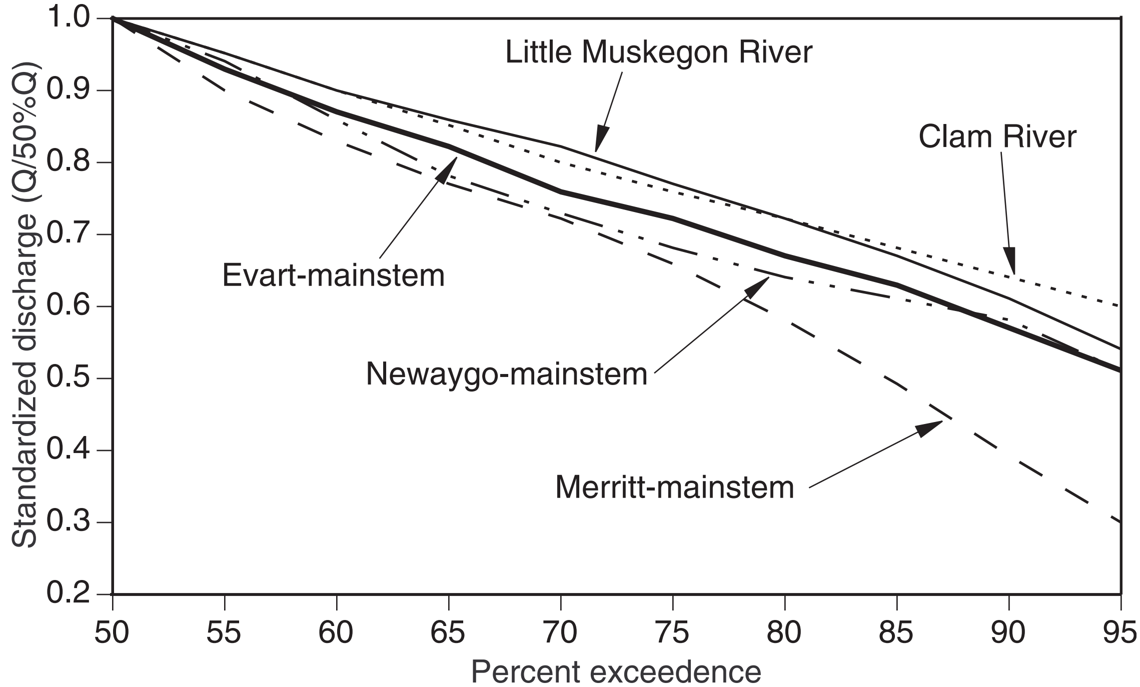

Figure 6.–Standardized low flow curves for the Muskegon River and two tributaries. Data from Blumer et al. (1991).

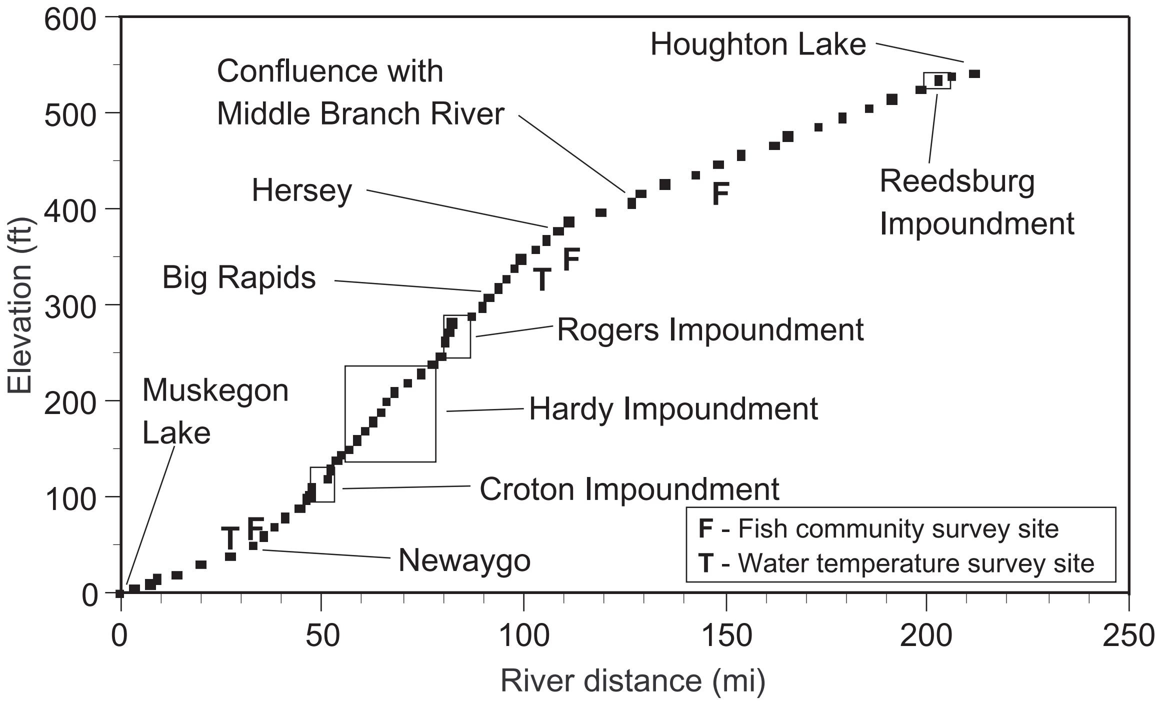

Figure 7.–Muskegon River gradient profile, and fish community and water temperature sites used during 1989 and 1992. Data from Michigan Department of Natural Resources, Fisheries Division records.

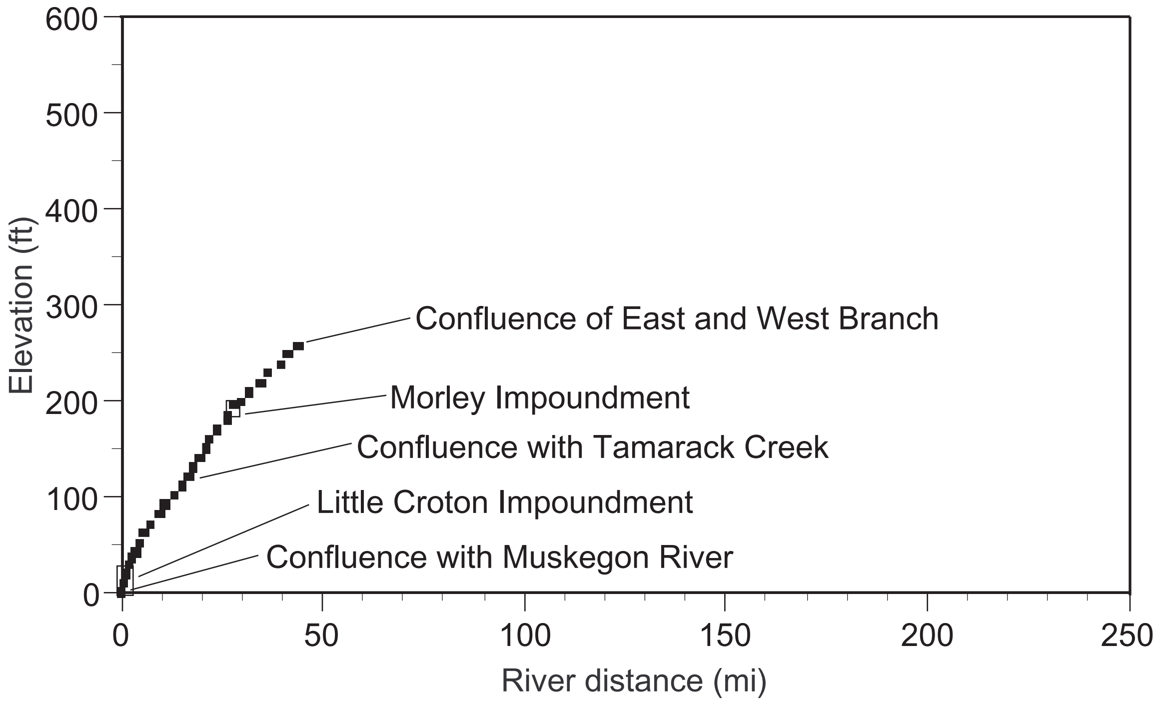

Figure 8.–Little Muskegon River gradient profile. Data from Michigan Department of Natural Resources, Fisheries Division records.

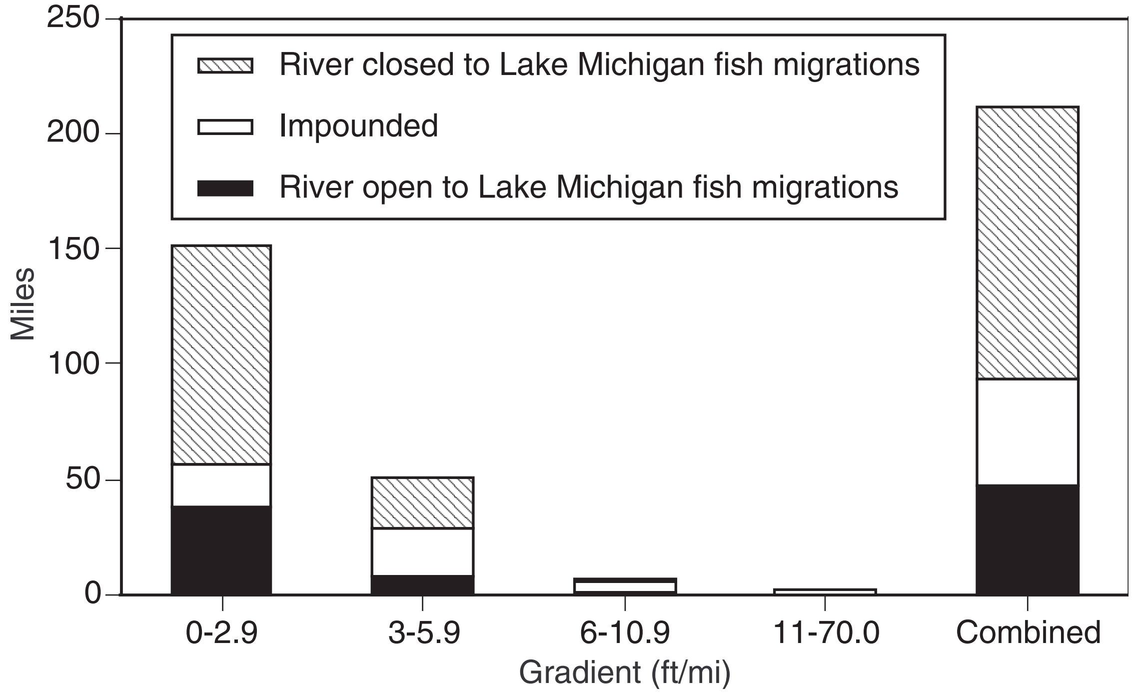

Figure 9.–Muskegon River gradient distribution. Data from Michigan Department of Natural Resources, Fisheries Division records.

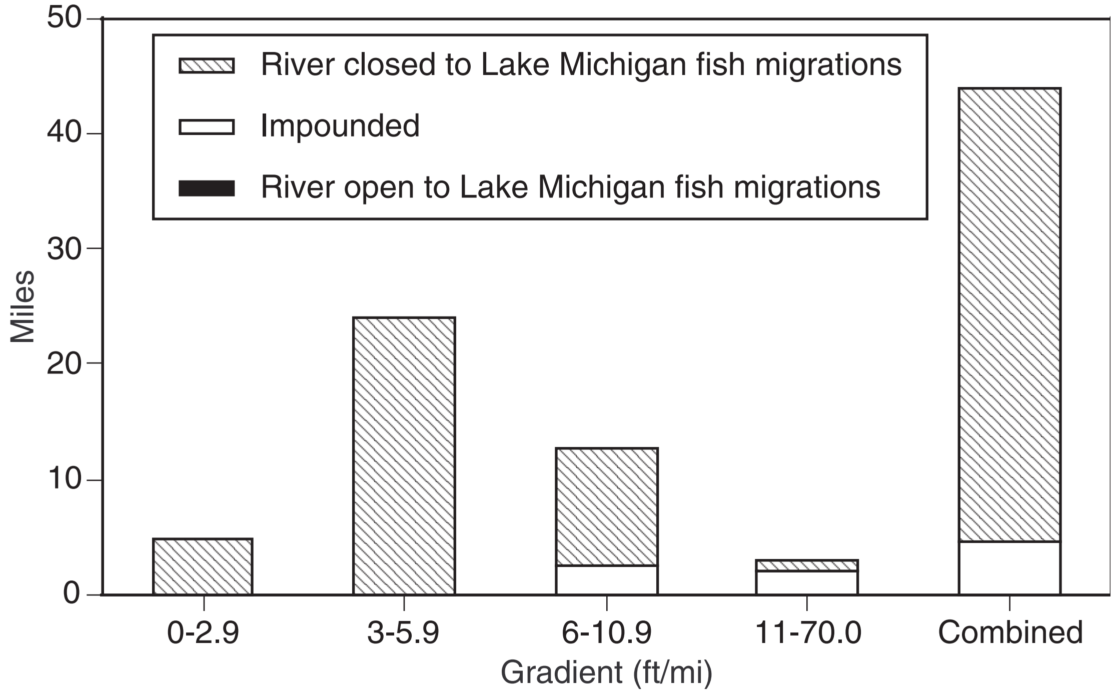

Figure 10.–Little Muskegon River gradient distribution. Data from Michigan Department of Natural Resources, Fisheries Division records.

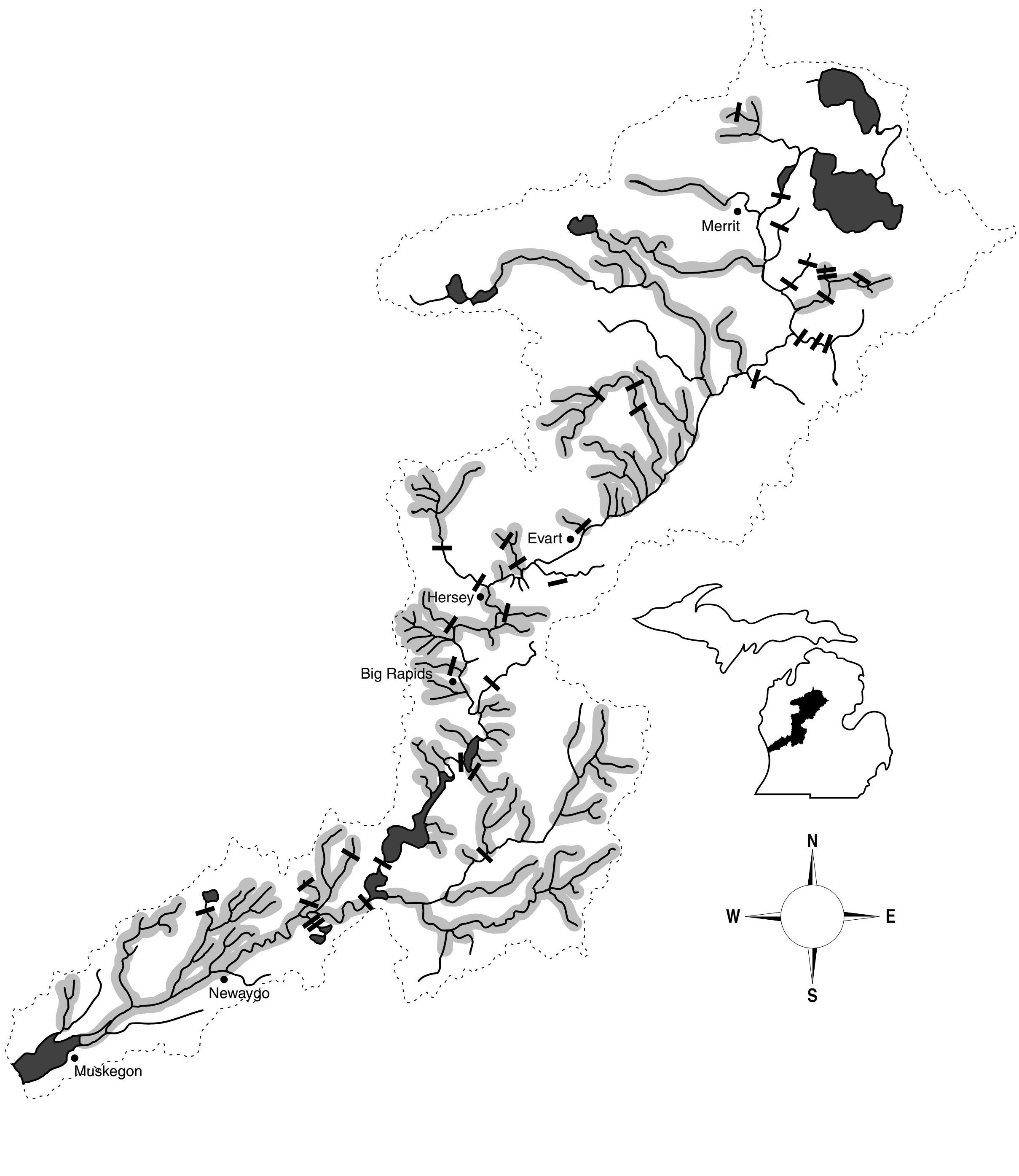

Figure 11.–Designated trout streams and dams in the Muskegon River watershed. Data from Michigan Department of Natural Resources, Fisheries Division and Michigan Department of Environmental Quality, Land and Water Management Division.

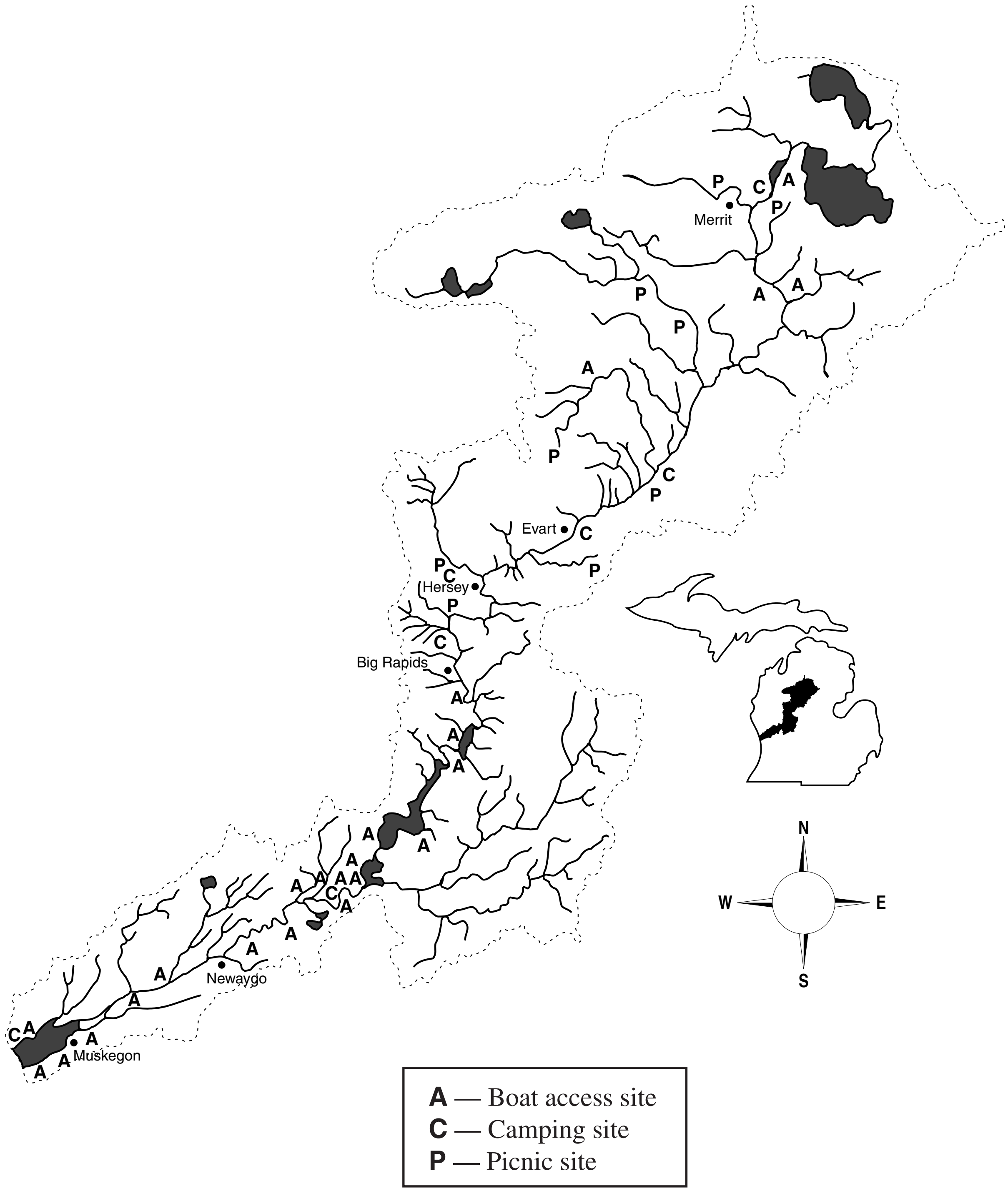

Figure 12.–Public access locations on the Muskegon River.

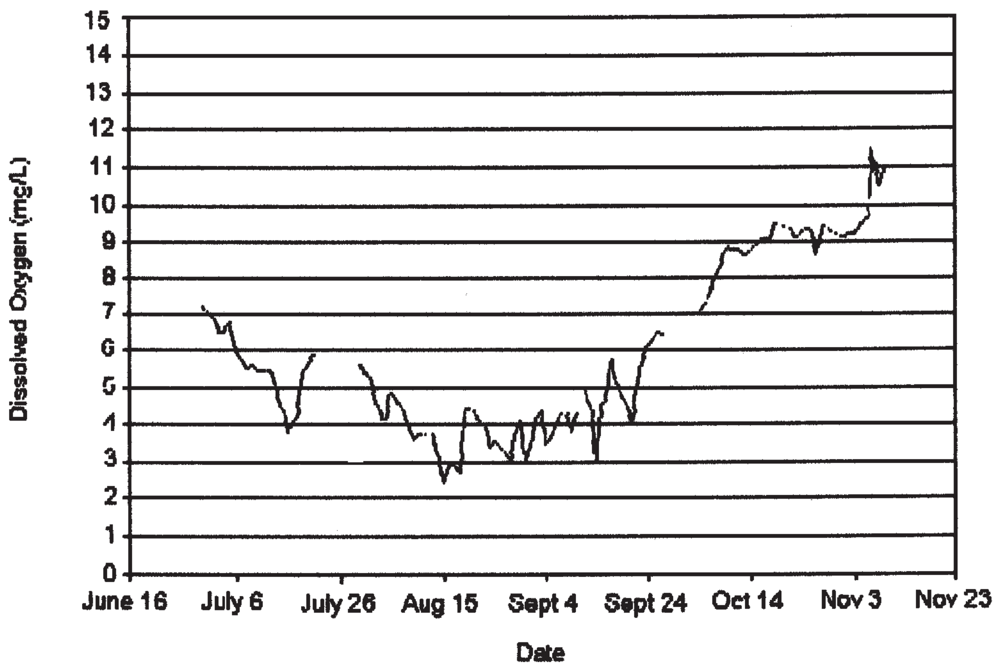

Figure 13.–Dissolved oxygen in Hardy Dam tailwater during 1990. Michigan Department of Environmental Quality, surface water quality standard for Croton Impoundment is 5mg/l or greater. Figure from Lawler, Matusky & Skelly Engineers (1991a).

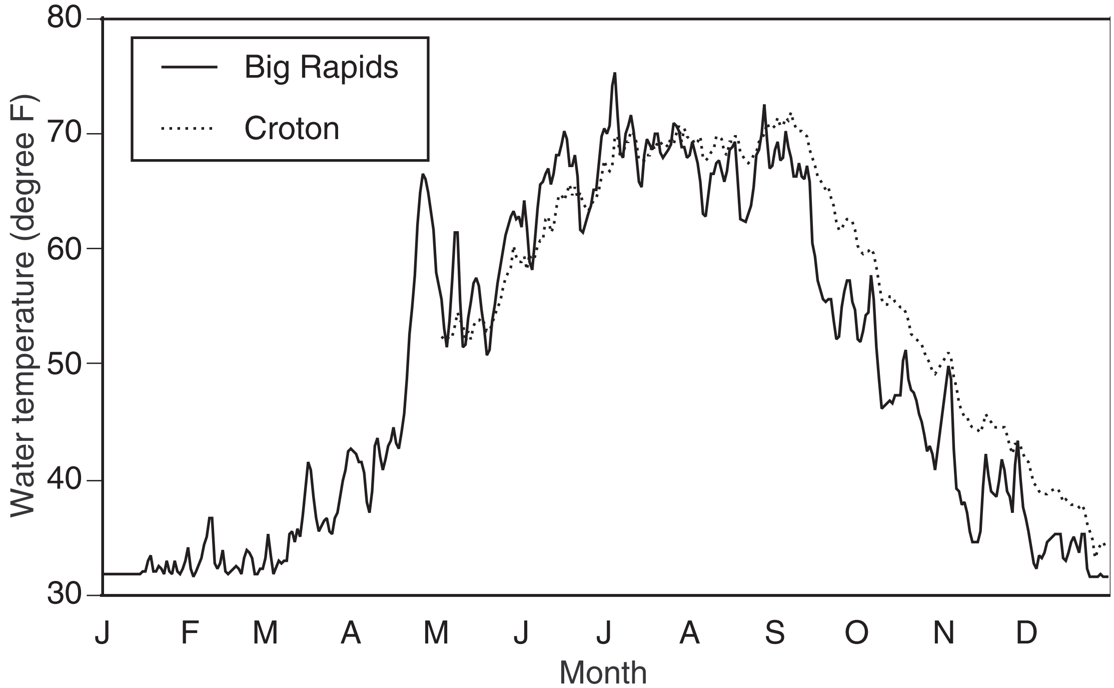

Figure 14.–Average daily water temperatures five miles upstream of Big Rapids, and four miles downstream of Croton Dam during 1990. Temperatures were collected at continuous two hour intervals. Data from Michigan Department of Natural Resources, Fisheries Division records.

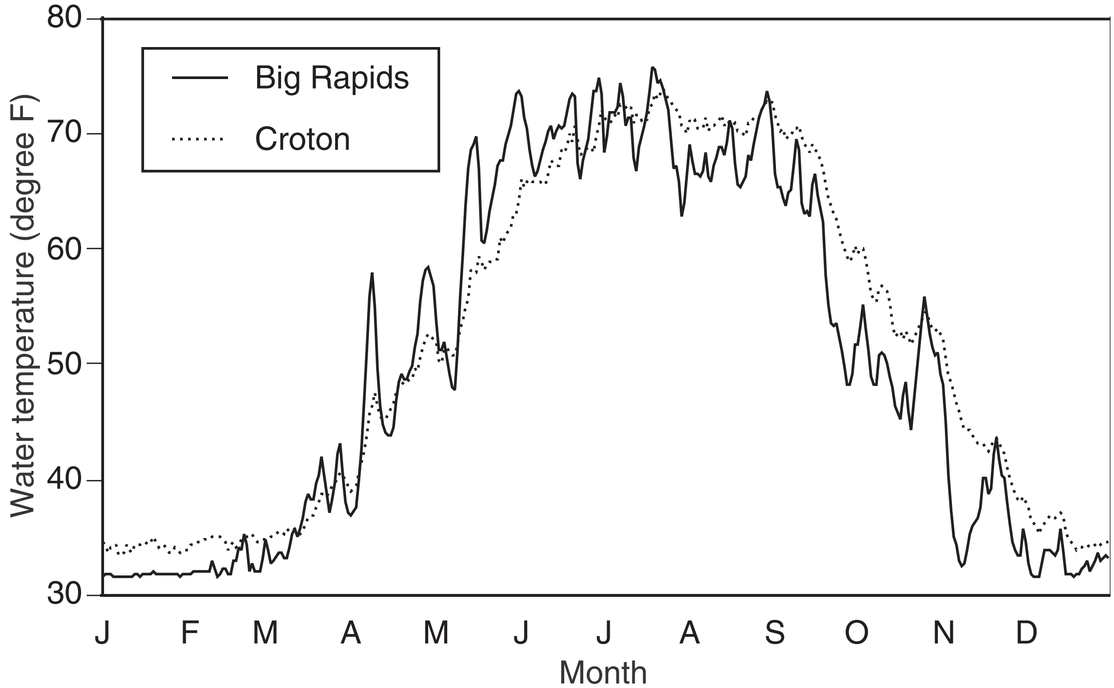

Figure 15.–Average daily water temperatures five miles upstream of Big Rapids, and four miles downstream of Croton Dam during 1991. Temperatures were collected at continuous two hour intervals. Data from Michigan Department of Natural Resources, Fisheries Division records.

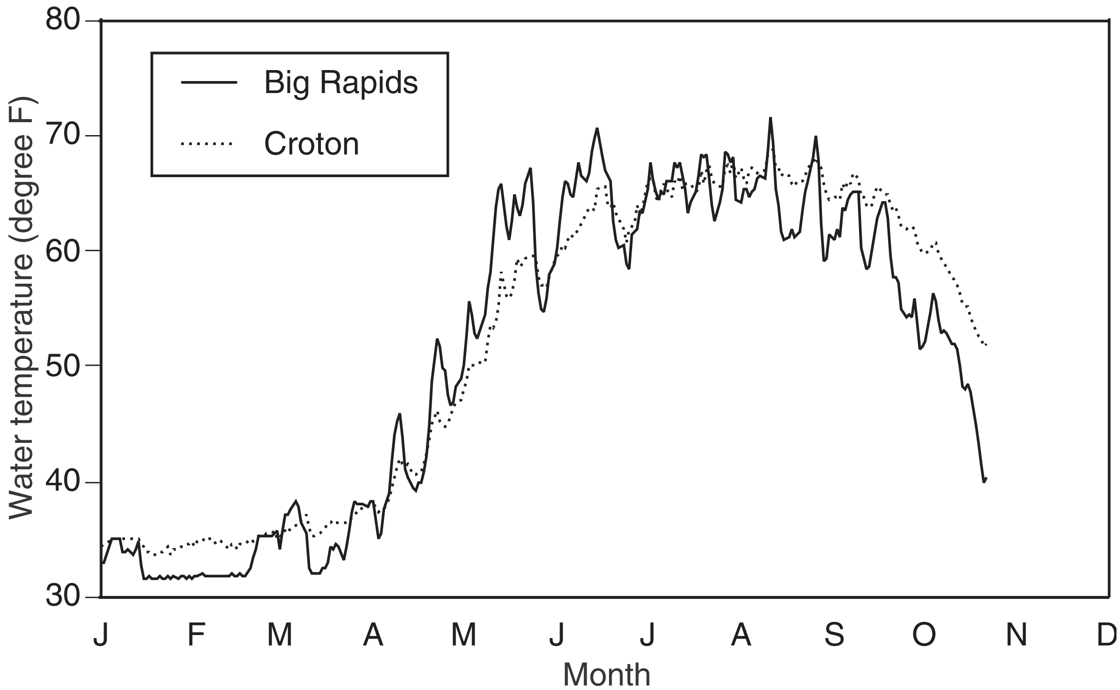

Figure 16.–Average daily water temperatures five miles upstream of Big Rapids, and four miles downstream of Croton Dam during 1992. Temperatures were collected at continuous two hour intervals. Data from Michigan Department of Natural Resources, Fisheries Division records.

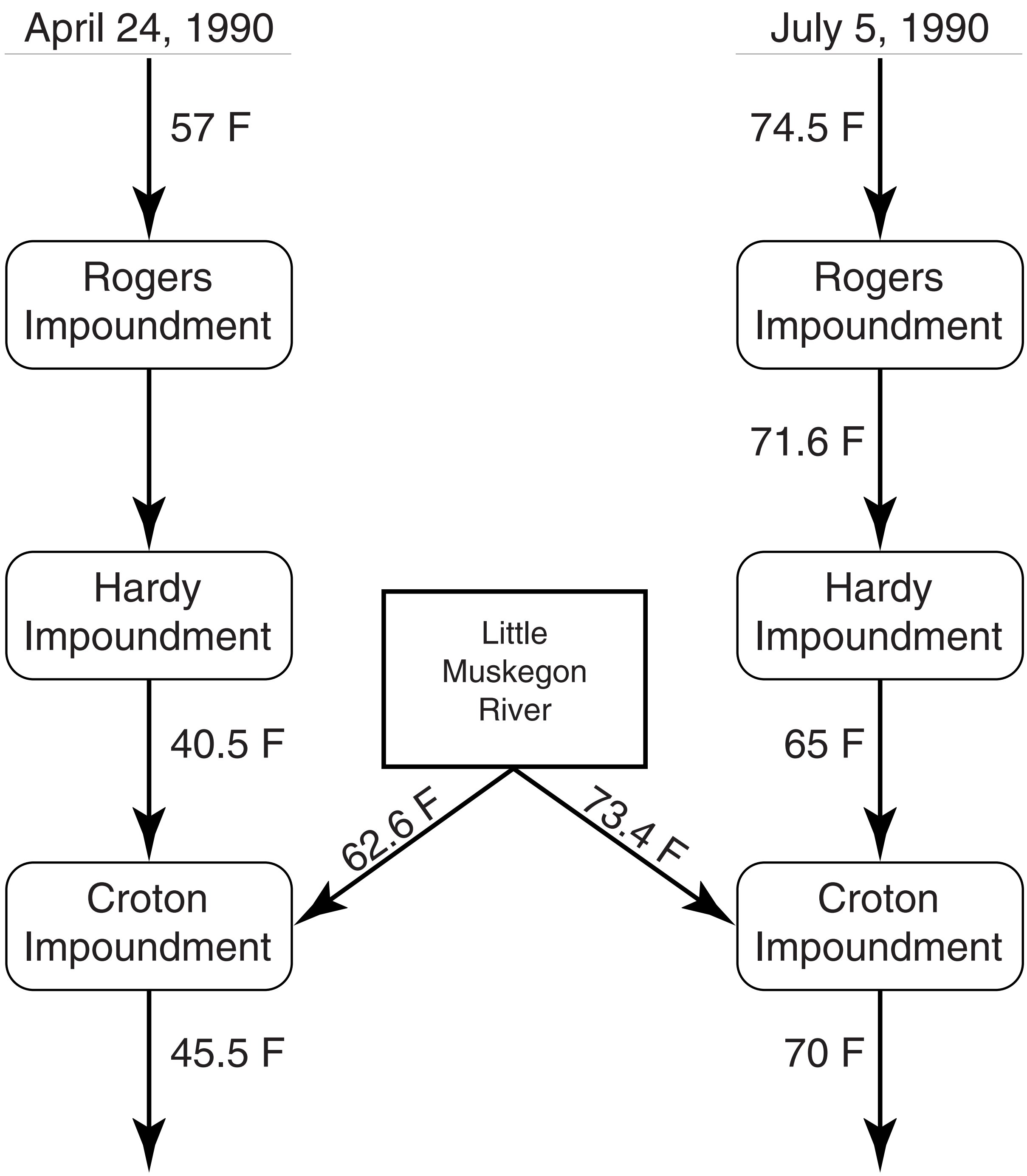

Figure 17.–Muskegon River water temperatures on April 24 and July 5, 1990. Temperature data from Consumers Power Company records.

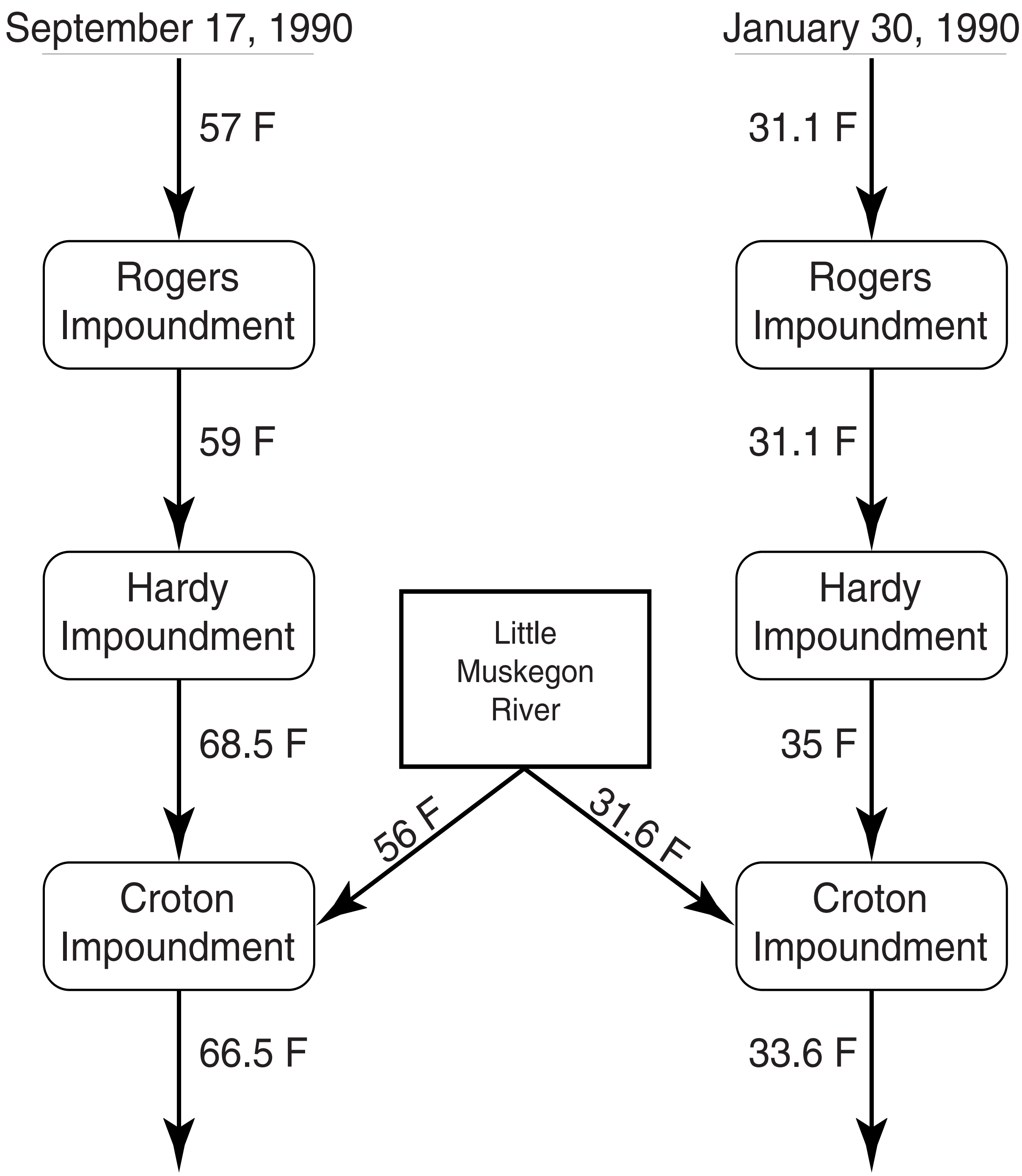

Figure 18.–Muskegon River water temperatures on September 17 and January, 1990. Temperature data from Consumers Power Company records.

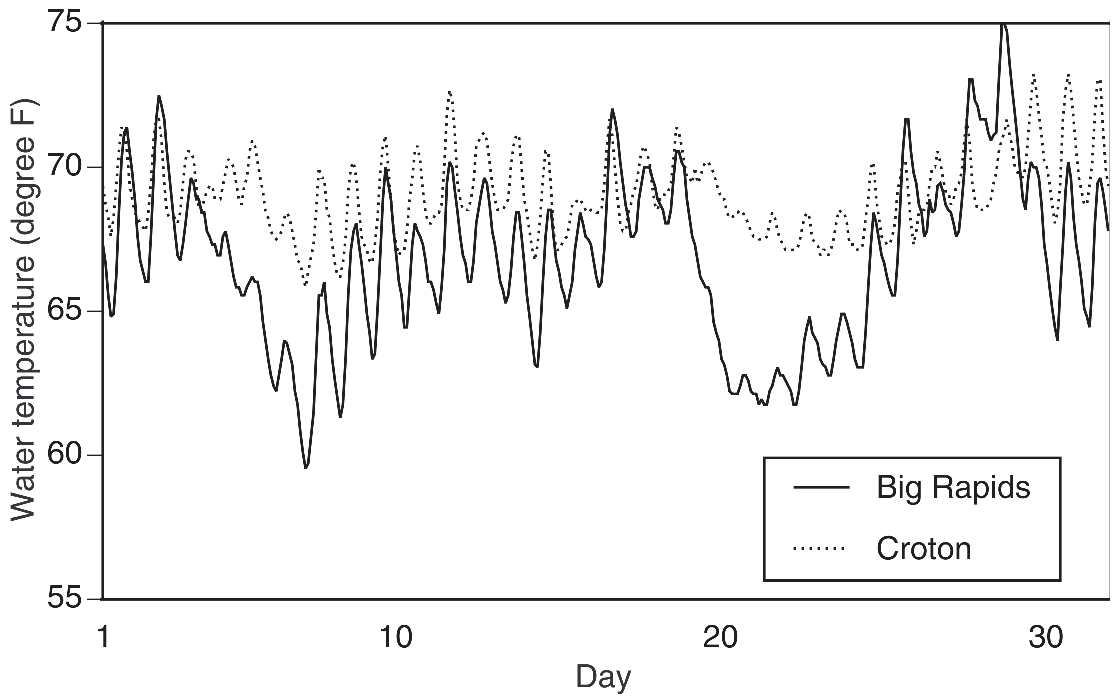

Figure 19.–August, 1990 water temperatures five miles upstream of Big Rapids, and four miles downstream of Croton Dam. Temperatures were collected at continuous two hour intervals. Data from Michigan Department of Natural Resources, Fisheries Division records.

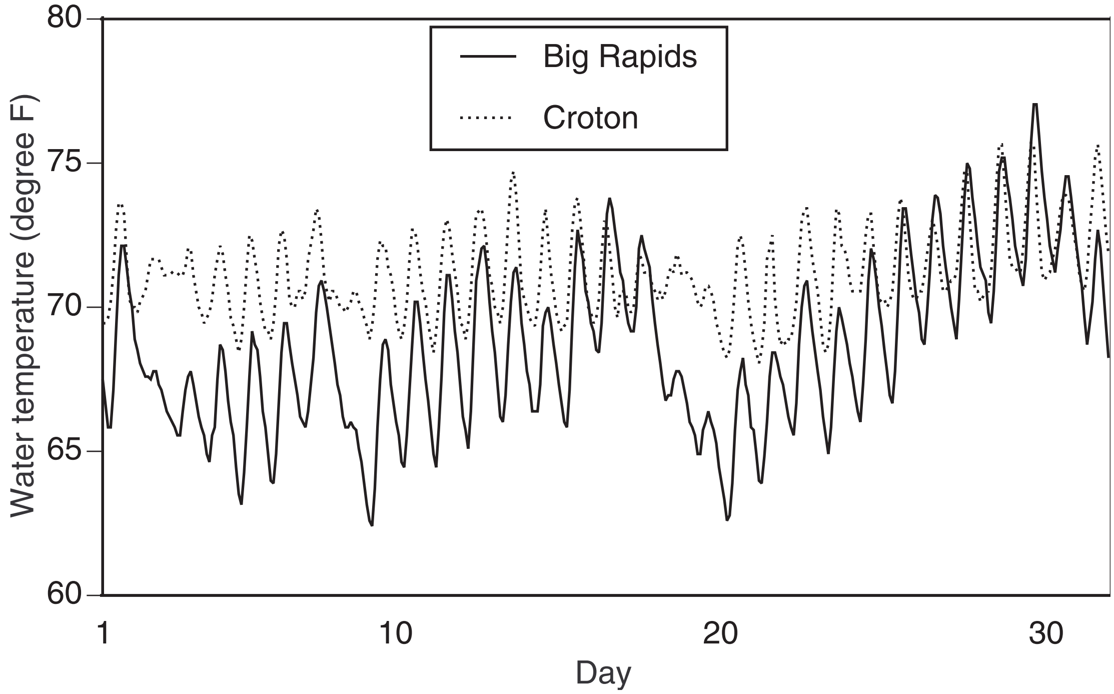

Figure 20.–August, 1991 water temperatures five miles upstream of Big Rapids, and four miles downstream of Croton Dam. Temperatures were collected at continuous two hour intervals. Data from Michigan Department of Natural Resources, Fisheries Division records.

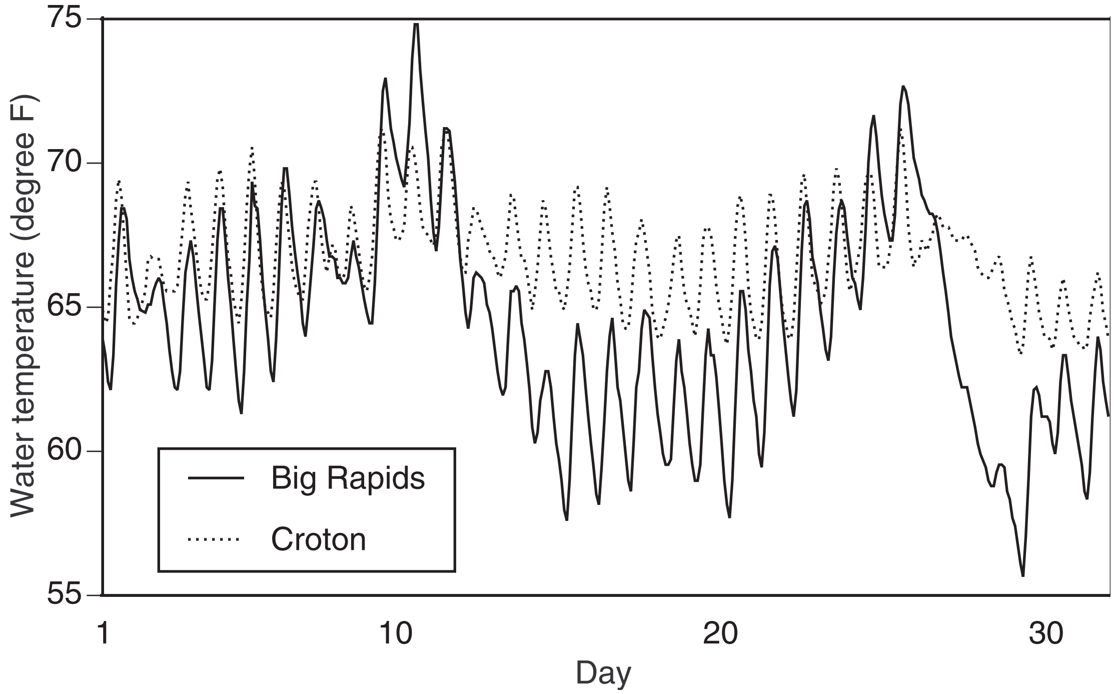

Figure 21.–August, 1992 water temperatures five miles upstream of Big Rapids, and four miles downstream of Croton Dam. Temperatures were collected at continuous two hour intervals. Data from Michigan Department of Natural Resources, Fisheries Division records.

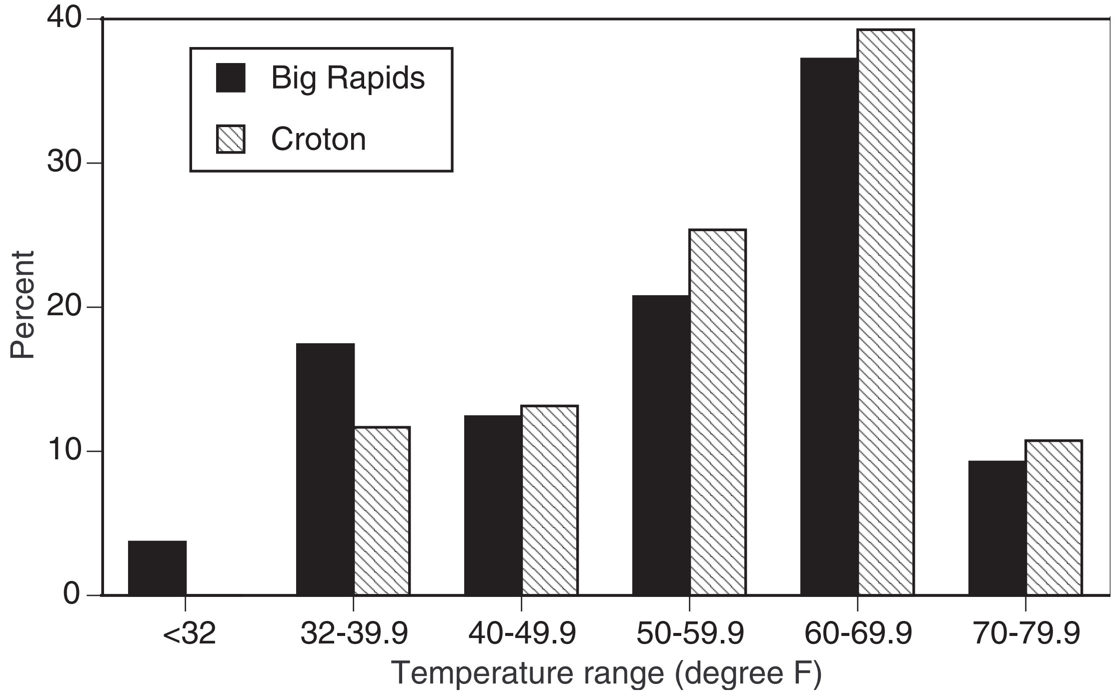

Figure 22.–Water temperature distributions five miles upstream of Big Rapids, and four miles downstream of Croton Dam, from May 3 through December 31, 1990. Data from Michigan Department of Natural Resources, Fisheries Division records.

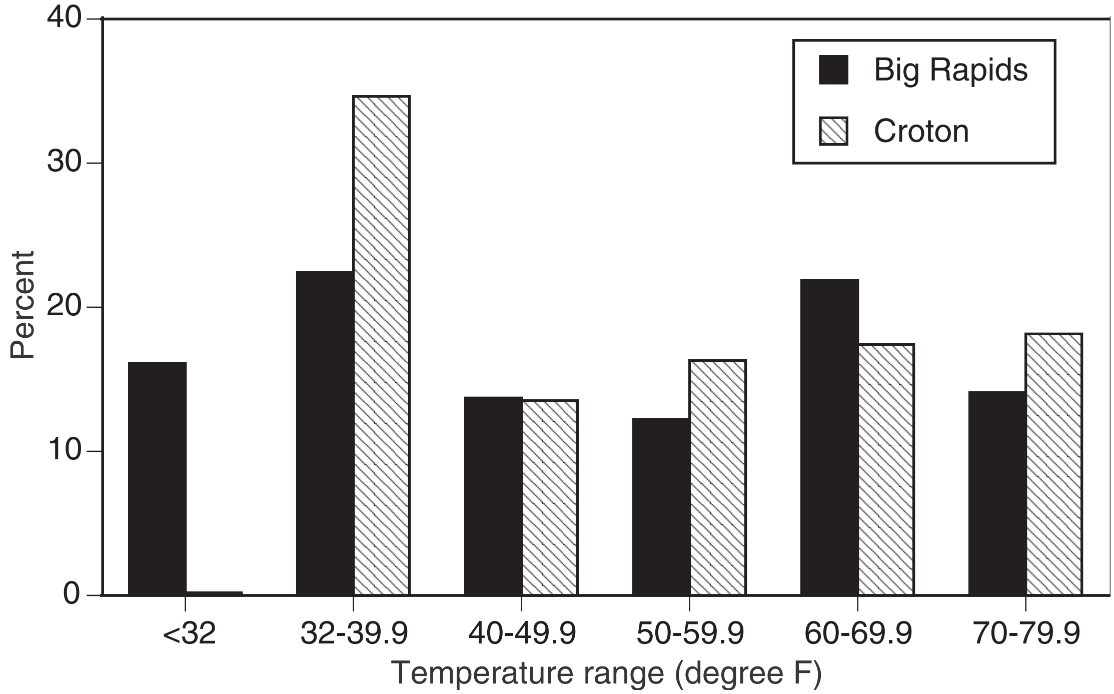

Figure 23.–Water temperature distributions five miles upstream of Big Rapids, and four miles downstream of Croton Dam, from January 1 through December 31, 1991. Data from Michigan Department of Natural Resources, Fisheries Division records.

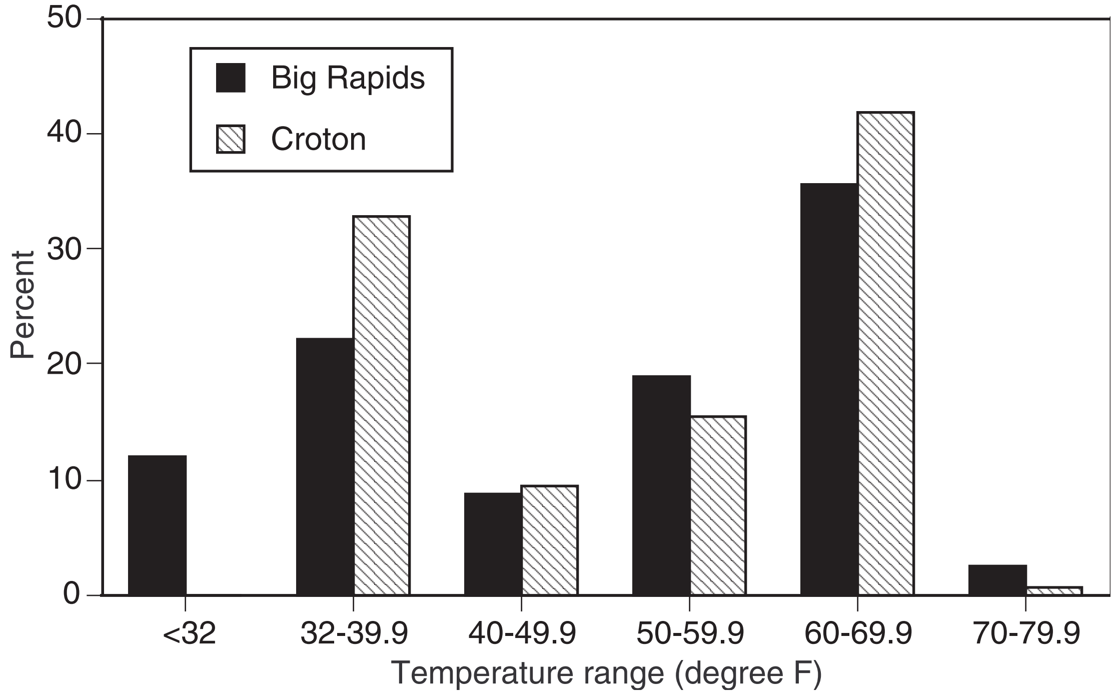

Figure 24.–Water temperature distributions five miles upstream of Big Rapids, and four miles downstream of Croton Dam, from January 1 through October 21, 1992. Data from Michigan Department of Natural Resources, Fisheries Division records.

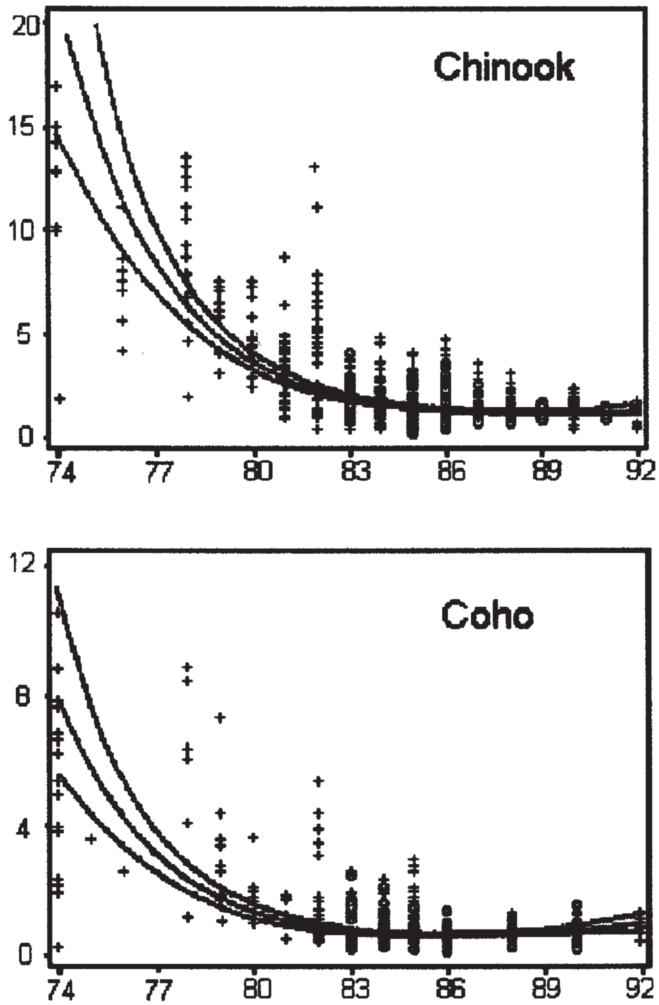

Figure 25.–PCB concentrations in Lake Michigan coho and chinook salmon fillets, 1974-92. Figure taken from Stow et al. (1995); lines represent three regressions evaluated for fit to the data.

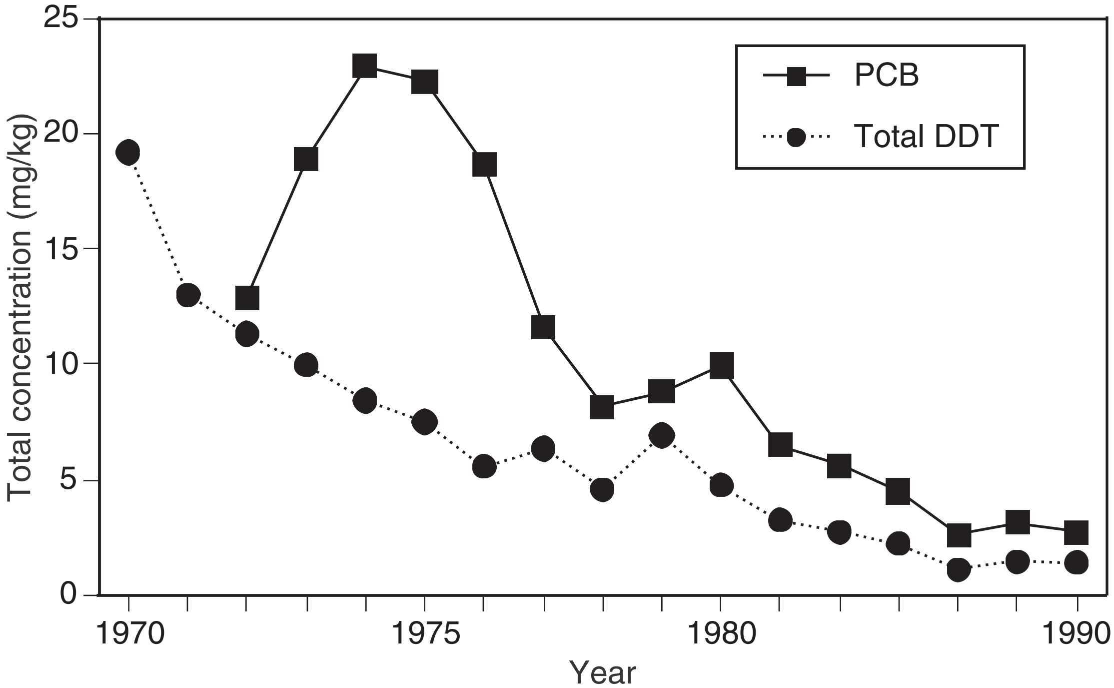

Figure 26.–Mean total PCB and DDT concentrations in whole lake trout from the Great Lakes, 1970-90. Data from Wood et al. (1995).

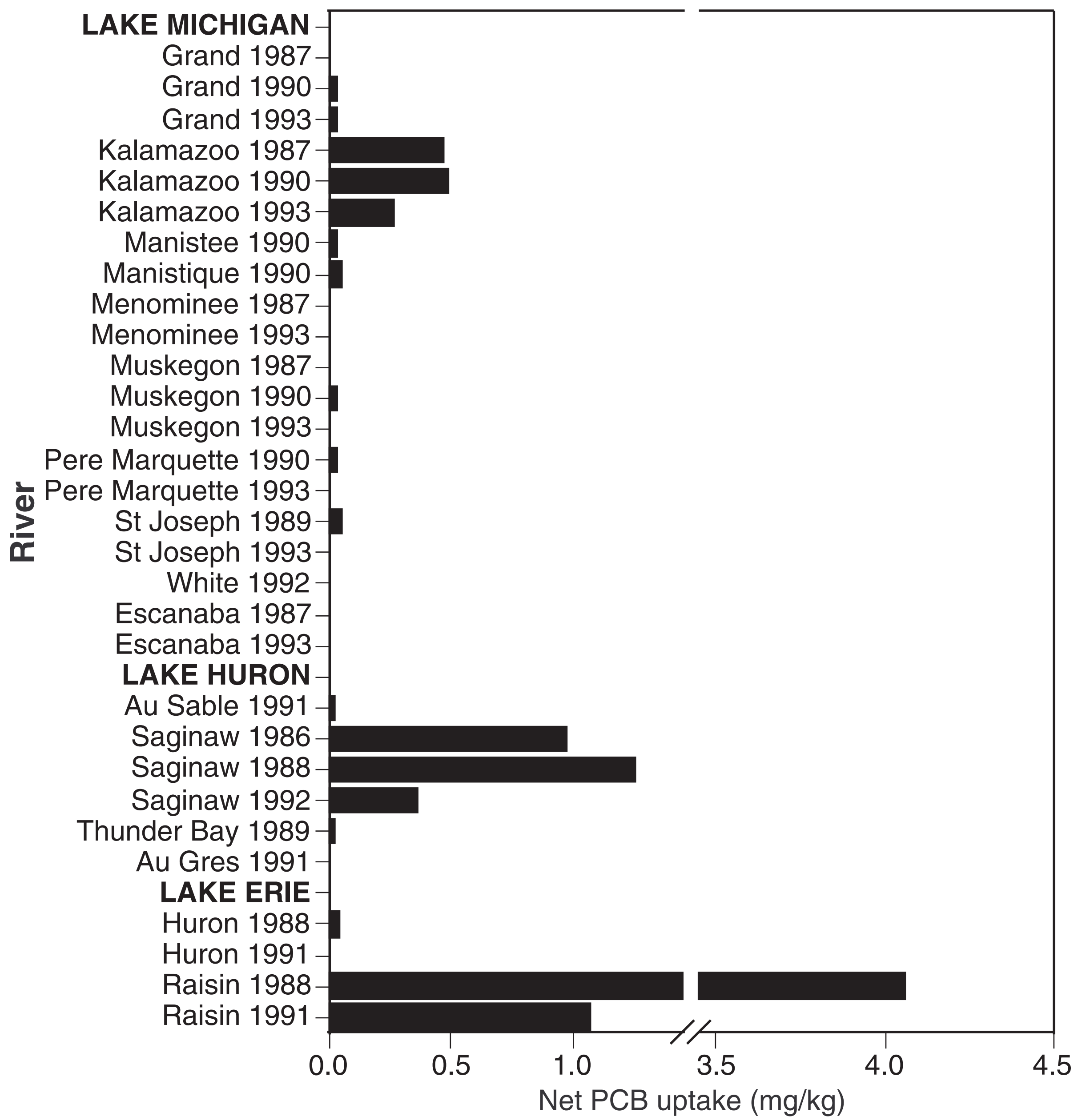

Figure 27.–Net uptake of PCBs in channel catfish caged for 27 to 29 days at the mouths of select Michigan rivers. Zero indicates no detectable uptake. Data taken from Wood et al. (1995).

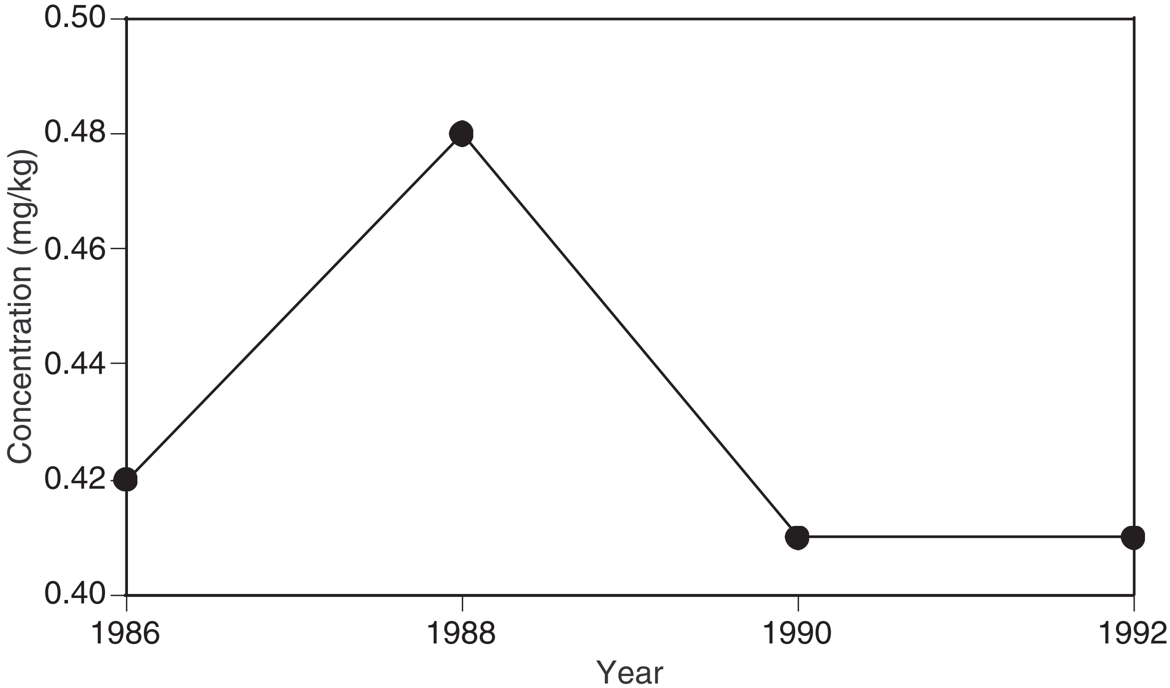

Figure 28.–Mean concentration of total chlordane in whole lake trout from Lake Michigan. Data taken from Wood et al. (1995).

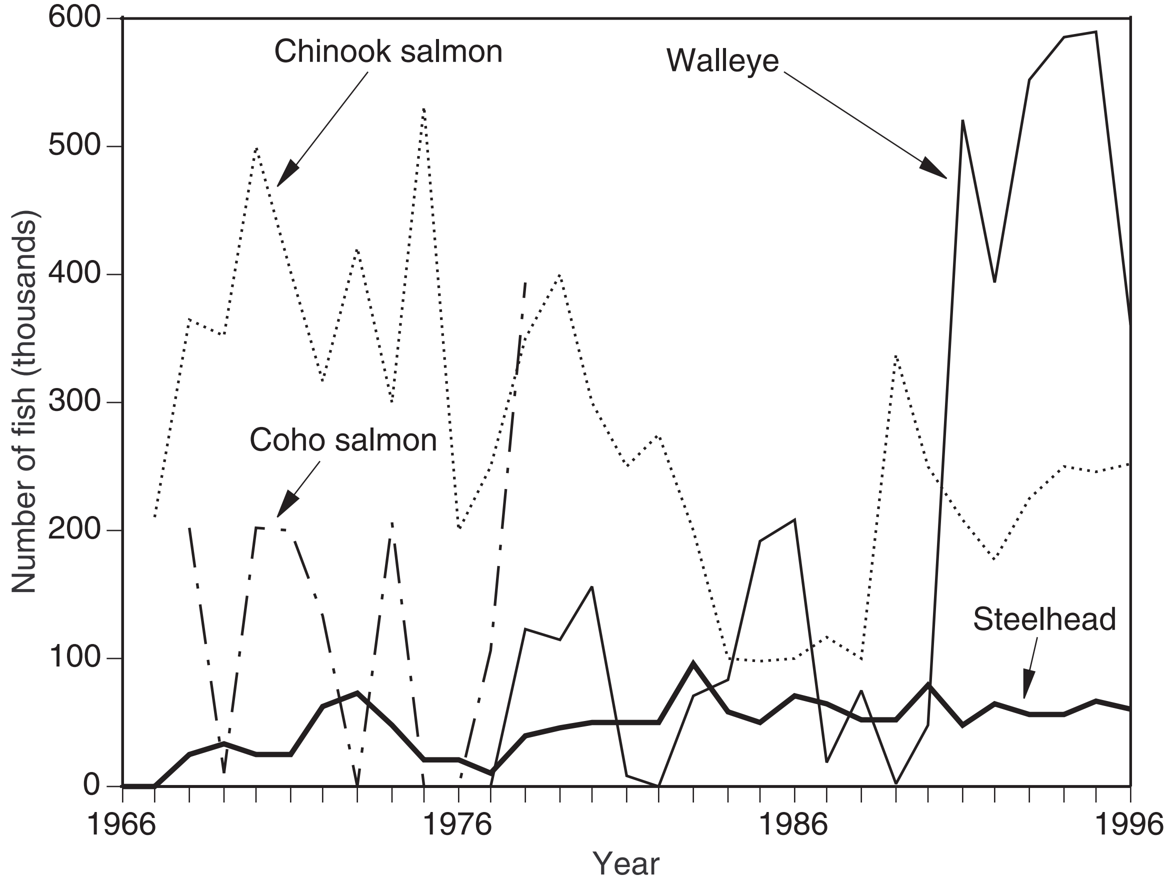

Figure 29.–Potamodromous fish stocking in the mainstem of the Muskegon River, downstream of Croton Dam, 1966-96. Data from Michigan Department of Natural Resources, Fisheries Division stocking records.

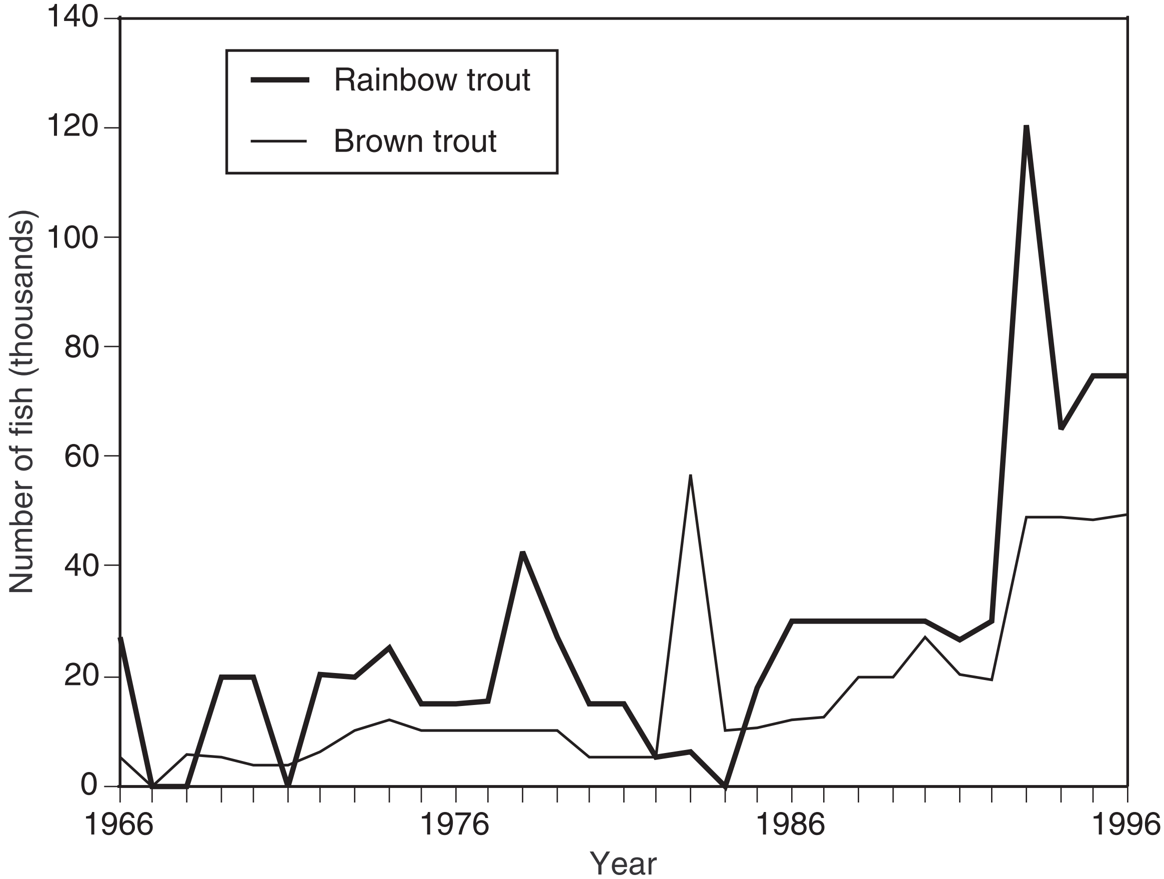

Figure 30.–River brown and rainbow trout stocking in the mainstem of the Muskegon River, downstream of Croton Dam, 1966-96. Data from Michigan Department of Natural Resources, Fisheries Division stocking records.