Water quality and restoration of the lower Oconto River, Oconto County, Wisconsin. No. 164 1989

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COVER. *The Machickanee Flowage as it looks today.*

ABSTRACT

The purpose of the Oconto River Restoration Project (1979-83) was to develop and implement a plan to restore the water quality, aquatic environment, and fish habitat of the lower Oconto River in Oconto County, Wisconsin. This river segment had been severely degraded for over 70 years by pulp mill effluent. Because of noncompliance with federal and state water quality standards, the mill was closed in 1978. The owner paid a court-ordered settlement, part of which was allocated to the Wisconsin Department of Natural Resources for development of a remedial plan.

The project area is in southwestern Oconto County, Wisconsin, and includes 32.5 km of the Oconto River downstream from the Scott Paper Company in Oconto Falls and part of Green Bay. The lotic portions of the river improved as soon as the pulp mill closed. The Machickanee Flowage below the mill did not improve as rapidly, due to the accumulation of sediment polluted with heavy metals. Aquatic macrophytes, aquatic macroinvertebrates, and substrate suitable for fish spawning remained scarce.

Beginning in 1979, we collected data on the following: water quality; sediment volume, elutriate, and compaction rates; zooplankton; aquatic macrophytes; aquatic macroinvertebrates; and fish populations and movement. Based on the data from 1979 and 1980, we designed a management plan for restoration of the area affected by discharge from the mill. The principal elements of the plan were: (1) an extended drawdown of the Machickanee Flowage to change the physical consistency of the accumulated sediment; (2) chemical treatment of fish populations in the Machickanee Flowage to eradicate rough fish; (3) fish stocking to establish game fish and panfish following the chemical treatment; (4) access development; (5) establishment of contingency funds for habitat improvement and additional fish stocking if necessary; (6) continuous monitoring for a three-year period to determine the effectiveness of the management techniques applied; and (7) an intensive public relations program conducted throughout the project.

We prioritized sections of the project area before beginning the restoration work, with the Machickanee Flowage as the first priority, followed next by the stretch of the Oconto River below the flowage and then the portion of Green Bay near the mouth of the river.

The Machickanee Flowage was drawn down in May 1981, and in September 1981 the water remaining in the flowage basin was treated with rotenone to eliminate rough fish. The flowage basin was refilled following the chemical treatment, and fish were stocked through 1981, 1982, and 1983.

Because of the drawdown the character of the sediment changed such that both numbers and species of aquatic plants and aquatic macroinvertebrates greatly increased. The amount of suitable substrate for fish spawning also increased.

A creel census and other surveys conducted after the management plan was implemented indicated that the aquatic ecosystem was more favorably balanced. Stocked fish grew rapidly, and game fish and panfish reproduced. Fishing and other recreational uses of the Machickanee Flowage increased, as did user satisfaction. None of the management techniques had a lasting negative effect on the 22.5-km stretch of the Oconto River below the flowage.

KEY WORDS: Lower Oconto River, Machickanee Flowage, Scott Paper Company, water quality analysis, pulp mill effluent, management plan, flowage drawdown, sediment studies, zooplankton, aquatic macrophytes and macroinvertebrates, fish populations and movement, public relations program.

WATER QUALITY AND RESTORATION OF THE LOWER OCONTO RIVER, OCONTO COUNTY, WISCONSIN

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INTRODUCTION

BACKGROUND

Water Quality and Legal History

The pollution problems on the lower Oconto River were caused by a pulp mill in Oconto Falls, Wisconsin. A pulp and paper mill has been located there since the 1890s, and records of water quality problems go back almost that far. While the pulp mill is no longer operated, finished paper products are still manufactured at the site. Serious problems developed when the mill switched in 1931 to a sulfite pulping process based on ammonia (NH_3).

Both state government records and recollections by local residents verify the severity of the pollution problem. State records show that in 1941 a Wisconsin Conservation Department warden investigating a fish kill in the river found the dissolved oxygen (DO) concentration to be 0 mg/L in the city of Oconto, 32 km downstream from the pulp mill. Wisconsin Department of Natural Resources (DNR) files contain other examples of nearly total DO depletion. Local residents recall that in the 1960s gases from the river discolored white paint on houses in Oconto. Residents of the small town of Stiles, 10 km downstream from the mill, remember odorous gases from the river discoloring porcelain kitchen and bathroom fixtures as well as cups and saucers in closed cupboards. Fish kills were periodically noted between 1953 and 1977. At times tributary streams were the scenes of mass migrations of fish looking for fresh water.

Attempts were made to abate or at least decrease the impact of the pulp mill waste. The Scott Paper Company, which purchased the mill in 1953, constructed a storage lagoon for spent sulfite liquor with the capacity to discharge the liquor into the river under both high-flow and low water-temperature conditions. The company also constructed a waste clarifier to reduce biochemical oxygen demand (BOD_5) and dissolved solids. Later, the clarifier was used to evaporate spent sulfite liquor. In the mid-1960s the Scott Paper Company installed a mechanical aerator at Stiles Dam. Unfortunately these measures had little positive effect. The storage lagoon leaked, and despite the clarifier, the river continued to carry a heavy load of pollutants. By 1975, from a single pulp and paper mill, the Oconto River was discharging 1,100 metric tons ammonia nitrogen/year to Green Bay. The river was then the largest source of that pollutant discharging to the Wisconsin side of Lake Michigan. In comparison, the highly polluted Fox River nearby, which has a greater flow and serves as the receiving stream for many pulp and paper mills, contributed only 740 metric tons ammonia nitrogen. In 1977 discharges from the Scott Paper Company outfall, waste clarifier, and spent liquor lagoon averaged 18,144 kg BOD_5/day. During drainage of the lagoon in November and December 1977, the total daily discharge of BOD_5 was as high as 54,423 kg (T. Rasman, Wis. Dep. Nat. Resour., unpubl. data).

Changes in the federal Water Quality Act in 1972 and later water quality legislation in Wisconsin provided a more effective means of regulating and enforcing water quality standards. In 1977 the Scott Paper Company was cited for noncompliance with its wastewater discharge permit. A suit against the corporation was later brought by the DNR and the U.S. Environmental Protection Agency (USEPA). The company closed its pulp mill in February 1978 but continued to manufacture finished paper.

On 6 January 1979 the suit against the Scott Paper Company was settled out of court and the company agreed to pay a forfeiture of $1,000,000. As part of the judicial decree that closed the case, $600,000 of the settlement was allocated to the DNR. The agency was ordered by the court to use the award to develop and implement a management plan that would restore the aquatic environment and fish habitat in the portions of the Oconto River and Green Bay that had been damaged by discharges from the mill.

The Management Plan

Responsibility for developing and implementing a remedial plan—the Oconto River Restoration Project—was delegated to the DNR's Lake Michigan District, which organized the Oconto River Committee (ORC). The ORC consisted of 12 DNR staff members and included specialists in water quality, fisheries management, wildlife management, law enforcement, water regulation, environmental impact, and public information.

When the project began in early 1979, the ORC knew that pollutant levels had been high enough to adversely affect the river ecosystem, but the committee did not know precisely what the effect of these pollutants had been. For instance, the ORC knew that discharge from the mill had contained high concentrations of suspended solids, but they did not know if the bulk of these solids had settled in the Machickanee Flowage or if they had remained suspended and moved through the river system to Green Bay. There were also questions about contaminant levels in the sediment and biota and about the overall status of aquatic plant, invertebrate, and fish populations.

The ORC spent two years, 1979-80, identifying the physical and biotic problems in the river system and developing potential solutions. The ORC staff reviewed the literature and consulted environmental experts from the DNR and other agencies and institutions. From the project area, the staff collected data on water quality; sediment volume, elutriate, and compaction rates; zooplankton; aquatic macrophytes; aquatic macroinvertebrates; and fish populations and movement. By late 1980, enough information had been collected to develop a corrective management plan that would address the problems revealed by this initial investigation (Amundson et al. 1980).

Because it had suffered the most long-lasting damage, the Machickanee Flowage was selected as the first priority for restoration. The 22.5-km stretch of the river below the flowage was selected as the second priority, and a portion of Green Bay near the river's mouth was chosen as the third.

The principal elements of the plan were: (1) an extended drawdown of the Machickanee Flowage to change the physical consistency of the accumulated sediment; (2) a chemical treatment of fish populations in the Machickanee Flowage to eradicate rough fish; (3) fish stocking to establish game fish and panfish following the chemical treatment; (4) access development; (5) establishment of contingency funds for habitat improvement and additional fish stocking if necessary; (6) continuous monitoring for a three-year period to determine the effectiveness of the management techniques applied; and (7) an intensive public relations program conducted throughout the project.

STUDY AREA

The study (project) area is located in southeastern Oconto County, Wisconsin (Fig. 1). It includes 32.5 km of the Oconto River downstream from the Scott Paper Company in Oconto Falls and a small portion of Green Bay. For study purposes this area was segregated into four subunits: (1) 4 km of the Oconto River, beginning at the Scott Paper Company in Oconto Falls and ending at the upper end of the Machickanee Flowage (Subunit 1); (2) the 188-ha Machickanee Flowage (Subunit 2); (3) 22.5 km of the Oconto River downstream from the Machickanee Flowage (discharging to Green Bay) (Subunit 3); and (4) a small portion of Green Bay near the mouth of the Oconto River (Subunit 4).

The Oconto River Between the Scott Paper Company and the Machickanee Flowage (Subunit 1)

This 4-km segment of the Oconto River has an average width of 35 m and an average depth of 0.4 m with a gradient of 1.1 m/km. Mean flow is approximately 16 m^3/s. In August 1981 the pH was 7.3, and the methyl purple alkalinity was 117. Bottom materials were 50% sand, 25% rubble, and 25% boulders. At the upper end of this segment, a rock outcropping creates the falls from which the city of Oconto Falls derives its name. These falls drop vertically 6 m and have in the past blocked upstream movement of anadromous fish from Green Bay. Atop the rock outcropping is a dam owned and operated by the Scott Paper Company. Waste discharge pipes from both the Scott Paper Company and the city of Oconto Falls are located 1 km downstream from the dam. During pulping operations this river segment carried extremely high concentrations of pulp mill effluent.

The Machickanee Flowage (Subunit 2)

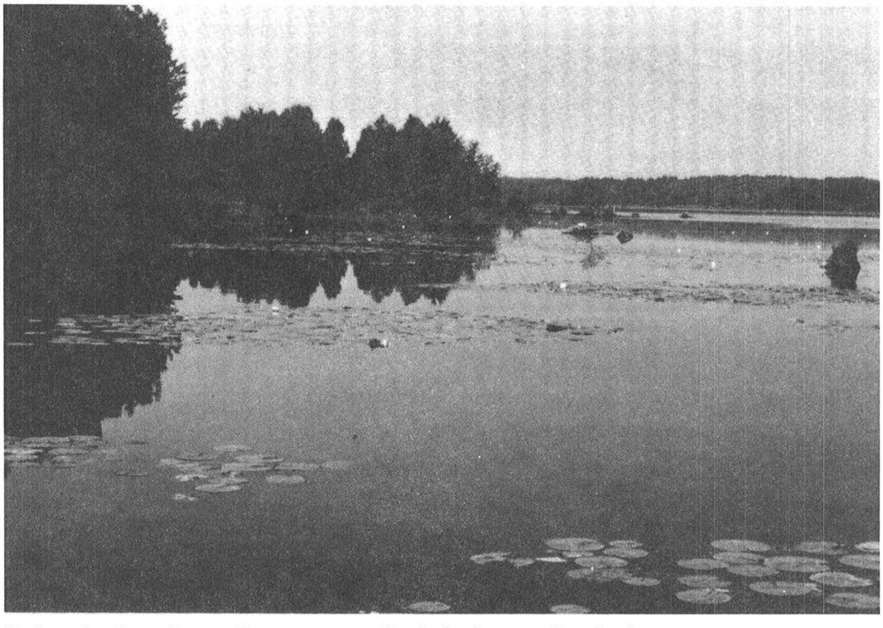
The upstream end of the Machickanee Flowage is located 4 km downstream from the Scott Paper Company in Oconto Falls (Fig. 2). This flowage is a 188-ha impoundment of the Oconto River created by the Stiles Dam in Stiles, Wisconsin. The Stiles Dam is owned by the Oconto Electric Cooperative and is used to generate electricity. Before the flowage drawdown in 1981, a 5.8-m head was maintained. Daily depth fluctuation from 1979 through 1983 often approached or exceeded 0.3 m. Maximum depth was 7 m. The flowage turned over once every 2.6 days at 16.4 m^3/s river flow. Flowage water was slightly alkaline, medium brown in color, and of low transparency. The flowage was a settling basin for effluent solids generated during operation of the pulp mill in Oconto Falls, and it suffered severe environmental damage.

The Oconto River Between the Machickanee Flowage and Green Bay (Subunit 3)

The Machickanee Flowage and Green Bay are 22.5 km apart on the Oconto River. This segment of the Oconto River varies in width from 24.4-45.6 m and in depth from 0.2 m upstream to 6.1 m near the mouth. Daily depth varies greatly depending on generation of hydroelectricity at Stiles Dam. Average stream gradient is 0.42 m/km. Mean flow is approximately 16 m^3/s. The $Q^7 10$, or low flow occurring once every 10 years over 7 consecutive days, is 5.8 m^3/s. The water is slightly alkaline and light brown in color. The river substrate is sand with numerous rubble riffles. These riffles could provide good spawning habitat for smallmouth bass (*Micropterus dolomieui*) and other fish species.

Green Bay (Subunit 4)

The court settlement stipulated that those waters of Green Bay affected by discharges from the mill would be within the project area. Because clear delineation of this area was difficult, the ORC assumed that most of the bay was affected.



Before the drawdown, the most extensive bed of vegetation in the Machickanee Flowage consisted of lily pads, which offered scant cover for young fish or adequate substrate for aquatic insects.

Additional Study Areas

The Oconto Falls Flowage was used to compare conditions within the Machickanee Flowage. It is a 76.5-ha impoundment of the Oconto River located 5 km upstream from the Machickanee Flowage. The impounding dam is owned by the Wisconsin Electric Power Company and is operated to produce electricity. An 8.5-m head is maintained for generation. Daily water level fluctuation is minimal because the facility is operated to discharge run-of-the-river flow. The flowage is morphologically similar to the Machickanee Flowage.

The Oconto Falls Flowage supports moderately heavy recreational use including boating, swimming, water skiing, and fishing. The north shore is a residential area within the city of Oconto Falls. The nearest upstream point source polluter is the city of Gillett's sewage plant, 29 km away.

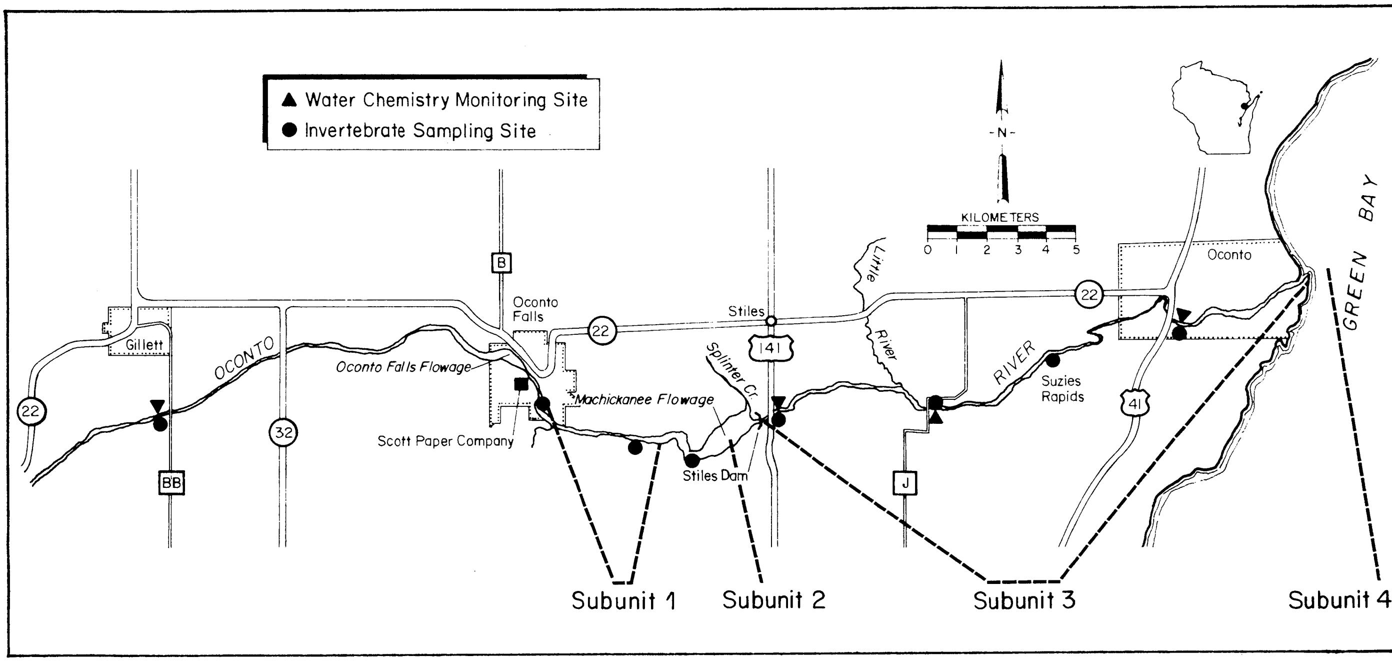


FIGURE 1. *Project area, subunits, and study sites, Oconto River Restoration Project.*

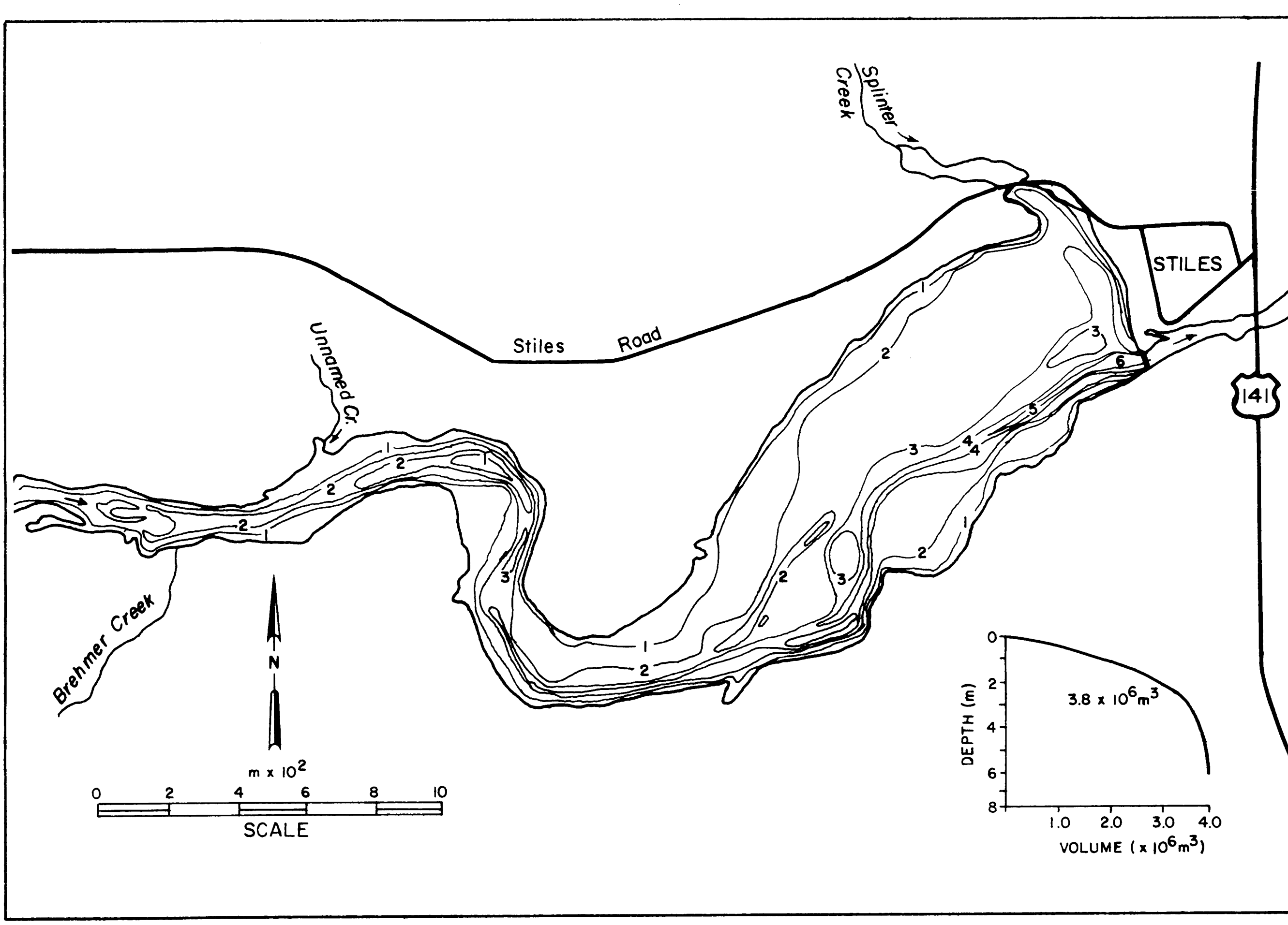


FIGURE 2. *Bathymetric map of Machickanee Flowage, 1978.*

METHODS

WATER CHEMISTRY

We selected water chemistry and biology monitoring stations based on historical data. The DNR had monitored the Oconto River since 1973 at County Trunk Highway BB (CTH BB), 14.5 km above Oconto Falls, and at US 41, 19.3 km below Oconto Falls (Fig. 1). Samples from these two sites provided a comparison of a relatively unpolluted segment of the river with the segment below the Scott Paper Company's waste outlets.

Chemical parameters at both sites included DO, water temperature, pH, conductivity, BOD_5, fecal coliform, total phosphorus, ortho phosphorus, suspended solids, total Kjeldahl nitrogen, ammonia nitrogen, nitrite plus nitrate (NO_2 + NO^3), chlorophyll-*a*, silica, and chlorides. We collected, preserved, and sent samples to the State Laboratory of Hygiene (SLOH) in Madison, Wisconsin, for analysis according to standard procedures.

During the drawdown and throughout the open water season of 1981, we examined these parameters at three sites downstream from the Machickanee Flowage. Sites were located downstream from the dam in Stiles (0.5 km downstream), at County Trunk Highway J (CTH J) (6.4 km downstream), and in the city of Oconto (22.5 km downstream).

We collected water column samples from the Machickanee Flowage in 1979, 1981, 1982, and 1983 near Stiles Dam and had them analyzed for mercury, cadmium, copper, nickel, and zinc by SLOH in Madison. Six wells adjacent to the Machickanee Flowage were examined in 1979 to determine ground water contamination. Vegetation from the flowage was analyzed for heavy metals in 1981 and 1983 by SLOH.

DETERMINATION OF SEDIMENT VOLUME

In early summer 1979, fall 1979, and summer 1982, we determined the volume of sediment in the Machickanee Flowage by pushing a steel reinforcing rod 1.6 cm in diameter into the flowage bottom until we met strong resistance. We then measured water depth using a sounding line with an aluminum plate 10 cm in diameter as a weight that was light enough not to sink into the sediment. Sediment depth was calculated by subtracting the water depth from the depth reading on the steel reinforcing rod. We recorded 65 calculations from the flowage during each sampling period.

We prepared a contour map showing depth of sediment and, using a planimeter, measured the area included within each contour line. We determined the volume of sediment by multiplying the area by the average sediment depth.

SEDIMENT AND ELUTRIATE ANALYSES

Sediment samples were collected at five sites randomly chosen within the Machickanee Flowage on 1 July 1979. At each site we examined the sediment to determine basic physical characteristics. The SLOH then analyzed the sediment for total solids, volatile solids, chemical oxygen demand, Kjeldahl nitrogen, oil and grease, mercury, lead, zinc, total phosphorus, ammonia nitrogen, manganese, nickel, arsenic, cadmium, chromium, magnesium, copper, iron, polychlorinated biphenol (PCB), sulfate, sulfide, and sulfite. The water or elutriate was analyzed for BOD_5, total organic carbon, Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total phosphorus, ortho phosphorus, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, zinc, and PCB's. To determine sediment oxygen demand, we collected cores from the Machickanee Flowage on 22 August 1979, one from the upper end and one from the middle of the flowage, according to the method of Dean Hammermeister (Sullivan et al., 1978).

SEDIMENT STATIC BIOASSAY

A static bioassay was conducted on Oconto Falls and Machickanee Flowage sediments, using fathead minnows *(Pimephales promelas)* and adult crayfish *(Cambarus bartoni)* under laboratory conditions. We set up twelve 15-L aquaria containing flowage sediment and a holding tank for acclimation of the test organisms. We transferred 112 northern fathead minnows to eight aquaria containing sediment from the Machickanee Flowage and 56 fish to four aquaria containing sediment from the Oconto Falls Flowage. Four crayfish were placed in the aquaria containing Machickanee Flowage sediment and two were placed in a control aquarium. The system was aerated continuously.

DETERMINATION OF SEDIMENT COMPACTION RATES

We collected sediment from the Machickanee Flowage to determine the rate and degree of compaction of exposed drawdown sediment in May 1980. The collected sediment was placed in a wooden bin 1 m by 1 m by 0.6 m, open at the bottom and lined with porous polyethylene feed bags to allow drainage of liquid while retaining solid material. Further, we placed two 0.250-ml sediment samples in open glass containers and allowed them to air dry. We placed a third 1.0-L wet sample in a plastic tube and sealed it. After two weeks all standing water in the tube was decanted, and the tube was resealed and stored for eight months.

During the drawdown of the Machickanee Flowage, we determined the rate and degree of vertical compaction of exposed sediment. As the flowage water level dropped, we drove wooden stakes measuring 2.5 cm by 7.5 cm by 2.4 m through the accumulated sediment into what we judged to be the original flowage bottom. We ran four transects across the flowage at approximate right angles to the flowage axis. Two of these transects were located across narrow portions of the upper one-third of the flowage, and the other two were located in the wider lower one-third of the flowage. Stakes were also randomly placed in other accessible areas of the flowage. We did not run transects across the middle of the flowage because it was not totally accessible. Compaction data were collected during three time intervals in 1981: 3-5 June, 26 June-1 July, and 10-17 August.

COLLECTION AND ANALYSES OF ZOOPLANKTON

In 1979 we collected 36 plankton samples from the Machickanee and Oconto Falls flowages. We used three methods for sample collection: a Kemmerer water sampler, a two-cycle water pump powered by gasoline, and vertical plankton tows, each with a no. 20 mesh (80-micron) Wisconsin plankton net. Samples were preserved in the field with a 4% formalin solution.

In 1982 and 1983 samples were collected from the Machickanee Flowage. We collected zooplankton biweekly from 28 April-30 September 1982 and

28 April-29 September 1983. We collected samples with one vertical tow at each of six stations and estimated the volume sampled by multiplying the length of the tow by the area of the net opening ($132.7\ cm^2$). Zooplankton were killed with a 90% alcohol solution and preserved in alcohol or a mixture of alcohol and Lugol's solution. Zooplankton in an entire sample, or in subsamples of 1/16-1/4 of a total sample, were analyzed. We noted the presence or absence of larger zooplankton in each sample, along with the most abundant genera of net phytoplankton. Samples collected in 1982 and 1983 were analyzed by Dr. Stanley Dodson, University of Wisconsin-Madison.

We identified crustaceans using Edmondson (1959) and Torke (1976); rotifers using Stemberger (1979); and algae using Edmondson (1959), Needham and Needham (1962), and Walter (1962).

Wooden stakes 2.4 m long were used to judge sediment compaction over time.

SURVEY AND COLLECTION OF AQUATIC MACROPHYTES

We conducted surveys to determine the occurrence and relative abundance of aquatic plants in the Machickanee Flowage in July and August of 1980, 1982, and 1983, and in the Oconto Falls Flowage during 1980. The flowages were divided into 174 and 126 quadrats, respectively. Each quadrat on the Machickanee Flowage had an area of 1.5 ha, and on the Oconto Falls Flowage each quadrat had an area of 0.8 ha. The distance between intersects was 122 m and 91 m, respectively. We located sampling stations at the intersection of each transect line. Where transect lines did not intersect near shore, a sampling station was established in that area. Each sampling station was circular with a radius of 1.8 m. This circular area was divided into four pie-shaped sections (quadrants). We visually estimated the number of plants in each quadrant or sampled them using a garden rake. The terms *abundant, common,* and *present* were used to describe the species density in each quadrant (Jessen and Lound 1962).

In 1982 and 1983, aquatic plants were sampled using a garden rake.

SURVEY AND COLLECTION OF AQUATIC MACROINVERTEBRATES

We sampled macroinvertebrate communities within the project area and at one location upstream from the project area (Fig. 1).

We used Hilsenhoff's biotic index (Hilsenhoff 1982) to obtain a qualitative measure of stream enrichment for samples collected from river sites. Surber square samplers and plastic artificial substrates were also used for collecting some flowage samples during 1979-80 (Greeson et al. 1977).

We obtained samples at two river sites before the pulp mill closed in February 1978. In January 1979 one sample was collected from the Oconto River 26 km upstream from the paper mill, and another was collected from the Oconto River at U.S. 141 (0.8 km downstream from Stiles Dam). In June 1979 permanent river sample sites were established (Fig. 1), and all permanent sites were subsequently sampled with a D-frame net. We collected river samples from the six sites twice yearly from 1979-83, except in 1981 when samples were collected before, during, and after the refilling of the Machickanee Flowage. In 1980 an artificial sampler was used on the Oconto River, the Oconto Falls Flowage, and the Machickanee Flowage.

After the drawdown, we collected D-frame samples three times during the open water seasons of 1982 and 1983 at five sites in the Machickanee Flowage. The habitats at these sites included sand-gravel substrates, vegetation on hard-packed sediments, clay-gravel substrates, sand substrates with stumps and vegetation, and an area with sand substrate that was downstream from a tributary (Splinter Creek). In 1983 we also placed artificial substrates in the river channel to collect spring and fall species.

STUDIES OF FISH POPULATIONS

Survey Techniques

We sampled flowage populations with fyke nets (4.4-cm and 1.9-cm stretch mesh), a three-person boom shocker, a two-person boom shocker, and shoreline seines. Fyke nets were placed to sample different habitat types. Shoreline sets were usually made perpendicular to shore, but some double-ended sets were also made in open water at depths up to 3.7 m. Most fishing effort was made with fyke nets. Boom shocking was done near shore during both daylight and nighttime hours.

We sampled river populations mainly with a 250-v pulsed dc boom shocker and occasionally with a two-person mini-shocker. On the lower Oconto (Subunit 3, Fig. 1), twenty-one 0.4-km index stations were established to represent existing habitat types. When possible, we surveyed the river monthly during the open water season. Fish of all species were collected and measured within the index stations, but only game fish and panfish were collected and measured between stations. All fish collected during surveys were identified, counted, and measured to the nearest millimeter (Append. A).

Population Estimates and Catch per Unit Effort

We used the Schnabel multiple mark/recapture method to estimate population size of ten fish species found in the Machickanee Flowage: black bullhead *(Ictalurus melas)*, yellow bullhead *(Ictalurus natalis)*, common carp *(Cyprinus carpio)*, white sucker *(Catostomus commersoni)*, black crappie *(Pomoxis nigromaculatus)*, bluegill *(Lepomis macrochirus)*, pumpkinseed *(Lepomis gibbosus)*, rock bass *(Ambloplites rupestris)*, northern pike *(Esox lucius)*, and yellow perch *(Perca flavescens)*. We estimated populations for all of these species except northern pike with data from fyke net collections during June 1979; the northern pike population was estimated from data collected in spring 1981. We did not calculate population estimates in 1980, 1982, or 1983. Therefore, pre- and post-drawdown and chemical treatment comparisons were described in catch per unit effort (CPE). CPE's were expressed in catch per net day.

Age and Growth Estimates

Scales from bluegills and black crappies in each 10-mm size interval were collected from the Machickanee Flowage in spring and fall 1979, 1980, 1982, and 1983 for age determination. These species were sampled in the Oconto Falls Flowage in 1979. From the lower Oconto River, scales were collected only from smallmouth bass. We made scale impressions on acetate slides and examined them using a 49-power microfilm reader.

Determination of Condition Factors

We determined condition factors for white suckers caught in September 1979 in both the Machickanee and Oconto Falls flowages. The condition factor K was calculated using the formula of Ricker (1958).

Shoreline Seining

During summer 1980 we established 31 shoreline seining sites on the Machickanee Flowage to assess natural reproduction of game fish and panfish. Seventeen sites were established on the Oconto Falls Flowage for comparison. Sample stations were set up at 390-m intervals along the shoreline of both flowages. Seine haul length was 7.6 m. The seine used was 0.5-cm stretch mesh, 7.6 m by 1.2 m. We made one haul per station from 28 July-18 August on the Machickanee Flowage and from 3-4 September on the Oconto Falls Flowage. Hauls were made perpendicular to the shoreline.

Seining the Machickanee Flowage in 1980 was difficult because of many stumps, an overabundance of blue-green algae (*Oscillatoria* spp. and *Hydrodictyon* spp.), and flocculent sediment. Ten sites could not be seined. At many sites we sorted through large amounts of sediment and algae to locate captured fish. Four sites could not be seined on the Oconto Falls Flowage in 1980.

Seventeen sites on the Machickanee Flowage were seined from 8-11 August 1982. Eleven sites were seined from 15-16 August 1983. Seining in 1983 was difficult because of abundant aquatic vegetation.

Creel Census

We conducted a creel census from 21 May-16 November 1979 at the Machickanee Flowage, the mouth of the Little River (a tributary to the lower Oconto), bridges in the city of Oconto, boat landings in the city of Oconto, and a pier at the mouth of the Oconto River. The format followed was the standard DNR Great Lakes creel census (Wis. Dep. Nat. Resour. 1973). A creel census was conducted at the same locations from 18 April-30 October 1982.

Analysis of Fish Tissue

White sucker, common carp, black bullhead, northern pike, black crappie, bluegill, and common shiner were collected from the Machickanee and Oconto Falls flowages in 1979 and sent to SLOH in Madison for analysis. These samples were checked for PCB's, arsenic, cadmium, chromium, copper, lead, and mercury concentrations. Samples of white sucker, common carp, northern pike, walleye *(Stizostedion vitreum vitreum)*, bluegill, and rainbow trout *(Salmo gairdneri)* were analyzed in 1982 and 1983 to determine concentrations of heavy metals and PCB's.

Marking

We tagged all suitably sized game fish with return-addressed Floy tags during electrofishing and fyke net surveys. Tagging was restricted to fish judged to be large enough (usually at least in their second season) to survive handling stress and tag implantation. We tagged 5,276 fish from 1979-83.

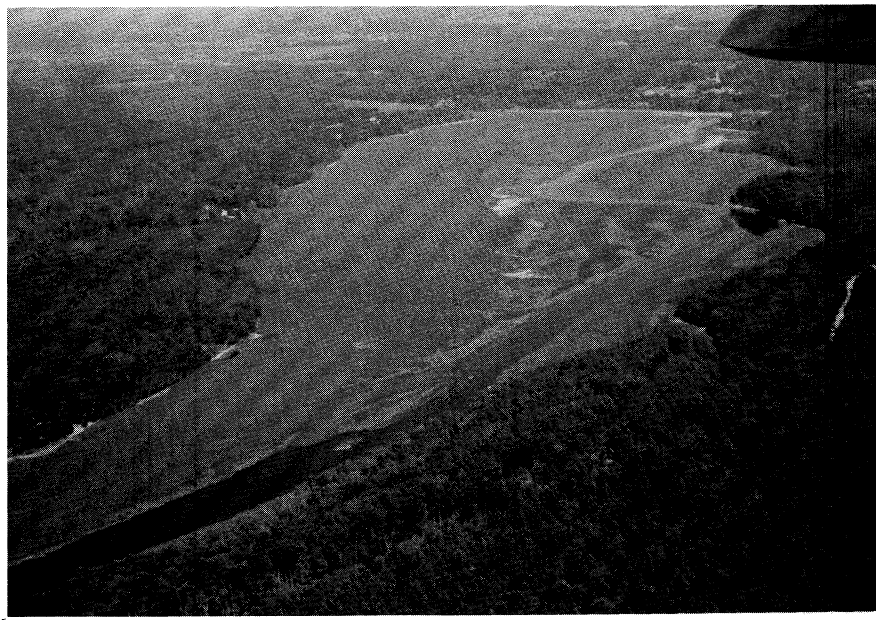
MANAGEMENT METHODS

Drawdown of the Machickanee Flowage

Drawdown of the Machickanee Flowage began on 5 May 1981, and the flowage was not refilled until 30 September 1981. From 10 May-30 September 1981, water in the flowage basin was confined to the river channel that existed before the flowage was created.

Draining the flowage took ten days. The first 0.6 m of vertical decrease in flowage water level was achieved by passing water through the electrical generators in the Stiles Dam to minimize the cost of reimbursement for lost electrical generation. Once the flowage water level reached the point at which air might enter the generator turbines (causing overspeeding and consequent damage to the generators), water was passed through the dam tainter gates. Since the tainter gates rested on the dam sill when closed and the top of the sill was approximately 3 m above the flowage bottom, raising the gates resulted in discharge at approximately mid-depth of the flowage.

The planned discharge rate from the flowage was 1.63 cm/hour of constant vertical decrease in flowage depth. This slow discharge rate was intended to minimize (1) sloughing of flocculent sediment into the main current, with resultant flushing of sediment into the river below; and (2) downstream flooding, which could eliminate fishing and endanger human safety.



From May-September 1981, water in the flowage basin was confined to the river channel that existed before the flowage was created.

Access Development

A boat-launching and parking facility was developed on the Machickanee Flowage in 1981. In 1983 the facility was improved to provide toilet facilities and a park-like setting. Construction was contracted by Oconto County (the owner of the property) and was funded totally with restoration project funds. Oconto County also agreed to maintain the facility.

Citizen Involvement

When the restoration project began, the ORC discussed the importance of citizen participation in the project and approved a Citizen Involvement Program. The program consisted of (1) frequent public information meetings; (2) news releases; (3) a newsletter series; (4) radio, television, and newspaper reports; (5) presentations by ORC members to organizations such as sport clubs, public service organizations, school groups, and town meetings; and (6) public contact by field crews (Append. B).

Television interviews with project personnel helped to keep the public informed about management activities.

Chemical Treatment of the Machickanee Flowage

Chemical treatment began on 9 September 1981. During the drawdown the flowage was treated as a river system rather than an impoundment. Treatment began at the Scott Paper Company Dam in Oconto Falls and ended at Stiles Dam. Ten kilometers of stream were treated. Discharge during treatment was restricted to 3 m^3/sec to reduce the cost of required chemicals and to further confine the target fish species. Rotenone was applied at a constant rate of 500 cm^3/min for 8 hours just downstream from the Scott Paper Company Dam. We applied 475 L of Nusyn-noxfish.

Approximately 7 L of dry fluorescein dye were applied at the beginning and end of the rotenone application. Just after the final introduction of fluorescein dye, we added 7 L of Rhodamine WT to further delineate the trailing edge. A fluorimeter was set up at the detoxification station to detect the presence of the Rhodamine WT, which is reportedly detectable at a concentration of 250 ml/1.5 m^3 river discharge (L. Liebenstein, Wis. Dep. Nat. Resour., pers comm. 1981). We introduced a detoxicant, potassium permanganate ($KMNO_4$) at a concentration of 10 ppm, above the tainter gates at Stiles Dam. Detoxification was continued for 1½ hours after the Rhodamine WT was detected at the dam.

Fish Stocking

Seven species of fish were stocked in the Machickanee Flowage during 1981-83 (Table 1). The Oconto River below Machickanee Flowage also received 25,000 walleye fingerlings/year in 1982, 1983, and 1984.

TABLE 1. *Species and numbers of fish stocked in the Machickanee Flowage, 1981-83.*

Year	Rainbow Trout	Walleye Fry	Walleye Fingerling	Smallmouth Bass	Largemouth Bass	Bluegill	Fathead Minnow
1981	5,000	0	0	0	0	0	338 kg
1982	12,500	2,000,000	46,500	18,000	21,000	4,000	0
1983	0	0	46,500	18,000	18,000	0	0

RESULTS AND DISCUSSION

DRAWDOWN OF THE MACHICKANEE FLOWAGE

Rate of Discharge

The actual rate of decrease in flowage depth was 1.55 cm/hour, 0.08 cm/hour less than planned. During one four-hour period on 11 May 1981, flowage water level increased 20.32 cm despite constant gate adjustments. Discharge of the river below the flowage did not exceed 63.7 m^3/sec (Fig. 3). Flows in excess of 85 m^3/sec are not uncommon in this part of the river during annual periods of spring runoff. No excessive downstream flooding occurred, and the magnitude of discharge did not hinder fishing below the dam. In fact fishing was good, since many northern pike from the flowage were swept through the open gates.

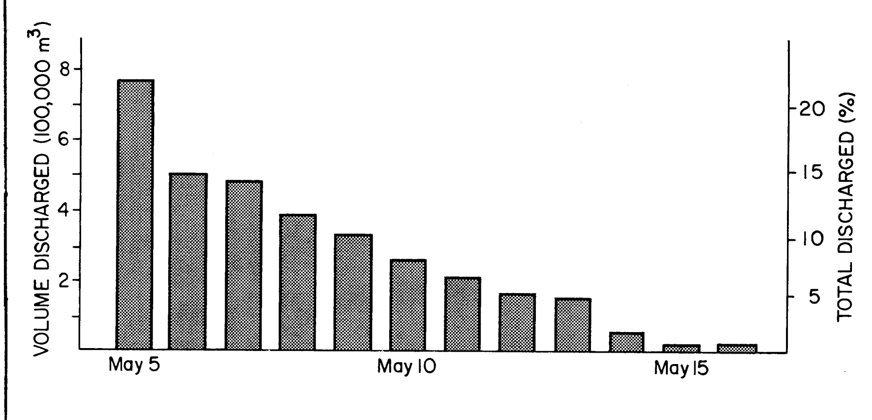


FIGURE 3. *Water volume discharged daily during the drawdown of the Machickanee Flowage, 5-16 May 1981.*

Movement of Flowage Sediment

Seventy-two hours after the drawdown began, scouring of the river channel also began at the upper end of the flowage, increasing turbidity. Disturbed sediment became suspended in the main flow and eventually moved into the river below the flowage. Water samples collected at three sites downstream from the flowage indicated that the concentration of suspended solids reached a high of 588 mg/L on 14 May 1981, ten days after the drawdown began. Suspended solids concentrations returned to the pre-drawdown (background) level of 15 mg/L on 1 July 1981 (Fig. 4).

We learned by sampling water from the three sites that most of the sediment discharged from the flowage settled first in the river, and only a proportionately small quantity was discharged directly to Green Bay. The upper two sampling sites had high concentrations of suspended solids, while samples taken near the mouth of the river had low concentrations (Fig. 4).

The quantity of sediment that settled in the river was estimated in July 1981 to be approximately 16,820 m^3, 1% of the total estimated volume in the flowage before the drawdown began. Because some of the sediment moved directly to Green Bay, the original estimate of 25,229 m^3 total discharge of sediment was fairly accurate. We estimated this amount by multiplying the area the river channel originally occupied within the flowage basin by the sediment depth within each sediment depth contour. We created a sediment depth contour map in 1979 to estimate the total sediment volume in the flowage basin. The sediment that settled in the river was flushed to Green Bay during spring runoff in 1982.

Suspended solid concentrations increased during the drawdown, but DO concentrations and BOD_5 remained within acceptable limits. At Stiles Dam the DO concentration did not drop below 9.2 mg/L, even though at one point the suspended solid concentration there was 584 mg/L. The DO concentrations ranged from 9.2-11.8 mg/L, and BOD_5 ranged from 3.1-4.9 mg/L (Table 2).

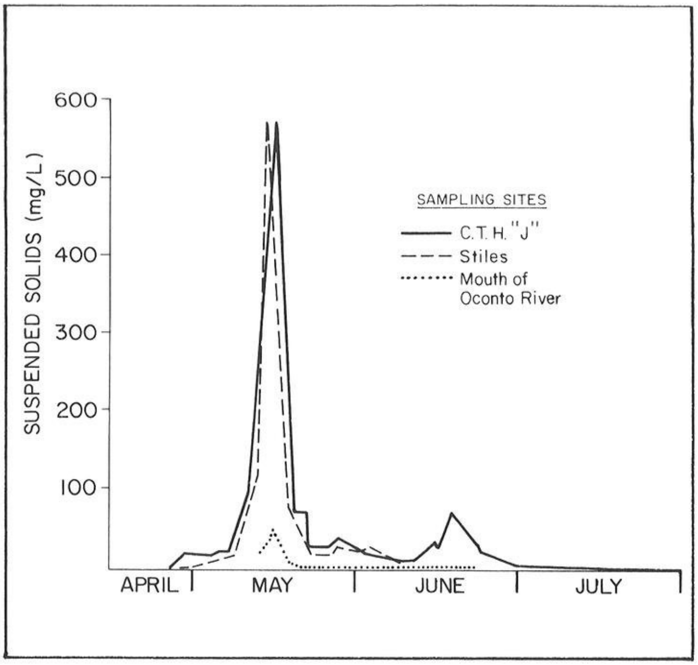


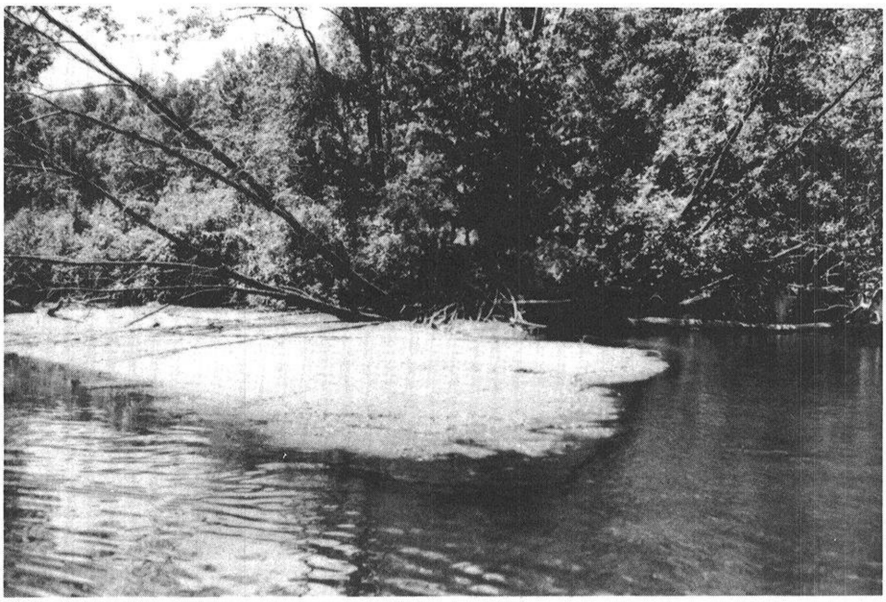
FIGURE 4. *Suspended solids monitored at three sites on the Oconto River downstream from the Machickanee Flowage, 1981.*

TABLE 2. *Dissolved oxygen, temperature, flow, suspended solids, and biochemical oxygen demand of the Oconto River at Stiles Dam, April 1981 - to July 1981.*

Date	Time	DO (mg/L)	Temp. (C)	Flow (m^3/sec)	SS (mg/L)	BOD_5 (mg/L)
27 Apr 1981	1150	11.3	11.0	30.6	6	—
29 Apr 1981	920	12.0	8.5	26.5	5	—
5 May 1981	2105	10.3	13.0	54.9	6	—
6 May 1981	0710	9.6	11.5	50.1	8	—
7 May 1981	1030	10.0	12.5	54.1	11	1.6
7 May 1981	1310	10.0	13.0	—	11	0.8
8 May 1981	1025	9.2	12.5	52.1	12	2.0
11 May 1981	1005	9.4	9.0	Avg.	72	4.3
	1205	9.8	10.0	33.7	84	4.3
	1540	9.4	11.5	—	84	3.7
12 May 1981	0905	9.1	9.5	Avg.	102	4.6
	1330	9.7	13.0	29.2	116	—
13 May 1981	1245	10.1	13.5	25.9	584	8.2
15 May 1981	1305	11.8	17.0	22.8	376	8.2
18 May 1981	1100	9.1	14.0	18.4	116	4.9
21 May 1981	1120	9.4	16.5	15.8	70	3.1
22 May 1981	1315	9.8	18.0	14.1	44	—
26 May 1981	1300	8.9	19.0	15.7	46	3.3
27 May 1981	1345	11.9	18.5	18.9	49	3.4
8 Jun 1981	1440	10.0	21.5	12.7	28	3.7
1 Jul 1981	1417	12.3	23.5	12.9	14	4.1

From 5-14 May 1981 DO concentrations at CTH J ranged from 8.6-10.7 mg/L, and BOD_5 ranged from 2.0 mg/L on 7 May to 10 mg/L on 14 May 1981 (Table 3). At this site monitoring continued until 15 September 1981. The DO concentration never dropped below 7.9 mg/L, and the BOD_5 concentration never exceeded 9.2 mg/L. The highest concentration of suspended solids recorded during the drawdown was observed at this site on 14 May 1981 (588 mg/L).

DO concentrations in the city of Oconto during the drawdown did not fall below 8.1 mg/L. A low of 7.1 mg/L was observed on 15 May 1981, one day after completion of the drawdown (Table 4). The BOD_5 concentration reached a high of 9.2 mg/L on 15 May 1981, as did the concentration of suspended solids (55 mg/L). Concentrations of DO, suspended solids, and BOD_5 at these sites were not considered indicative of damage to fish or other biota of the river.



Sediment flushed from the Machickanee Flowage settled on the inside of river bends and in eddies.

Water Quality Ratings and Collection of Macroinvertebrates

We rated water quality during 1981 as good at the sampling site on CTH BB and, at the sampling site just above the Machickanee Flowage, as good to very good. Water quality above the Machickanee Flowage was therefore comparable to water quality above the project area. One invertebrate sample was collected in September on the exposed river channel of the upper Machickanee Flowage. This area upstream from Stiles Dam was one of the first to be scoured during the drawdown. The sample showed that invertebrates were populating the new habitat created by the drawdown. We rated water quality at this site as good.

We collected one invertebrate sample at the sampling site on U.S. 141 on the day of the drawdown. Water quality was good at that time. Macroinvertebrate samples taken less than a month later showed that the water quality dropped to fair, but it returned to a good rating in September 1981. This suggests that the drawdown had a short-term adverse impact on water quality immediately below the flowage.

TABLE 3. *Dissolved oxygen, temperature, flow, suspended solids, and biochemical oxygen demand of the Oconto River at County Highway J, 27 April 1981 - 15 September 1981.*

Date	Time	DO (mg/L)	Temp. (C)	Flow (m^3/sec)	SS (mg/L)	BOD_5 (mg/L)
27 Apr 1981	1130	11.8	11.0	32.0	8	—
29 Apr 1981	900	11.5	8.0	34.0	19	—
5 May 1981	1255	9.0	12.5	—	12	—
	1410	9.1	13.0	—	8	—
	1720	9.6	13.0	Avg.	8	—
	1910	9.8	13.0	60.9	9	—
	2040	10.3	12.0	—	—	—
	2225	10.7	12.0	—	8	—
	2307	—	—	—	—	—
6 May 1981	0250	9.5	12.0	Avg.	12	—
	0515	9.5	12.0	63.7	10	—
7 May 1981	1005	9.6	12.0	Avg.	12	2.0
	1330	10.0	14.0	62.6	11	2.5
8 May 1981	1005	8.6	13.0	58.9	12	2.0
11 May 1981	0945	9.3	9.0	Avg.	41	3.7
	1220	9.4	10.0	36.0	58	3.7
	1520	10.1	11.0	—	68	4.3
12 May 1981	0850	8.9	9.0	Avg.	78	5.1
	1355	9.2	13.5	32.0	92	3.8
13 May 1981	0900	8.6	10.5	28.9	356	12.0
14 May 1981	1115	8.6	12.5	25.2	588	10.0
15 May 1981	1215	10.2	16.5	24.6	368	9.2
18 May 1981	1020	7.9	13.5	19.7	114	5.3
19 May 1981	0900	8.3	12.5	18.0	110	—
21 May 1981	1102	7.9	16.5	17.1	120	4.6
22 May 1981	1245	8.1	17.5	15.6	49	—
26 May 1981	1340	8.4	19.0	17.3	49	3.3
27 May 1981	1410	11.3	18.5	19.7	57	4.0
2 Jun 1981	0900	8.3	16.0	13.8	39	3.5
3 Jun 1981	0930	8.6	17.5	Avg.	53	4.3
	1330	9.4	21.5	15.8	50	3.7
4 Jun 1981	1300	10.5	21.0	15.0	30	2.4
8 Jun 1981	1420	10.1	21.0	12.8	22	4.1
11 Jun 1981	1230	12.1	21.5	12.1	25	—
15 Jun 1981	1415	8.1	21.5	13.1	70	7.4
16 Jun 1981	1005	8.0	21.0	13.6	53	4.5
18 Jun 1981	0850	8.0	19.0	19.5	96	6.1
22 Jun 1981	1350	9.3	19.0	21.1	57	5.3
23 Jun 1981	1345	9.7	20.0	18.6	33	2.9
29 Jun 1981	1350	9.1	21.0	13.1	25	3.3
1 Jul 1981	1417	12.3	23.5	12.4	14	4.1
9 Jul 1981	1245	10.5	27.0	10.2	16	4.1
23 Jul 1981	0845	8.1	18.0	8.3	8	1.8
29 Jul 1981	1420	12.6	21.0	8.3	2	2.1
15 Sep 1981	0945	10.0	17.0	5.7	1	1.2

TABLE 4. *Dissolved oxygen, temperature, flow, suspended solids, and biochemical oxygen demand of the Oconto River at Oconto, Wisconsin, 13 May 1981 - 23 June 1981.*

Date	Time	DO (mg/L)	Temp. (C)	Flow (m^3/sec)	SS (mg/L)	BOD_5 (mg/L)
13 May 1981	1430	10.1	13.5	28.9	20	1.8
14 May 1981	1400	8.1	13.5	25.2	36	2.3
15 May 1981	1107	7.1	16.5	24.6	55	9.2
18 May 1981	1345	8.0	15.0	19.7	20	2.5
21 May 1981	1230	7.3	19.0	17.1	12	3.7
27 May 1981	1500	9.7	16.5	19.7	6	3.7
3 Jun 1981	1015	9.1	20.5	Avg.	9	2.0
	1400	7.6	21.5	15.8	8	2.4
23 Jun 1981	1300	7.7	20.0	18.6	12	2.9

TABLE 5. *Total number, estimated weight, and average length of game fish and estimated total weight and average length of rough fish removed by chemical treatment with rotenone from 10 km of the Oconto River, 9 September 1981.*

Species	Total No. Fish	Weight* (kg)	Avg. Length (cm)
Game fish			
Walleye	64	376.9	40.0
Smallmouth bass	888	226.8	23.4
Northern pike	126	173.7	57.2
Lake sturgeon	3	27.2	115.6
Chinook salmon	19	134.7	81.3
Rainbow trout	131	377.8	58.2
Pink salmon	2	2.3	52.3
Brown trout	109	239.9	56.4
Rough fish			
Common carp		19,386.4	43.2
Suckers		615.5	30.5
Minnows		11.3	—
Burbot		1.0	—

*Total weight of fish removed = 21,785.6 kg (93% rough fish, 7% game fish by weight).

CHEMICAL TREATMENT OF THE MACHICKANEE FLOWAGE

During the chemical treatment, 21,785.6 kg of fish were removed from the Machickanee Flowage (Table 5). Game fish accounted for only 7% of this total, and trout and salmon accounted for 50% of the game fish total. These salmonids were not native to the Machickanee Flowage but were fish from Green Bay on their annual spawning run up the river.

We tried to rescue stressed game fish of all species by placing them on the downstream side of the catch net in un-

During chemical treatment of the Machickanee Flowage, fish were collected below Stiles Dam.

treated water, but we were unsuccessful. A better approach, particularly for public relations, would have been to place stressed fish in holding tanks and return only those fish that would survive.

It was difficult to determine precisely when to stop detoxification. Rhodamine WT did not effectively delineate the trailing edge of the rotenone prism. Moreover, the trailing edge passed the detoxification station at night, making visual detection of the fluorescein dye impossible and thus compounding the problem. A solution would have been to set up a gas chromatograph capable of detecting rotenone at the lower end of the treatment zone to provide instantaneous detection of in-stream concentrations. The necessary concentration of potassium permanganate required for detoxification could then have been determined immediately and adjusted accordingly.

We thought at first that all fish species had been killed. Later surveys showed that the treatment did not kill all species, since black bullheads previously fin-clipped in the flowage were recaptured.

WATER QUALITY

BOD_5

Concentrations of DO were often less than 2.9 mg/L during the summer before the pulp mill closed in February 1978. Lack of sufficient DO caused periodic fish kills and limited fishing. Since mid-1978 DO levels have remained above 5 mg/L, except in 1982 and 1983 when concentrations briefly fell below that level in the hypolimnion of the Machickanee Flowage.

Water quality improved rapidly after the pulp mill closed in February 1978. Through much of the 1970s extremely high BOD_5 had been measured as far downstream as the city of Oconto. Discharge of BOD_5 from the pulping operation often exceeded 18,000 kg/day. In-stream BOD_5 loadings below the pulp mill from 1975 to February 1978 often exceeded 13,000 kg/day and were occasionally as high as 60,000 kg/day. Loadings exceeded 13,000 kg only three times from 1978, when the mill closed, through 1982: once in 1980, once during the drawdown of the Machickanee Flowage in 1981, and once in 1982. Except for these three exceptions, loadings have ranged from 200 to 8,000 kg/day. For comparison of conditions before and after the mill closed, consider that daily average BOD_5 discharge from the outfall of the Scott Paper Company in 1983 was only 1% of the discharge that occurred in December 1977 alone.

Ammonia Nitrogen

Ammonia nitrogen loading was also very high before pulping stopped. In 1977 1,100 metric tons of ammonia nitrogen were discharged to Green Bay via the Oconto River. The Scott Paper Company was the only heavy industry on the river at that time. The Fox River, with one of the greatest concentrations of pulp and paper mills in the world, discharged 740 metric tons that same year. The flow of the Oconto River is equal to approximately 14% of the flow of the Fox River, yet it exceeded the Fox River in annual discharge of ammonia nitrogen, sometimes by almost double. Again to compare conditions before and after the closing of the pulp mill, consider that ammonia levels in 1982 were 4.5% of what they were in December 1977.

Chlorophyll-*a*

Chlorophyll-*a* is an indicator of algae abundance, and high levels were measured in the Machickanee Flowage in 1978 and 1980. Levels were lower in 1982-83. Macrophyte populations after the 1981 drawdown continuously expanded, which could have resulted in an uptake of nutrients previously available for algae growth.

Water net or *Hydrodictyon* was seen in 1982, and masses of this material floating on the surface were a nuisance along the windward shores. Along with a decrease in chlorophyll-*a*, planktonic algae appeared to decrease in 1983 and 1984.

Periphyton

A shift from pollution-tolerant organisms to a more desirable (less tolerant) biota occurred after the pulp mill closed in February 1978. Before the mill closed, *Sphaerotilus natans* (a type of filamentous bacteria) covered almost all substrate of the river from the mill to the river mouth (Marshall et al. 1979). Surveys conducted in October 1978 and January 1979 revealed no slimes, except for an area just downstream from the Oconto Falls municipal treatment plant and Scott Paper Company outfall. Slimes occurred at this site only from 1978 on.

Heavy Metals in the Water Column and Vegetation of the Machickanee Flowage

Because sediment from the Machickanee Flowage was contaminated with heavy metals, the ORC anticipated the potential for exchange of heavy metals from the sediment to the flowage water column.

Mercury concentrations in the flowage water column were above minimum detectable levels on four occasions from September 1979 to September 1983, with the highest reading at 0.4 μg/L. Eleven of the 15 samples collected exhibited no detectable concentrations (Table 6).

Mercury concentrations of unpolluted rivers in 31 states where natural mercury deposits are unknown are less than 0.1 μg/L (Wershaw 1970). The USEPA suggests that livestock tissue with concentrations not exceeding 0.5 μg/L may be safely consumed. Mercury was not considered a threat to the flowage ecosystem through 1983. We planned to continue periodic monitoring to ensure that future concentrations did not become excessive.

Other heavy metals for which tests were conducted—cadmium, lead, arsenic, copper, nickel, zinc and chromium—were below detectable limits, except for chromium. Chromium was detected at a concentration of 34 μg/L in a water column sample taken in September 1979, but it was not detected in 13 later samples. The high concentration from September 1979 may have been due to a sampling error or an analytical error.

Arsenic concentrations from two vegetation sampling sites in the Machickanee Flowage in 1981 were 2.8 mg/kg and 1.7 mg/kg. The concentration at the single site sampled in 1983 was 16 mg/kg. Chromium measured at one site in the flowage was 10 mg/kg in 1981 and 20 mg/kg in 1983. Higher concentrations of metals were detected in September 1983 (Table 7). Based on water quality analyses, the metals in the vegetation did not appear to be entering the water column.

Ground Water Contamination

We examined the possibility of ground water contamination from the leaching of heavy metals from flowage sediment. Six private wells near the Machickanee Flowage were tested, and the concentrations found were all below detectable limits.

Water Quality Ratings in the Lower Oconto River

Based on aquatic invertebrate samples collected during the 1960s, we know that during the pulping operation the water quality of the Oconto River below the mill was poor (Marshall et al. 1979). The ratings quickly improved to fair and then to

TABLE 6. *Heavy metal concentrations measured in the Machickanee Flowage water column at Stiles Dam, 5 September 1979 - 22 September 1983.*

Date	Depth (m)	Mercury (μg/L)	Cadmium (μg/L)	Lead (μg/L)	Arsenic (μg/L)	Chromium (μg/L)	Copper (μg/L)	Nickel (μg/L)	Zinc (μg/L)
5 Sep 1979	5	*	*	*	*	34	*	*	*
	3	0.2	*	*	*	*	*	*	*
21 Oct 1981	1	—	*	*	*	*	—	*	—
	5	*	*	*	*	*	—	—	—
8 Mar 1982	1	*	*	*	*	*	—	—	—
30 Sep 1982	1	*	*	*	*	*	—	—	—
	5	*	*	*	*	*	—	—	—
2 Aug 1982	1	*	*	*	*	*	*	*	*
	4	0.3	*	*	*	*	*	*	*
15 Feb 1983	1	*	*	*	*	*	—	—	*
	5	0.2	*	*	*	*	—	—	*
20 Apr 1983	6	*	*	*	*	*	—	—	*
27 Jul 1983	1	*	*	*	*	*	*	—	*
	5	0.4	*	*	*	*	*	—	*
22 Sep 1983	1	*	—	—	—	—	—	—	—
	5	*	—	—	—	—	—	—	—

*Indicates levels below detectable limit.

TABLE 7. *Concentration of heavy metals in vegetation in the Machickanee and Oconto Falls flowages, 21 October 1981-23 September 1983.*

Site	Date	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	Nickel (mg/kg)	Copper (mg/kg)
Machickanee Flowage (middle)	21 Oct 1981	2.8	*	10	*	0.04	—	—	—
Machickanee Flowage (upper)	21 Oct 1981	1.7	*	10	*	0.04	—	—	—
Oconto Falls Flowage (Monkey Island)	21 Oct 1981	8.9	*	10	*	0.03	—	—	—
Oconto Falls Flowage (public beach)	21 Oct 1981	12.0	*	30	*	0.04	—	—	—
Machickanee Flowage (upper)	23 Sep 1983	16.0	*	20	40	0.10	62	10	22

*Indicates levels below detectable limit.

very good after the mill closed in February 1978.

Water quality improved progressively over time, with exceptions. From June 1979 through late October 1979, ratings ranged from good to very good. Succeeding fall samples through 1983 indicated good water quality ratings. Exceptions to this improvement occurred during spring in 1981, 1982, and 1983, when only fair ratings were observed. The fair rating in spring 1981 may have been associated with a decrease in water quality because of the drawdown. As the drawdown proceeded, water quality appeared to decrease progressively. Once the flowage was completely drawn down and sediment loading of the river decreased, water quality downstream from the mill improved progressively until all sites were rated as good to very good by November 1981. Therefore, while the drawdown negatively affected water quality, the duration of the impact was short. We do not know the reason for the decrease in water quality ratings in the springs of 1982 and 1983.

A very poor rating was recorded in the Oconto River in 1982, suggesting that the river system was contaminated or enriched between November 1981 and June 1982, probably from Oconto Falls.

Water quality at the sampling site on CTH J was rated as fair in 1978, as good in 1979 and spring 1980, and as fair in fall 1980. In spring of 1981, 1982, and 1983, water quality was rated as fair. Fall ratings during these years were good.

At Suzie's Rapids water quality ratings improved to a good rating in 1979 and from 1979 to 1983 remained within the good to very good range. No spring decreases to fair ratings occurred, as was observed at upstream sites, suggesting that water quality was not negatively impacted by the 1981 drawdown, as it was in the upstream sites. Observations from the sampling location at US 41 were similar to those from Suzie's Rapids.

SEDIMENT

Volume

Most of the bottom of the Machickanee Flowage was covered with a thick layer of fine flocculent sediment. This material had a jelly-like consistency and in places was nearly 3 m deep. The estimated volume of the sediment before the drawdown (1979) was 1,543,700 m^3. Volumes calculated for both early summer and fall 1979 were the same, which was surprising since flows of the Oconto River passing through the flowage were higher than normal during the summer of 1979. Because much of the sediment was flocculent, we expected that the volume would decrease by fall due to scouring throughout the summer; however, this did not occur.

Results of Chemical Analysis (1979)

Through chemical analysis in 1979, we learned that the sediment was polluted with or by concentrations of BOD_5, lead, total phosphorus, manganese, nickel, arsenic, cadmium, chromium, copper, iron, mercury, zinc, and volatile solids (Table 8). These items exceeded USEPA limits for sediments in Great Lakes harbors. Results of elutriate analysis showed that these pollutants were not entering the water column at appreciable levels (Table 9). Apparently the sediment was chemically stable, and water quality was not adversely affected by sediment in the flowage.

TABLE 8. *Chemical analysis of bottom sediment from five sites in the Machickanee Flowage, 1979.**

Parameter	Site				
	1	2	3	4	5
Total solids (%)	8.28	—**	7.77	6.87	7.73
Volatile solids (%)[a]	36.10	—	35.60	33.90	34.40
COD	567,000.00	—	537,000.00	566,000.00	557,000.00
Kjeldahl nitrogen	18.30	—	12.30	12.20	15.00
Oil and grease	14.80	—	19.20	21.00	12.00
Mercury	6.80	—	5.80	3.00	4.00
Lead	<210.00	—	<230.00	<250.00	<270.00
Zinc	24.00	—	24.00	39.00	22.00
Total phosphorus	1,040.00	—	476.00	1,033.00	750.00
Ammonia nitrogen	0.93	—	0.60	0.30	1.13
Manganese	345.00	—	230.00	150.00	300.00
Nickel	42.00	—	45.00	100.00	55.00
Arsenic	6.00	—	6.00	6.00	6.00
Cadmium	<10.00	—	<11.00	<12.00	<14.00
Chromium	<114.00	—	<125.00	<137.00	<150.00
Magnesium	10,040.00	—	860.00	8,110.00	8,230.00
Copper	43.00	—	48.00	37.00	18.00
Iron	17,400.00	—	19,200.00	25,100.00	19,800.00
PCB	<0.26	—	<0.22	<0.27	<0.31
Sulfate	96,600.00	—	—	58,200.00	48,600.00
Sulfide	217.00	—	220.00	1,063.00	350.00
Sulfite	3,040.00	—	1,090.00	10,100.00	5,160.00

*All analyses listed are mg/kg dry weight unless otherwise indicated.
**Insufficient sample for analysis.
[a]Shaded values exceed USEPA limits for sediments in Great Lakes harbors. Parameters that are not shaded are not listed in USEPA index.

Results of Static Bioassay

Results of the laboratory static bioassay indicated that, even when disturbed, Machickanee Flowage sediment did not release concentrations of pollutants to the water column in quantities sufficient to cause immediate mortality of fathead minnows and adult crayfish. After 91 hours in an aquarium containing agitated sediment from the Machickanee Flowage, only 7 of 112 fathead minnows died. In the aquarium containing sediment from the Oconto Falls Flowage 2 out of 56 fathead minnows died within the same period. These results represented 6% and 4% mortality of the fathead minnows, respectively. None of the 6 crayfish in the two aquaria died. These results suggest that sediment flushed from the Machickanee Flowage during a drawdown would not create toxic levels of pollutants in the water column.

TABLE 9. *Chemical analysis of sediment sample elutriate from five sites in the Machickanee Flowage, 1979.*

Parameter	Site				
	1	2	3	4	5
COD (mg/L)	52.000	48.000	62.000	42.000	48.000
Total organic carbon (mg/L)	15.000	9.000	15.000	15.000	13.000
Kjeldahl nitrogen (mg/L)	14.100	0.660	9.770	6.560	7.220
Ammonia nitrogen (mg/L)	4.070	0.050	2.720	6.190	5.680
Nitrate nitrogen (mg/L)	0.040	0.060	0.040	0.176	0.025
Nitrite nitrogen (mg/L)	0.018	0.024	0.011	0.014	0.008
Total phosphorus (mg/L)	0.230	0.060	0.240	0.160	0.100
Ortho phosphorus (mg/L)	0.210	0.020	0.180	0.090	0.050
Arsenic (μg/L)	2.000	0.500	21.000	5.000	5.000
Cadmium (μg/L)	<3.000	<3.000	<3.000	<3.000	<3.000
Chromium (μg/L)	<70.000	220.000	<70.000	<70.000	<70.000
Copper (μg/L)	<30.000	<30.000	<30.000	50.000	<30.000
Iron (μg/L)	2,100.000	480.000	1,950.000	340.000	1,420.000
Lead (μg/L)	<200.000	<200.000	<200.000	<200.000	<200.000
Mercury (μg/L)	5.800	2.100	8.200	2.200	4.700
Nickel (μg/L)	63.000	<40.000	<40.000	<40.000	<40.000
Zinc (μg/L)	<10.000	<10.000	<10.000	<10.000	<10.000
PCB (μg/L)	<2.000	<2.000	<2.000	<2.000	<2.000

Results of Compaction Studies

Sediment placed in the experimental wooden bins before the drawdown compacted rapidly when drying. Bin samples compacted 72% after 113 days. Ninety percent of the compaction occurred within the first 22 days. Substantial cracking of the sediment also occurred with cracks extending vertically from the top to the bottom of the bins.

Because the bins were placed on a dry upland site, we feel that the experiment simulated a near-maximum rate and degree of compaction of drawn down sediment. Sediment placed in open glass containers decreased 75% in volume when dry, and sediment in the sealed glass container decreased 30% in volume.

Sediment During the Drawdown: Volume, Compaction, and Consistency

The drawdown greatly reduced the volume of sediment in the flowage. In July 1982 the flowage contained approximately 761,940 m^3 of sediment, a 49% reduction from the estimated volume before the drawdown in 1979.

During the drawdown the sediment compacted vertically, contracted horizontally, and hardened, as predicted from the bin study. Compaction created hard, dry blocks of sediment, visibly different from the original flowage bottom. We walked or drove a three-wheeled vehicle on the compacted sediment.

Most of the sediment remained in place during the drawdown. The only significant amount of sediment flushed from the flowage was from the original river channel. First the main channel was flushed, then sediment was sloughed into the main channel from attached oxbows. Periodic rainfall and running springs also contributed small amounts of sediment to the main channel. We estimated the total amount of sediment flushed from the flowage during the drawdown to be 16,820 m^3.

Compaction varied from site to site within the flowage, and the rate of compaction decreased over time. Total vertical compaction was 42% in the upper one-third of the flowage, 49% in the middle one-third, and 26% in the lower one-third, with most compaction occurring within the first 22 days after the flowage was drawn down (Table 10). Sediment that was initially between 100 cm and 150 cm deep showed the most compaction (Table 11).

We observed that sediment comprised of sawdust-sized particles and larger wood chips compacted less than finer, originally more flocculent material. At the upper end of the flowage the sediment consisted of coarse wood chips, while at the lower end it was composed of fine, flocculent organic matter.

Horizontal contraction was substantial. Contraction resulted in a lattice of cracks often extending to the original flowage bottom, and these cracks exposed an estimated 5-10% (roughly 9-19 ha) of the original flowage bottom. Many plants later rooted in the substrate exposed by these cracks.

When dried, sediment on some elevated areas of the flowage was light and loose enough to be windblown; this exposed 4-6 ha of "clean" sand substrate. Additional areas of gravel or rubble substrate were not exposed. These substrates occurred only in limited areas near shorelines and originally held little accumulated sediment.

Following the drawdown, project personnel were able to walk on the compacted sediment of the Machickanee Flowage.

DISTRIBUTION AND ABUNDANCE OF ZOOPLANKTON BEFORE AND AFTER THE DRAWDOWN

The structure of the zooplankton population in the Machickanee Flowage changed significantly following the 1981 management activities. Marshall (1980) reported that in 1979 zooplankton were small and scarce. *Bosmina longirostris* and *Eubosmina* species were the dominant zooplankters. Rotifers were diverse (at least 23 species) and often as abundant as one or more per liter. Populations in 1979 exhibited characteristics of those living in a riverine situation (Marshall et al. 1979). A more lake-like zooplankton assemblage existed in the flowage in 1982-83. *Bosmina* continued to dominate at the peak of its abundance, but seven other common cladoceran species existed. Of those seven, all but one, *Chydorus sphaericus*, are larger than *Bosmina*. Two cyclopoid copepods, *Acanthocyclops vernalis* and *Machrocyclops albidus*, were also more abundant in 1982-83 than in 1979.

Marshall et al. (1979) also reported the presence of *Eubosmina* sp. in the flowage in 1979. It was dominant and abundant at one location. All the animals examined in the 1982-83 samples were *Bosmina longirostris*. Goulden (1964) and others have suggested that a shift from dominance by *Eubosmina* to *Bosmina* shows a process of eutrophication, but this explanation could be a misinterpretation of the situation in the Machickanee Flowage in 1982-83. More likely, the shift in species probably indicated a change in the available food supply. Since zooplankton were more numerous in the 1982-83 samples despite a higher population of planktivorous fish before 1981, more phytoplankton were probably available to the zooplankton.

A puzzling aspect of the zooplankton association in 1982-83 was the low density of cyclopoid copepods. *Machrocyclops* showed an increasing density from 1982 to 1983, perhaps in response

TABLE 10. *Sediment compaction in the Machickanee Flowage during three periods in 1981.*

Location	% Vertical Compaction 15 May-5 Jun	5 Jun-1 Jul	1 Jul-17 Aug	Total
Upper flowage	34	6	2	42
Middle flowage	43	2	4	49
Lower flowage	25	5	-4	26

TABLE 11. *Sediment compaction in the Machickanee Flowage at five depth intervals.*

Sediment Depth (cm)	% Vertical Compaction 15 May-5 Jun	5 Jun-1 Jul	1 Jul-17 Aug	Total
50	39	9	-5	43
50-100	37	3	2	42
100-150	41	8	3	52
150-200	11	2	1	14
200-250	14	0	1	15

During the drawdown, lush vegetation flourished on the bottom of the Machickanee Flowage.

to the high densities of *Bosmina*, a food for the larger developmental stages of *Machrocyclops*. We expected that *Acanthocyclops* or another copepod species would be more common than the cladocerans, especially in a situation of moderate fish predation (Zaret, 1980). Rotifers showed little change from 1979 to 1983. We observed 20 species in 1982-83, and densities were similar to those reported in 1979.

The many zooplankton species commonly found in vegetation probably reflected the extensive beds of vegetation that developed after the drawdown. However, the species more characteristic of open water were also more common at collection sites located in vegetation. Planktivorous fish feed by visually locating prey; therefore these fish have the greatest impact on zooplankton in open water (Zaret 1980). Thus, vegetation was probably a refuge for the open water zooplankton species. If there were few or no planktivorous fish in the flowage, the open water species would still have been living in vegetation, but they would have been more common in open water. In late 1981, 1 L of *Daphnia galeata mendotae* from Green Lake was stocked in the Machickanee Flowage to increase the food base for the many fry and fingerling fish to be stocked in 1982. The flowage hosted a large population of this daphnid by summer 1982. Unfortunately, we cannot say whether the inoculum from Green Lake was totally responsible for the abundance of *Daphnia* noted in 1982. *Daphnia* could also have been introduced upstream or by waterfowl depositing resting eggs; *Daphnia* may have been present in numbers too low to detect in 1979.

Though many planktivorous fish either migrated to or were stocked in the flowage, the size structure of the zooplankton population in 1982-83 suggested that fish predation was not excessive. Other factors confirming that the fish in the flowage did not eat an extreme amount of plankton include the presence of a small population of intermediate-sized *Daphnia galeata mendotae* and *Diaphanosoma* spp., a dense population of *Bosmina* spp., and the lack of large zooplankton such as *Daphnia pulex* (Brooks and Dodson 1965, Galbraith 1967, Zaret 1980).

For those species that had been stocked, we compared the zooplankton densities before and after the introduction of the fish. None of the observations suggested that the stocking program acutely affected the zooplankton populations. The major zooplankton populations showed considerable variation, but the variation did not seem to be correlated with instances of fish stocking (Fig. 5). Except for *Bosmina*, *Daphnia* and *Machrocyclops*, the zooplankton species were less common in 1983 compared to 1982. However, these were small decreases, and the increases in *Bosmina* and especially *Daphnia* indicate that competitive interaction between the zooplankton species, rather than fish predation, may have been responsible for the changes.

Much of the flowage was occupied by rooted macrophytes in 1982 and 1983, with the associated aufwuchs, microcrustaceans, and insects. The number of zooplankton may have been insignificant as a food source for fish larvae. The existence of some *Daphnia* suggested that zooplankton were still available as a supplement to food associated with vegetation.

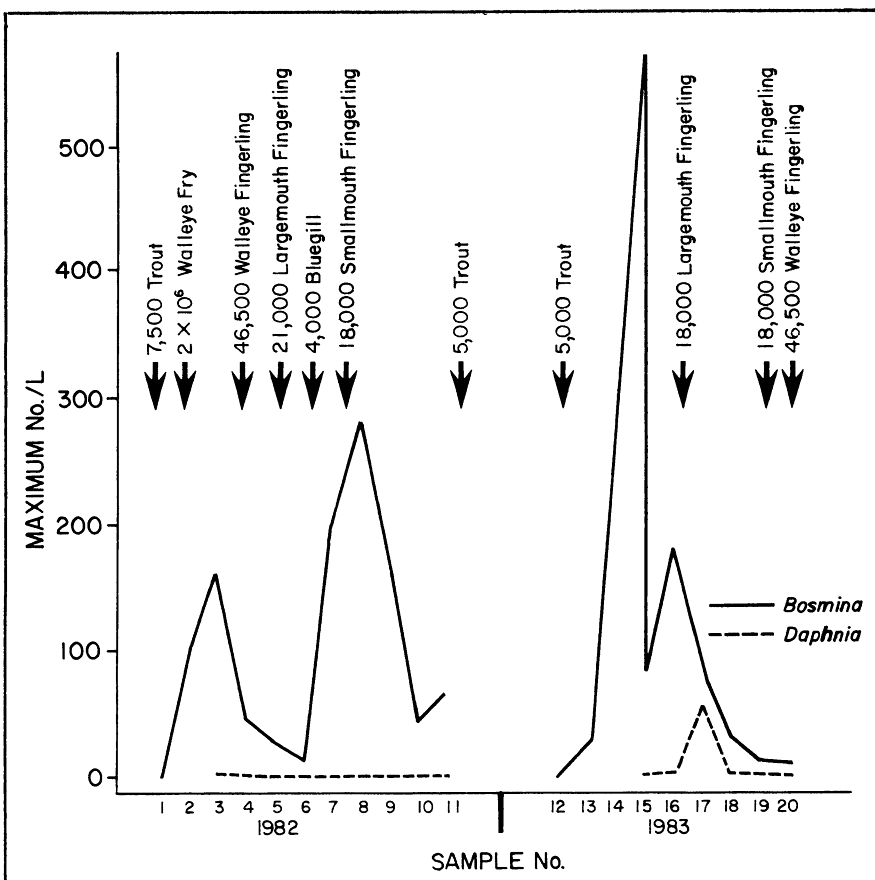


FIGURE 5. *Numbers of* Bosmina *and* Daphnia *compared to instances of fish stocking in the Machickanee Flowage, 1982 and 1983.*

AQUATIC MACROPHYTES BEFORE AND AFTER THE DRAWDOWN

Before the drawdown the Machickanee Flowage was unable to support aquatic plant life similar to that found in the Oconto Falls Flowage, probably because of the unconsolidated, flocculent bottom sediment in the Machickanee Flowage. Vegetation was found in 17 of 524 sites sampled before the drawdown in the Machickanee Flowage, and only three genera were identified (Table 12). By contrast, the Oconto Falls Flowage contained a rich, diverse flora normally expected in Wisconsin lakes and flowages (Table 13).

The change in the aquatic plant community after the drawdown was noticeable. The Machickanee Flowage supported a more diverse flora than it had before, as shown from the samples taken in August 1982 and 1983. One year after the drawdown, emergent vegetation such as *Sagittaria, Leersia, Scirpus,* and *Typha* flourished in the Machickanee Flowage (Table 14). Populations were advancing successionally from an emergent community to a submergent community in 1983 (Table 15). The Oconto Falls Flowage upstream contributed to the rapid repopulation of the Machickanee Flowage, as shown by the similar species composition of the two flowages.

The chemical composition of the sediments in the Machickanee Flowage changed little before and after the drawdown; therefore, this was not a major factor inhibiting plant growth in the flowage. The improvement in the numbers and types of aquatic macrophytes after the drawdown is due to the change in the consistency of the sediment from flocculent to a firmer, more consolidated material.

AQUATIC MACROINVERTEBRATES BEFORE AND AFTER THE DRAWDOWN

In the Machickanee Flowage

Chironomid larvae were the only invertebrates inhabiting the sediments of the Machickanee Flowage before the drawdown. The sediment of the Oconto Falls Flowage, by comparison, hosted a more diverse representation of benthic organisms, including abundant burrowing mayfly (*Hexagenia limbata*), midge larvae (*Cryptochironomus* spp. and *Procladius* spp.), and representatives of the *Pentaneurini* group (McNaughton 1980).

TABLE 12. *Percent occurrence and relative abundance of species in 524 quadrats (131 sampling sites) in the Machickanee Flowage, July 1980.*

Species	Occurrence No.	Occurrence %	Relative Abundance (%) Abundant	Common	Present
Nymphaea spp.	9	2	1	1	2
Potamogeton spp.	5	1	1	0	0
Ceratophyllum demersum	3	1	1	0	0

TABLE 13. *Percent occurrence and relative abundance of species in 428 quadrats (107 sampling sites) in the Oconto Falls Flowage, July 1980.*

Species	Occurrence No.	Occurrence %	Relative Abundance (%) Abundant	Common	Present
Vallisneria americana	241	56.0	26.0	26.0	4.0
Elodea canadensis	113	26.0	6.0	15.0	5.0
Potamogeton zosteriformis	98	23.0	5.0	11.0	7.0
Ceratophyllum demersum	94	22.0	3.0	9.0	10.0
Heteranthera dubia	39	9.0	0	4.0	5.0
Potamogeton amplifolius	27	6.0	0	2.0	5.0
Myriophyllum spp.	25	6.0	1.0	2.0	3.0
Lemna minor	14	3.0	0	1.0	2.0
Potamogeton epihydrus	11	3.0	0	1.0	1.0
Nymphaea spp.	10	2.0	2.0	0	0.5
Potamogeton foliosus	9	2.0	0	0.5	2.0
Butomus umbellatus	8	2.0	0	1.0	1.0
Potamogeton natans	4	1.0	0	0.5	0.1
Chara spp.	4	1.0	0	1.0	0.2
Najas flexilis	2	0.5	0	0.2	0.2
Sparganium spp.	2	0.5	0	0	0.5
Potamogeton Richardsonii	1	0.2	0	0	0.2

TABLE 14. *Percent occurrence and relative abundance of species in 524 quadrats (131 sampling sites) in the Machickanee Flowage, August 1982.*

Species	Occurrence No.	Occurrence %	Relative Abundance (%) Abundant	Common	Present
Sagittaria spp.	153	29.0	2.0	18.0	10.0
Leersia spp.	119	23.0	4.0	10.0	8.0
Scirpus validus	38	7.0	0	3.0	4.0
Ludwigia spp.	33	6.0	0	1.0	6.0
Typha spp.	28	5.0	0	1.0	4.0
Elodea canadensis	27	5.0	0.2	2.0	3.0
Potamogeton epihydrus	19	4.0	0.5	2.0	2.0
Ceratophyllum demersum	13	2.0	0	1.0	2.0
Eleocharis spp.	9	2.0	0	1.0	1.0
Potamogeton pectinatus	6	1.0	0.5	1.0	0.2
Potamogeton foliosus	6	1.0	0	0.2	1.0
Nymphaea spp.	6	1.0	0	0	1.0
Sparganium spp.	4	1.0	0	0.2	1.0
Potamogeton Richardsonii	4	1.0	0	0	1.0
Butomus umbellatus	3	1.0	0	0	1.0
Najas flexilis	2	0.5	0	0	0.5
Polygonum spp.	1	0.2	0	0	0.2
Lemna minor	1	0.2	0	0	0.2

TABLE 15. *Percent occurrence and relative abundance of species in 524 quadrats (131 sampling sites) in the Machickanee Flowage, August 1983.*

Species	Occurrence No.	Occurrence %	Relative Abundance (%) Abundant	Common	Present
Elodea canadensis	350	67.0	12.0	31.0	23.0
Ceratophyllum demersum	68	13.0	0.5	2.0	10.0
Potamogeton pusillus	53	10.0	0.2	5.0	5.0
Potamogeton foliosus	36	7.0	0	2.0	4.0
Potamogeton epihydrus	18	3.0	0	2.0	2.0
Potamogeton gramineus	15	3.0	0.2	1.0	2.0
Potamogeton nodosus	14	3.0	0	2.0	1.0
Potamogeton Richardsonii	14	3.0	0	0.5	2.0
Nymphaea spp.	12	2.0	0	1.0	1.0
Scirpus validus	10	2.0	0	1.0	1.0
Najas flexilis	9	2.0	0.2	0.2	1.0
Potamogeton zosteriformis	9	2.0	0	1.0	2.0
Potamogeton pectinatus	9	2.0	0	0	2.0
Sparganium spp.	7	1.0	0	1.0	0.2
Sagittaria spp.	4	1.0	0	0.2	1.0
Tyhpa spp.	3	1.0	0	0.2	0.5
Butomus umbellatus	2	0.5	0	0	0.5
Leersia spp.	2	0.5	0	0	0.5

TABLE 16. *Categorical quality determinations, based on Hilsenhoff (1982).*

Biotic Index	Water Quality	State of Stream
0-1.75	E = Excellent	No organic pollution
1.76-2.25	VG = Very Good	Possible slight pollution
2.26-2.75	G = Good	Some pollution
2.76-3.50	F = Fair	Significant pollution
3.51-4.25	P = Poor	Very significant pollution
4.26-5.00	VP = Very Poor	Severe pollution

The river channel coursing through the basin of the Machickanee Flowage after the drawdown in 1981 was populated with ephemeropterans, trichopterans, and dipterans. The presence of these organisms apparently resulted from downstream drift, and the newly exposed substrate was rapidly populated in both the river channel and, eventually, the refilled flowage.

An extremely large mayfly hatch occurred in the Machickanee Flowage the year following the drawdown (1982), the first such hatch observed since work on the flowage began in 1979. Thousands of mayflies were seen near the water's surface, and many casts were noted on rushes and other emergent vegetation. Many ephemeropteran nymphs were also seen swimming in shallow shoreline areas. In May 1982, ephemeropteran nymphs and dipteran larvae constituted 97% of the D-frame net samples, along with a few plecopterans.

Fewer invertebrates were collected in July and October 1982. Sampling with the D-frame net was more difficult because of an increase in the abundance of algae, decaying vegetation, and ongoing siltation. Samples collected in July were dominated by dipterans (*Gammarus* spp.) and ephemeropterans. Samples taken in October were dominated by dipterans, ephemeropterans, and *Hyalella* spp. A flowage-wide mayfly hatch was again observed in early 1983. The May 1983 samples were dominated by ephemeropterans, hyalellans, and *Asellus* spp., with a few plecopterans.

The flowage substrate, the aquatic plant populations, and the macroinvertebrate populations had not stabilized by the end of 1983. However, the macroinvertebrate populations had expanded numerically and specifically to the extent that they were similar to populations of other unpolluted water bodies. We attributed these changes to variations in the flowage substrate and to expanded aquatic macrophyte populations resulting from the drawdown. Water quality and substrate also improved upstream from the Machickanee Flowage, leading both to the rapid repopulation of the river segment between the Scott Paper Company and the flowage and to the increased drift of macroinvertebrates into the flowage basin.

In the Oconto River

During the pulping operation, most of the river bottom at a sampling site downstream from the mill was covered by sewage bacteria (*Sphaerotilus natans*). Invertebrate populations consisted of pollution-tolerant organisms, sludge worms, and midge fly larvae. If samples had been interpreted at that time with Hilsenhoff's water quality rating system (not then in use), only poor to very poor water quality ratings would have been found (Table 16).

In 1961-62 the river bottom was covered with *Sphaerotilus natans* at the US 141 sampling site just below Stiles Dam (Marshall et al. 1979). The only aquatic invertebrates found there were midge fly larvae and sludge worms. Three of four lentic species collected were pollution-tolerant organisms. In 1968 we collected only a few organisms, again pollution-tolerant species. Lush vegetation grew at the sampling site on CTH J from 1961 to 1968. Lentic organisms were principally midge fly larvae and sludge worms. Large mats of *Sphaerotilus natans* and thick vegetation also grew at Suzie's Rapids from 1961 to 1968. The substrate supported pollution-tolerant midge fly larvae and sludge worms.

By October 1978 the substrate had improved, and invertebrate populations had expanded at all sites on the lower Oconto River only eight months after the pulp mill closed.

FISH POPULATIONS

The Machickanee Flowage

Species Composition and Abundance. The Machickanee Flowage was dominated by rough fish, as shown by population estimates before the drawdown and chemical treatment. Black bullhead, yellow bullhead, common carp, and white sucker composed over 90% of the total estimated population, while black crappie, bluegill, pumpkinseed, rock bass, yellow perch, and northern pike numerically made up less than 10% of the total population. Black bullhead was the most abundant species, estimated at 148 fish/ha, followed by common carp at 145 fish/ha and white sucker at 97 fish/ha. Black crappie was the most abundant panfish at 16 fish/ha (Table 17). Forage fish, such as golden shiner (*Notemigonus crysoleucas*), fathead minnow, bluntnose minnow (*Pimephales notatus*), and common shiner (*Notropis cornutus*), were extremely abundant in the Machickanee Flowage and contributed significantly to the total biomass.

Fish populations in the Machickanee Flowage in 1982-83 reflected the results of the drawdown, chemical treatment, fish stocking, and immigration. Fourteen fish species were captured with survey gear less than nine months after the chemical treatment (Table 18). Of these, only rainbow trout had been stocked.

TABLE 17. *Population estimates and fish per hectare in the Machickanee Flowage, 1979.*

Species	Total No. Marked	Minimum Size (mm)	Population Estimate	95% Confidence Interval	No. Fish/Ha
Black bullhead	3,202	115	27,771	24,273-32,447	148
Yellow bullhead	62	115	289	166-1,115	2
Common carp	1,214	200	27,192	19,534-42,809	145
White sucker	1,165	230	18,310	13,802-27,190	97
Black crappie	751	115	3,008	2,159-3,732	16
Bluegill	388	100	1,885	1,451-2,689	10
Pumpkinseed	167	100	682	481-1,172	4
Rock bass	36	100	162	82-8,076	1
Northern pike*	318	220	1,550	1,131-2,462	8
Yellow perch	130	160	664	432-1,455	4
Total	7,434		81,513		435

*The population of northern pike was estimated in 1981.

TABLE 18. *Species and size range of 14 fish species captured with fyke nets in the Machickanee Flowage, 5-15 May 1982.*

Species	No. Caught	Size Range (cm)
Rainbow trout	125	13.9-32.2
Northern pike	10	28.5-62.9
Bluegill	27	4.8-19.0
Black crappie	21	5.0-25.5
Pumpkinseed	3	9.4-15.4
Rock bass	3	19.6-19.7
Yellow perch	16	10.6-21.8
Black bullhead	169	7.1-28.1
White sucker	43	10.6-37.2
Common carp	1	36.1
Common shiner	5	12.5-17.7
Golden shiner	11	7.6-17.2
Fathead minnow	20	6.3-7.5
Creek chub	2	—

Presence of nonstocked species was attributed primarily to downstream movement of fish from the two impoundments above the Machickanee Flowage. This movement was documented by tag returns in 1979, 1980, and 1981. None of the three dams within the project area effectively prevented downstream movement of any fish species. Another reason that nonstocked species were present was that the chemical treatment was not 100% effective in eliminating all fish from the flowage. No fish were captured during fyke-net and boomshocking surveys conducted in fall 1981. These survey results were initially interpreted as indicating a 100% kill, but this interpretation later proved to be inaccurate. Several bullheads fin-clipped during population estimates in 1979 were captured in the Machickanee Flowage in spring 1982.

The wide range of lengths and ages of fish captured during early 1982 surveys shows that recruitment to the Machickanee Flowage populations was not restricted to a particular size range or age class for any species. Both sexually mature and immature fish of most species were captured. Consequently the potential existed for in-flowage natural reproduction of northern pike, black crappie, pumpkinseed, black bullhead, white sucker, fathead minnow, golden shiner, common shiner, rock bass, creek chub *(Semotilus atromaculatus)*, and yellow perch by spring 1982. The natural reproduction of most of these species in 1982 was documented by surveys in late 1982 and in 1983.

Black bullheads became abundant less than a year after the chemical treatment and remained so through 1983 (Table 19). In September 1982, 40,769 bullheads were removed from the Machickanee Flowage without an apparent decline in fyke net CPE. In 1983, 69,734 bullheads were removed, again without an apparent decline in CPE. Most of the bullheads captured in 1982 and 1983 were young of the year (YOY) and yearlings. Schools of YOY were a common sight in shoreline areas.

We do not know what the long-term impact of the bullhead population will be on other species. Bullhead population explosions have been noted following other chemical treatments, and numbers sometimes decline after a few years (M. Primising, Wis. Dep. Nat. Resour., pers. comm. 1983).

The forage base, which was extremely large before the chemical treatment, subsequently declined. Common shiners were abundant in 1979 and 1980, but none were caught in the final four sampling periods in 1982 and 1983. Many predatory species were stocked in 1982 and 1983, and other predatory species migrated to the Machickanee Flowage. These fish probably reduced the number of forage fishes. Fyke net CPE of white suckers declined following the chemical treatment, but carp apparently did not decline in relative abundance.

The relative abundance of game fish and panfish increased following the chemical treatment. Bluegill CPE in 1982 and 1983 represented a substantial increase in abundance, while black crappie exhibited a similar, though lesser, increase. Smallmouth bass CPE did not vary greatly during the four-year sampling period, even though many were stocked in 1982 and 1983. The catch of walleye ranged from zero before stocking in 1982 to 0.4 fish/net day in April 1983. Because over 2,000,000 fry and 93,000 fingerlings were stocked and so few were later captured, we question whether walleye will ever contribute to the Machickanee Flowage fishery.

No rainbow trout were captured in the Machickanee Flowage before stocking in 1981. Following stocking in fall 1981 and spring 1982, trout were captured at rates of 4.7/net day in May 1982, 5.3/net day in September 1982, 2.5/net day in April 1983, 2.2/net day in May 1983, and < 0.1/net day in September 1983. This progressive decline in abundance was related to a combination of factors. Rainbow trout sustained considerable fishing pressure from the time they were first stocked in fall 1981 through spring 1983, and water temperatures were high during the summer of 1983. Both of these factors contributed to a high mortality rate. Rainbow trout were also preyed upon by the abundant northern pike. Stocking rainbow trout in fall 1982 and spring 1983 was apparently futile because almost no fish from these plants were seen in the survey gear or angler creels. The trout that showed the greatest survival rate were those stocked before populations of other species had become established.

More northern pike were captured in April 1983 than during any previous spring sampling as far back as 1979. This high CPE was influenced by netting during the peak of the spawning run, but also reflected a strong year class in 1982.

Age, Growth, and Condition. Before the 1981 drawdown, growth rates of game fish and panfish from the Machickanee Flowage were similar to those in other water bodies, even though population numbers were low. Growth rates of bluegills from the Machickanee Flowage were similar to those of bluegills from the Oconto Falls Flowage (Bruch et al. 1980) and seven northern Wisconsin drainage lakes (Snow 1969). Growth rates of black crappies from the Machickanee and Oconto Falls flowages were also similar.

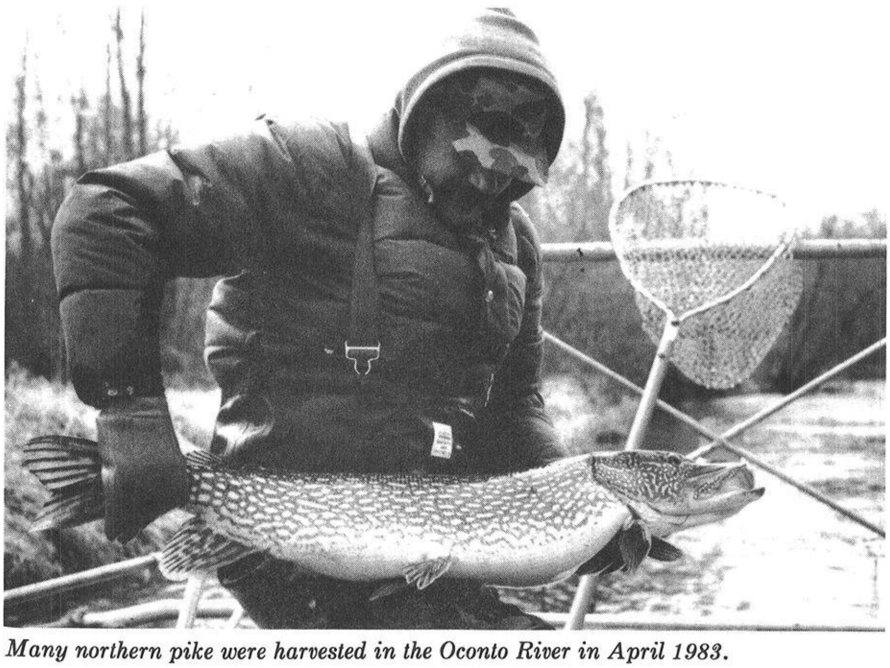
Northern pike captured in the

TABLE 19. *Catch per net day and percent of total catch of 19 fish species caught with fyke nets in the Machickanee Flowage in 1979, 1980, 1982, and 1983.*

	Catch/Net Day									Total Catch (%)								
	1979		1980		1982		1983			1979		1980		1982		1983		
Species	Jun	Sep	Apr	Sep	May	Sep	Apr	May	Sep	Jun	Sep	Apr	Sep	May	Sep	Apr	May	Sep
Rainbow trout	0.0	0.0	0.0	0.0	5.7	5.3	2.5	2.2	0.1	0.0	0.0	0.0	0.0	27.4	0.3	0.7	0.1	0.1
Brown trout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Brook trout	0.0	0.0	0.1	0.0	0.0	0.2	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.1	0.1	0.0
Northern pike	0.4	0.7	3.1	0.9	0.5	3.2	25.9	6.0	2.6	0.7	0.8	3.0	0.7	2.2	0.2	7.6	0.3	0.3
Largemouth bass	0.0	0.0	0.0	0.1	0.0	1.2	0.2	0.0	6.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.7
Smallmouth bass	0.1	0.5	0.3	0.1	0.0	0.1	0.1	0.0	0.4	0.2	0.5	0.3	0.1	0.0	0.1	0.1	0.0	0.1
Bluegill	2.1	4.4	0.1	1.1	1.2	16.1	9.0	9.9	19.2	3.8	4.8	0.1	0.9	5.9	0.8	2.7	0.5	2.3
Black crappie	4.7	6.6	0.7	1.0	1.0	12.9	11.5	1.5	7.8	8.6	65.1	0.7	0.8	4.6	0.7	3.4	0.1	0.9
Pumpkinseed	0.6	4.7	3.7	11.9	0.1	0.6	0.6	0.7	28.9	1.1	5.0	3.6	10.0	0.7	0.1	0.2	0.1	3.4
Rock bass	0.2	1.8	1.1	1.4	0.1	0.0	0.0	0.0	0.7	0.4	1.9	1.0	1.1	0.7	0.0	0.0	0.0	0.0
Walleye	0.0	0.0	0.1	0.1	0.0	0.1	0.4	0.1	0.3	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Yellow perch	0.5	1.5	1.4	0.4	0.7	0.4	13.4	0.8	11.6	1.0	1.6	1.3	0.3	3.5	0.1	4.0	0.1	1.4
Black bullhead	16.2	60.5	67.0	84.7	7.7	1,853.1	270.6	1,745.7	766.5	29.7	65.1	64.9	71.1	37.1	97.0	79.9	98.7	90.5
White sucker	7.0	6.2	17.6	16.2	2.0	2.0	3.4	0.8	0.9	12.9	6.7	2.6	14.5	9.4	0.1	1.0	0.1	0.1
Common carp	4.8	2.2	1.2	0.2	0.1	4.7	0.3	0.3	2.0	8.9	2.4	1.2	0.2	0.2	0.2	0.1	0.1	0.2
Common shiner	8.8	0.1	2.7	0.1	0.2	0.0	0.0	0.0	0.0	16.1	0.1	2.6	0.1	1.1	0.0	0.0	0.0	0.0
Golden shiner	9.0	3.7	4.4	0.1	0.5	3.6	0.4	0.3	0.1	16.6	4.0	4.2	0.1	2.4	0.2	0.1	0.1	0.1
Fathead minnow	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0
Creek chub	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0

Machickanee Flowage before the drawdown were not aged but had an average total length of 51.6 cm. The average length of northern pike captured in the Oconto Falls Flowage was 49.0 cm. The percentage of fat in northern pike from the Machickanee Flowage indicated the relatively good growth and condition of those fish. Five pike from the Machickanee Flowage collected in May 1979 had an average fat concentration of 4.4%, while 4 pike from the Oconto Falls Flowage had a fat concentration of 1.6%. The good condition of pike from the Machickanee Flowage was probably a response to the availability of a sizable forage base and an almost total lack of forage fish cover (aquatic macrophytes).

The abundant rough fish grew slowly. Black bullheads from the Machickanee Flowage were of a smaller average size than black bullheads from the Oconto Falls Flowage, and carp from the Machickanee Flowage were both in poorer condition and of a smaller average size than carp from the Oconto Falls Flowage. White suckers over 350 mm were more abundant in the Oconto Falls Flowage than in the Machickanee Flowage.



Many northern pike were harvested in the Oconto River in April 1983.

Condition factors of white suckers exemplified the poorer condition of rough fish species observed in the Machickanee Flowage. Carlander (1969) established standards for using condition factors to define poor and excellent conditions of white suckers in Minnesota lakes. Using this method, we determined that white suckers from the Machickanee Flowage exhibited a poorer average condition (and size) than fish from the Oconto Falls Flowage (Fig. 6).

Fish from the Machickanee Flowage grew rapidly following the chemical treatment. For example, 125 rainbow trout stocked in the Machickanee Flowage in May 1982 nearly doubled their mean length by late September 1982 (Fig. 7). Rainbow trout continued to grow in the winter months. A 33.8-cm rainbow trout Floy-tagged on 21 September 1982 measured 37.5 cm when caught through the ice on 12 January 1983. Another rainbow trout, tagged when 32.0 cm long on 24 September 1982, was 36.8 cm long when caught on 11 January 1983.

Stunted 6-year-old bluegills from Koonz and Beaulieu lakes in Shawano county ranged in size from 10.0 cm to 17.2 cm, with a mean length of 14.1 cm when stocked in the Machickanee Flowage in spring 1982. In October 1982 this same age class ranged from 16.9 cm to 22.2 cm and had a mean length of 19.0 cm. Other bluegill age groups also grew rapidly.

Stunted bluegills from Koonz and Beaulieu lakes developed a unique scale impression signature that enabled identification of these fish for at least

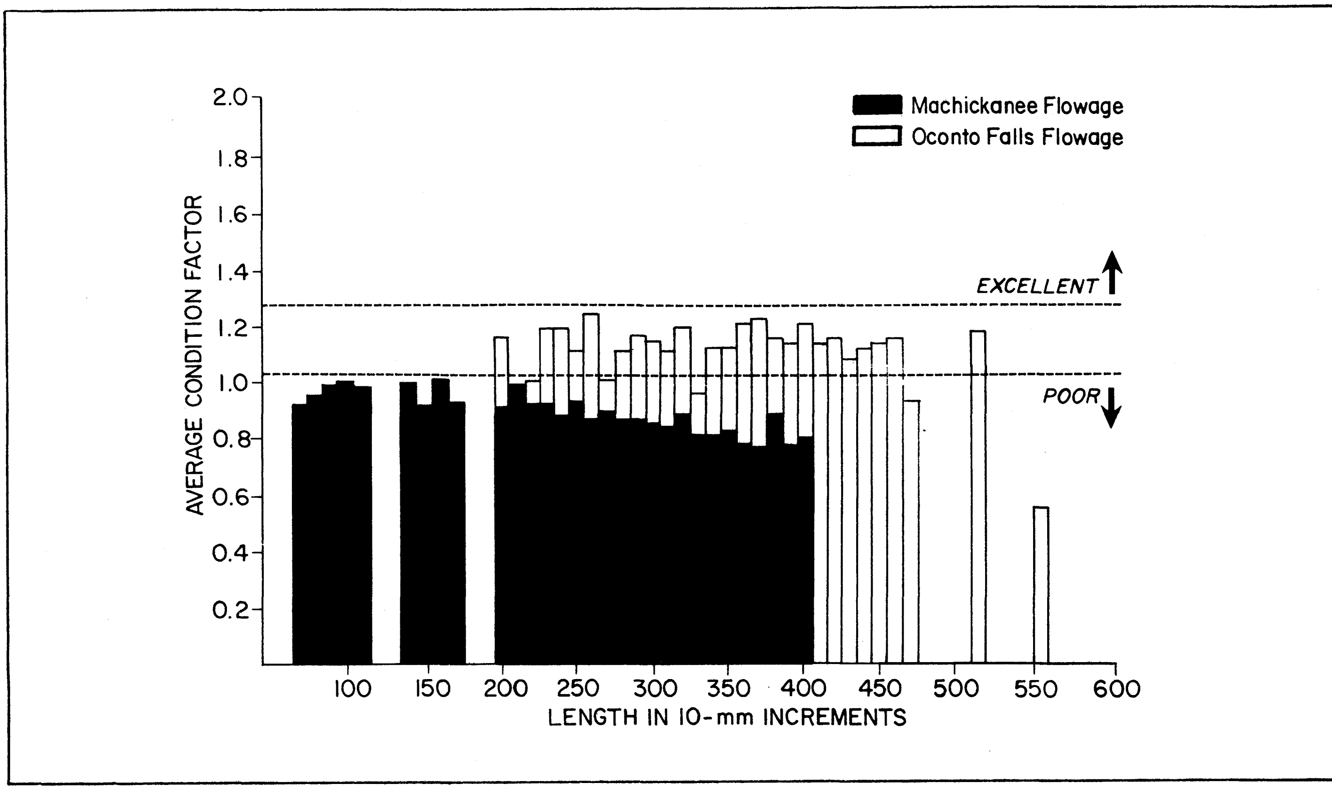


FIGURE 6. *Condition factors of white suckers from the Machickanee and Oconto Falls flowages, 1979.*

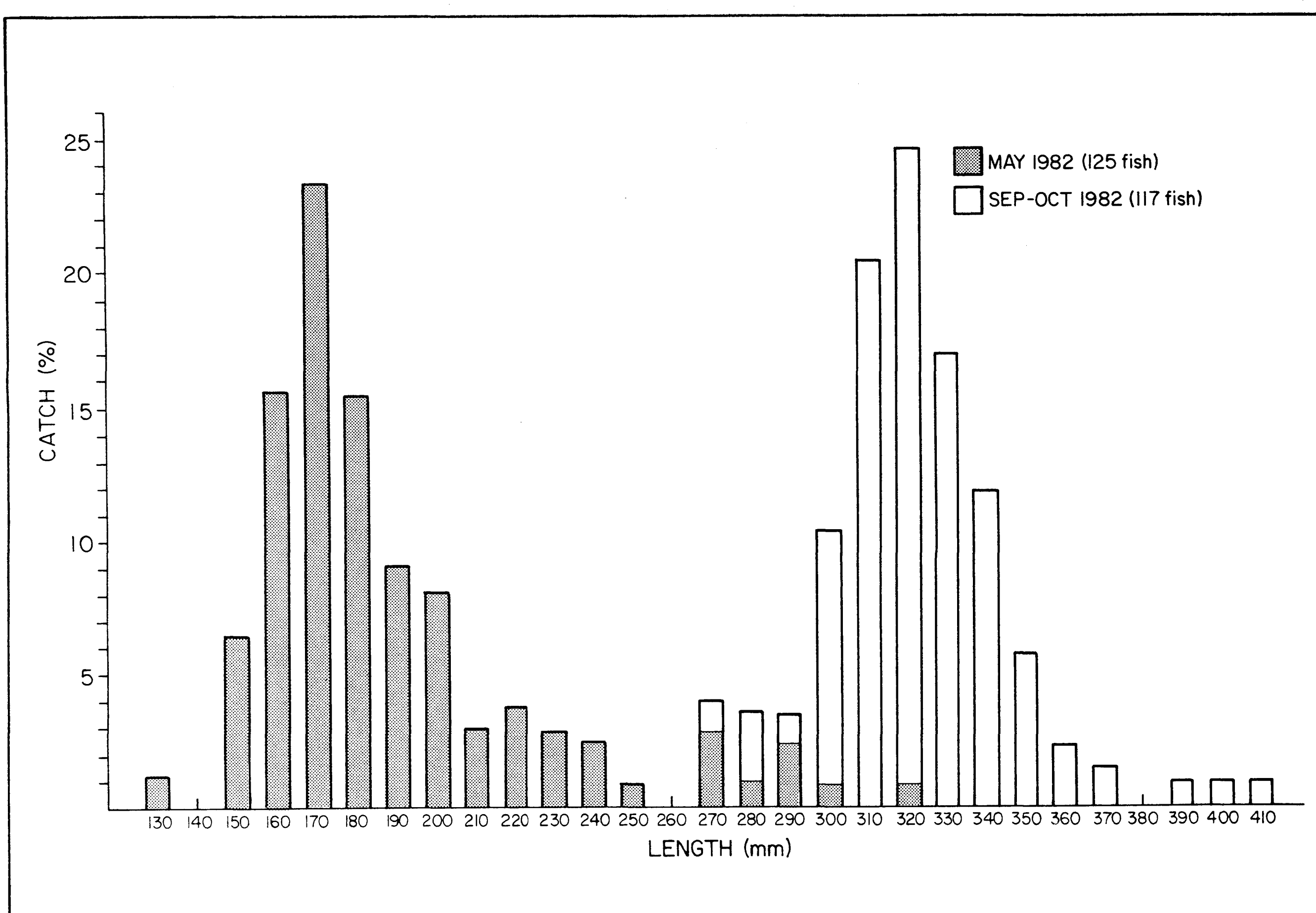


FIGURE 7. *Length frequency of rainbow trout captured from the Machickanee Flowage, 1982.*

TABLE 20. *Total catch, frequency of occurrence, and catch per hectare at sites seined from the shoreline on Oconto Falls Flowage in 1980 and Machickanee Flowage in 1980, 1982, and 1983.*

	Oconto Falls Flowage 1980 (seined 0.16 ha)			Machickanee Flowage 1980 (seined 0.25 ha)			Machickanee Flowage 1983 (seined 0.2 ha)			Machickanee Flowage 1983 (seined 0.13 ha)		
Species	Total Catch	Frequ. of Occur. (%)	Catch/Ha	Total Catch	Frequ. of Occur. (%)	Catch/Ha	Total Catch	Frequ. of Occur. (%)	Catch/Ha	Total Catch	Frequ. of Occur. (%)	Catch/Ha
Largemouth bass	37	77	231	6	10	24	14	35	70	15	82	116
Smallmouth bass	3	15	19	20	48	80	14	12	70	5	36	39
Bluegill and pumpkinseed	1,161	92	7,256	672	86	2,688	44	47	220	1,371	82	10,546
Black crappie	9	38	56	2	10	8	4	12	20	13	64	100
Yellow perch	1	8	6	0	0	0	162	65	810	3 YOY	27	23
Northern pike	1	8	7	1	5	4	2	12	10	1	9	8
Black bullhead	581	69	3,631	595	10	2,380	1	6	5	15	36	116
White sucker (1mm)	0	0	0	44	14	176	25	29	125	381	18	2,931
Common carp	0	0	0	2	9	8	1	6	5	0	0	0
Bluntnose minnow	114	46	713	1,666	90	6,664	17	6	85	1	9	8
Fathead minnow	0	0	0	428	71	1,712	12	6	60	0	0	0
Common shiner	68	54	425	174	52	696	0	0	0	1	9	8
Golden shiner	95	62	594	101	29	404	0	0	0	52	45	400
Creek chub	0	0	0	1	5	4	0	0	0	20	9	154
Johnny darter	11	8	69	297	86	1,188	26	12	130	6	9	46
Rosyface shiner	2	8	13	25	9	100	0	0	0	0	0	0
Redbelly dace	0	0	0	3	5	12	0	0	0	0	0	0
Hornyhead chub	1	8	6	0	0	0	0	0	0	0	0	0
Madtoms	0	0	0	1	5	4	0	0	0	0	0	0
Sculpins	0	0	0	0	0	0	22	6	110	1	9	8
Sticklebacks	0	0	0	0	0	0	0	0	0	8	9	62
Log perch	0	0	0	0	0	0	11	18	55	0	0	0
Rock bass	0	0	0	2	9	8	0	0	0	0	0	0
Northern pike (mature)	0	0	0	0	0	0	0	0	0	0	0	0
Yellow perch (mature)	0	0	0	0	0	0	0	0	0	0	0	0
Bluegill (mature)	0	0	0	0	0	0	0	0	3	27	0	23

two years following stocking. In fall 1982, workers noticed that Koonz and Beaulieu fish could be identified by the 4, 5, 6, or 7 annuli closely grouped on a scale impression. The radius of the scale would then nearly double in a single growing season. These unique scales were commonly observed in 1982, but in 1983 they were scarce. This change suggests that the Koonz and Beaulieu bluegills grew rapidly during the first year following stocking, but then suffered substantial mortality.

All species appeared to be in good condition in 1982 and 1983. White suckers in particular appeared more robust than they had in 1979 and 1980.

Shoreline Seining. Results of shoreline seining at 21 sites on the Machickanee Flowage before the drawdown are shown in Table 20. Minnow species were best represented in the catch and reflected the sizable forage base in the flowage. Bluntnose minnows were most abundant. Bluegills and pumpkinseed, at 2,688/ha, were the most abundant YOY panfish captured in the flowage.

Three species of game fish YOY were captured before the drawdown—smallmouth bass (80/ha), largemouth bass *(Micropterus salmoides)* (24/ha), and northern pike (4/ha). Smallmouth bass, as well as being most abundant, occurred at the most sites (48%) (Table 20). The Oconto River above the Machickanee Flowage may have provided most of the recruitment to the smallmouth bass population in the flowage, because the river offered good spawning habitat. Many adult smallmouth bass were captured in the river during other surveys.

The amount of suitable nursery area in the flowage before the drawdown was limited. All of the YOY largemouth bass, 30% of the YOY smallmouth bass, 77% of the YOY bluegill, and 50% of the YOY sunfish were captured in three sampling sites in Splinter Bay. These sites accounted for only 14% of the total sampling effort. They were in one of the few areas in the flowage with significant quantities of aquatic vegetation before the drawdown.

More shoreline habitat became suitable as nursery areas following the 1981 drawdown. Before the drawdown, two of the above three sites in Splinter Bay accounted for 59% of the total number of bluegill and pumpkinseed captured during seining. The same sites accounted for only 21% of the total after the drawdown. Bluegill and pumpkinseed were more evenly distributed through all sampling stations after the drawdown.

In addition to being more evenly distributed, natural reproduction of bluegill and pumpkinseed substantially increased following the drawdown, chemical treatment, and fish stocking. In 1983 1,371 YOY were captured through seining 0.13 ha of flowage shoreline. The 1983 catch was 10,546/ha, as compared to 220/ha in 1982 and 2,688/ha in 1980. Catch per hectare in 1983 exceeded the catch per hectare of bluegill and pumpkinseed from the Oconto Falls Flowage in 1980. This increase may be due to the improved spawning substrate, greater availability of suitable food organisms for fry and older fish, as well as an increase in cover that possibly limited predation.

The frequency of occurrence and catch per hectare of black crappie from the Machickanee Flowage also increased following the chemical treatment. Catch per hectare and frequency of occurrence of black crappie in 1983 were greater than for samples obtained from the Oconto Falls Flowage in 1980.

A strong year class of yellow perch was produced in 1982, when perch were caught in shoreline seines at a density of 810/ha, the highest catch rate of any species encountered. This year class carried through to 1983 (Fig. 8), but in 1983 no YOY perch were captured during shoreline seining surveys. Northern pike YOY were captured in similar numbers in the Machickanee Flowage from 1980-83. However many yearling northern pike were captured in fyke nets in 1983, revealing a strong 1982 year class of this species.

Common carp were present after the chemical treatment, as shown by fyke net and electrofishing surveys, but few were captured with the shoreline seine. One carp was captured in 1982, and none were caught in 1983. A combination of survey methods indicated that natural reproduction of carp was occurring after the chemical treatments, but at levels that did not threaten other populations.

Numbers of cyprinids (excluding carp) captured with seining gear declined greatly following the drawdown. Black bullheads were abundant in the flowage in 1982 and 1983, but they could not be caught effectively by seining.

The frequency of occurrence of YOY largemouth bass in the Machickanee Flowage shoreline seines progressively increased from 1980 to 1983. Though the increase was at least partially due to the numbers stocked, it may also indicate that more vegetation made the shoreline better suited for holding the young of this species. Largemouth bass prefer shallow, weedy bays as holding habitat (Hubbs and Lagler 1947, Trautman 1981).

Analysis of Fish Tissue. No significant differences were found in the amount of toxic compounds tested for, when comparing fish from the Machickanee and Oconto Falls flowages before the drawdown (Table 21). Concentrations of all toxic substances in fish flesh from both the Machickanee and Oconto Falls flowages represent normal background levels found in most Wisconsin streams and rivers (L. Liebenstein, Wis. Dep. Nat. Resour., pers. comm. 1983).

The low concentrations of toxics in 1979 in the elutriate samples from the Machickanee Flowage indicated stability of most of the pollutants in the sediments. Fish from the Oconto Falls Flowage also had low concentrations of toxics (Table 21).

Concentrations of toxics in the fish examined did not increase because of the drawdown or other activities. White sucker, carp, northern pike, walleye, bluegill, and rainbow trout samples showed less than detectable limits of arsenic, cadmium, lead, and PCB's during 1982 and 1983. Mercury levels ranged from 0.05 ppm to 0.18 ppm.

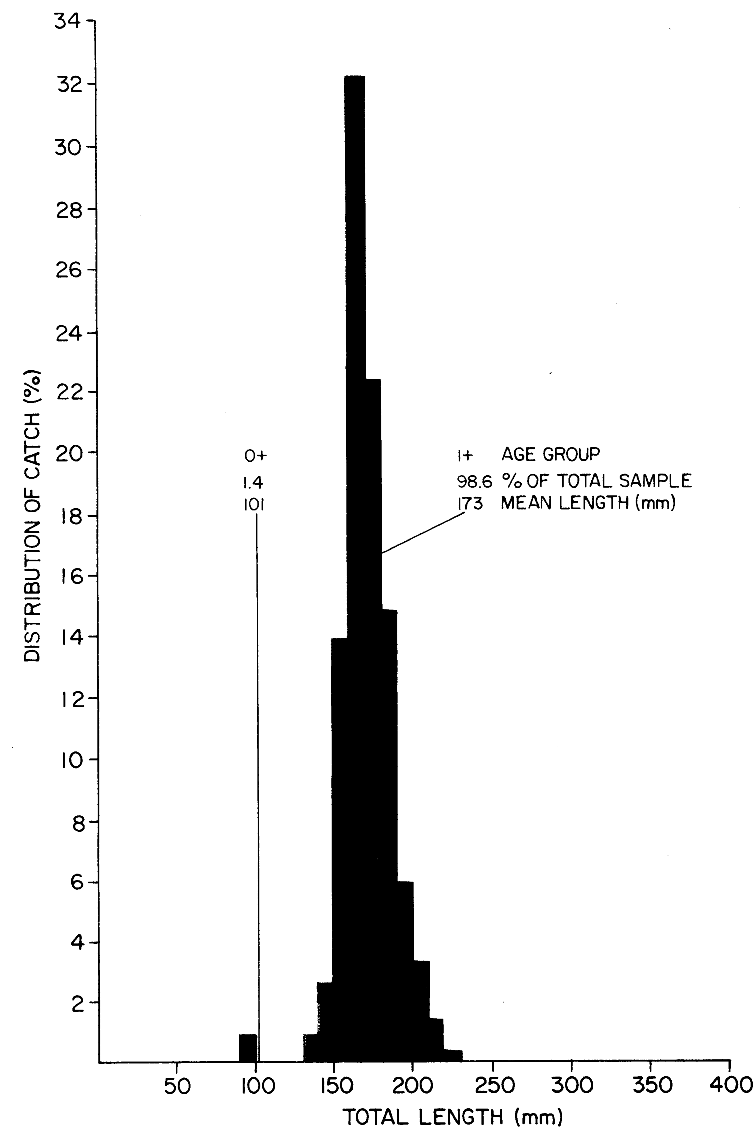


FIGURE 8. *Length frequency of 357 yellow perch captured from the Machickanee Flowage, September 1983.*

Angler Effort and Success in the Machickanee Flowage and Lower Oconto River

The Machickanee Flowage was responsible for only 2% of the angler pressure before the drawdown, compared with 68% for the river sites and 30% for boat landings at the Oconto harbor. Low angler effort in the Machickanee Flowage reflected lack of interest and public access, as CPE in the Machickanee Flowage was similar to the average CPE enjoyed by anglers fishing the five river sites (Table 22). Panfish at the mouth of Splinter Creek accounted for most of the catch in the Machickanee Flowage. Again, this area was one of a few on the Machickanee Flowage with significant aquatic macrophyte cover and was also one of the few netting and boomshocking sites where YOY as well as adult panfish and game fish were caught. Total fish caught in the Machickanee Flowage increased from 349 in 1979 to 1,190 in 1982. In the 1982 census stocked rainbow trout were the only fish from Machickanee Flowage kept by anglers.

Fishing pressure on the Machickanee Flowage in 1982 was 11 times greater than in 1979. An estimated 3,846 anglers used the flowage in 1982 as compared to 486 in 1979. Fishing pressure within the project area increased from 37,682 angler hours in 1979 to 72,097 angler hours in 1982,

TABLE 21. *Concentration of toxic substances in fish from the Machickanee and Oconto Falls flowages, determined by tissue analysis, 1979.*

	White Sucker MF*	White Sucker OFF**	Common Carp MF	Common Carp OFF	Black Bullhead MF	Black Bullhead OFF	Northern Pike MF	Northern Pike OFF	Black Crappie MF	Bluegill OFF	Common Shiner MF
Collection date	3 May	23 Aug	3 May	23 Aug	3 May	23 Aug	3 May	23 Aug	3 May	23 Aug	3 May
No. in sample	5	5	5	5	5	5	5	4	5	5	5
Avg. length (inches)	11.30	14.00	15.90	22.60	8.20	8.00	23.00	18.00	7.40	5.80	6.80
Avg. weight (kg)	0.49	0.59	0.80	2.30	0.18	0.15	1.80	0.60	0.19	0.98	0.09
Portion	wf[a]	wf	wf	wf	wf	wf	wf	wf	wf	wf	wf
Fat (%)	1.10	4.10	2.30	9.40	1.60	4.20	4.40	1.60	1.10	1.60	2.60
PCB (ppm)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.58	<0.20	<0.20	<0.20	<0.20
Arsenic (ppm)	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00
Cadmium (ppm)	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Chromium (ppm)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Copper (ppm)	1.40	1.70	1.40	1.70	1.70	1.30	1.10	1.20	1.00	0.90	1.60
Lead (ppm)	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Mercury (ppm)	0.13	0.07	0.05	0.14	0.05	0.07	0.18	0.17	0.06	0.05	0.04

*MF = Michickanee Flowage.
**OFF = Oconto Falls Flowage.
[a]wf = whole fish.

TABLE 22. *Creel census information for the Oconto River Restoration Project, 1979 and 1982.*

	No. Fish Caught															
	Boat Landings				Shoreline Sites											
	Oconto Harbor Landings		Machickanee Flowage		Oconto Pier		Oconto Bridges		Suzie's Rapids		Little River		Stiles Dam		Shoreline Totals		Grand Totals	
Species	1979	1982	1979	1982	1979	1982	1979	1982	1979	1982	1979	1982	1979	1982	1979	1982	1979	1982
Yellow perch	2,571	5,677	29	0	3,755	14,292	155	16	78	0	8	0	37	0	4,033	14,308	25,633	19,985
Smallmouth bass	493	37	20	0	718	1,760	520	1,029	139	1,382	119	477	152	493	1,648	5,149	2,161	5,186
Northern pike	0	0	6	0	83	33	0	48	0	126	98	0	262	0	443	207	449	207
Walleye	0	0	0	0	0	0	0	0	19	0	0	0	0	0	19	0	19	0
Rainbow trout	44	0	0	1,910	48	300	0	31	0	0	0	0	52	1,230	100	1,561	144	3,471
Brown trout	58	0	0	0	378	1,312	0	63	19	223	0	45	128	584	525	2,227	583	2,227
Chinook salmon	0	185	0	0	23	155	0	142	0	84	0	0	81	710	104	1,091	104	1,276
Other	457	498	349	0	724	945	0	271	0	0	43	583	499	39	1,266	1,838	2,072	2,336
Total no. fish caught	22,623	6,397	404	1,910	5,729	18,805	675	1,600	255	1,815	268	1,105	1,211	3,056	8,138	26,381	31,165	34,688
Total no. anglers	3,549	7,593	486	3,840	8,767	11,333	1,506	1,974	575	2,571	724	1,322	2,422	5,557	13,994	22,757	17,939	34,196
Total no. angler hours	11,366	9,197	847	9,579	14,954	27,994	3,029	2,563	792	5,289	1,237	2,201	5,457	15,274	25,469	53,321	37,682	72,097
No. fish caught/hour	1.99	0.70	0.48	0.19	0.38	0.67	0.22	0.62	0.32	0.34	0.22	0.50	0.22	0.20	0.32	0.49	0.83	0.48

while the number of anglers using the area almost doubled—17,939 in 1979 compared with 34,196 in 1982. Total number of fish caught in the project area also increased slightly in 1982. An estimated 31,165 fish were caught in 1979, and 34,688 were caught in 1982.

FISH MOVEMENT

Of 5,276 fish tagged from 1979-83, 867 were eventually recaptured (Table 23). The recovery rate, not including multiple recoveries, was 15.3%. In the Oconto Falls Flowage 124 northern pike were tagged, and most were recaptured there. However, one was recaptured in the Machickanee Flowage and another in the Oconto River below the Machickanee Flowage. Assuming that this latter fish moved of its own accord, it traveled through or over all three dams within the project area over a three-year interval. Recaptures of fish tagged in the Machickanee Flowage also revealed that Stiles Dam was not a total impediment to downstream movement (Table 24). Of the seven species tagged, only two species—brown trout and walleye—were not caught again below the dam. The only muskellunge *(Esox masquinongy)* captured in the Machickanee Flowage was later recaptured in the river below.

The drawdown of the Machickanee Flowage strongly influenced the down-

TABLE 23. *Tag and recovery records of all fish species, 1979-83.*

Year Tagged	No. Tagged	Recovery Source: Anglers	Netting/ Electrofishing	Total
1979	803	30	15	45
1980	1,381	88	156	244
1981	1,013	112	122	234
1982	1,013	54	51	105
1983	1,066	154	85	239
Total	5,276	438	429	867

TABLE 24. *Tag and recapture locations of fish marked in the Oconto River Project area, 1979-83.*

Tagging Location and Species	No. Tagged	No. Recaptured by Location: Oconto Falls Flowage	Machickanee Flowage	Lower Oconto River	Green Bay	Other Lake Michigan-Green Bay Tributaries
Oconto Falls Flowage						
Northern pike	124	15	1	1	0	0
Machickanee Flowage						
Rainbow trout	263	0	103	6	0	0
Brown trout	14	0	2	0	0	0
Muskellunge	1	0	0	1	0	0
Northern pike	880	0	126	98	0	0
Smallmouth bass	164	0	21	4	0	0
Walleye	22	0	2	0	0	0
Yellow perch	246	0	59	5	0	0
Lower Oconto River						
Rainbow trout	567	0	0	62	6	2
Brown trout	963	0	1*	68	15	4
Northern pike	450	0	0	47	0	0
Largemouth bass	8	0	0	1	0	0
Smallmouth bass	714	0	0	71	1	1
Walleye	445	0	0	33	3	5
Yellow perch	249	0	0	31	4	0
Total	5,110**	15	315	428	29	12

*Caught during drawdown period (gates were open).
**166 miscellaneous fish of other species are not included here.

stream movement of flowage fish. During the drawdown, 68 tagged northern pike, 2 tagged smallmouth bass, 5 tagged yellow perch, and 1 tagged muskellunge left the flowage and were recaptured in the river below. Many of these fish left the flowage during the first week of the drawdown.

Of the 567 rainbow trout tagged in the Oconto River, most were recaptured there. Results of the electrofishing surveys showed that most rainbow trout spent varying amounts of time in outlying waters and ran the river during spawning periods. One trout tagged in the lower river was caught near Washington Island, 105 km from the mouth of the river. Two trout were caught in Lake Michigan-Green Bay tributaries other than the Oconto River. Most brown trout tagged in the lower Oconto River were also recaptured there.

Smallmouth bass, walleyes, and yellow perch tagged in the lower river exhibited a similar pattern of movement. Most were recaptured there and a few were captured in Green Bay and other Lake Michigan-Green Bay tributaries.

FISH POPULATIONS IN THE LOWER OCONTO RIVER

The halt of pulping operations at the Scott Paper Company in 1978 caused substantial changes in the fish populations of the lower Oconto River. As water quality rapidly improved, Green Bay provided a source of species for rapid habitation of the lower river. Forty-seven species of fish were captured from 1979 to 1981 (Append. A). The species composition and relative abundance varied seasonally (Table 25). Adults of some species, such as brown trout *(Salmo trutta)*, rainbow trout, white sucker, spottail shiner *(Notropis hudsonius)*, and rainbow smelt *(Osmerus mordax)*, were present primarily during spawning migrations from Green Bay. Smallmouth bass were found in varying densities during the summer throughout the lower river. From late fall through early spring, few smallmouth bass were found.

We aged smallmouth bass from surveys in June and September 1982 and September 1983. There were large percentages of 0+ and I+ age class fish. The I+ year class made up 73% of the total catch in September 1982 (Fig. 9). In June 1982 40% of the aged fish were age II+ or less; by September 90% were in this age range. The occurrence of so many age 0-II+ fish may

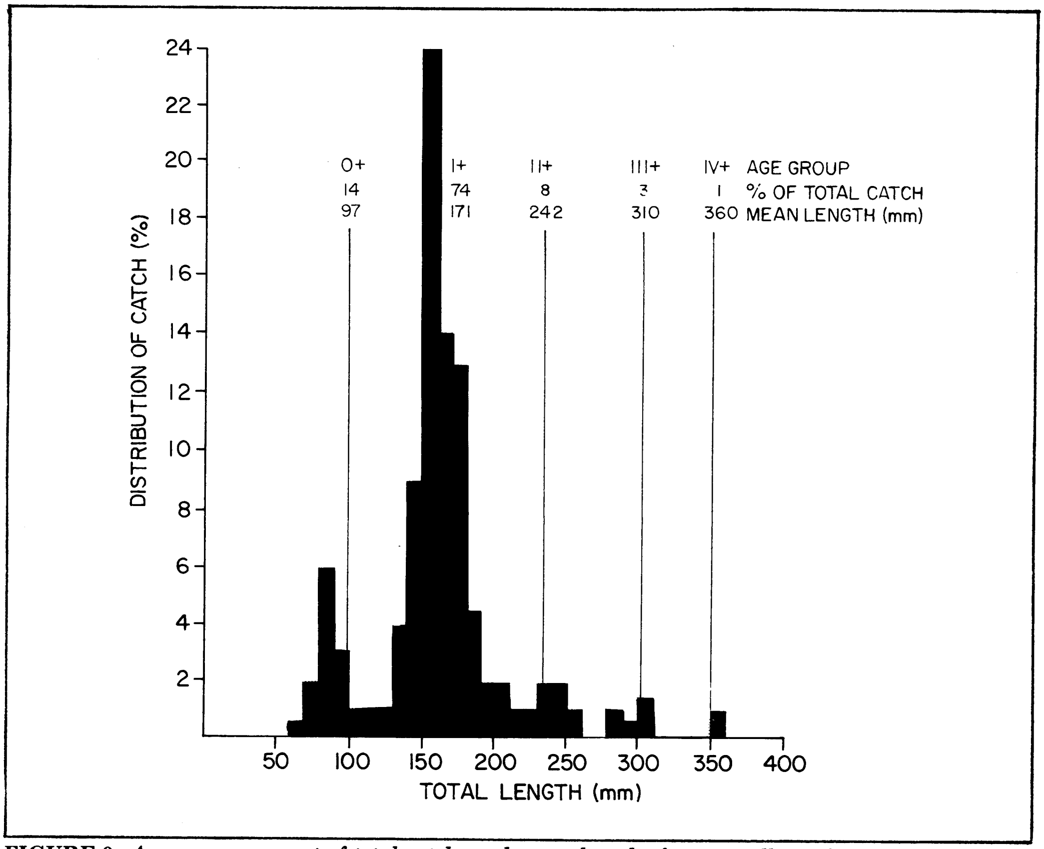


FIGURE 9. *Age group, percent of total catch, and mean length of 401 smallmouth bass caught by electrofishing in the Oconto River below the Machickanee Flowage, 14-16 September 1982.*

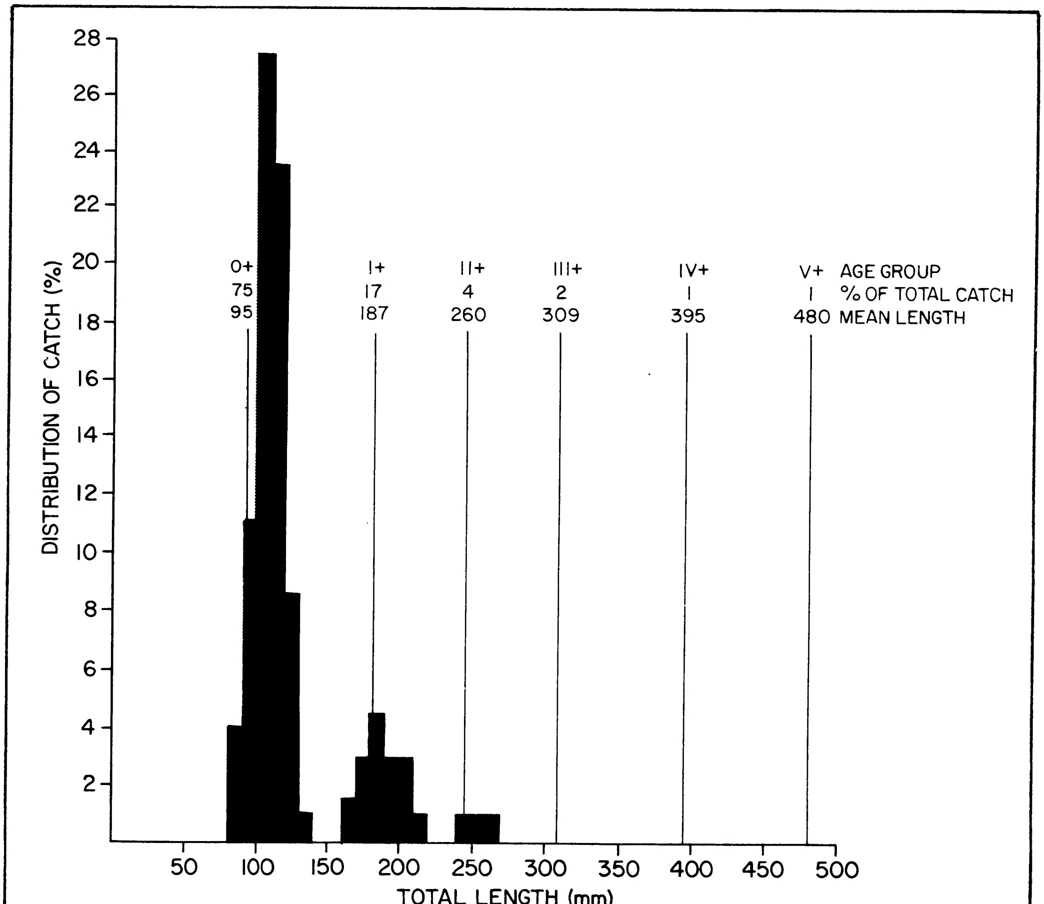


FIGURE 10. *Age group, percent of total catch, and mean length of 473 smallmouth bass caught by electrofishing in the Oconto River below the Machickanee Flowage, 6-8 September 1983.*

TABLE 25. *Number and relative abundance (%) of Oconto River fish species captured during electrofishing surveys of 21 index stations established on 22.5 km of the Oconto River downstream from the Machickanee Flowage, 1979-81.*

	No. (and Relative Abundance)								
	April			May			June		
Species	1979	1980	1981	1979	1980	1981	1979	1980	1981
Chestnut lamprey	—	0	0	—	0	0	1(0.02)	0	—
Lake sturgeon	—	0	0	—	0	0	1(0.02)	0	—
Bowfin	—	0	0	—	0	0	0	0	—
Alewife	—	0	0	—	0	14(0.13)	2,255(36.25)	321(14.87)	—
Gizzard shad	—	0	0	—	0	0	1(0.02)	0	—
Chinook salmon	—	0	0	—	0	0	7(0.11)	0	—
Coho salmon	—	0	0	—	0	0	0	0	—
Brook trout	—	0	0	—	0	0	6(0.15)	0	—
Brown trout	—	8(0.41)	7(0.12)	—	23(0.74)	23(0.58)	32(0.51)	6(0.28)	—
Rainbow trout	—	32(1.63)	58(0.99)	—	210(6.71)	0	18(0.29)	87(4.03)	—
Rainbow smelt	—	0	10(0.17)	—	82(2.62)	0	0	0	—
White sucker	—	1,680(85.58)	5,231(88.98)	—	1,487(47.55)	1,681(42.60)	483(7.76)	461(21.35)	—
Shorthead redhorse	—	0	1(0.02)	—	4(0.13)	5(0.13)	21(0.34)	8(0.37)	—
Northern hog sucker	—	0	0	—	0	0	0	0	—
Common carp	—	31(1.58)	204(3.47)	—	291(9.30)	285(7.22)	1,233(19.82)	311(14.40)	—
Longnose dace	—	0	0	—	1(0.03)	0	0	1(0.05)	—
Golden shiner	—	2(0.10)	9(0.15)	—	6(0.19)	82(2.08)	6(0.10)	6(0.28)	—
Common shiner	—	60(3.06)	188(3.20)	—	168(5.37)	521(13.20)	437(7.02)	140(6.48)	—
Rosyface shiner	—	0	0	—	0	0	0	0	—
Spottail shiner	—	16(0.18)	26(0.44)	—	388(12.40)	710(17.99)	1,170(18.81)	436(20.19)	—
Spotfin shiner	—	0	3(0.05)	—	16(0.51)	5(0.13)	0	30(1.39)	—
Fathead minnow	—	0	0	—	10(0.32)	0	0	11(0.51)	—
Bluntnose minnow	—	12(0.61)	8(0.14)	—	41(1.30)	0	16(0.26)	5(0.23)	—
Black bullhead	—	60(3.06)	19(0.32)	—	87(2.78)	80(2.02)	228(3.67)	140(6.48)	—
Yellow bullhead	—	0	0	—	0	0	0	0	—
Tadpole madtom	—	0	0	—	0	0	0	1(0.05)	—
Central mudminnow	—	0	0	—	0	0	0	0	—
Northern pike	—	16(0.81)	27(0.46)	—	36(1.15)	60(1.52)	17(0.27)	11(0.51)	—
Muskellunge	—	0	0	—	0	0	0	0	—
Burbot	—	0	0	—	0	0	0	0	—
Trout-perch	—	0	12(0.20)	—	10(0.32)	165(4.18)	8(0.13)	11(0.51)	—
White bass	—	0	0	—	0	0	0	0	—
Yellow perch	—	85(4.33)	63(1.07)	—	179(5.70)	40(1.01)	131(2.11)	70(3.24)	—
Walleye	—	12(0.61)	4(0.07)	—	3(0.09)	13(0.33)	11(0.18)	7(0.32)	—
Logperch	—	0	0	—	7(0.22)	0	5(0.08)	29(1.34)	—
Johnny darter	—	0	0	—	8(0.25)	1(0.02)	0	0	—
Smallmouth bass	—	0	5(0.09)	—	46(1.47)	128(3.24)	99(1.59)	52(2.41)	—
Largemouth bass	—	0	0	—	0	0	1(0.02)	0	—
Pumpkinseed	—	0	0	—	8(0.25)	5(0.13)	23(0.37)	1(0.55)	—
Green sunfish	—	0	0	—	1(0.03)	0	0	0	—
Longear sunfish	—	0	0	—	1(0.03)	0	0	0	—
Bluegill	—	0	0	—	0	0	5(0.08)	1(0.05)	—
Rock bass	—	1(0.05)	3(0.05)	—	8(0.25)	14(0.35)	8(0.13)	1(0.05)	—
Black crappie	—	2(0.10)	1(0.022)	—	7(0.22)	3(0.08)	4(0.06)	1(0.05)	—

have been caused by migration from other sources, exceptionally strong year classes, or conditions related to increased efficiency of electrofishing. Little River-Kelley Brook contributes to the lower Oconto River smallmouth bass population. Young fish from this watershed may migrate annually into the lower river during late summer months. Again in 1983 more than 90% of the fish in the September sample were 0-II+ age class (Fig. 10). A large mortality (natural or creeled) of age II+ and older fish may have occurred. An estimated 5,000 smallmouth bass were caught from the lower river, based on the 1982 creel census data. Age II+ or older fish are probably being kept by anglers.

The growth of smallmouth bass was comparable for samples taken from 1979, 1982, and 1983. Based on the apparent size of the 1981 year class, increased sediment loading during the drawdown apparently did not affect smallmouth bass reproduction.

Walleye numbers in the lower river have increased substantially since 1981. From 1979 to 1981, 212 fish were captured from the 21 index stations during electrofishing surveys. The total from surveys conducted in 1982 and 1983 was 661 fish. A more intensive survey effort was partially responsible for this increase. However, the greater portion can be attributed to the stocking program started in 1982. Length-frequency histograms and scale samples indicated the predominance of the 1982 year class. The October 1982 sample shows how much this 0+ age class stands out (Fig. 11). In September 1983, 81% of the sample was composed of I+ age fish (Fig. 12).

Results of surveys after the drawdown showed no significant changes in species composition because of the increased sediment loading in 1981. Trout returned during the annual spawning runs. Numbers of smallmouth bass and walleye were higher than observed before the 1981 drawdown.

TABLE 25. *Continued.*

Species	No. (and Relative Abundance)											
	July			August			September			October		
	1979	1980	1981	1979	1980	1981	1979	1980	1981	1979	1980	1981
Chestnut lamprey	0	—	0	0	0	—	0	—	—	0	0	0
Lake sturgeon	0	—	0	0	0	—	0	—	—	0	0	0
Bowfin	0	—	18(1.18)	2(0.18)	4(0.76)	—	9(0.46)	—	—	2(0.35)	1(0.10)	2(0.19)
Alewife	0	—	217(14.28)	2(0.18)	0	—	0	—	—	0	0	0
Gizzard shad	63(13.91)	—	0	0	0	—	0	—	—	0	0	0
Chinook salmon	0	—	0	0	0	—	3(0.15)	—	—	2(0.35)	9(0.92)	1(0.09)
Coho salmon	0	—	0	0	0	—	1(0.05)	—	—	0	1(0.10)	1(0.09)
Brook trout	2(0.44)	—	0	1(0.09)	0	—	3(0.15)	—	—	0	1(0.10)	0
Brown trout	5(1.10)	—	1(0.07)	6(0.55)	8(1.51)	—	13(0.66)	—	—	56(9.77)	80(8.22)	162(15.03)
Rainbow trout	10(2.21)	—	0	0	2(1.51)	—	38(1.93)	—	—	108(18.85)	43(4.42)	84(7.79)
Rainbow smelt	0	—	0	0	0	—	0	—	—	0	0	0
White sucker	44(9.71)	—	401(26.38)	126(11.52)	94(17.77)	—	105(5.34)	—	—	117(20.42)	172(17.68)	315(29.22)
Shorthead redhorse	6(1.32)	—	32(2.11)	12(1.10)	65(12.29)	—	20(1.02)	—	—	6(1.05)	31(3.19)	19(1.76)
Northern hog sucker	1(0.22)	—	0	0	0	—	2(0.10)	—	—	0	2(0.20)	5(0.46)
Common carp	79(17.44)	—	269(17.70)	328(29.98)	114(21.55)	—	206(23.29)	—	—	134(23.29)	102(10.49)	182(16.88)
Longnose dace	0	—	0	1(0.09)	0	—	1(0.05)	—	—	0	0	0
Golden shiner	3(0.66)	—	14(0.92)	5(0.46)	0	—	12(0.61)	—	—	0	25(2.57)	0
Common shiner	12(2.65)	—	139(9.14)	64(5.85)	43(8.13)	—	934(47.46)	—	—	44(7.68)	360(37.00)	144(13.36)
Rosyface shiner	0	—	1(0.07)	0	0	—	0	—	—	0	0	0
Spottail shiner	0	—	17(1.11)	0	0	—	0	—	—	0	0	0
Spotfin shiner	13(2.87)	—	0	8(0.73)	3(0.57)	—	6(0.30)	—	—	0	0	0
Fathead minnow	0	—	44(2.89)	0	0	—	8(0.41)	—	—	0	0	0
Bluntnose minnow	0	—	0	24(2.19)	3(0.57)	—	103(5.23)	—	—	10(1.75)	0	0
Black bullhead	96(21.19)	—	17(1.11)	240(21.94)	34(6.42)	—	153(7.77)	—	—	16(2.79)	17(1.75)	315(29.22)
Yellow bullhead	0	—	191(12.51)	7(0.64)	2(0.38)	—	1(0.05)	—	—	0	0	2(0.19)
Tadpole madtom	0	—	0	0	0	—	0	—	—	0	0	0
Central mudminnow	0	—	0	0	0	—	0	—	—	1(0.17)	0	0
Northern pike	25(5.52)	—	13(0.86)	21(1.92)	9(1.70)	—	1(0.05)	—	—	25(4.36)	18(1.85)	11(1.02)
Muskellunge	0	—	0	0	0	—	0	—	—	1(0.17)	0	0
Burbot	0	—	0	0	0	—	1(0.05)	—	—	0	0	0
Trout-perch	0	—	0	0	0	—	0	—	—	0	0	0
White bass	0	—	10(0.70)	0	1(0.19)	—	0	—	—	0	0	0
Yellow perch	17(3.75)	—	18(1.18)	73(6.67)	20(3.78)	—	79(4.01)	—	—	12(2.09)	26(2.67)	12(1.11)
Walleye	2(0.44)	—	22(1.44)	10(0.91)	12(2.27)	—	21(1.07)	—	—	5(0.87)	21(2.16)	16(1.48)
Logperch	3(0.66)	—	21(1.38)	10(0.91)	6(1.13)	—	13(0.66)	—	—	1(0.17)	0	1(0.09)
Johnny darter	0	—	0	0	0	—	1(0.05)	—	—	0	0	0
Smallmouth bass	38(8.39)	—	64(4.21)	57(5.21)	98(18.52)	—	124(6.30)	—	—	10(1.75)	45(4.62)	31(2.88)
Largemouth bass	0	—	0	0	3(0.57)	—	0	—	—	0	0	0
Pumpkinseed	14(3.09)	—	5(0.33)	41(3.75)	4(0.76)	—	44(2.24)	—	—	6(1.05)	15(1.54)	4(0.37)
Green sunfish	0	—	0	0	0	—	0	—	—	0	0	0
Longear sunfish	0	—	0	0	0	—	0	—	—	0	0	0
Bluegill	5(1.10)	—	0	0	1(0.19)	—	3(0.15)	—	—	0	1(0.10)	1(0.09)
Rock bass	5(1.10)	—	1(0.07)	23(2.10)	2(0.38)	—	21(1.07)	—	—	7(1.22)	2(0.20)	4(0.37)
Black crappie	10(2.21)	—	5(0.33)	33(3.12)	1(0.19)	—	22(1.12)	—	—	10(1.75)	1(0.10)	0

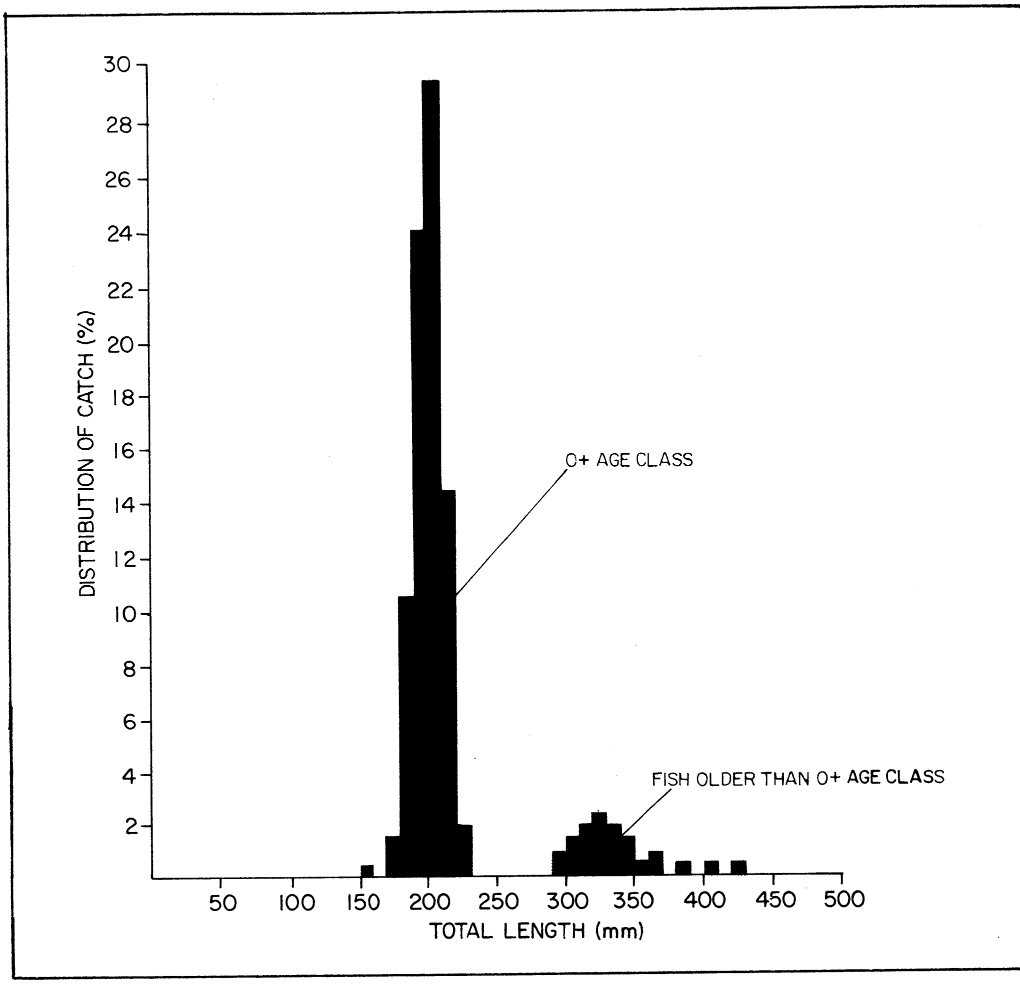


FIGURE 11. *Length frequency of 412 walleyes caught by electrofishing in the Oconto River below the Machickanee Flowage, 12-14 October 1982.*

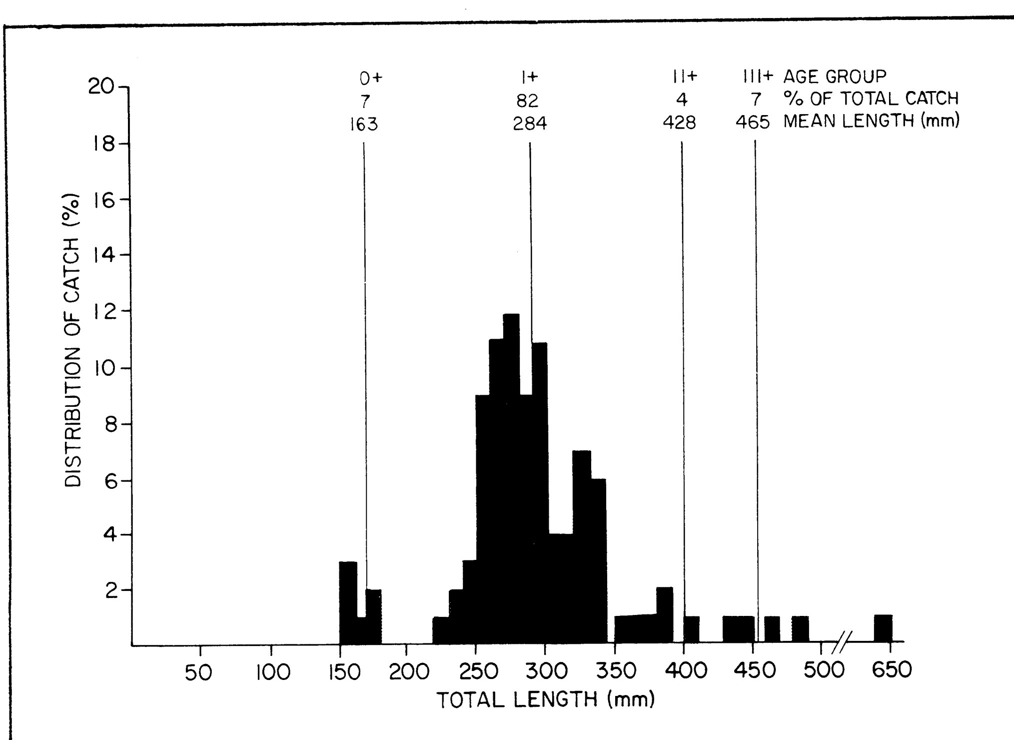


FIGURE 12. *Age group, percent of catch, and mean length of 90 walleyes caught by electrofishing in the Oconto River below the Machickanee Flowage, 6-8 September 1983.*

SUMMARY AND CONCLUSIONS

For many years the lower Oconto River was severely degraded by pulp mill effluent. In early 1978 the pulp mill closed, and in 1979 the owner of the mill paid a $1,000,000 court-ordered settlement. Of this amount, $600,000 was allocated to the DNR to develop and implement a management plan to restore the water negatively affected by the pulp mill discharge. In early 1979 the ORC began investigating the area impacted by the pollutants.

Management activities on the lower Oconto River continued for five years. In 1979 and 1980, we collected preliminary data on water quality; sediment volume, elutriate, and compaction rates; zooplankton; aquatic macrophytes; aquatic macroinvertebrates; and fish populations and movement. By late 1980 we had collected enough information to develop a plan that would correct the problems revealed by our initial investigation. The management plan involved: (1) a drawdown of the Machickanee Flowage to improve the bottom by making it more suitable for fish spawning, growth of aquatic macrophytes, and production of aquatic macroinvertebrates; (2) chemical treatment of the Machickanee Flowage to eliminate rough fish; (3) fish stocking to establish game fish and panfish populations; (4) access development; (5) establishment of contingency funds for habitat improvement and additional fish stocking if necessary; (6) monitoring for a three-year period to determine the effectiveness of the management techniques applied; and (7) an intensive public relations program conducted throughout the project. In 1981 we drew down and chemically treated the Machickanee Flowage, and by late 1983 we had assessed the effects of the drawdown and chemical treatment.

WATER QUALITY

When we examined the water quality within the project area we learned that waste loading of the Oconto River was extremely high before the closing of the pulp mill in February 1978. The BOD_5 loading was occasionally as high as 60,000 kg/day before the mill closed, and afterwards it ranged from 200-800 kg/day. Daily average BOD_5 discharge in 1983 was only 1% of what it had been when the pulp mill was operating. Ammonia nitrogen levels before the closing were also high. Discharge of ammonia nitrogen via the Oconto River in 1977 exceeded the discharge to the nearby Fox River, even though the flow of the Oconto River is only 14% of that of the Fox River. The ammonia level in 1982 was only 4.5% of what it was in December 1977.

High levels of chlorophyll-*a* were measured in 1978 and 1980, but levels were lower after the drawdown of the Machickanee Flowage in 1981. Decreases in both chlorophyll-*a* and planktonic algae occurred. These decreases were probably related to the expansion of aquatic macrophyte populations after the drawdown and their subsequent incorporation of nutrients.

A shift from pollution-tolerant organisms to a more desirable, less tolerant biota occurred after the pulp mill closed. Before the mill closing *Sphaerotilus natans* (slimes) covered almost all river substrate from the mill to the river mouth. Most of the river substrate was free of these organisms nine months after the mill closed.

The water in the Machickanee Flowage was tested for concentrations of heavy metals in 1979. Detectable levels of mercury and chromium were recorded in a few samples. The mercury level was not considered a threat to the flowage ecosystem, and the high chromium concentration was thought to be due to a sampling or analytical error. No elevated levels of heavy metals were found in six private wells next to the flowage.

Vegetation in the Machickanee Flowage was tested for concentrations of heavy metals in 1981 and 1983. Arsenic levels from two sites sampled in 1981 were 2.8 mg/kg and 1.7 mg/kg, respectively. Chromium measured at one site was 10 mg/kg in 1981 and 20 mg/kg in 1983. The metals in the vegetation did not appear to be entering the water column.

By using aquatic macroinvertebrates as indicators of water quality, we knew that during the pulping operation the water quality of the Oconto River below the mill was poor. The ratings quickly improved to fair and then to very good after the mill closed in February 1978.

Use of Hilsenhoff's (1982) biotic index indicated that water quality ratings in the lower Oconto River improved progressively over time, with exceptions. As the drawdown of the Machickanee Flowage proceeded, water quality appeared to decrease progressively. Once the flowage was completely drawn down and sediment loading of the river decreased, water quality downstream from the mill improved progressively until all sites were rated as good to very good. Therefore, while the drawdown negatively affected water quality, the duration of that impact was short.

SEDIMENT

In 1979 sediment from the Machickanee Flowage was found to be polluted by concentrations of BOD_5, lead, total phosphorus, manganese, nickel, arsenic, cadmium, chromium, copper, iron, mercury, zinc, and volatile solids. These concentrations exceeded USEPA limits for sediments in Great Lakes harbors. The results of elutriate analysis indicated that these pollutants were not entering the water column at appreciable levels. Apparently the sediment was chemically stable, and water quality was not adversely affected by sediment in the flowage. We learned from results of the laboratory static bioassay that, even when disturbed, the flowage sediment did not release concentrations of pollutants to the water column in quantities sufficient to kill fathead minnows and adult crayfish.

During the drawdown the sediment compacted vertically, contracted horizontally, and hardened, as predicted from a bin study. Most of the sediment remained in place during the drawdown. Compaction varied within the flowage, and the rate of compaction decreased over time. The drawdown reduced by half the volume of sediment originally in the flowage.

ZOOPLANKTON

The drawdown of the Machickanee Flowage caused changes in the zooplankton population in the flowage. The pre-drawdown population was small, with the characteristics of lotic populations. A more lentic population existed after the drawdown, dominated by *Bosmina* and seven other cladoceran species. The numbers and species of zooplankton found after the drawdown suggest that more phytoplankton were then available as food.

We stocked the flowage with *Daphnia galeata mendotae* to increase the food base for stocked fish. This daphnid increased in numbers significantly in one year. We also stocked the flowage with many planktivorous fish, but this did not adversely affect the numbers of zooplankton.

AQUATIC MACROPHYTES AND MACROINVERTEBRATES

Before the drawdown, the Machickanee Flowage lacked suitable substrate to support aquatic plant life. Following the drawdown, aquatic vegetation rapidly repopulated the flowage, with emergent vegetation occurring one year after the drawdown. Within two years, the flowage was densely populated with submergent vegetation. In some areas vegetation was overly abundant.

Macroinvertebrate populations were also limited in the Machickanee Flowage before the drawdown. However, two years after the drawdown these populations had expanded numerically and specifically to the extent that they were similar to populations of other unpolluted water bodies.

During the pulping operation, the bottom of the Oconto River downstream from the mill was covered by sewage bacteria. The only aquatic invertebrates found were midge fly larvae and sludge worms. Eight months after the closing of the mill, invertebrate populations had expanded at all sites on the lower Oconto River.

FISH POPULATIONS AND MOVEMENT

Before the drawdown and chemical treatment, the Machickanee Flowage was dominated by rough fish. Nine months after the management activities in the flowage, 14 fish species were captured, including stocked rainbow trout. We attributed the presence of non-stocked species to downstream movement of fish from the two impoundments above the flowage. Recruitment to fish populations within the flowage was not restricted to a particular size range or age class of any species. The forage base in the flowage, which was large before the chemical treatment, declined afterwards because of stocked predatory species. The relative abundance of game fish and panfish increased following the chemical treatment.

Before the drawdown, growth rates of game fish and panfish from the Machickanee Flowage were similar to other water bodies, even though population numbers were low. Northern pike appeared to thrive because of the sizable forage base and lack of forage fish cover. Rough fish grew slowly and showed a poor condition.

Fish from the flowage grew rapidly following the chemical treatment. Stunted bluegills stocked in the flowage developed a unique scale impression signature that enabled identification of fish for two years following stocking. These scales depicted a near doubling of scale radius length in one growing season in the Machickanee Flowage.

No significant differences were found in the amount of toxic compounds tested for, when comparing fish from the Machickanee and Oconto Falls flowages before the drawdown. Concentrations of toxics did not increase following the drawdown or other activities.

Dams within the project area did not prevent the downstream movement of fish. Because of this movement 14 fish species were reproducing naturally in the flowage nine months after the chemical treatment. Some of these species were those for which the chemical treatment had originally been intended—common carp, black bullhead, and white sucker. We learned from surveys conducted later in 1982 that these species had successfully reproduced. By the end of the year black bullhead had become abundant. However, carp and white sucker, which were overabundant before the treatment, did not again become abundant. Other more desirable migrants—northern pike and yellow perch—became important aspects of the flowage fishery. Strong year classes of some fish species were observed in 1982. Some of these same species, for example yellow perch, produced weak year classes in 1983.

Fish populations in the lower Oconto River in 1982 and 1983 showed damage neither from the drawdown nor the chemical treatment of the Machickanee Flowage. The river continued to afford seasonal habitat for fish species that winter in Green Bay and also provided year-round habitat for the species indigenous to the Oconto River.

ANGLER EFFORT AND SUCCESS

Fishing pressure on the Machickanee Flowage in 1982 was 11 times greater than it was in 1979. Close to 4,000 anglers used the flowage in 1982 as compared to only 500 in 1979. Fishing pressure within the entire project area doubled between 1979 and 1982. The total number of fish caught in both the Machickanee Flowage and the project area increased significantly between 1979 and 1982.

CONCLUSION

Although significant improvements did occur, the restoration project did not return the Machickanee Flowage and the Oconto River to their original conditions prior to the heavy pollutant loading. Total reclamation would have required removal of all the sediment deposited in the flowage and the river from the pulp mill operation, an effort far beyond budget limitations. Flowage sediment may cause future problems, and fish populations may require future management. Monitoring of the river system has continued under standard DNR water quality, waste management, and fisheries management programs.

APPENDIX A

Fish Species of the Lower Oconto River

Fish caught during electrofishing surveys of 21 index stations on 22.5 km of the Oconto River downstream from the Machickanee Flowage, 1979-81.

SALMONIDAE	
Rainbow trout	*Salmo gairdneri*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Lake trout	*Salvelinus namaycush namaycush*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Pink salmon	*Oncorhynchus gorbuscha*
ACIPENSERIDAE	
Lake sturgeon	*Acipenser fulvescens*
AMIIDAE	
Bowfin	*Amia calva*
CLUPEIDAE	
Alewife	*Alosa pseudoharengus*
Gizzard shad	*Dorosoma cepedianum*
CATOSTOMIDAE	
White sucker	*Catostomus commersoni*
Shorthead redhorse	*Moxostoma macrolepidotum*
Northern hog sucker	*Hypentelium nigricans*
PETROMYZONTIDAE	
Chestnut lamprey	*Ichthyomyzon castaneus*
Sea lamprey	*Petromyzon marinus*
GADIDAE	
Burbot	*Lota lota*
PERCOPSIDAE	
Trout-perch	*Percopsis omiscomaycus*
PERCIDAE	
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*
Logperch	*Percina caprodes*
Johnny darter	*Etheostoma nigrum*
CENTRARCHIDAE	
Longear sunfish	*Lepomis megalotis*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
Rock bass	*Ambloplites rupestris*
Black crappie	*Pomoxis nigromaculatus*
Green sunfish	*Lepomis cyanellus*
CYPRINIDAE	
Common carp	*Cyprinus carpio*
Hornyhead chub	*Nocomis biguttatus*
Golden shiner	*Notemigonus crysoleucas*
Rosyface shiner	*Notropis rubellus*
Common shiner	*Notropis cornutus*
Spottail shiner	*Notropis hudsonius*
Weed shiner	*Notropis texanus*
Spotfin shiner	*Notropis spilopterus*
Fathead Minnow	*Pimephales promelas*
Bluntnose minnow	*Pimephales notatus*
ICTALURIDAE	
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Tadpole madtom	*Noturus gyrinus*
UMBRIDAE	
Central mudminnow	*Umbra limi*
ESOCIDAE	
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
PERCICHTHYIDAE	
White bass	*Morone chrysops*

APPENDIX B

Public Relations in the Oconto River Restoration Project

A report by Dave Crehore, Public Information Officer, Lake Michigan District.

MEANS AND ENDS

Public relations and public participation practices contributed to the Oconto River Restoration Project. These practices included the evaluation of potential public relations problems and opportunities before the work began, the involvement of a public relations professional, and the development and execution of a public relations plan.

THE INITIAL EVALUATION

During organizational meetings early in 1979, the Oconto River Committee (ORC) evaluated the potential public relations situation through discussion, review of news stories and editorials, and consultation with area residents. The committee realized that local concerns and public opinion would be important to the success of the project for six reasons:

1. The project's visibility: Area residents knew that the lower Oconto River was polluted and that the state had taken enforcement action against the Scott Paper Company, an important local employer. Citizen interest was and continued to be high.

2. The amount of money involved: Citizens knew that the paper company had paid a settlement of $1,000,000 to the state and federal governments, $600,000 of which was to be used for restoration of the river system. Area residents regarded this amount as public money and expected to be fully informed about the ORC's plans and expenditures.

3. A local interest group: The Machickanee Flowage Property Owners Association existed before and during the field work phase of the project. Anglers and flowage property owners expected improvement in the fishery and recreational quality of the flowage.

4. The pulp mill closure: Although the state did not require or force the closing of the pulp mill, some area residents assumed that the DNR had closed the mill, causing economic losses for employees and the Oconto Falls area. The ORC felt that this belief would stimulate scrutiny of the project and the use of funds.

5. The importance of the river and flowage as regional resources: Oconto County has many lakes and rivers, but most are 30-40 miles northwest of the project area. Southern Oconto County, where the Machickanee Flowage is located, and densely populated Brown County immediately to the south have few large inland waters. If restored, the lower Oconto River and Machickanee Flowage would become important recreational resources for more than 100,000 residents of the Green Bay area, as well as for the cities of Oconto and Oconto Falls. The ORC assumed that as the goals of the project became widely known people in this wider area would also become interested.

6. A concentration of news media in the area: Fourteen news media served the project area: two radio stations, a daily newspaper, and three weekly newspapers in Marinette and Oconto counties, as well as three VHF television stations, three radio stations, and two daily newspapers only 30 miles away in the city of Green Bay.

Because of these factors, the committee anticipated that the project would stimulate discussion and controversy. The committee also regarded the project as an opportunity to conduct a major, integrated natural resource management project in the full glare of the spotlights, showing every step of the process. Looking back, the committee feels that the open approach to planning and management was a good choice. Their experience shows the importance of evaluating the public relations situation for a project before implementation begins.

THE INVOLVEMENT OF A PUBLIC RELATIONS SPECIALIST

Too often in resource management agencies, public information specialists are expected only to produce occasional news releases, to serve infrequently as consultants, or to play firefighter after crises have developed. Consequently, the potential for contributions by these specialists to a team effort is limited.

As the DNR Lake Michigan District public information officer, I was a member of the original ORC. I attended all meetings, observed the field work, and assisted other team members as well as the many reporters who covered the project. My day-to-day involvement as a part-time writer, photographer, and media contact freed other ORC personnel from some of these responsibilities.

THE PUBLIC RELATIONS PLAN

Because the management plan of the restoration project was not developed in 1979, the public relations plan emphasized methods. The objective of the plan was to foster public understanding of the study phase, so that the eventual management recommendations could be appreciated in the context of what had been learned. Three efforts were planned to achieve this objective: 1) To encourage personal contact between project personnel and the public; 2) To solicit public interest and comment, and to invite the public to participate in the process of the project; 3) To provide the media and public with pertinent information during the initial study and planning phases of the project.

1. Personal contact was achieved in two ways:

a. The ORC field personnel, who were usually most qualified to answer reporters' questions, were the principal speakers. This practice built a first-name relationship between reporters and project personnel. In the process, field personnel received valuable experience in dealing with reporters and understanding their needs. The project chair and I occasionally served as speakers.

b. Project personnel regularly showed bystanders what they were working on. Shoreline property owners on the Machickanee Flowage, for example, also developed first-name acquaintanceships with ORC personnel who showed residents the results of seine hauls or other investigations. Both of these approaches built credibility and understanding.

2. Public comment was solicited at three public meetings. Two were held during the initial study and planning process, and a final meeting was held when the management plan was presented. To encourage public participation, the meetings were held on weekday evenings. The first two meetings were held at a veterans' hall about one mile from the flowage. At these informal sessions, staff members explained their work and some of the economic,

engineering, and biological concepts of the restoration. Questions and comments from the public were solicited and answered. As the project progressed, these public responses were our single most important source of information about public attitudes and concerns.

The third meeting was held in the city of Oconto. At this more formal meeting, all proceedings and comments were tape-recorded and later transcribed. ORC staff presented all elements of the management plan, then answered many questions and listened to statements of opinion read into the record.

In addition to the public meetings called by the ORC, members of the ORC staff attended and participated in two annual meetings of the Machickanee Flowage Property Owners Association, and spoke before other local user groups and service clubs.

3. Information was provided to the media and the public in three ways:

a. Newsletters: Three issues of a four-page ORC newsletter were mailed during the project to a list of meeting attendees. The newsletters were mailed to 112 addresses, and probably reached 200-300 people. These newsletters did not play a large part in the overall communications effort, but did serve to bring lengthy and detailed information to people interested in the project, free from the limitations of space and time typically imposed by news media.

b. News releases: Twelve news releases were mailed to area media from early 1979 through late 1981. In many cases, the releases were printed or broadcast largely as written, but they also stimulated reporters to do their own stories. Every major finding or development was described in a news release, and a steady flow of information to the media was maintained. In other instances, when time did not permit the preparation of a written release, I informed the media of developments and story ideas through telephone calls. The releases and calls were an important part of our initiative to provide information.

c. Assisting media: The Oconto River Restoration Project received much favorable newspaper and television coverage. The story was covered extensively by local newspapers, as well as by papers in Milwaukee, Madison, Wausau, and Chicago. Green Bay television stations covered aspects of the restoration dozens of times during 1979-81. This thorough and usually helpful coverage was the product of three elements of the public relations effort: 1) news releases, which informed reporters and maintained their interest; 2) continual encouragement by the ORC staff for coverage of the project; and 3) most important, the willingness to cooperate with the media, to understand their needs, and to assist in the production of stories. The ORC went out of its way to provide both information and facilities, such as camera boats and other transportation. The fisheries management personnel and I spent hours guiding reporters up and down the river, and this effort produced much of the favorable and complete news coverage.

CONCLUSION

An agency must win the confidence of the public in managing natural resources. Good performance will prove an agency's abilities and good intentions. Sensitivity to both rational and emotional expressions of public opinion will show that the agency intends to cooperate, not dictate. The Oconto River Restoration Project used public relations techniques to encourage mutual understanding rather than persuasion and to openly undertake a process rather than to conceal or manipulate it.

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