Michigan Department of Natural Resources

Remedial Action Plan

for

TORCH LAKE

Area of Concern

October 27, 1987

Michigan Department of Natural Resources
Surface Water Quality Division
Great Lakes and Environmental Assessment Section
P.O. Box 30028
Lansing, Michigan 48909

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PREFACE

This document is the final draft of a Remedial Action Plan (RAP) for the Torch Lake Area of Concern (AOC). The first two drafts were prepared by a Contractor (SAIC) under contract with the Great Lakes National Program Office (GLNPO), in accordance with the Guidance for Preparing an Area of Concern Remedial Action Plan (SAIC, 1985). This guidance document (and this RAP) reflect International Joint Commission (IJC) guidelines for RAP content and format, in large part. The Michigan Department of Natural Resources (MDNR), Surface Water Quality Division has been responsible for coordination of review, preparation of the final draft and public participation in conjunction with the MDNR Office of the Great Lakes. The coordinator for this AOC was Dr. Elwin Evans.

1. EXECUTIVE SUMMARY

Torch Lake, located on the Keweenaw Peninsula and tributary to Lake Superior, came to the national forefront in 1982 when abnormal or tumorous growths were described from the liver, spleen, and mesenteries of the lake's old sauger and walleye. The highly visible external tumors on these species have been are associated with viral infections and are common in Great Lakes populations. All other fish in the diverse fish community did not exhibit either external or internal growths considered abnormal.

The Michigan Department of Public Health issued a fish consumption advisory, shortly thereafter, on Torch Lake sauger and walleye even though these fish move freely to Portage Lake and Lake Superior. The advisory was issued, as a precaution, until the causative agent or agents, if present in Torch Lake, could be determined. Consumption of fish with tumors or abnormal growths, while aesthetically displeasing, are not known to transmit tumors to humans. Since Torch Lake was the center of an outstanding sauger fishery for many years prior the closing of the riparian copper mills and smelter, it seemed reasonable to concentrate considerable study effort on Torch Lake and the copper industry for possible fish tumor inducers.

Torch Lake received approximately 200 million tons of copper ore tailings between the late 1860's and the 1960's. Over 20 percent of this 1100 hectare lake (present mean depth 17 meters) was filled with tailings, and relatively small amounts of industrial and municipal trash. Raw sewage and mine pumpage were also discharged to the lake. Similar types of wastes were discharged to Lake Superior and Portage Lake.

Stamping the copper ores and recovering the native copper was a relatively inefficient process initially, and considerable copper was known to exist in the coarse tailings (stamp sands). In 1915, leaching of conglomerate tailings with cupric ammonium carbonate began. Flotation with coal tar creosotes and pyridine oil was added to this process in 1916. By 1929, flotation using xanthates (to recover copper) was practiced by all the mills in the Copper District. Gravity concentration and leaching of conglomate ores continued, in addition to flotation thereafter. Only flotation was used on the amygdaliod ores following gravity concentration. Once these processes were perfected, the various tailings piles in Torch Lake were removed by hydraulic dredges screened, reground gravity concentrated, floated and leached when practical. Tailings, along with the remaining copper concentrating chemicals, were then discharged to the lake. This resulted in a very turbid lake with a changing shoreline configuration.

In addition to xanthates, wood creosote, pine oil, and sometimes lime, were used in various combinations depending on the ore and process water, during the last years of the copper industry on Torch Lake. Of these substances, both wood creosote and xanthates are biologically active compounds in the liver. Both are readily degradable. Short term fish bioassays of these compounds revealed hepatic abnormalities. Further long term exposures and continuous low level exposure using xanthates and wood creosote with fish are desirable.

Bioassays of sediment and water from Torch Lake for mutagenic activity were completed using bacteria, rainbow trout embryos and fry, as well as hamster ovary cells. All tests have been negative or similar to controls. Significant amounts of mutagenic substances are apparently absent from Torch Lake at this time.

Analysis of sediments and tailings in Torch Lake and Portage Lake for both heavy metals and mineralogy is probably the most extensive of any inland water body in Michigan. Copper is at high concentrations in many areas while zinc, lead and tin have high concentrations near the smelter on Torch Lake.

The aquatic animal communities living in or on sediments with high copper concentrations, are reduced in diversity, density and biomass, but these effects are not evident in Portage Lake in the area influenced by the Torch Lake discharge. Besides the fish consumption advisory, the impact on the bottom dwelling animal community is the only other impaired use in Torch Lake. A diverse phytoplankton and zooplankton community exists in Torch Lake, even though total copper concentrations range between 20 and 80 ug/l. Almost 70 percent of the copper load leaving Torch Lake is from its major tributary, the Trap Rock River, and it is apparently a natural loading. Copper concentrations in the lake have not changed since 1972.

Fish tissues (muscle, spleen, liver, tumors) have been analyzed for parasites, heavy metals and chlorinated organic compounds. Although these chemical data are limited, neither heavy metals or chlorinated organic compounds were found at concentrations of concern. Parasites were not implicated in tumor induction. At this time, there is no evidence that suggests that Torch Lake contains materials other than copper concentrations in the water, that are at levels significantly different than in Portage Lake nor that require regulatory action. Since tumor inducing agents have not been found in Torch Lake, the basis for the fish consumption advisory and thus the designation as an AOC no longer exists. Unless the basis for the consumption advisory is changed, it is recommended that this AOC be reclassified as a category six (6).

Remedial actions considered to enhance the recovery process around Torch Lake include: continue to upgrade wastewater treatment on the watershed; promote the revegetation of lakeshore tailings to further minimize air borne particulate matter, and institute a sauger/walleye restocking. Monitoring of the sauger/walleye population will provide a test of the hypothesis of historical chemical exposure and/or sensitivity to environmental conditions.

In addition, Torch Lake will be sampled in 1988 as part of Michigan's inland lakes water quality monitoring program. Fish populations will also be analyzed in 1988 from both Torch Lake and Portage Lake and samples will be collected for Michigan's fish contaminants monitoring program. Tumors and growth anomalies will also be evaluated in sauger and walleye collected during these surveys.

Given the wide distribution and large volumes of tailings deposited in Torch Lake, Portage Lake and Lake Superior, no other remedial actions to improve the benthic community have been considered nor do any seem feasible, practical or necessary. Natural transport, deposition and burial of these copper tailings appears to be the best way to proceed as this valuable aquatic ecosystem continues to recover from past activities.

2. INTRODUCTION

2.1 BACKGROUND

Torch Lake is located near the base of the Keweenaw Peninsula in Michigan's Upper Peninsula and is tributary to Portage Lake and the Keweenaw Waterway that bisects the base of the peninsula (Figure 2.1). This region is known as the Copper Country because of deposits of native (elemental) copper in a narrow belt extending from the tip of the Keweenaw Peninsula southwest to the Wisconsin border, a distance of over a hundred miles (Figure 2.2).

Prehistoric copper mining occurred in this area and on Isle Royale in an estimated 5000 pits, some to 30 feet in depth. From 500 million to more than a billion pounds of native copper were estimated to have been recovered (Drier 1961). Over 10.5 billion pounds of native copper were produced from this area between the mid-1840's and 1968 when the mills were closed (Wilband 1978) (Figure 2.3). More than 96 percent of the native copper produced during this period came from an area about 28 miles long that extends from southwest of Painesdale to east of Mohawk. More than half of this copper was processed along the shores of Torch Lake from the late 1860's until 1968. At least 20 percent of the lakes original volume was filled with an estimated 200 million tons of copper ore tailings (Markham 1985). In addition, the lake received municipal and industrial trash, sanitary wastes and mine pumpage. Consequently, the sediments of Torch Lake are enriched with copper and other heavy metals.

Torch Lake supported a popular sports fishery for many years prior to the closing of the riparian copper processing activities. Michigan record saugers were caught in the lake and were so abundant that creel limits were increased to 30 per day for the lake. In 1979 and 1980, old sauger and walleyes were found to have both external and internal tumorous growths (Black et al. 1982). Previously, descriptions of some growth anomalies in Torch Lake sauger were reported as part of a thesis on sauger growth (Tomljanovich 1974). The external tumors found on the sauger and walleye are not uncommon on these species throughout their range, especially on the older fish. External tumors of this type have been associated with viruses (Walker 1967). The tumors of the liver and the unique periviseral masses were of concern since fish tumors have been associated with water pollution in numerous studies.

In 1983, the Michigan Department of Public Health issued a consumption advisory for sauger and walleye caught in Torch Lake, even though tumors from fish cannot transmit cancer to humans (Hesse 1983). It was felt that the tumor inducing agents might still be present in the fish or environment, and until better information was available on probable cause(s), it was prudent to issue an advisory against eating walleye and sauger. All other species of fish from Torch Lake and its tributary waters are not known to have tumors at rates of concern and were not included in the advisory. The International Joint Commission's (IJC) Water Quality Board (WQB) designated Torch lake as a Great Lakes Area of

Figure 2.1 Communities and water bodies at the base of the Keweenaw Peninsula of Michigan.

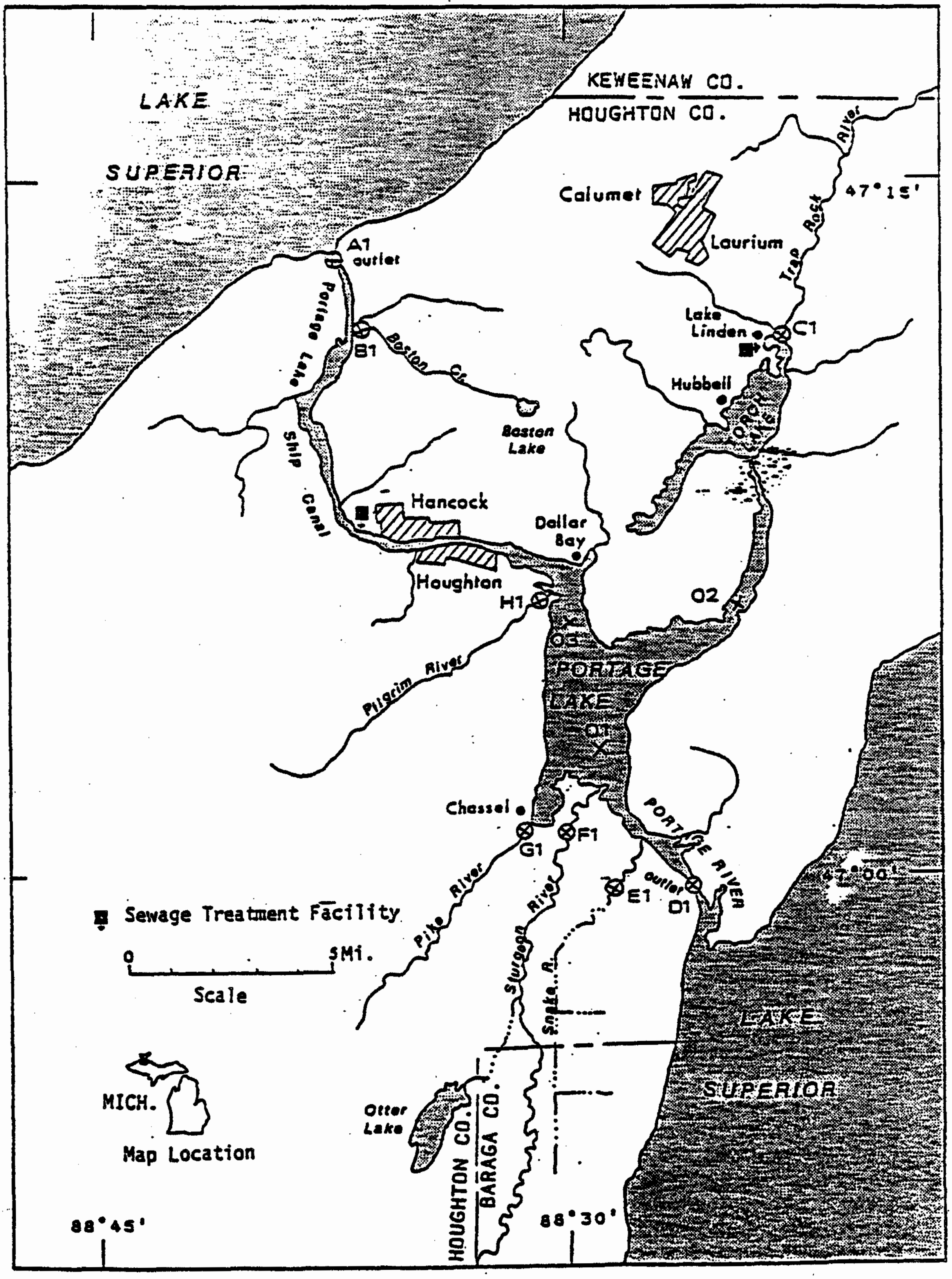
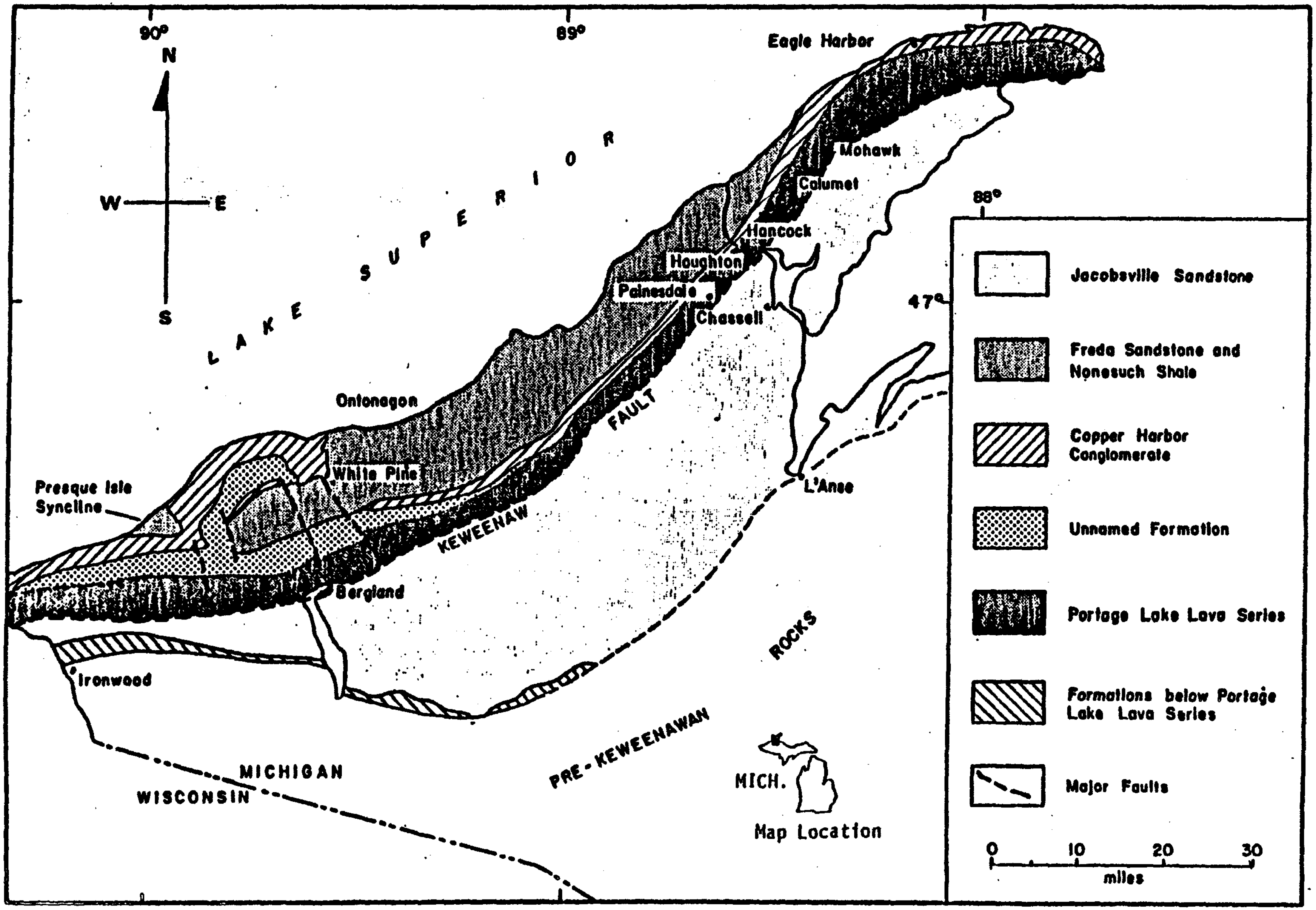
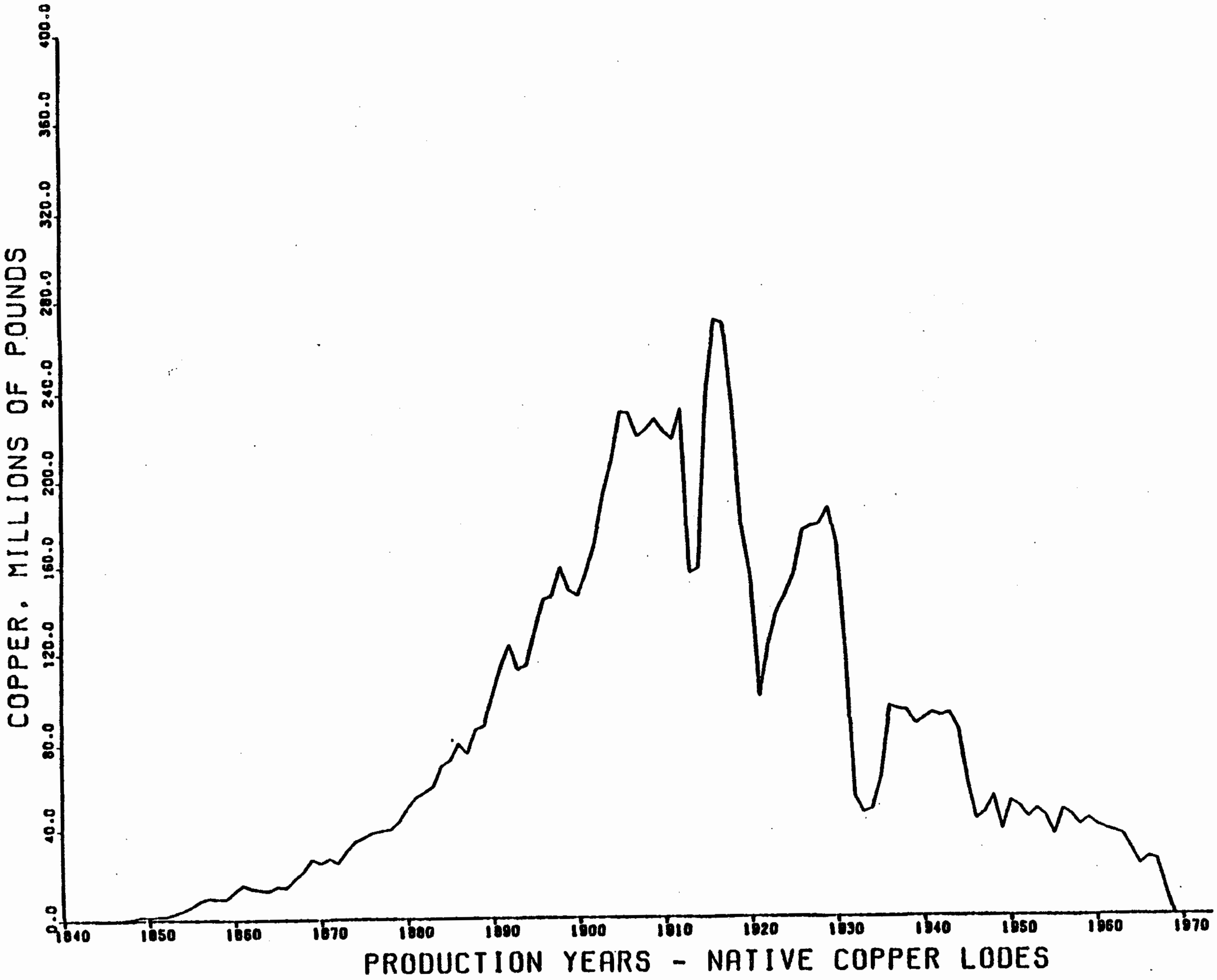


Figure 2.2 Geological formations of the Keweenaw Peninsula of Michigan.



Source: Wilband 1978

Figure 2.3 Copper production in the Keweenaw Peninsula Copper District of Michigan to 1968.



Source: Wilband 1978

Concern (AOC) solely on the basis of the fish consumption advisory limited to sauger and walleye (IJC 1985).

Benthic communities in Torch Lake, Portage Lake and Lake Superior have been reduced in areas of copper tailings disposal (Evans 1973, Kraft 1979, Kraft and Sypniewski 1981, Malueg et al. 1984). According to a recent revision in Michigan's Water Quality Standards, this is an impaired use. Bioassays of Torch Lake sediments have shown them to be toxic, as well as copper tailings from other areas in the region (Malueg 1984).

Water chemistry data on Torch Lake during the years of copper production were not found, although discharges of tailings created very turbid conditions in most of the lake for many years. After copper production ceased along Torch Lake, water clarity gradually increased to where secchi depths of 10 feet have been measured (Evans 1979). Conductivity, chlorides and hardness have decreased considerably, along with a number of other water quality parameters which were less frequently measured. Primary production in the lake is not sufficient to cause significant oxygen depletion during summer stratification and hypolimnetic oxygen is sufficient to support coldwater fish species (6.0 mg/l) (Evans 1973, 1979; Wright et al. 1983).

Torch Lake is unique because of high concentrations of copper. Concentrations of total copper in the water column have ranged between 20 and 80 ug/l since 1971 (Evans 1973, Warburton 1986). A large part of the copper in the water column is from the Trap Rock River, the major tributary to the lake. Tailings also contribute to the copper budget of this lake and the load discharged to Portage Lake (Warburton 1986). These copper concentrations exceed the IJC water quality objective of 5 ug/l.

Concentrations of copper within the above ranges would also exceed values that would be calculated for NPDES discharge limits according to Michigans Water Quality Standards, Rule 323.1057, regarding toxic substances. According to procedures established under this rule, discharges to Torch Lake would be limited, such that copper concentrations did not exceed 11 ug/l at the edge of the mixing zone, for the long term protection of aquatic life. The concentrations of copper at the point of discharge would be either 38 ug/l (coldwater) or 76 ug/l (warmwater), depending on the water body classification, in order to prevent acute toxicity in the mixing zone. In this case, 76 ug/l would be permitted at the point of discharge to Torch Lake, but a discharge to the Trap Rock River which is classified as coldwater (trout stream), the limit would be 38 ug/l.

In spite of the high concentrations of copper in the water column, the lake has a diverse and abundant phytoplankton community, some submergent and emergent macrophytes in many areas of the lake and a very complex fish community containing both coldwater and warmwater species (Evans 1973, 1979, Juetten 1979). Apparently, the dissolved organic substances (7.0 mg/l) in the water that give this lake its dark color, chelates the copper, making it non toxic.

2.2 GREAT LAKES WATER QUALITY MANAGEMENT

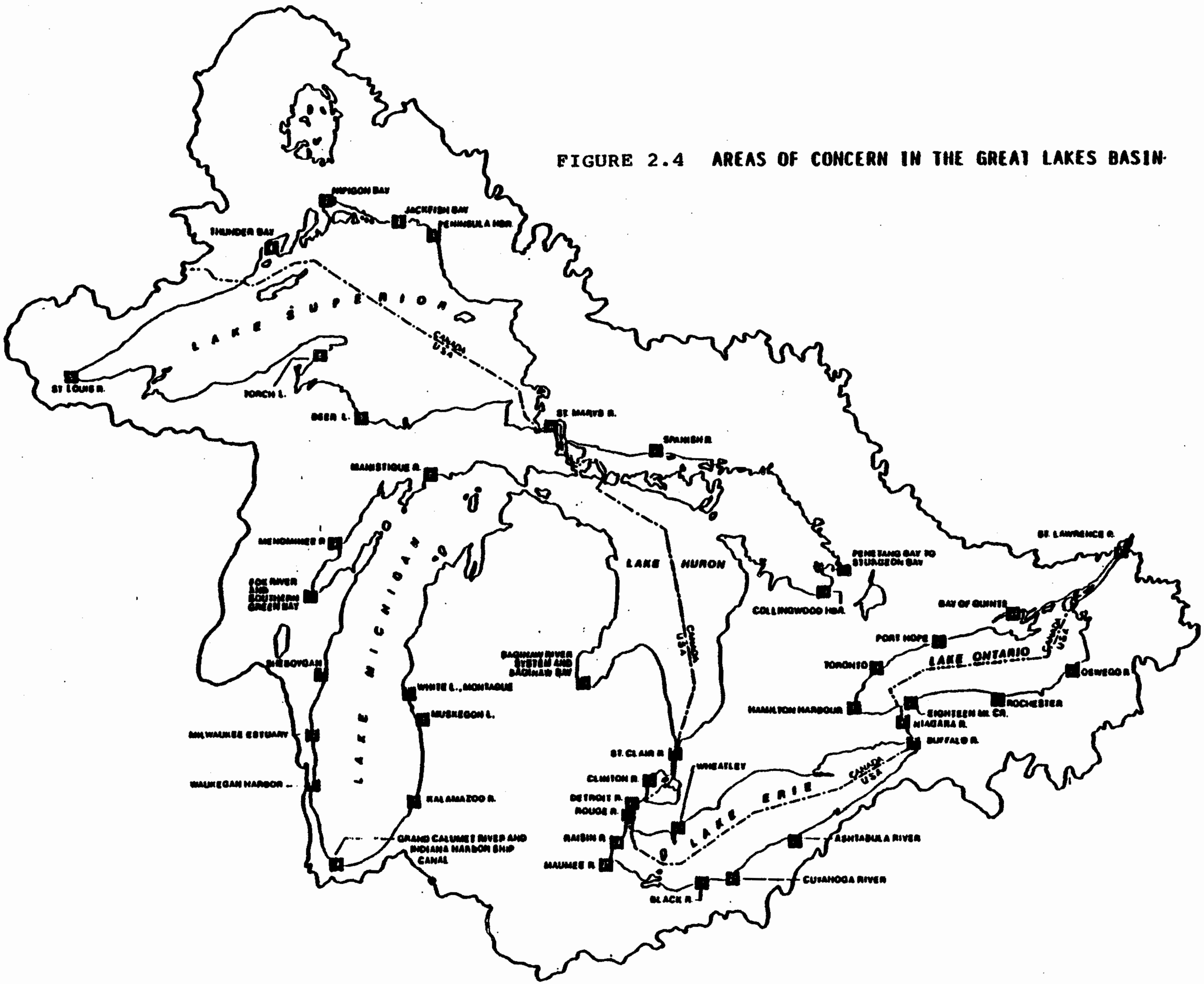
The Great Lakes are a unique natural resource that also form a portion of the international boundary between the United States and Canada. Both countries have jurisdiction over their use. In order to protect this vast resource and cooperatively address problems along their common border, the U.S. and Canada interact through an agency known as the International Joint commission (IJC) established under the authority of the Boundary Waters Treaty of 1909. Lake Michigan is not a boundary water since it lies entirely within the boundaries of the United States. However, it has been included in the Areas of Concern effort since it is an integral part of the Great Lakes System.

During the mid 1970s, Michigan, in conjunction with the IJC, identified specific pollution "problem areas" in Michigan's Great Lakes waters. Pollution problems in these areas varied in scope, severity, and complexity. Corrective actions also varied according to state and local priorities and resources. Problems associated with municipal discharges were often remedied through the construction grants program and the industrial pre-treatment program. Industry-related problems were remedied or minimized through the National Pollution Discharge Elimination System (NPDES) permit program. Some groundwater or sediment contamination problems were remedied through federal or state programs, including dredging, federal Superfund and the state 307 program. Under these programs, water quality throughout the state continues to improve, but detailed guidance for further improvement in specific areas is needed.

In 1981, the "problem areas" were renamed "Areas of Concern" (AOCs). The name change reflected the IJC's desire to shift the problem perspective from water quality alone to an "ecosystem perspective" that is based on environmental quality data for all media, and to evaluate the areas with uniform criteria. An Area of Concern is defined by the Water Quality Board (WQB) of the IJC as an area where there is known impairment of a designated use. IJC agreement objectives, jurisdictional standards and water quality criteria or guidelines are used as tools to measure use impairment. Impaired designated uses include but are not limited to, unusable public water supply, inability to use the waters for swimming or fishing, barriers to navigation, and the inability of the waters to support indigenous aquatic life and wildlife.

Forty-two (42) Areas of Concern were identified in the Great Lakes Basin (Figure 2-4). Fourteen (14) of the AOCs are in Michigan. These AOCs have been categorized based on the status of the information base, programs underway to fill information gaps and remedial efforts. No attempt was made to rank the AOCs by importance or significance of the problem(s). The AOC Classification System is presented in Table 2-1. In 1985, the State of Michigan has determined that Torch Lake was a Category 2 AOC, initially.

FIGURE 2.4 AREAS OF CONCERN IN THE GREAT LAKES BASIN



2.3 GOAL AND OBJECTIVES

The objectives of the Torch Lake Remedial Action Plan (RAP) are to: assemble and summarize all existing data on the Area of Concern, identify impaired designated uses, sources of the problems and data gaps, and propose alternatives to restore impaired designated uses and resolve identified problems (where sufficient data exists). Where sufficient data to define a problem or source do not exist, the RAP will propose investigations to provide the needed data. The goal of the Remedial Action Plan is to guide actions that will restore impaired designated uses within the Area of Concern.

Table 2.2 AOC CLASSIFICATION SYSTEM

CATEGORY	
(1)	Causative factors are unknown and there is no investigative program underway to identify causes.
(2)	Causative factors are unknown and an investigative program is underway to identify causes.
(3)	Causative factors known, but remedial action plan not developed, and remedial measures not fully implemented.
(4)	Causative factors known, and remedial action plan developed, but remedial measures not fully implemented.
(5)	Causative factors known, remedial action plan developed, and all remedial measures identified in remedial action plan have been implemented.
(6)	Confirmation that uses have been restored and future deletion as an Area of Concern in the next Water Quality Board Report.

According to the WQB (1985), resolution occurs when evidence can be presented that the full complement of uses has been restored. The site can then be removed from the Area of Concern list.

3. ENVIRONMENTAL SETTING

3.1 LOCATION

Torch Lake is located north of Portage Lake and the Keweenaw Waterway in the middle of the Keweenaw Penninsula, Houghton County Michigan. This corresponds to approximately 47° north latitude and 88° west longitude (Figure 2-1). Two communities, Lake Linden (population 1,181) and Hubbel (population 1,278) are situated on the northwest side of the lake. Torch Lake is a tributary to Portage Lake, which is part of the Keweenaw Waterway that flows to Lake Superior. Torch Lake is about 22 km (14 mi) by water from Lake Superior. Historically, these waterways were used for transportation to support a large copper mining and refining industry.

The Area of Concern (AOC) is confined to Torch Lake and its immediate environs on the basis of the fish consumption advisory and the long and intensive use of the lake for waste disposal that continued until copper production ceased in the area. Copper ores and processing were similar at other mills in the district for more than a decade before closure but their wastes were discharged to Lake Superior and widely dispersed. Therefore, it seemed reasonable to concentrate on Torch Lake for evidence as to the cause(s) of tumors in sauger and walleye since the best fishing for sauger existed there for many years.

3.2 NATURAL FEATURES

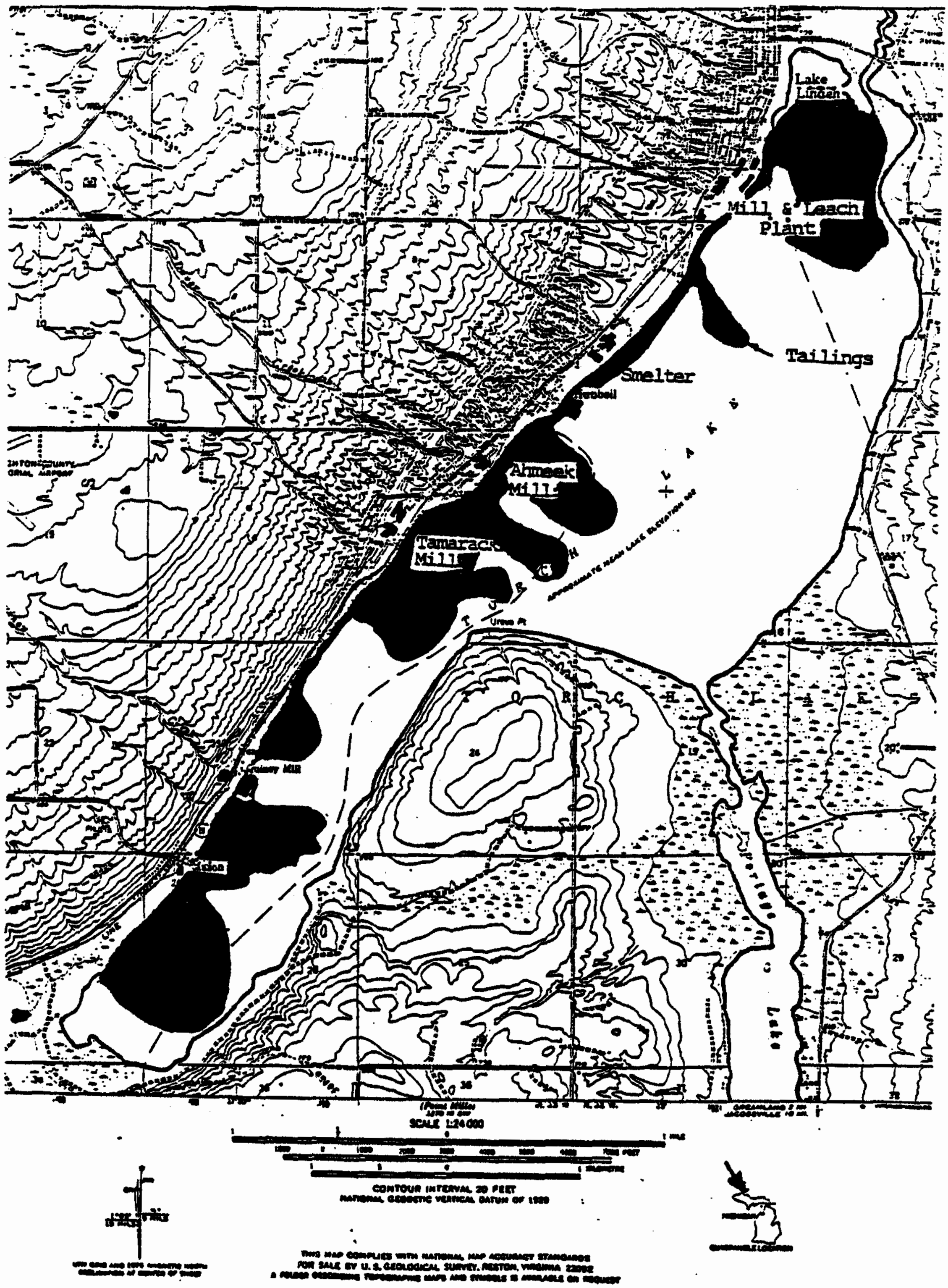
3.2.1 Drainage Basin Size

The watershed is approximately 200 km^2 (78 mi^2) which is about 12 percent of the Portage Lake basin. Together with relatively high local precipitation, the watershed annually contributes to the lake an amount of water equal to about half the lake volume (187×10^6 m^3). The lake surface area is approximately 1,100 hectares (2717 acres), with a maximum depth exceeding 35 meters (115 ft) and a mean depth of 17 meters (56 ft). The major tributary to the lake is the Trap Rock River. Several small creeks also discharge to Torch Lake.

3.2.2 Topography

The area surrounding the west side of Torch Lake is steep, rising from approximately 600 feet at lake level to over 1200 feet within about 5 km (3 mi) (Figure 3.1). The Trap Rock River enters Torch Lake on its northeastern end, running along the base of the steep hills to the north. The discharge from Torch Lake to Portage Lake is near mid lake along the southwestern shore. The western shoreline has been greatly modified by tailings deposits near the mill sites. To the east of Torch Lake towards Portage Lake, the topography is relatively flat with some wetlands.

Figure 3.1 Torch Lake, Houghton County, Michigan Showing Mill Sites, Smelter, Leach Plant and Copper Tailings Deposits above the Lake Surface.



3.2.3 Hydrology

Warburton (1986) estimated the long-term annual hydrologic budget for Torch Lake (Table 3-1). The Trap Rock River contributes 55 percent of the inflow to the lake with an estimated average annual discharge of 57.7 x $10^6 m^3$. Estimated basin runoff of 93.7 x $10^6 m^3$ is somewhat less than the outflow from the lake estimated at 98.5 x $10^6 m^3$.

3.2.4 Soil Types

The surficial soils in the area are sandy loam, loam, and silt. In some areas the top soil is underlain at shallow depths by reddish clay over bedrock. Tailings that make up most of the western shoreline of Torch Lake consist of finely textured reddish clay like particles and coarse pebbles (Figure 3.1). The crushed rock consists of two types: conglomerate, a coarse sediment with rhyolite pebbles and secondary calcite, quartz, and other minerals; and basalt, a volcanic rock that contains numerous vesicles filled with the same secondary minerals. Both conglomerate and basalt are common to the Upper Peninsula (Rose *et al*. 1986). Erosion from the tailings mounds results in the transport finer particles to the lake leaving the coarser materials behind.

3.2.5 Limnology

Torch Lake is about 9.3 km (5.8 mi.) long and 2.2 km (1.4 mi.) wide at its widest near-mid lake. The Keweenaw fault parallels the northern shoreline of this relatively deep, brown water, lake having a mean depth of 17 m (56 ft) (25 platinum units) (Evans 1979). Thermal stratification begins in early summer and extends into early fall with the thermocline reaching a depth of about 12 m before fall turn-over (Evans 1973; Wright *et al*. 1973). Oxygen decreases in the hypolimnion during stratification to about 6.0 mg/l, normally, and does not pose a problem for cold water fish (Evans 1973; Wright *et al*. 1972; Evans 1979, 1980, unpub.). In part, this reflects the low to modest productivity of the lake. Wright *et al*. 1973, averaged total phosphorus values from samples collected during stratification and indicated that 0.020 mg/l T-PO4 was an average value for the lake. Total phosphorus concentrations have not been measured recently but are probably in the same range or slightly lower, since sanitary wastes from the larger communities in the water shed are now treated.

Chlorides and conductivity have changed markedly in Torch Lake since mine pumpage ceased. In 1967, the average chloride value was 210 mg/l with conductivity of 700 umhos/cm (Yanko 1969). By 1970, chlorides had decreased to 84 mg/l and by 1972 had decreased to 23 - 34 mg/l (Evans 1973, Wright *et al*., 1973). As of 1979, chlorides averaged 13 mg/l with conductivity of 136 umhos/cm (Evans 1979 unpub.). Warburton 1986, found conductivity to range from 125 to 145 umhos/cm in 1985.

Torch Lake is a soft water lake with total alkalinity between about 40 - 50 mg/l from 1967 to 1979 (Evans 1973, Wright *et al*. 1973; Evans 1979 unpub.). Hardness has decreased from about 75 mg/l in 1972 to 45 mg/l in 1979 (Evans 1973; Evans 1979 unpub.). Warburton (1986) reported an average hardness of 40 mg/l in Torch Lake.

Table 3.1 Long Term Average Annual Hydrologic Budget for Torch Lake, Houghton County Michigan. (Warburton 1986, Michigan Technological University).

Sources	Volume Millions m^3	Percent of Total
INPUT		
Precipitation on Lake Surface	11.1	10.5
Groundwater	0.7	0.7
Surface Runoff		
Trap Rock River	57.7	54.7
McCallum Creek	14.7	13.9
Sawmill Creek	11.7	11.1
Dover Creek	9.6	9.1
TOTAL	105.5	100.0
LOSS		
Evaporation from Lake Surface	7.0	6.6
Outflow to Portage Lake	98.5	93.4
TOTAL	105.5	100.0

The pH has fluctuated between 6.5 and 8.0 depending on sample location, depth and season. Warburton (1986), summarized the pH data for Torch Lake and indicated that no long range trends were evident over the previous 14 years.

Numerous other water chemistry parameters have been sampled on a limited basis as part of the studies cited above. These parameters include various forms of nitrogen (organic-N, NO_3 , NH_3) chemical oxygen demand, turbidity, suspended solids, dissolved solids, chlorophyll a, biochemical oxygen demand, sodium, potassium, calcium, magnesium, manganese, silica, sulphates, total organic carbon, iron, cadmium, chromium, zinc and copper. Of these water quality parameters, only copper concentrations are unusual for surface waters and have ranged between 20 and 80 ug/l since 1970. Where several samples have been taken over an extended time period, most of the above parameters have decreased over the past two decades.

One event occurred in 1971-1972 that measurably influenced Torch Lake water chemistry for a period of time. A discharge of copper leaching liquor (cupric ammonium carbonate) resulted when the Lake Linden leaching plant was being dismantled and salvaged. At least 27,000 gallons of blue liquor were discharged on a single day in June 1972 with a copper concentration of 1400 mg/l, ammonia at 20,000 mg/l and a pH of 11. This highly toxic solution readily dissociated in the lake increasing copper in the water to almost 1.0 mg/l in the spill area (Wright et al. 1973). A considerable area of the embayment receiving the discharge had blue sediments indicating that the discharge of leaching liquor was much greater than measured and had occurred over an extended time period (Evans 1973, Wright et al. 1973). In addition to increased copper concentration in the water column, pH, carbonate alkalinity and ammonia increased while dissolved oxygen in the hypolimnion decreased somewhat compared to previous concentrations. Warburton (1986) found copper concentrations in the water column from about 20 to 60 ug/l in 1985 with an average concentration of 33 ug/l ± 5.7 ug/l. These values are from filtered water samples. He concluded that present day copper concentrations were not significantly different than copper concentrations prior to the leaching liquor discharge in 1972.

Based on filtered water samples, Warburton (1986) estimated that 3480 kg of copper was discharged from Torch Lake to Portage Lake annually. Approximately 68 percent or 2380 kg of this load came from: the tributaries, primarily, the Trap Rock River (2000 kg). Internal loadings from lake sediments and tailings contributed 1010 kg or 29 percent of the annual loading to Portage Lake. Copper concentrations will likely remain markedly elevated in both Torch Lake and its discharge for many years. The total amount of copper in this budget is probably about 20 to 25 percent higher.

3.2.6 Air Quality

Area residents have complained about wind borne particulates for a number of years. Rose et al. 1986, measured air borne particulates at two locations near waste deposits on the lake shore. Samples near a tailings deposit had a concentration of 70 ug/m^3 on a windy day (gusts to 50 mph).

Particulates were composed mainly of silica, aluminum, calcium and iron. At the second site, near a copper recovery operation, only 4 ug/m^3 of particulates were collected but these contained high concentrations of copper and zinc. They concluded that particulates from past disposal areas were volumetrically insignificant in terms of loadings to the lake and do not represent a serious human health problem. As revegetation of tailings and waste deposits proceeds, wind blown particulates will become less of a problem for lakeside residents and distribution of tailings and wastes into the lake by the wind will be further reduced.

3.3 LAND USES

Land in the Torch Lake watershed is primarily forested. Due to the steep terrain, very little agriculture exists. Historically, mining was the major industry. Towns in the area were formed to provide housing support for the mining industry. Mining is no longer a viable industry in the area and the mines remain closed. Only a small percentage of the watershed is residential or commercial.

3.4 WATER USES

Torch Lake has been used for industrial water supply, sport fishing, contact recreation, waste assimilation, and navigation. Uses have changed over time with changing public perceptions of water quality and the decline of the mining industry. At this time, the lake is used for sport fishing, boating, limited contact recreation, non contact cooling water supply, treated municipal waste assimilation and wildlife habitat.

3.4.1 Fish and Wildlife Habitat

Despite past high turbidity and siltation Torch Lake supports a wide diversity of fish species (Juetten 1979, Tables 3-1, 3-2). Sauger, walleye, northern pike, perch, and small mouth bass are the major sport fish inhabiting the lake. The sauger population was only represented by older age classes (9 years and older). No young sauger were found suggesting that no recruitment was occurring, a situation that probably began sometime prior to the mills closure in 1968-1969.

Migratory water birds use the lake in the spring and fall. Nesting gulls are numerous at times on the tailings and an active bald eagle territory exists in the vicinity.

3.4.2 Water Supply

Water from Torch Lake is used by one small industry for non-contact cooling water. No other industrial users are known to exist. Public water supply for Hubbel and Lake Linden is derived from groundwater wells.

3.4.3 Commercial Fishing

No commercial fishing exists in Torch Lake.

Table 3.2 Fisheries Survey Data, 1979

CONS.8065
REV. 4/83

FISH DIVISION

LAKE FISH COLLECTION AND AGE-GROWTH SUMMARY

Lake: Torch

County: Houghton   T. 55N   R. 32-33W   Sec. Many   Date: 9/11-13/79

Weather: Rain   Air Temperature: 50's   Water Temperature: 55° surf.

Seine   Acres Seined   No. Hauls   Snags

Nets: Gill nets   Length: 600' per mesh size   Mesh: 2 1/2" 3 1/2" 4   No. Sets: /   No. Lifts: /

Other Gear: 1750' exp. gill net fished over night (14 nets)

Species	2"	4"	6"	8"	10"	12"	14"	16"	18"	20"	22" +	Total No.	Total Wt.	Ave. Size	Per cent Catchable
Walleye						1	2	1	3	3	13	23	81.6	19.8	87
Sauger									7	1	12	20	82.6	21.6	100
N. pike										1	11	12	75.7	27.9	100
Sm. bass					1		1		1			3	5.0	13.7	67
Cisco				1			1					2	0.8	10.8	100
Whitefish								1				1	1.0	15.0	100
Y. perch			136	72	12	2						222	31.3	6.9	14
R. bass			28	2	3							33	9.0	6.5	100
Rbw. trout			1		1	3						5	2.3	10.1	60
W. sucker			2	6	54	6						68	39.0	9.9	-
Alewife			62									62	3.1	6.0	-
Blk bullhd				1	5							6	2.2	9.7	83
Burbot										1	1	2	5.3	20.5	100
Sea lamprey				1								1	.1	8.3	-
Totals........			229	83	76	12	4	2	11	6	37	460	339.0	-	83

Analysis and comments: Total effort: 3550' gill net fished 24 hrs. All sauger were heavily infected by internal and external parasites.

Fishing reports: Poor for sauger.

Catchables: Bluegill and Pumpkinseeds, 6"; Crappie and Perch, 8"; Bass, 10"; Pike, 20".
Inch Groups: 2" Group 1.0-2.9; 4" Group 3.0-4.9; 6" Group 5.0-6.9, etc.

(Over)

Table 3.2 Continued

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

Cons. 8070
9/60

FISH GROWTH ANALYSIS

Lake or stream: Torch Lake

County: Houghton

T. 55N R. 32-33W Sec. M

Date(s) fish were collected: 9/11-13/79

Collector: R.P. Juetten

Section:

Method(s) of collection: Gill net

Analyzed by: R.P. Juetten

Section:

Species *		Age Group**	Number of fish	Length range (inches)	Mean length (inches)	State avg. length	Growth index (by age group)	Mean growth index for species
Sauger	all males	IX	4	17.3-18.5	17.9			
Sauger	males	X	2	18.5-18.7	18.6			
Sauger	females	X	4	22.5-24.0	23.4			
Sauger	males	XI	1	18.8	18.8			
Sauger	females	XI	7	23.5-25.5	24.1			
Sauger	females	XII	1	22.5	22.5			
Sauger	male	XIV	1	19.5	19.5			
Walleye		II	1	11.5	11.5	13.3	-1.8	
"		III	2	13.9-14.7	14.3	15.2	-0.9	
"		IV	1	16.5	16.5	17.2	-0.7	
"		VII	10	18.0-19.5	19.0	19.6	-0.6	
"		IX	2	21.0-22.0	21.5	21.4	+0.1	
Northern pike		III	4	20.2-23.5	21.9	22.2	-0.3	
		V	2	28.0-28.2	28.1	26.5	+1.6	
		VI	4	30.0-30.5	30.1	28.9	+1.2	
		VII	1	32.5	32.5	32.7	-0.2	
		VIII	1	37.0	37.0	33.4	+3.6	

* Several species may be listed on one card

** Given in calendar years. Fish become one year older on January 1.

(over)

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

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CONS. 3077
8.60

Lake or Stream: Torch Lake

County: Houghton

T 55N R 32 33 Sec. Many

NOTES AND REFERENCES

Subject: Comparisons of 1971 and 1979 surveys

Walleye: Catch/unit effort increased 3 x's over the 1971 survey. % of catch by weight and number increased 6 x's over 1971 survey. Average length increased by 20 mm.

Sauger: Catch/unit effort declined 6 x's from 1971 survey. Catch composition % by weight and number significantly decreased since 1971 survey. Age data from 1971, 1974 and 1979 indicate little recruitment since late 1960's. Average length of 1971 saugers was 434 mm. In 1974 it was 490 mm and in 1979 it was 549 mm. All saugers were heavily infected by internal and external tumors.

Northern pike: Catch composition percentages by weight and number increased 2 x's since 1971 survey. Average length increased slightly. Catch/unit effort was the same as encountered in 1971.

Smallmouth bass: Too few collected in both surveys to compare.. Trends indicate population is increasing.

Yellow Perch: Catch/unit effort declined slightly since 1971. Population appears stable. Slight increase in average lengths.

Rock Bass: Significant increase in numerical and weight percentages in catch composition. Catch/unit effort increased 33 x's over 1971.

W. Sucker: Slight decrease in catch composition percentage by weight, numerical percentages increased. Average lengths declined.

OVER

Prepared by | Section | Date

Copies to (check): Lansing ( ), Region ( ), District ( ), I.F.R. ( ).

Lake or Stream Torch Lake

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

CONS. G077
8/60

County Houghton   T 55N   R 32 33   Sec. Many

Page 3

NOTES AND REFERENCES

Subject:

Miscellaneous species: Rainbow trout, coho, whitefish, cisco, bluegill, burbot, alewife, smelt, redhorse, sea lamprey, and bullheads were collected in low numbers in 1971 and in this survey. Trends cannot be determined.

Summary: In 1971, 67% of biomass in collection was n. pike, walleye, sauger and sm. bass, with sauger comprising 51% of the collection biomass. In 1979 these species were 72% of the biomass in the collection, with saugers accounting for 24% of the survey biomass. It appears the total game fish biomass relation to other species has not changed but walleyes and n. pike are replacing saugers.

Prepared by R. Juetten   Section   Date 9-13-79

Copies to (check): Lansing ( ), Region ( ), District ( ), I.F.R. ( )

3.4.4 Sport Fishing

Sport fishing has been a major activity in Torch Lake. During the period of the milling activities when the water was described as turbid red, sport fishing for sauger was at its height. Walleye have displaced sauger as the most numerous large percid in Torch Lake (Juetten 1979). Less turbid waters tend to favour walleye over sauger where they coexist (Nelson and Walburg 1976, Ali et al. 1977). Biomass of gamefish has remained rather constant but walleye and northern pike have replaced sauger (Juetten 1979). Changes in fish community structure do not necessarily constitute an impairment of use.

The Trap Rock River and all of the smaller creeks that supply Torch Lake are designated trout streams. Information on the extent of fishing in Torch Lake and its tributaries is limited at this time and a creel census has not been completed since 1977.

3.4.5 Contact Recreation

Although Torch Lake is protected for full body contact recreation, it is not a major use of the lake. Swimming and other water contact sports are enjoyed during the summer months, however. A small park with a beach and boat launching facility were recently constructed in Lake Linden and may be expanded in the future.

3.4.6 Navigation

Historically, Torch Lake was the shipping point for copper mined in the area and a receiving point for coal and supplies. Ships traveled from Torch Lake, through Portage Lake and the Keweenaw Waterway, to Lake Superior. Since mining activities have ceased, major navigation in the area has dwindled. The Keweenaw Waterway is still a harbor of refuge for large ships carrying coal, grain and iron ore through Lake Superior. Torch Lake, however, is no longer used for commercial navigation.

3.4.7 Non-contact Recreation

No information is presently available on the forms of non-contact recreation in the Torch Lake area.

3.4.8 Waste Disposal

Torch Lake receives some municipal effluent from a few small municipal sources via Trap Rock River. Historically, Torch Lake was used mainly for disposal of waste material from copper milling and smelting and, to a lesser extent, wastes from municipal sources. The tailings, which have filled at least 20 percent of the original lake volume, are evidence of decades of waste disposal. Presently, the only direct discharge to Torch Lake is non-contact cooling water (748,000 gallons per day).

4. DEFINITION OF THE PROBLEM

The impaired uses of Torch Lake are: 1) the sport fishery for sauger and walleye and 2) the bottom dwelling animal community or benthic biota. A fish consumption advisory for Torch Lake sauger and walleye has been in effect since 1983 on the basis of tumors in old specimens. The advisory was issued as a precautionary measure and was not based on known human health risks. All other species of fish from Torch Lake can be utilized for food.

The benthic biota are greatly reduced in most of Torch Lake where copper mine tailings have been deposited, because of their toxic effects. Extensive areas in Portage Lake and Lake Superior along the Keweenaw Peninsula have deposits of copper tailings similar to those in Torch Lake.

Residents of the Torch Lake area have become concerned about the possibility of carcinogenic impacts on human health from water contact, fish consumption, and contact with dust particles from the tailings. A Lake Linden Village letter to Governor James Blanchard requesting financial and technological assistance stated:

> "The potential health hazards due to contaminants along with the adverse sociological and economic impact on our community caused by the negative publicity received by Torch Lake in the local, State, and national news media has prompted the Village of Lake Linden to take positive action to alleviate the negative impacts on our community" (J. Aittama 1983).

4.1 IMPAIRED USES

4.1.1 Biological Communities

The biota of ecosystems, in large part, determine their value and conditions over time. These organisms integrate the physical, chemical and biological conditions in the system over both short and extended time periods depending on the nature of the organism and its community structure. Higher trophic levels in aquatic ecosystems, such as fish, reflect conditions at lower trophic levels of biological organization (zooplankton, phytoplankton, macrobenthos), as well as physical and chemical conditions. Thus, a diverse, stable and productive fish community, with low levels of contaminants and in good health, would usually indicate good resource conditions over an extended period.

4.1.2 Fish Community

Torch Lake has had a diverse fish community for many years. Fisheries surveys have found more than 20 species of fish not including minnows (Juetten 1979, 1980; Tomljanovich 1974). Walleye, sauger, northern pike, smallmouth bass and perch are the most important sports fish. Changes in fish community structure has occurred since milling activities ceased along Torch Lake with sauger being replaced by walleye and other species (northern pike, smallmouth bass).

All the sauger in Torch Lake survey of 1979 were very old fish (9+ years). Fish growth and abudance surveys performed on Torch Lake suggested little or no recruitment since the late 1960's (Juetten 1979). Most of the fish species captured in Torch Lake are known to travel considerable distances during their lifetimes. Fish in Torch Lake have ready access to the Trap Rock River, Portage Lake, and Lake Superior and their tributaries.

Examination of fish from Torch Lake in the early 1970's revealed abnormal growths of several types in old walleye and sauger (Tomljanovich 1974). Accurate descriptions of all abnormal growths and their histopathology were not completed at that time. Black et al. (1982) found that walleye and sauger were commonly infected with three types of abnormal growths: hepatomas, dermal fibromas, and multiloculated gelatinous masses possibly originating from the visceral peritoneum or spleen. Livers and hearts of these fish were also heavily parasitized with trematodes. The dermal fibromas are associated with viruses and are common in old sauger and walleye in their ranges (Walker 1967). Up to 15 percent of the walleyes captured during spring runs in the Tittabawassee are infected with dermal sarcoma/fibroma/lymphocystics (Keller et al. 1987). Tumors of the liver are frequently associated with exposure to organic chemicals since these compounds may be activated or detoxified in this very metabolically active organ.

Most of the saugers examined had atrophied gonads which is not uncommon in old fish. Many of their gonads were heavily infiltrated with lipogranuloma-like lesions that consisted of aggregations of macrophage-like cells filled with a yellow crystalloid-appearing material (Black et al. 1982).

Since 1982, fish have been sampled several times in Torch Lake by sutdents at Michigan Technological University, but these population data are not complete nor comparable to previous surveys.

The incidence of liver tumors in recent samples of Torch Lake sauger and walleye are abnormally high while the other species of fish in the lake are not known to have tumors (Black et al. 1982). Tomljanovich (1974) examined more than 7000 fish representing 21 species, from the Keweenaw Waterway of which 122 were sauger. Large accumulation of fat were found in all but a few individuals while the "fat" lesions and ossifying fibromas were found in 9% and 10.6% of the sample, respectively. Black et al., 1982 necropised 8 northern pike, 8 white suckers, 5 smallmouth bass, 4 rainbow trout and one brook trout from the 1979 Torch Lake survey (Appendix 1). No internal or external tumors or abnormal growths in these species were observed. Twenty saugers and 11 walleye were also necropsied from this fish collection. On the basis of nodules found on the liver during gross examination, 100% appeared to have liver neoplasms. Nodule prevalence was not determined for the walleye. Affected livers from 8 saugers and 3 walleyes from the same sample were subsequently examined microscopically. All had liver neoplasms. Two sauger and one walleye from their subsample also had dermal neoplasms but virus particles were not detected in these tumors as reported in dermal fibromas by Walker (1976).

A third type of growth was observed in these two species and occurred as large perivisceral masses attached to the spleen, mesenteriec fat or mesenteries. Since this growth was not known previously, its incidence cannot be determined for sauger and walleye in the 1979 sample. These growth are described as multiloculated gelatinous masses and do not have a precise classification.

In 1980, Black et al. 1982, collected 3 sauger and 1 walleye from Torch Lake for further examination (Appendix I). All sauger had liver tumors, one a dermal fibroma and two had perivisceral masses. Among the walleye, three had liver tumors, two had dermal fibromas and two had perivisceral masses.

In 1983 and 1984, students from Michigan Technological University sampled fish populations in Torch Lake and Portage Lake and estimated the incidence of tumors and parasites by gross examination. Costanza and Oakes (1984) collected a total of 28 walleye and 56 sauger in 1983 and 45 walleye and 72 sauger in 1984. Of those fish examined, 13% of the walleye sampled in 1983 had liver tumors. Further tumor analysis was apparently incomplete for this sample. In the 1984 sample, walleye had dermal fibromas in 12% (6 of 50) of the sample, liver tumors in 4% (2 of 45) and perivisceral masses in 2% (1 of 43). Thirty-six percent (25 of 70) of the sauger had dermal fibroma. All were judged to have liver tumors (72 of 72) and 32% (19 of 60) had perivisceral masses. Although many other fish were captured, no data on these fish were apparently recorded.

Markham (1984) collected 18 walleye and 9 sauger in Torch Lake in the fall of 1984. Three walleye (17%) had dermal fibromas, one (6%) had a liver tumor and one (6%) had a perivisceral mass. Seven of the sauger (78%) had dermal fibromas, all sauger were judged to have liver tumors and one (11%) had a perivisceral mass. Other fish data were not recorded.

Spence (1986) collected 25 perch, 25 walleye and 11 sauger from Torch Lake to determine the relationship between parasites and tumors. Perch had neither liver tumors or dermal fibromas but two had perivisceral masses of an undetermined nature. Walleye did not exhibit liver tumors but 16% (4 of 25) had dermal fibromas and 8% (2 of 25) had perivisceral masses. Nine of 10 (90%) sauger had liver tumors, 30% (3 of 10) had dermal fibromas and 50% had perivisceral masses. It is not clear if all tissues were analyzed microscopically.

Black and Evans (1986 unpub.) found that among 434 fish collected from the Keweenaw Waterway, only sauger and occasionally walleye had obvious tumors or abnormal growths. Sixty-six sauger, 106 walleye, 21 bullheads, 23 smallmouth bass, 86 white suckers, 23 redhourse suckers, 90 yellow perch, 13 salmonids and 6 burbot were necropsied from this sample and examined for gross signs of tumors. Liver tissue samples from 25 sauger, 15 walleye, 7 perch and 4 bullheads were examined microscopically. Two perch had non-cancerous abnormalities in their liver and the bullheads were normal. Fifty-three percent (34 of 64) sauger had liver tumors, 44% (28 of 64) had dermal fibromas and two were normal. Both sauger from Otter Lake, a control, were normal. Six of 105 (6%) walleye had dermal fibromas and four (4) had liver tumors. One walleye from Otter Lake was normal. Data on perivisceral masses were not included since these abnormal growths are not considered neoplastic at this time.

Since all sauger and walleye in this sample were not examined in the same way, some estimate between tumor rates determined by gross examination and by microscopic examination were undertaken. In only two of 25 diagnosis (8%) among sauger was there a discrepancy between gross and microscopic examination. However, 6 of 15 cases (40%) examined microscopically were at variance with gross determinations. Among 10 cases grossly negative, two were determined to have tumors. Among five walleye considered to have gross signs of liver tumors, four (80%) were found to be negative upon microscopic examination.

Black and Evans (1986 unpub.) also examined 10 sauger and one walleye in the University of Michigan Museum collection. Specimens were collected between 1927 and 1955 from Houghton County or Portage Lake. Although parasite assemblages were similar to those found today, a tumor was found in only one sauger collected in 1955.

The data presented to this point on abnormal growths in fish from Torch Lake and its adjoining waters, demonstrate that old saugers and some old walleye have had high incidences of certain types of tumors or abnormal growths. Of these tumors, only those of the liver and dermis are presently considered neoplastic (Black and Evans 1986 unpub.). The dermal fibromas may eventually be shown to be non-neoplastic. As indicated, before dermal fibromas have been associated with viruses, and are not uncommon in older walleye and sauger.

Liver tumors are frequently associated with organic substances and are more frequent as animals age. The incidence of liver tumors presented in the above reports does not consider this fundamental fact.

Aging old sauger and walleye is difficult, at best, even for somebody familiar with the population in question. Tumor incidence might better be compared to total length or weight by sex, since male sauger and walleye tend to be smaller than females once they mature. The importance of analyzing tumor data in this fashion is illustrated by analyzing the tumor data presented above on museum specimens. Of the 10 sauger examined, only the largest 40 cm (16 inches) had a tumor of a comparable size/age to these saugers captured later with tumors. A conclusion that tumor incidences had increased in sauger would be erroneous based on the data and our understanding of tumors.

Much of the tumor incidence data presented above is also based on gross examinations which can interject considerable error, even when performed by experienced investigators. This probably would not cause a significant error in the determinations of the incidence of liver tumors in sauger, but the walleye data are more questionable. Future evaluations of liver tumors in walleye and sauger, require microscopic examination.

The high incidence of parasitism complicates the identification of liver tumors in sauger and walleye because parasites cause visible tissue growths when encysted. Thus data collected from gross examination can be in error to some degree.

Spence (1986) examined the relationship between fish-specific parasites and the incidence of tumors. The study found no apparent physical relationship between parasites and host tumors but could not dismiss a possible physiochemical association. Large numbers of encysted parasites were present and probably caused mechanical damage to the liver by causing prolonged, substantial engorgement of the hepatic vasculature and increased liver mitotic rates for tissue repair (Spence 1986). The author noted that this engorgement could increase the livers exposure to possible carcinogenic action by parasite metabolites and/or environmental pollutants.

4.1.3 Fish Consumption Advisories

A fish consumption advisory limited to only sauger and walleye in Torch Lake was announced in April 1983. The Michigan Department of Public Health (MDPH) published the health advisory and distributed it to fishermen as they purchased fishing licenses in Houghton, Baraga, and Keweenaw Counties. A news release followed in May 1983.

Presently, the consumption advisory for Torch Lake sauger and walleye is included on the Public Health Advisory List in Michigan's Fishing Guide that is given to all licensed fisherman in Michigan (Figure 4-1).

Negative publicity arising from news bulletins, notices at the local, State, and national levels created public apprehension and concern. MDPH published the advisory as a precautionary measure until the causative factor(s) of the tumors and the potential risks to humans could be identified. Analysis of cancer mortality rates in Houghton County for humans do not appear unusual (Hesse 1983).

4.1.4 Benthic Macroinvertebrates

The animals living in or on the bottom of lakes and streams are excellent indicators of local environmental conditions over extended time periods since they are relatively immobile compared to fish. These animals lack a backbone and are visible to the naked eye and include snails, clams, worms, insects and others. Some species, such as clams, live many years in a limited area while some insects may pass through their life cycle in a few days.

Evans (1973) reported macroinvertebrate densities ranging from 22 to $1774/m^2$ with an average of $251/m^2$ for 26 samples in 1970 and from 0 to $1539/m^2$ with an average of $243/m^2$ for 28 samples in 1972. Evans (1979 unpub.) found that macroinvertebrates ranged from 0 - $301/m^2$ with an

Figure 4.1 Torch Lake Health Advisory

MICHIGAN FISHING GUIDE 1987

DNR

Rules Apply April 1, 1987 Through March 31, 1988

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PUBLIC HEALTH ADVISORY

You should be aware that some fish from some locations contain one or more chemical contaminants at levels of public health concern. Mercury, PCB, PBB, DDT, Dieldrin, Chlordane, Toxaphene and Dioxin are among the list of such contaminants. It should not be assumed that fish from waters which are not listed below are contaminant-free. Many lakes and streams have not yet been tested. Even in the locations listed, not all of the fish species in the waterway have been tested in some cases.

As an eating precaution, it is advised that fish be skinned, trimmed, and filleted to remove fatty portions and cooked by baking, barbecuing or broiling on a rack to reduce the level of contaminants.

Based on available monitoring data, the following additional precautions are advised:

1. DO NOT EAT ANY FISH caught from: Deer Lake, Carp River and Carp Creek (Marquette County); Pine River (downstream from St. Louis, Gratiot and Midland Counties); South Branch Shiawassee River (M-59 to Byron Rd.)
2. DO NOT EAT LISTED SPECIES caught from: Lake Michigan* (Applies to Michigan, Indiana, Illinois, and Wisconsin waters): brown trout over 23", lake trout over 32", chinook salmon over 32", carp, and catfish; Green Bay (Wisconsin waters south of Marinette/Menominee): rainbow trout over 22", chinook salmon over 25", brown trout over 12", brook trout over 15", splake over 16", northern pike over 28", walleye over 20", white suckers, white bass, and carp; Lake Superior (Applies to Michigan, Minnesota and Wisconsin Waters): lake trout over 30"; Lake Erie (Applies to Michigan, Ohio, and Pennsylvania waters): carp and catfish; Lake St. Clair (Applies to Michigan and Ontario waters): largemouth bass over 14", muskie and sturgeon; St. Clair River (Applies to Michigan and Ontario waters): gizzard shad over 10"; Saginaw River and Saginaw Bay: carp and catfish; Rouge River (Wayne County): carp; Detroit River: carp; Kalamazoo River (downstream from city of Battle Creek to Morrow Pond Dam, Kalamazoo County): carp; Kalamazoo River (downstream from Morrow Pond Dam to Lake Michigan) and Portage Creek (downstream from Monarch Millpond Dam): carp, suckers, catfish, and largemouth bass; Torch Lake (Houghton County): walleye and sauger; Langford Lake (Gogebic County): walleye over 23"; Shiawassee River (Byron Road to Owosso): carp; Cass River (downstream from Bridgeport): catfish; Tittabawassee River (downstream from Midland): carp and catfish; Lake Macatawa (Ottawa County): carp; Hersey River (downstream from Reed City): bullheads and brown trout; St. Joseph River (downstream from Berrien Springs Dam): carp; Manistique River (downstream from M-94/Old US-2): carp; River Raisin (downstream from Winchester Bridge, Monroe): carp.
3. RESTRICT CONSUMPTION. Michigan recommends no more than one meal per week of the following fish: Lake Michigan* (Applies to Michigan, Indiana, Illinois and Wisconsin waters): lake trout 20-23", coho salmon over 26", chinook salmon 21-32", and brown trout up to 23"; Green Bay (Wisconsin waters south of Marinette/Menominee): splake up to 16"; Lake Superior: lake trout up to 30"; Lake Huron*: rainbow trout, lake trout and brown trout; Lake St. Clair (Applies to Michigan and Ontario waters): walleye over 18", white bass over 14", smallmouth bass over 14"; yellow perch over 12", carp over 22", rockbass over 8", black crappie over 10", largemouth bass 12-14", bluegill and pumpkinseed over 8", freshwater drum over 12", carpsucker over 18", brown bullhead over 10", catfish over 22", and northern pike; Saginaw Bay*: rainbow trout, lake trout, and brown trout; Kalamazoo River (downstream from Morrow Pond Dam to Lake Michigan) and Portage Creek (downstream from Monarch Millpond Dam): all species except those listed in category 2 above for these same waters; Chicagon Lake (Iron County): walleye over 18"; Lake Michigamme, Michigamme Reservoir, Peavy Pond, Paint River Pond, and the Michigamme River system to its junction with the Menominee River: rock bass over 9", northern pike, walleye, smallmouth bass and muskie; Langford Lake (Gogebic County): walleye 15-23", northern pike over 22"; Duck Lake (Gogebic County): walleye over 16"; Caribou Lake (Chippewa County): walleye over 18" and rock bass over 10"; Cass River (downstream from Bridgeport): carp; Grand River (Clinton County): carp; White Lake (Muskegon County): carp;

*Advisory also applies to listed species migrating into streams tributary to these waters.

NOTE: NURSING MOTHERS, PREGNANT WOMEN, WOMEN WHO ANTICIPATE BEARING CHILDREN, FEMALE CHILDREN OF ANY AGE, AND MALE CHILDREN AGE 15 OR UNDER SHOULD NOT EAT THE FISH LISTED IN ANY OF THE CATEGORIES LISTED ABOVE.

For further information, call the Center for Environmental Health Sciences at 1-800-648-6942.

average of $155/m^2$ in 15 samples. These low density benthic communities were dominated by worms and midges and indicated toxic conditions.

Kraft and Sypniewski (1981) also found benthic communities depaupered where sediment copper concentrations exceeded 500 mg/kg dry weight at the north end of Portage Lake. At the south end of Portage Lake, where the discharge of Torch Lake might exert some influence, sediment copper was 33 mg/kg dry weight. Macroinvertebrates averaged $1296/m^2$ at the north station in Portage Lake and $5508/m^2$ near the Torch Lake discharge.

Malueg *et al*. (1984b), also found reduced numbers of macroinvertebrates in the north of Portage Lake ($110/m^2$) and higher densities in the south ($491/m^2$). Copper content in sediments in the north averaged 612 mg/kg and 24 mg/kg in the south.

Bioassays of Torch Lake sediments, using mayflies (*Hexagenia*) and *Daphnia*, found sediments to be toxic (Gakstatter 1982). Malueg *et al*. (1984a) bioassayed sediments from Portage Lake using the same animals and found sediments with high copper concentrations from the north in Portage Lake, to exhibit toxicity while sediments from the south did not. Kraft and Sypniewski (1984) also concluded that high levels of copper in sediments in the northern end of Portage Lake, were the likely cause of low diversity and numbers of macroinvertebrates.

4.1.5 Zooplankton

Limited data exist on Torch Lake zooplankton. Evans (1980 unpub.) found a rather diverse zooplankton community which was low in numbers (178 - $278/m^3$) in July 1980. A high percentage of copepods and low numbers of rotifers generally indicate good water quality (Table 4.1).

Waybrandt (1979) carried out a 48 hour bioassay of Torch Lake water using *Daphnia magna* and concluded that the water was not harmful.

4.1.6 Phytoplankton

Phytoplankton data from Torch Lake are also limited. Evans (1973) presented data from a series of surface water grab samples collected in the fall of 1970 and 1972 (Table 4.2). Algal cell density ranged from 113 to 345/ml (average 211/ml) in 1970 and from 532 to 3062 (average 1286/ml) in 1972. Diatoms and coccoid green algae dominated this diverse phytoplankton community. Good water quality was indicated.

4.1.7 Macrophytes

Aquatic macrophytes or weeds were observed in the shallow waters of Torch Lake at several locations in 1972 (Evans 1973). Dense beds of *Myriophyllum* (milfoil) were located in the vicinity of the mouth of the Trap Rock River. Bullrushes (*Scirpus*) were visible from Ureux Point to the Torch Lake outlet while isolated plants were seen in the shallow water at the narrow southwest end of the lake where extensive tailing deposits exist.

Table 4.1 Relative abundance of zooplankton collected from Torch Lake, Houghton County, July 25, 1980 in 30 ft. vertical tows using a 9.25 in. diameter plankton net.

Taxa	Off Hubbel Boat Launch-40 ft Aliquots		Near Sunken Dredge-65 ft Aliquots		Off Twin Stacks at Hubbel 100 ft Aliquots		Total	%
	I	II	I	II	I	II		
Alona sp.	L	L						
Bosmina longirostris	20	19	8	6	4	33	90	17
Calanoid copepods	17	3	19	15	12	73	139	26
Cyclopoid copepods	5	1	0	1			7	1
Copepod nauplii			1	0	1	1	3	1
Daphnia retrocurva	45	30	60	40	9	86	270	51
Kiratella cochlearis	2	0	14	0	3	0	19	4
Leptadora kindtii			2	1			3	1
Total/aliquot	89+	53+	104	13	29	193	531	
average/station	71		84		111			
Number/m^3 (x 2.5)	178		210		278		x=222	

Identified by:
D. Kenaga, Aquatic Biologist, 1980

Table 4.2 Genera and numbers of algae occurring in surface water grab samples in Torch Lake, Houghton Co., Sept. 29, 1972 compared with similar samples collected Oct. 26-28, 1970.

Algae Genera	Inlet		I		II		III		VI	VII A	VIII	X Outlet	
	1970	1972	1970	1972	1970	1972	1970	1972	1972	1972	1972	1970	1972
Coccoid Green													
Oocystis				9	3	5		12		2			9
Coelastrum		18	3	23		12		14	12	2	16	2	16
Scenedesmus	16	692		1318	22	1219	11	1035	1771	221	771	6	1021
Crucigena		138				5		5					2
Sphaerocystis		16				5				2			
Chaetopeltis	8	7											
Pediastrum	3	5	3										
Golenkinia		9				7							
Tetraëdron		5			3								
Dictyosphaenum						5		7	2				2
Echinospaerella									2				
Dimorphococcus									2				
Ankistrodesmus									2				
Acanthosphaera									2				
Selinastrum											2		
Actinastrum											2		
Chlorella					3								
Chroococcus			3		11							1	
Micractinium													
Westella												1	
Undetermined	19	28	5	37	57	30	16	16	2	37	108	1	35
Filamentous Green													
Mougeotia		2						2				1	
Cladophora								2			5		
Undetermined		2		2		5			78		9		
Blue Green													
Anacystis		2		9		18			28	5	12		9
Calothrix				2					2				
Anabaena				12				2	23		9		7
Gomphosphaeria		2		7		9		7	14	2	2		5
Oscillatoria						5							
Gloetrichia											7		
Coelosphaerium													12
Unknown					3								
Pennate Diatoms													
Gyrosigma			22									1	
Asterionella	105	14	63	2	71	7	44	7	7	16	14	73	7
Navicula	3	53	5	2	16	7	13	30	25	21	2		14
Synedra	3	18		2		16	11	14	9	51	2	1	12
Fragilaria	76	14		5	41	5	25	14	35	9	2	14	21
Achnanthes													2
Diploneis										2			
Cocconeis	3	5							2				2
Nitzschia	3	9		5		5	3	12	12		2		2
Pinnularia						2			2	9			
Amphora		7						5		2			
Cymbella	8					5							2
Surirella		2		2									
Diatoma	13		11		8		11					1	
Unknown	19		8				14						
Centric Diatoms													
Melosira	3			5									2
Stephanodiscus	11	212			3	9	3	7	9	7	14		9
Cyclotella	11	5	14	2	11	14	3			9		3	12
Rhizosolenia				5	41	7		7	5	2			
Unknown	22		19		36							7	
Desmids													
Arthrodesmus				2							12		
Staurastrum				2									2
Cosmarium		39				9			2		9		
Euastrum									5				
Unknown												1	
Flagellates													
Mallomonas		46		5		18		9	5	2	7		9
Glenodinium		9				5		2		124			
Euglena						2							
Dinobryon								2		7	5		
Peridinium									2		2		
Phacus											2		
Miscellaneous													
Vorticella									2			5	
Codonella													2
Total phytoplankton ml/ station 1970	307		153		343		140					113	
1972		1359		1458		1426		1213	2062	532	1021		1216
Total Genera /ml /station 1970	17		10		16		10					14	
1972		26		20		26		21	27	20	24		24
Grand Mean Phytoplankton/ ml/station 1970	211												
1972	1286												

4.2 SEDIMENT QUALITY

Sediment and tailings have been analyzed throughout the Keweenaw Waterway, Torch Lake and in nearby Lake Superior on many occassions, either as part of dredging projects, biological studies or mineralogical evaluations. Data from some of these studies (Table 4.3) have been used to create figures showing the general distribution high concentrations of sediment copper (Figure 4.2) with individual sample copper concentrations given in Figure 4.3. Zinc sediment concentrations are shown in Figure 4.4, arsenic in Figure 4.5, lead in Figure 4.6 and tin in Figure 4.7. The highest values for copper (12,000 mg/kg), zinc (2600 mg/kg), lead (4300 mg/kg), and tin (1300 mg/kg) were found in a small area of Torch Lake near the Hubbel smelter. High sediment copper concentrations are widespread as a result of tailings disposal. Similar copper concentrations can be found in tailings deposited in Lake Superior near Freda and Red Ridge, west of the north entrv to the Portage Ship Canal (Babcock and Spiroff 1970). These tailings are transported to the canal by shoreline currents. The other significant tailings deposit is to the east of the Keweenaw Peninsula near Gay. These tailings are transported to the south towards the south entry to Portage Lake where they are intercepted by a breakwall.

Evans (1973) in an earlier study, reported nutrient and sediment heavy metals concentrations from seven stations in Torch Lake. Average concentrations in mg/kg dry weight were: TPO_4-P 593, organic nitrogen 434, Ni 37, Hg 0.06, Pb 27, Cr 29 As 4.5, Cu 644 - (pore water 0.15 mg/l), Zn 66, and Cd 0.9. A flocculent, light brown ooze covered the reddish tailings in 1970. The sediment profile in deep water has changed and the reddish clay-like tailings are now covered by a 5-6 cm band of dark brown sediments. Black et al. (1982) found copper concentrations in this layer ranging from 1700 to 2400 mg/kg dry weight. Lead ranged from 80-270 mg/kg and zinc from 180 to 250 mg/kg in the upper dark layer. Chromium (30-40 mg/kg) and nickel (90-120 mg/kg) had higher concentrations in the reddish clay layer. They also noted that copper, lead, and zinc may still be entering the aquatic ecosystem, being bound by biota or particulate matter and are settling to the bottom.

Tailings were analyzed in 1984 from the upper and lower halves of a 36 inch core sample, taken in the deposits near Mason at the southwest end of the lake (Evans 1984 unpub.). Heavy metal concentrations in these tailings are presented in Table 4-4. Copper ranged from 840 to 1130 mg/kg dry weight, while lead had an average concentration of 5 mg/kg and zinc averaged approximately 65 mg/kg dry weight.

Malueg et al. (1986) also conducted bulk sediment analysis on Torch Lake sediments. They found copper concentrations of 1800 mg/kg (dry weight basis). In addition, they estimated concentrations of chromium, nickel, lead and zinc to be 180 mg/kg, 150 mg/kg, 140 mg/kg and 310 mg/kg, respectively.

Three sediment samples collected from undescribed locations in Torch Lake were analyzed for polynuclear aromatic hydrocarbons (PAHs). Except for chrysene and benzo (a) pyrene (BaP), other PAHs were not detected above their detection limits of 5 ug/l dry weight of sediments. Chrysene and

Table 4.3 Sources of sediment data on Torch Lake, Portage Lake and the Keweenaw Waterway used in Figures 4.2 through 4.7

Study (Author and Date of Publ.)	Map Symbol (W/Metals sampled)	Sampling Date	Sampling Technique	Detection Limits
Rose, et al., 1986	* (Cu, Zn, As, Sn, Pb)	1982-1983	Single Grab Sample, Surface Dredge	N.A.
Malueg, et al., 1983a Malueg, et al., 1983b	○ (Cu, Zn, Pb)	June-Oct. 1982	Single Grab Sample, Surface Dredge	N.A.
Draft EIS, U.S. Army Engineers, 1985	+ (Cu, Zn, As, Pb)	Cu, As, Pb; Nov. 79 Zn; Sept. 74	N.A.	N.A.
MDNR, Interoffice Communication, 1979	★ (Cu, Zn, Pb)	Sept. 1979	Single Grab Sample, Surface Dredge (One Location Only)	N.A.
Kraft & Sypniewsky, 1981	△ (Cu)	Oct. 1975	3 Replicates, Surface Dredge	N.A.
Lopez & Lee, 1977	□ (Cu, Zn)	June 1972- April 1973	Single Grab Samples, Surface Dredge	N.A.

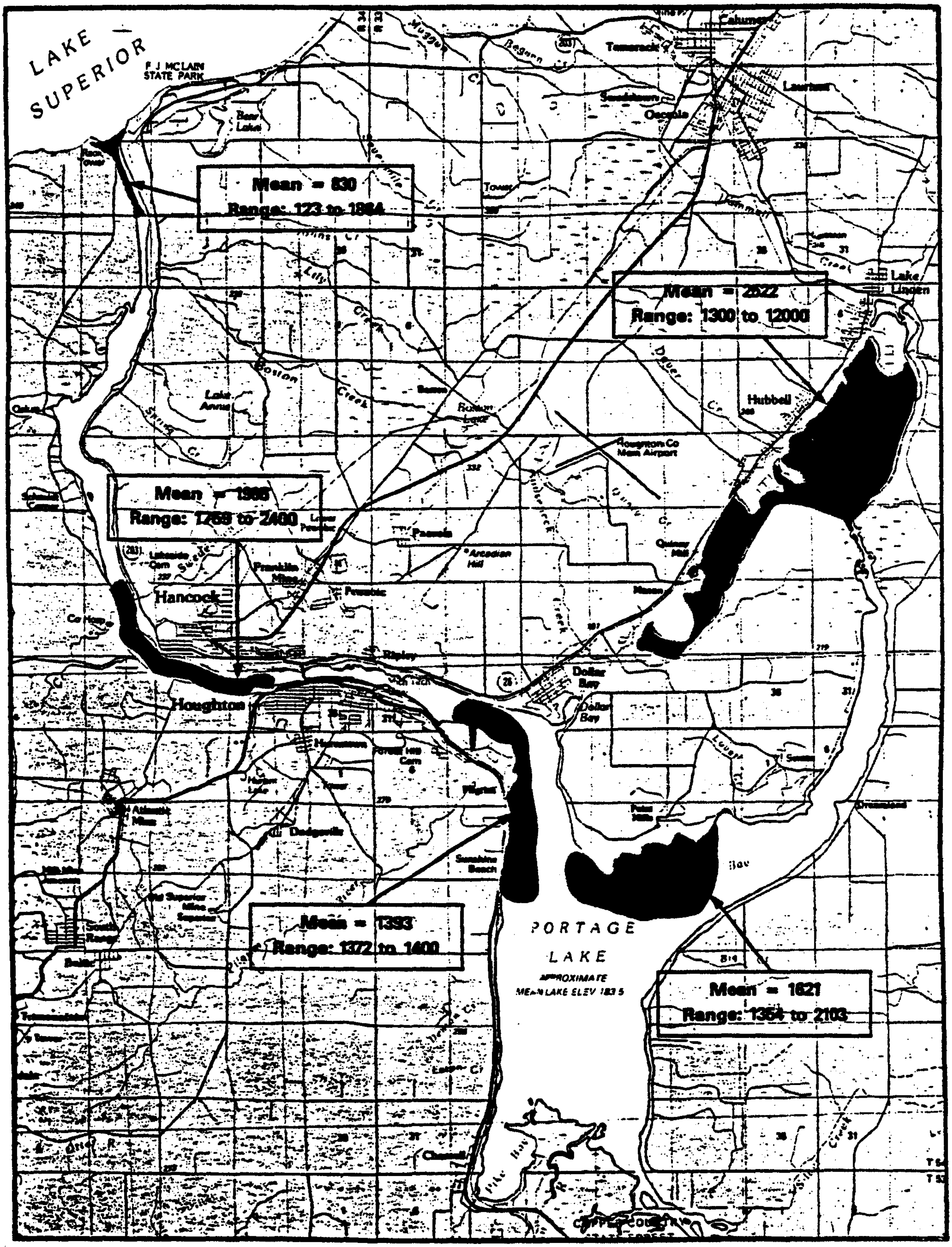

Figure 4.2 **Regional Distribution of Copper in Torch Lake, Portage Lake, and the Keweenaw Waterway (mg/kg)**

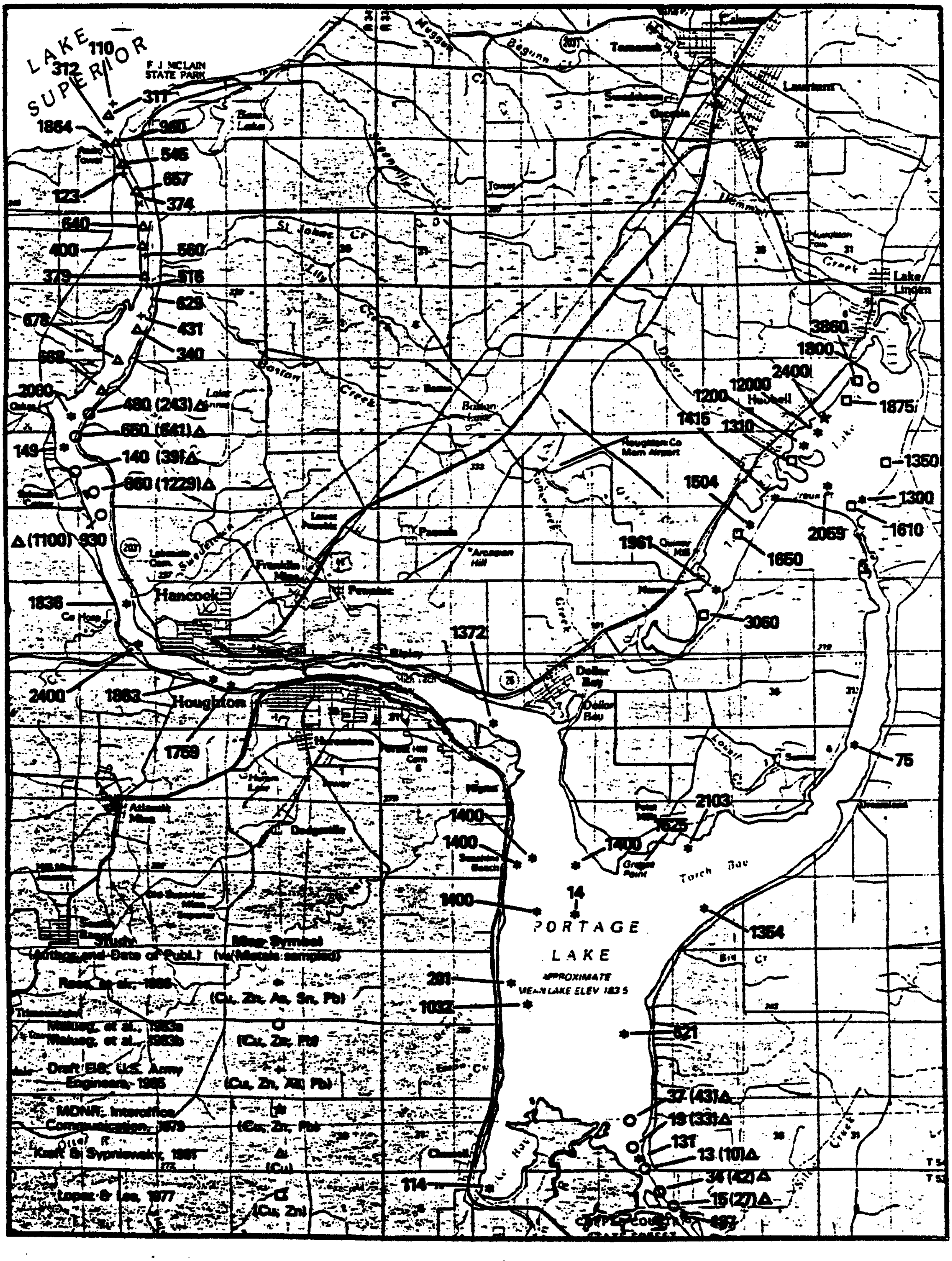

Figure 4.3 Copper in Sediments of Torch Lake, Portage Lake, and the Keweenaw Waterway (mg/kg)

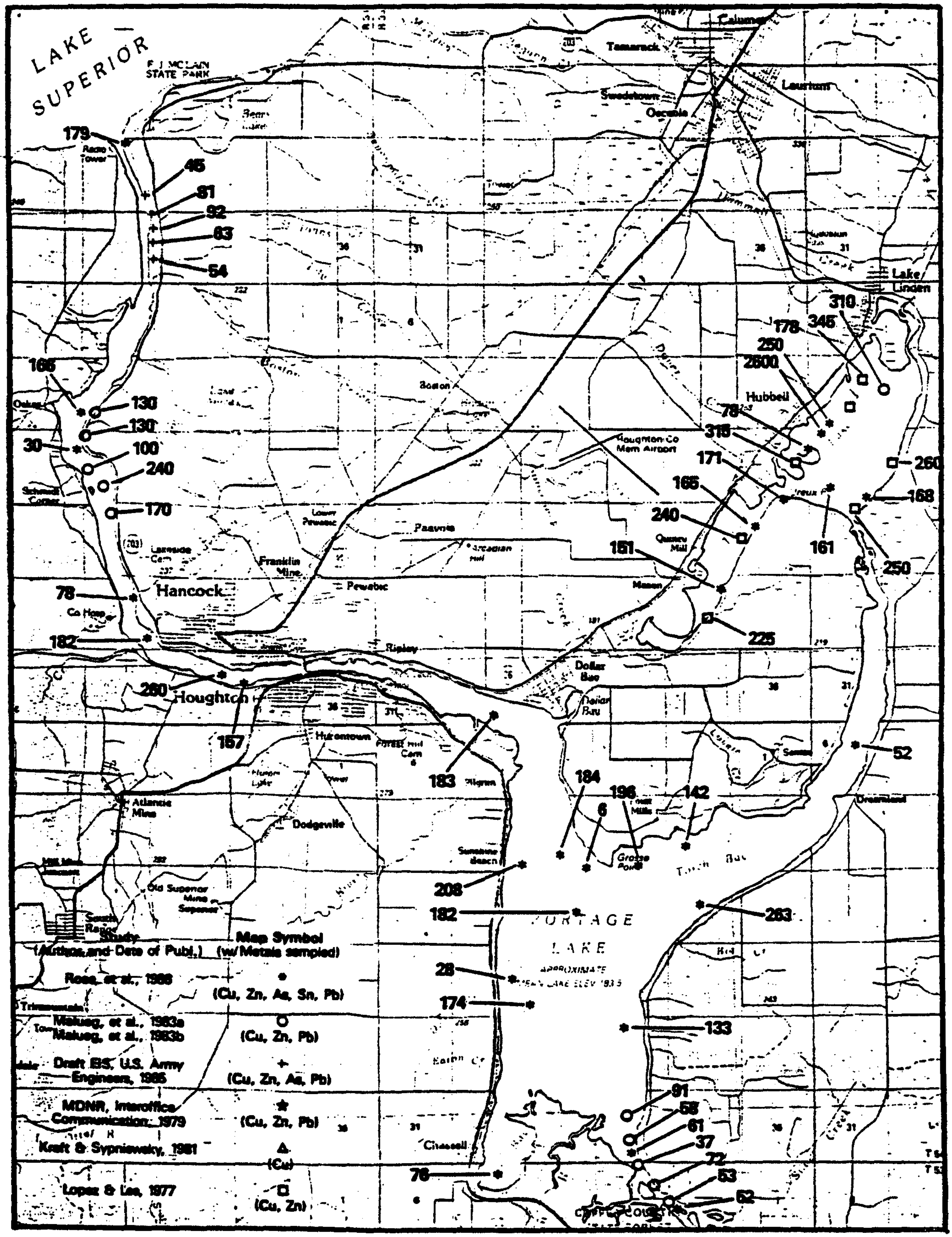

Figure 4.4 Zinc in Sediments of Torch Lake, Portage Lake, and the Keweenaw Waterway (mg/kg)

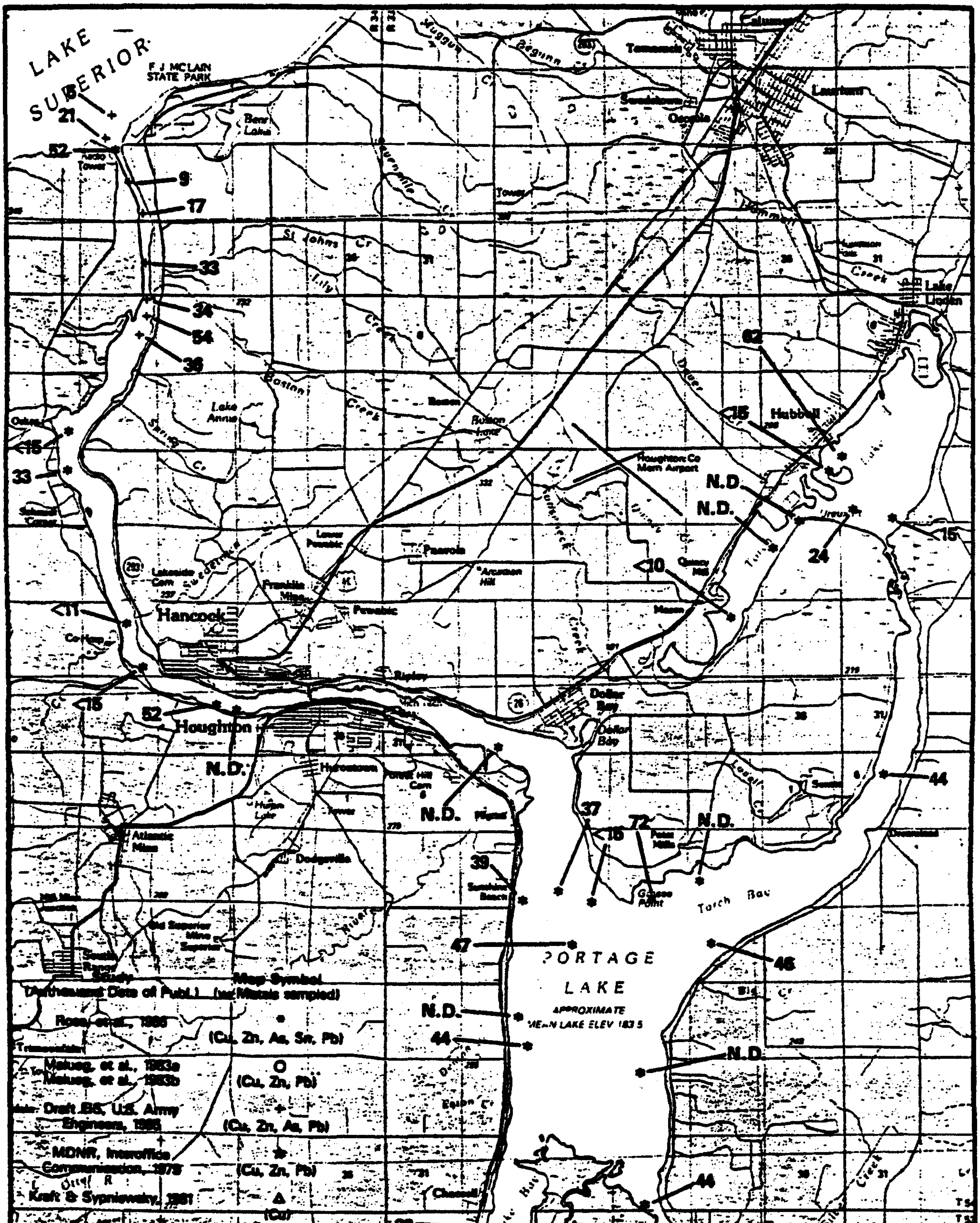

Figure 4.5 **Arsenic in Sediments of Torch Lake, Portage Lake, and the Keweenaw Waterway (mg/kg)**

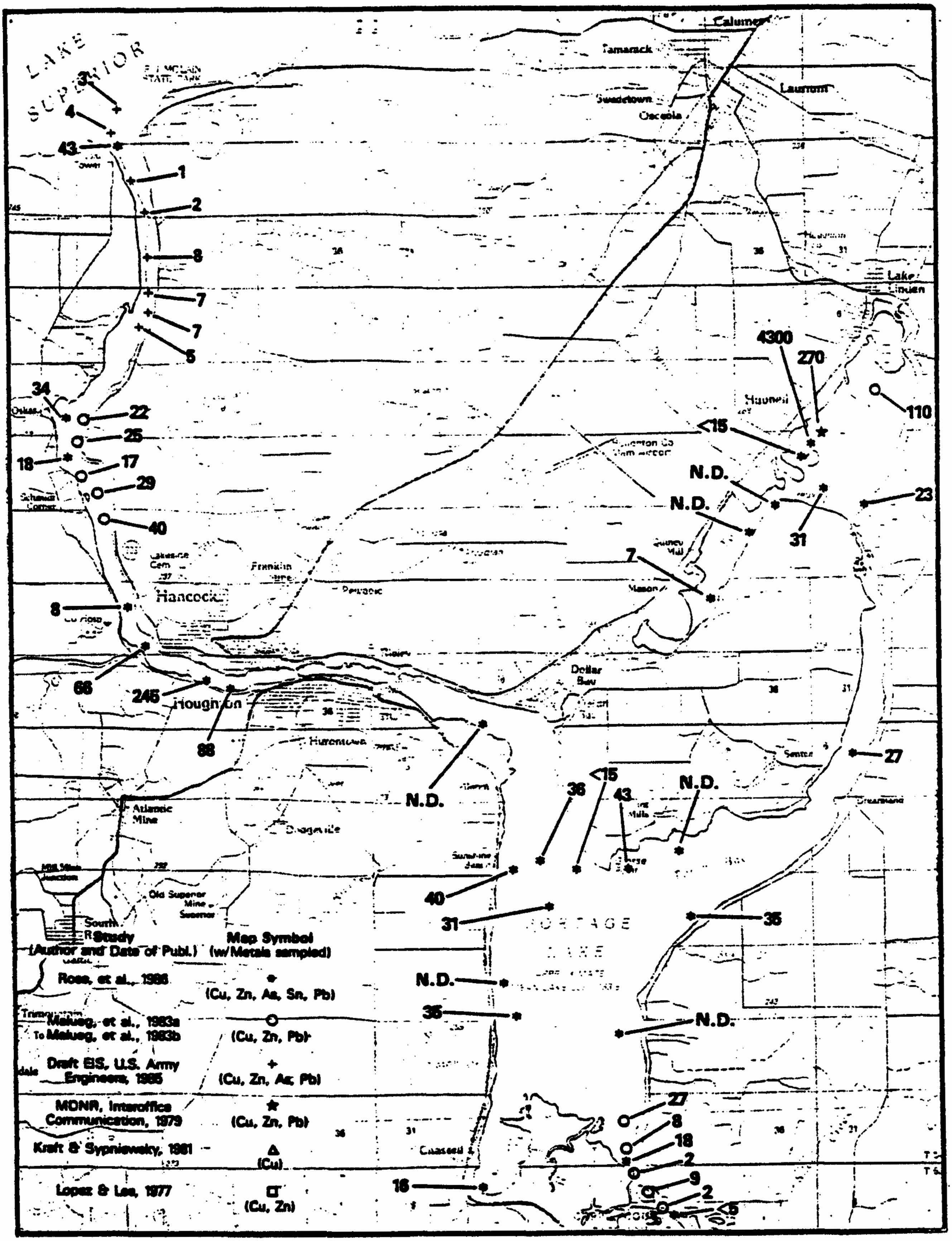

Figure 4.6 **Lead in Sediments of Torch Lake, Portage Lake, and the Keweenaw Waterway (mg/kg)**

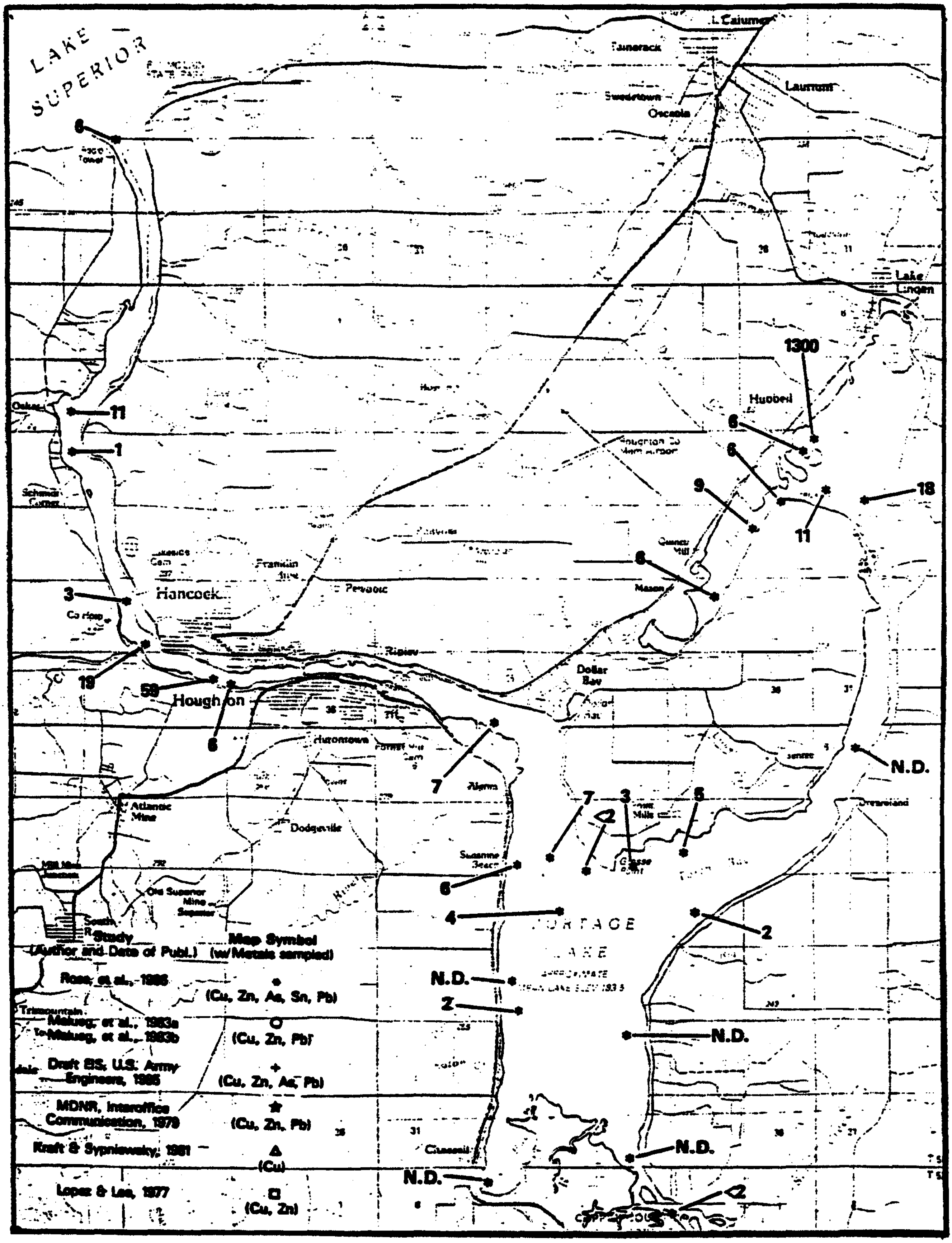

Figure 4.7 Tin in Sediments of Torch Lake, Portage Lake, and the Keweenaw Waterway (mg/kg)

Table 4.4 Some heavy metal concentrations in sediments from Torch Lake, Portage Lake and Lake Superior compared to U.S. EPA Guidelines for the Classification of Great Lakes Harbor sediments for dredging disposal options. All values in mg/kg or parts per million. Ranges in parenthesis.

	EPA(1)			LAKE SUPERIOR ($\bar{x}$s)(1)	
	NON POLLUTED	MODERATELY POLLUTED	HEAVILY POLLUTED	PRE-COLONIAL	PRESENT
Arsenic (As)	<3	3-8	> 8	--	1.7
Cadmium (Cd)	--	--	> 6	0.6	1.2
Chromium (Cr)	<25	25-75	> 75	51	163
Copper (Cu)	<25	25-50	> 50	62	82
Lead (Pb)	<40	40-60	> 60	21	44
Mercury (Hg)	<1	--	> 1	0.07	0.08
Nickel	<20	20-50	> 50	57	95
Zinc (Zn)	<90	90-200	> 200	106	97

	TORCH LAKE ($\bar{x}$s)		TAILINGS ($\bar{x}$s)		PORTAGE LAKE ($\bar{x}$s)
	1973 (N=7)(2)	1986 (N=17)(3)	1984 (N=2)(4)	1986 (N=2)(5)	1986 (N=16)(3)
Arsenic (As)	4.5 (0.7-6.5)	34 (N=15) (<10-66)	<0.5	<10 (<10)	45 (N=13) (<15-72)
Cadmium (Cd)	0.9 (0.4-1.6)	—	<2	—	—
Chromium (Cr)	29 (4.4-44)	245 (141-869)	48	109 (87-130)	129 (54-227)
Copper (Cu)	644 (110-1000)	3174 (1200-12000)	985	1646 (1242-2050)	866 (14-2103)
Lead (Pb)	27 (4-48)	471 (N=15)	<5	<10 (<10)	29 (<15-50)
Mercury (Hg)	0.06 (0.01-0.15)	—	<0.2	—	
Nickel	37 (4-50)	129 (61-166)	32	41 (39-42)	86 (8-178)
Zinc (Zn)	66 (13-90)	416 (47-2600)	65	81 (80-82)	131 (6-263)

(1) In Guidelines and Register for Great Lakes Dredging Projects IJC 1982
(2) Evans, E. 1973
(3) Rose *et al.*, 1986
(4) Evans, E., unpub., MDNR files "Mason sands"
(5) Rose *et al.*, 1986 "Quincy and Tamarack sands"

benzo (a) pyrene (BaP) were reported in sediments in the range of 2.8 to 17 mg/kg. PAHs are widely distributed in the environment and are much higher near urbanized areas. BaP in Lake Superior sediments (1 sample) was 0.028 mg/kg while in Lake Michigan (9 samples), BaP averaged 0.480 ± 0.246 mg/kg (Eadie 1984). Evans (1984 unpub.) did not find PAH's in tailings deposited on the shore of Torch Lake near Mason.

BaP is a known animal carcinogen, frequently causing liver tumors after sufficient exposure. If PAH contamination of sediments was significant in Torch Lake, it is highly improbable that only sauger and walleye would have tumors. Furthermore, sediment bioassays would probably have shown some mutagenic activity (see later discussion of bioassays).

Rose et al. (1986) completed a detailed and extensive analysis of the lake bottom and tailings in Torch and Portage Lakes. They compared heavy metal concentrations in tailings and sediments with a model mineralized amygdaloid composite, typical of the mineral composition in the area (Figure 4-8). The study found the Torch Lake sediments and tailings (stamp sands) enriched in: copper (cu), lead (Pb), tin (Sn), zinc (Zn), lanthanum (La), chromium (Cr),

Results of the various sediment analyses are compared to USEPA Guidelines for Classification of Great Lakes sediments for dredging projects (Table 4-4). In general, these studies show that copper, chromium, nickel, lead, and zinc are all at levels considered "heavily polluted" for Great Lakes area sediments and not suitable for open lake disposal if dredged. Precolonial and present day average surficial sediment heavy metals concentrations for Lake Superior are also included for comparison.

4.3 WATER QUALITY

The water quality parameter of interest in Torch Lake is copper. Concentrations of copper range from 20 to 80 ug/l and average about 40 ug/l. The IJC water quality objective for the Great Lakes is 5 ug/l copper. Michigan's Water Quality Standards under Rule 323.1057, would limit the concentrations of copper in a discharge to Torch Lake to 76 ug/l in the mixing zone and 11 ug/l at the edge of the mixing zone. Discharges to the Trap Rock River which has was chemistry similar to Torch Lake but classified as a trout stream, would have more stringent requirements and only 38 ug/l copper would be permitted in the mixing zone.

4.3.1 Drinking Water Supply

Although Torch Lake is not used as a source of drinking water, concern has been expressed by the public about the safety of contact with water in the lake and the accidental ingestion of the water during recreational activities. Communities bordering Torch Lake get their drinking water from groundwater wells as close as 300-400 feet from the tailings. Tests performed on municipal wells showed that the water was coming from sources at higher elevations. The wells were not found to have been affected by the copper tailings or any of the chemicals used in the

Source: Rose et al. 1986

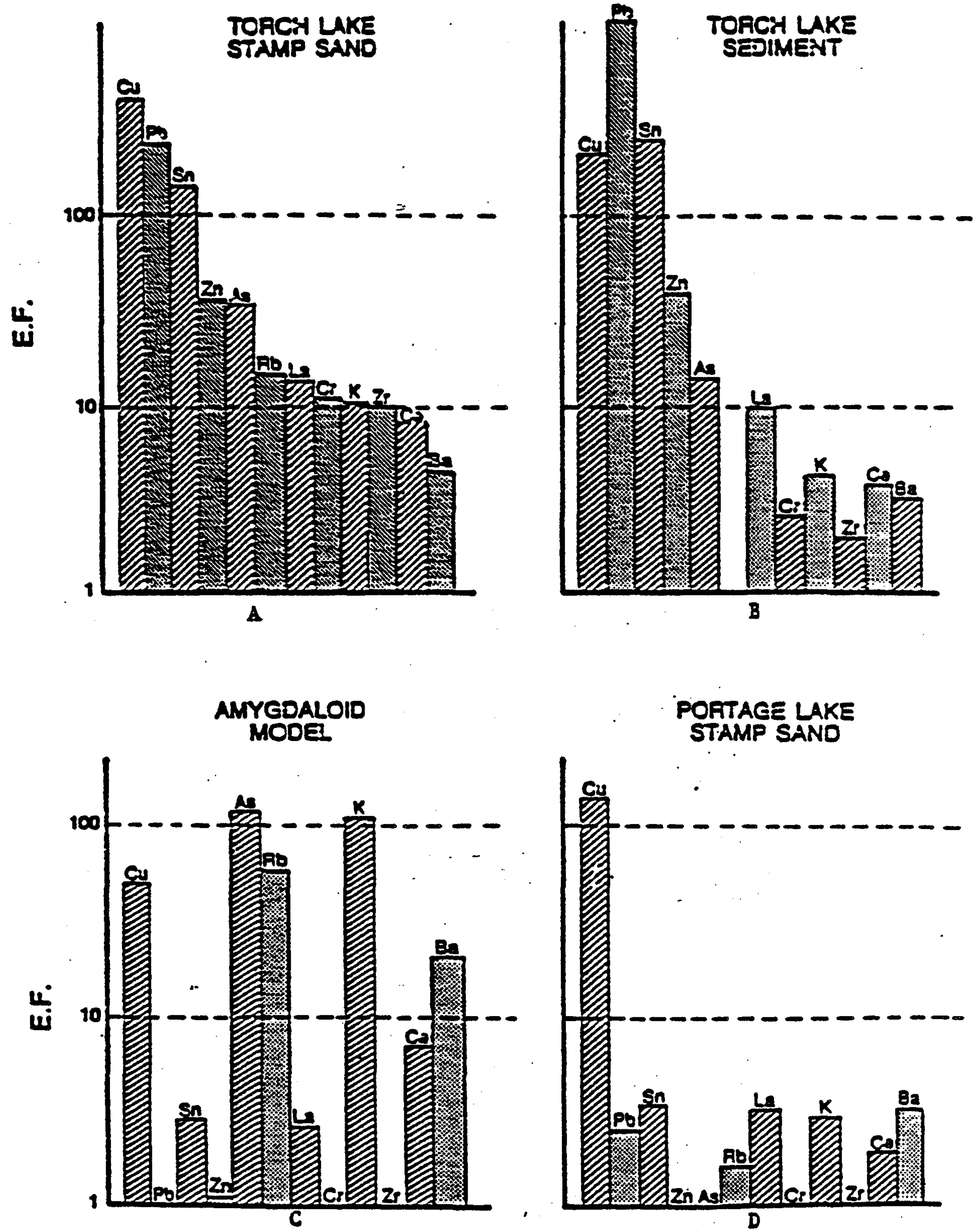

Figure 4-8 Plot of the relative enrichment factors (compared to average Portage Lake Basalt) for elements found in anomalous amounts in: A. Torch Lake stamp sands (maximum); B. Torch Lake bottom sediments (maximum); C. a model amydaloid, calculated from data on typical mineral compositions and known mineral proportions in amygdaloids; D. typical stamp sand from Portage Lake.

mining process (MDNR 1986). Warburton (1986) found copper concentrations in a well and spring in the vicinity of the lake to have 15 and 12 ug/l copper, respectively. The drinking water standard for copper is 1,000 ug/l.

4.4 CONTAMINANTS OF CONCERN

Substances known to induce tumors in animals have not been found in Torch Lake. Copper is not known to be carcinogenic, but levels in the water column and sediments are substantially higher than Lake Superior average concentrations of 3 ug/l and 82 mg/kg, respectively. Flotation chemicals (creosote and xanthates) used in the copper concentration processed are both biologically active compounds that were used for a long period of time and in relatively large amounts. At this time, these are the main suspected causative agents responsible for tumor induction in Torch Lake sauger and walleye but have not been found in the lake due to their rapid degradation.

4.4.1 Creosotes

Coal tar creosote used initially for copper flotation, is a complex mixture of organic products, resulting from the fractionation of coal tar or petroleum products. It consists mainly of polycyclic aromatic hydrocarbons (PAHs) which are hydrophobic, bind readily to sediments and degrade slowly in water, unless exposed to sunlight. Creosote and many of its components such as naphthalene, phenanthrene, and benzo (a) pyrene (BaP) have been implicated as carcinogens in animals and humans (Dunn and Fee 1979).

Wood creosote used during the last decades of copper flotation along Torch Lake, is composed largely of guaiacol derivatives (methoxy phenols) which are water soluble and degrade rapidly. A breakdown product of methoxyphenols, catechol, exhibited a pronounced cocarcinogenic effect on mouse skin when mixed with BaP (Van Duuren et al. 1973).

4.4.2 Xanthates

Xanthates, used in the frothing process, are salts of xanthic acid. They have a polar group that has an affinity for copper, while the nonpolar hydrocarbon group is oriented away from the water (hydrophobic). This hydrophobic film enables the mineral particles to be carried by an air bubble (Rao 1971). Xanthates are water soluble and degrade readily, however, they caused extensive liver damage in rainbow trout exposed continously for 30 days (Leduc et al. 1976).

Leddy (1986) evaluated the fate of xanthates in water and found that their half life in water with a pH of 7 to 8 was about two weeks.

4.4.3 Fish Contaminants

Heavy metals were analyzed in Torch Lake fish in 1970 and 1972 (Evans 1973). These data are limited, as only nine samples were analyzed, with the single sauger having a mercury concentration of 0.9 mg/kg wet weight which exceeds the present 0.5 mg/kg fish consumption advisory limit. Black and Evans (1986 unpub.) analyzed liver, spleen, muscle and tumorous tissue from Torch Lake sauger and walleyes for heavy metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn). Comparisons were made with heavy metal concentrations in walleye livers from areas with limited heavy metals contamination. Tissue from Torch Lake sauger and walleye had heavy metal concentrations within normal ranges.

The same tissues analyzed for heavy metals above, were also analyzed for percent fat, PCBs, DDD, DDE, DDT, heptachlor epoxide and HCB (Evans 1984 unpub.). Traces of most compounds were detected near their respective limits of detectability (0.01 to 0.04 mg/kg wet weight). All tissues were lower than consumption advisory limits, except for a sample of spleen that had 39% fat, 9.8 mg/kg PCB and 4.13 mg/kg total DDT. The eight other tissue samples averaged 0.9 mg/kg PCB (range 0.1 - 1.7 mg/kg), and did not exceed the present fish consumption advisory limit of 2.0 mg/kg for fillets. Samples of sauger and walleye were sent to the U.S. EPA Laboratory in Duluth for organochlorine analysis but results have not been sent to Michigan Technological University (D. Leddy, personal comm.).

4.4.4 Tumor Induction and Mutagenicity Studies

Stensland and Bowen (1986) performed tumor induction studies in a 4-month experiment. The Medaka fish, Oryzias latipes, were exposed twice during this period to copper flotation chemicals, namely, potassium-isopropyl xanthate or combinations of xanthate and creosote in the presence of sediments from either Torch Lake or from a control site. Histological evidence did reveal hepatic abnormalities such as micronodules after exposure to creosote. However, the limited duration of the exposure prevented the establishment of any conclusive causal link between the flotation chemicals and confirmed tumor induction. Further tumor induction studies with continuous exposure to flotation chemicals over an extended period are desirable.

Bagley (1986), using the Ames test with Salmonella typhinurium, with and without S-9 activation, on five Torch Lake sediment samples, did not report a mutagenic response.

Black and Evans (1986 unpub.) used both the Ames test and the sister chromatid/chromosome abnormal induction test in cultured Chinese Hamster ovary cells (CHO). Organic solvent extracts of sediments from 30 liters of water were utilyzed. The sediment sample was a composite of 10 sediment samples in the deeper waters of mid-lake. The latter were uniformly negative in tests for potential carcinogens, as were both extracts of the water. Ames tests of highly concentrated sediment organic solvent extracts of Torch Lake sediment exhibited a low but consistent degree of mutagenic activity. Concentrated extracts of sediments from Lake Michigamme exhibited a similar response.

Black and Evans (1986 unpub.) also exposed two strains of rainbow trout eggs to aqueous elutriates of Torch Lake sediments. Sac-fry of a third strain were exposed to a 0.5 percent sediment-water mixture. After a year, all survivors (196) were sacrificed and examined for tumors. No neoplasms were found. Sac-fry were also injected with sterile Torch Lake water at two concentrations. In the 180 treated survivors, no neoplasms were observed.

Studies conducted to ascertain reasons for tumor incidence in Torch Lake sauger and walleye have not revealed any definitive causative agents. Short-term tests for a mutagen in the water or sediments have been negative or, similar to control samples (Black and Evans 1986 unpub.; Bagley 1986). Black and Evans (1986 unpub.) feel that an organic chemical or chemicals, are still the best candidate for a causative agent. They noted that although the coal tar/creosote complex would be likely causative agents due to their known carcinogenicity in other areas (Black River, Ohio; Buffalo River, New York), the absence of any liver neoplasms in bottom feeding species from Torch Lake, such as suckers, make it less likely that the compounds present in sediments were the offending agents.

4.4.5 Benthic Macroinvertebrates

Bioassays of Torch Lake sediments, using mayflies (*Hexagenia*) and *Daphnia*, found them to be toxic (Gakstatter 1982). Malueg *et al.* (1984a) bioassayed sediments from Portage Lake using the same animals and found sediments with high copper concentrations from the north in Portage Lake, to exhibit toxicity while sediments from the south did not. Kraft and Sypniewski (1984) also concluded that high levels of copper in sediments in the northern end of Portage Lake, were the likely cause of low diversity and numbers of macroinvertebrates.

4.4.6 Phytoplankton and Zooplankton

The phytoplankton and zooplankton communities of Torch Lake are not apparently impaired by the high concentrations of copper in the water column. Waybrandt (1979) bioassayed Torch Lake water using *Daphnia magna* and concluded that the water was not harmful.

4.4.7 Macrophytes

A macrophyte community is present in Torch Lake in several locations. Impairment of these aquatic plant communities by copper in sediments of the water column has not been measured.

4.5 SUMMARY

Two impaired uses exist in Torch Lake at this time: a consumption advisory based on tumors in sauger and walleye and a degraded benthic macroinverte community due to sediment copper toxicity. A high incidence of liver tumors have been found in sauger (100%) with lower incidences in walleye. External tumors on these species have been associated with viruses and are present at rates comparable to other bodies of water. Sediment and water bioassays have not revealed mutagenic activity at levels of concern, although sediments are toxic to macroinvertebrates. Xanthates and wood creosote, both biologically active compounds used in the copper concentrating process in the past, were rapidly degraded in the environment.

Tumor induction studies using fish revealed liver abnormalities when exposed to xanthates and creosote. Other contaminants in fish, such as heavy metals and chlorinated organic compounds, have not been found at levels of concern. The fish community in Torch Lake is diverse with good populations of game fish.

Copper concentrations in the water of Torch Lake are high due to natural loadings from its major tributary, the Trap Rock River, and the release of sediment bound copper. Copper concentrations in the water exceed the IJC water quality objective and Michigan's Water Quality Standard NPDES permit limitations.

High concentrations of copper are widespread in Torch Lake and Portage Lake sediments. Near the smelter site on Torch Lake, lead, tin and zinc are also elevated in the sediments.

The biotic communities of Torch Lake, other than benthic macroinvertebrates, do not seem to be greatly inhibited by the unusually high copper concentrations. Fish, zooplankton, phytoplankton and macrophytes are present such that degraded conditions are not readily apparent.

5. SOURCES OF POLLUTION

5.1 PRIMARY SOURCES OF MAJOR POLLUTANTS

Historically, the primary sources of pollutants to Torch Lake were from the mining and milling operations which operated from the 1860's through the late 1960's along the lake. All of the milling operations were along the western shore (see Figure 3-1). Markham (1986) estimated that approximately 200 million tons of copper mine tailings were deposited in the lake. As milling and concentrating technologies improved (ca. 1915), it became possible to reclaim and reprocess the tailings from the lake. Chemical leaching of the conglomerate ore and tailings using cupric ammonium carbonate was practiced at the Tamarack and Lake Linden mills following gravity separation and flotation. Flotation processes using xanthates and/or creosotes were used to collect copper from all the ore and tailings. Amydaloid ore and tailings were treated by flotation only, following gravity separation. Xanthates, as potassium or sodium salts, were added at 0.05 lb/ton of ore with a pine oil mixture (G.N.S. No. 5) with Cleveland Cliffs No. 2 wood creosote at 0.15 lb/ton (Benedict 1955).

Xanthates were used from 1929 until mill closure in all the mills, while wood creosote was used in combination with xanthates on conglomerate ores (Benedict 1955). These substances plus pine oil, created a froth on the surface of the water and finely ground copper ore mixture when agitated. Native copper adhered to the bubbles which were removed with the copper concentrate and filtered. Part of the flotation chemicals went with the concentrate to the smelter while the remainder were either recycled or discharged with the tailings and the remainder of the flotation chemicals.

Mine pumpage with high chloride concentrations was discharged to Torch Lake via its tributaries until the late 1960's and measurably changed water quality. In the autumn of 1972, a spill of at least 27,000 gallons of cupric ammonium carbonate from the Lake Linden Leaching Plant which had occurred 3 months earlier was evaluated (Evans 1973). It was postulated that during the spill, concentrations of copper and ammonia most likely reached levels which would have been toxic to exposed flora and fauna. However, at the time of the investigation no deleterious effects on water, sediments, algae, benthic macroinvertebrates, or fish were noted outside the embayment receiving the discharge (Evans 1973).

Copper tailings deposited in Torch Lake serve as a source of copper to the water column, although the Trap Rock River serves as the major source. Rose _et al_. (1986) suggested that enrichments of Cu, Zn, Cr, Pb, and Sn near the Hubbel smelter could be due to reclamation operations between between 1940 and 1968. Large amounts of electrical material were transported into the area near the smelter. The insulating material was burned off, and the copper refined. Slag and other unwanted debris were dumped into the lake and on the tailings. The study went on to suggest that the solution of these elements is occuring at a slow rate and does not appear to influence water quality away from the sediment/water interface (Rose _et al_. 1986).

These sediment data, in addition to that accumulated in other studies discussed or studied in the RAP, comprise one of the most extensive and intensive series of sediment analysis carried out in the in-land waters of Michigan.

The other pollutant of local concern are the tailings deposits near residential areas. Dust from unconsolidated tailings and stamp sands periodically becomes wind borne and deposited on the lake surface and in the surrounding municipal areas. However, revegetation has stabilized much of the tailings, greatly reducing the frequency and magnitude of dust events. Other pollutant sources to Torch Lake are insignificant.

6. POLLUTANT TRANSPORT MECHANISMS

The purpose of this section is to describe the transport of pollutants from the sources described in Chapter 5 to the receiving waters.

6.1 POINT SOURCES

At this time, there are no significant controllable point source discharges of pollutants to Torch Lake.

6.2 NON-POINT SOURCES

Copper tailings in and along Torch Lake are the primary concern since the associated benthic community is impaired and the tailings serve as a source of copper to the water column. The influence of the copper tailings on Torch Lake is obviously greater than that of all other pollutants.

Sediments have interstitial copper concentrations of from 200 to 590 ug/l dissolved copper which is about 10 times the water concentration. This suggests that diffusion of copper from pore water is an important source of copper (Warburon 1986). Infiltration of copper bearing water through the extensive shoreline tailings deposits was also judged to be important by Warburton.

Wind blown tailings from the shoreline deposits have been of concern in nearby residential areas in Hubbel and Lake Linden. The extent of the transport of copper and other chemicals from the mine tailings to the lake has been studied by Rose _et al_. (1986). Analysis revealed that the airborne particles of stamp sands are typical silicate materials. The study concluded that the airborne transport of heavy metals to the lake is volumetrically insignificant. In the area of the Hubbel smelter, wind blown particles contribute to the high concentrations of copper, tin, zinc and lead in the near shore sediments.

Run-off from tailings is probably of even less significance than wind borne tailings. The coarse nature of the remaining tailings allows for rapid infiltration of groundwater and the tailings are gradually becoming revegetated.

7. HISTORICAL RECORD OF REMEDIAL ACTIONS

This section provides a catalog of completed actions and actions currently ongoing which were undertaken to understand and control pollution and restore beneficial uses.

Tumors were observed in Torch Lake sauger and walleye by Tomljanovich (1974) and later described by Black et al. (1982). Since that time, the remedial actions have focused on further defining the incidence of tumor and abnormal growths deducing the possible causative factors inducing tumor growth (parasites and flotation chemicals), determining the fate of flotation chemicals and the understanding influence of tailings and copper on the dynamics of the lake ecosystem.

7.1 COMPLETED ACTIONS

Torch Lake is listed 24th on the Michigan Sites of Environmental Contamination Priority List. State funds totaling $74,000 were expanded for five studies performed by Michigan Technological University for the MDNR. The studies were designed to evaluate tumor problems in sauger and walleye, determine the probable causes, and identify remedial actions.

Studies were completed on fish tumor induction, environmental fate of xanthates and creosotes, fish parasite-tumor relationships, airborne particle analysis and a copper budget for Torch Lake. Xanthates were found to be shore lived in the environment (Leddy 1986). Wood creosote is also readily degradable. Both substances are biologically active when present. No causal relationships between tumor induction and any inorganic or organic substance were found in the stamp sands, sediments, or the water column of Torch Lake. Other tumor induction studies using water and sediments from Torch Lake found no mutagenic activity, either.

7.2 ACTIONS CURRENTLY IN PROGRESS

Remedial actions currently in progress include some cleanup of debris on the tailings left over from copper ore processing, and the revegetation of the shoreline tailings. A program has been initiated to spray irrigate sludge on the bare tailings to help establish vegetation. This vegetation will help consolidate the tailings and reduce the amount of airborne particulate matter which currently impacts the lake and nearby communities. As much as 20-40 percent of the exposed tailings are currently vegetated (D. Leddy, personal communication 1986).

8. DEFINITION OF SPECIFIC GOALS, OBJECTIVES, AND MILESTONES FOR RESTORATION

The primary goal of this RAP is to remove the fish consumption advisory for Torch Lake sauger and walleye on the basis of its issuance. The advisory was issued as a precautionary measure until causative agents could be found in the lake, if still present. Tumor inducing agents have not been found in Torch Lake nor do fish from the lake appear to have contaminants at levels of concern. Unless the basis for the consumption advisory is changed, it should logically be removed. If the basis for the advisory is changed, al the connecting waters to Torch Lake should logically be included since most of the game fish readily move about in the Keweenaw Waterway.

Some concern has been expressed about removing the consumption advisory since tumor inducing agent(s) have not been found. As the problem appears to be due to historical exposures to short lived organic chemicals used in the copper concentrating process, it is unlikely that such agents will be found in the lake. Further, tumor induction studies using fish, xanthates and wood creosote are recommended to determine if these substances could have been the causative agents.

In light of uncertainties regarding causative factors and public health concerns, Michigan DNR has adopted interim remedial action plans. However, none of the actions directly address the problem of tumors in Torch Lake fish, since causation has yet to be established.

MDNR proposes to spend approximately $10,000 per year over a 5-year period to restock sauger or walleye in Torch Lake. This estimate is based on stocking 40,000 fingerlings per year. Walleye and sauger will be analyzed every few years and examined for tumors. Thus, long-term monitoring of these species would provide a low cost test of the hypothesis that tumor induction was caused by past chemical exposure.

Torch Lake water will be sampled in 1988 as part of Michigan's in-land lakes monitoring program. Fish populations will be evaluated by the MDNR in the Portage Lake and Torch Lake in 1988. Fish will also be retained for toxics material and tumor analysis, as part of the State fish monitoring program in 1988.

The second goal was to quantify the extent of benthic community impairment in order to ascertain if remedial actions are possible that would reestablish a normal benthic community. The vast amount of copper-contaminated sediments in and along Torch Lake and its connecting waters, precludes any direct action to remove or isolate them from the system. Over 200 million tons (a conservative estimate) of copper-enriched tailings exist in the Torch Lake, alone. Natural attenuation and isolation of the copper-enriched sediments through transport, depostion and burial presents the best approach to the contaminated sediments problem. Any attempt to disrupt the sediments would release copper and other heavy metals currently isolated from the system.

9. PROGRAMS AND PARTICIPANTS

Torch Lake is currently listed 24th on the Michigan Sites of Environmental Contamination Priority List. The priority listing of contaminated sites in Michigan is legislated under Act 307 PA of 1982. Act 307 provides for identification, risk assessment, and priority evaluation to provide for response activity, to prescribe certain powers and duties to the Governor, and to create an environmental response fund.

The potential for human health risks at Torch Lake prompted the USEPA to place Torch Lake on the National Priority List for funding under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Torch Lake is a Category III site. This means EPA Region V Hazardous Waste Enforcement is responsible for coordinating Superfund activities for Torch Lake. At present, only the Hazardous Ranking System scoring information is available. Other information is currently "enforcement confidential" and part of a potentially responsible party search (H. Tran, personal communication January 7, 1987).

Torch Lake is on the National Priority List (NPL) for funding under CERCLA. EPA is planning to conduct a remedial investigation and feasibility study (RI/FS) to determine whether or not a serious hazard exists and whether or not a cleanup under Superfund will occur (USEPA, B. Constantelos memorandum 1986).

The first public meeting on the Torch Lake AOC was held at Michigan Technological University (MTU) in Houghton which is a few miles from the AOC. During this meeting, the RAP process was discussed and a brief history of the Torch Lake situation was presented. The status of the diagnostic investigations carried out under a 307 contract of $74,000 to MTU was presented by their staff. Public concerns were expressed about the safety of swimming in Torch Lake, drinking its water or eating fish. Names and addressed (45) were obtained from attendees and a mailing list was made, including other interested persons not able to attend. This list contained 75 names and addresses, including members of the technical review committee and other interested government agencies and personnel. This meeting was announced about a week prior to the meeting date by radio and the newspaper.

The second meeting was held in August 1987 and was announced by newspaper, as well as in a cover letter for a copy of a revised draft of the RAP which was sent to all parties on the mailing list. In addition, most local citizens were contacted by telephone. Several new names were added to the mailing list at the second meeting. Written comments were received from two people not on the technical review committee or involved with the 307 contract. Less than 30 people attended this meeting.

At both meetings, the public was assured that the water in Torch Lake was safe to swim in and the risks from accidental ingestion would be similar to drinking from other surface waters in the area. The public was also informed that there is no evidence to suggest that consuming fish or other animals with tumors poses a risk of developing tumors in the consumer. They were also informed that tumor inducing agents of concern were not found.

The recommendation that the consumption advisory on sauger and walleye be removed, since the basis for its issuance (tumor inducing agents in the lake) could not be sustained by the data, was opposed by the local health department, a local environmental group, some members of the MTU staff, a U.S. EPA review of the report, and the Toxics Substances Control Commission. The basis for sustaining the fish consumption advisory needs to be changed, if the advisory is to be logically sustained.

Several activities are to be carried out on Torch Lake and Portage Lake by the MDNR to monitor water and fish, in addition to stocking 40,000 sauger or walleye annually for a period of five years. Fish populations in these waters will be surveyed in 1988 for comparison with previous surveys. Samples of these fish will be retained for further toxic contaminant analysis as part of Michigan's Fish Contaminant Monitoring Program. Fish tumor analysis will also be undertaken at this time. Torch Lake is to be included on the Inland Lakes Water Monitoring Programs in 1988.

10. REMEDIAL ACTION STEPS

Since causes of tumors in the Torch Lake walleye and sauger have not been ascertained, remedial actions cannot be proposed. However, further fish bioassays of the tumor induction potential of xanthates and wood creosotes are recommended. Results of these bioassays, if positive, would go a long way towards removal of a fish consumption advisory, the goal of the RAP. These bioassays could be carried out through the State 307 program, managed by the MDNR, at an estimated cost of $40,000 and be completed within two years once contracts were awarded.

Monitoring of fish populations for contaminants and tumors in Torch Lake and Portage Lake may also aid in removing the consumption advisory. Decreased incidences of liver tumors in sauger and walleye from these waters would serve as a basis for removing the advisory. These activities can be carried out under present funded MDNR activities and results would be available the following year.

Remedial actions to address the effects of deposits of tailings on benthic organisms are not proposed because of the vast expanse and volume of these substances. Natural transportation, deposition and burial seems to be the only feasible course of action. The MDNR will encourage further stabilization of shoreline tailings by revegetation and regulate dredging activities when they occur.

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APPENDIX I

FISHERIES DIVISION SURVEYS
1965-1980

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

CONS. 8076
8/60

MANAGEMENT RECORD

Lake or Stream: Torch

County: Houghton T. 55N R. 32,33W S. Many Drainage: Lake Superior

Size: acres, miles.

RECOMMENDATIONS (number each item)	By whom	Date	RECORD OF MANAGEMENT PRACTICES AND RESULTS	By whom	Date
1. Inventory fish populations.	BRY	3-71	1. Done 8-71; lake supports good populations of warmwater fish; many sauger larger than current state record captured.	BRY	8-71
2. Conduct creel census	RJ	10-77	2. Census 7/77 - 8/77 indicates success was low during period	RJ	10-77
3. Attempt population est. and creel census to determine status of sauger.	RJ	10-77	1. Contd. Netted 9/79. Overall predator to prey ratio appears unchanged since 1971. Saugers are declining significantly. Walleyes and no. pike are increasing significantly. Other species appear fairly constant.	RJ	12/79
			1. Cont'd. Netted 7/80. Saugers becoming extinct; walleye, sm.bass n.pike present in good numbers. Perch are small.	RPJ	10/80

Copies to (check): Lansing ( ), Region ( ), District ( ), I.F.R. ( ). (Over)

LAKE SURVEY

INSTITUTE FOR FISHERIES RESEARCH

DIVISION OF FISHERIES
MICHIGAN DEPARTMENT OF CONSERVATION
COOPERATING WITH THE
UNIVERSITY OF MICHIGAN

FISH COLLECTION SUMMARY

County: Houghton

Lake: Torch Lake

T. 55N R. 32W Sec. 5

Township

62

STATION	1	2	3	4	5	6	7	
LOCATION DESCRIPTION	600' SE of mouth of Trap Rock River, set off north shore 140' east of edge of pilings	NW of extensive pilings located on east side of bay & about 1500' directly SSE of confluence of Trap Rock River ~~River~~	Set 50' so. of south side of extensive pilings which are located at north end of neck 1800' SSE of mouth of Trap Rock R.	Set 125' SE of mouth of Trap Rock River & 50' east of drop off, set north to south	Set opposite shore from net #2 ⊥ to stamp sand off east side of peninsula & directly SE of Holy Rosary Church	Set off stamp sand bank just SE of Holy Rosary Ch., C & H Leaching plant in Lake Linden-NW corner of Torch L.	In extreme NW bay of Torch Lake set off stamp sand peninsula located ESE of leaching plant, south of Holy Rosary Church in Lake Linden & SE of dump	
TYPE OF GEAR	Fyke net 75' lead	Fyke net 100' lead	Fyke net 75' lead	Gill net 125' long 1 1/2" mesh	Gill net 125' long 1/2" mesh	Gill net 125' long 1 1/2" mesh	Fyke net 50' lead	
Depth—Ft.	<20	<20	<20	<20	<20	<20	<20	
Temp. water °F.	65° F	65° F	65 ° F	65 ° F	65 ° F	61° F	61° F	
REMARKS	2 w.sucker 10.5-16.0" 1 burbot 12.4"	4 y.perch 6.2-8.7"	1 y.perch 6.3" 1 w.sucker 15.6" 1 silver lamprey 5.4"	Nothing	2 w.sucker 13.3-14.9"	1 n. pike 21.6" 2 rock bass 8.1-8.4" 5 sauger 13.6-17.1" 4 w.sucker 13.0-13.8"	2 y.perch 5.6-5.6" 1 smallmouth bass 14.9 1 rock bass 6.2" 4 bl.crappie 4.5-11.5" 1 br.bullh. 8.8"	
DATE	6/17-18/65	6/17-18/65	6/17-18/65	6/17-18/65	6/17-18/65	6/17-18/65	6/17-18/65	
TIME	4:05 PM 9:05 AM	3:45 PM 12:35 AM	4:25PM 12:10PM	5:00PM 11:45AM	5:10PM 12 noon	6:00PM 10:50 AM	6:25 PM 11:05 PM	

COLLECTOR M.G. Galbraith & D. Cavis (I.F.R.), Dr. L. Peters (N.M.U.)

7-56

FISH LIST ON REVERSE copies: Lansing, Region, District, I.F.R.

LIST OF FISH CAUGHT (For data see reverse)

No.	GAME FISHES	Size Range in.	Young of Year	Station	Remarks	No.	OBNOXIOUS FISHES	Size Range in.	Young of Year	Station	Remarks
	Brook trout						Spotted gar				
	Brown trout						Longnose gar				
	Rainbow trout						Bowfin				
	Lake trout						Carp				
	Grass pickerel										
1	Northern pike	21.6		6			**FORAGE FISHES**				
7	Yellow perch	5.6-8.7		2,3,7			Pearl dace				
	Walleye						N. redbelly dace				
1	Smallmouth bass	14.9		7			Blacknose shiner				
	Largemouth bass						Blackchin shiner				
	Warmouth						Mimic shiner				
	Green sunfish						Sand shiner				
	Bluegill						Spottail shiner				
	Longear sunfish						Common shiner				
	Pumpkinseed						Golden shiner				
2	Rock bass	6.2-8.4		6,7			Bluntnose minnow				
4	Black crappie	9.5-11.5		7			Fathead minnow				
	Cisco						Mudminnow				
1	Burbot	12.4		1			Banded killifish				
5	Sauger	13.6-17.1		6			Logperch				
							Johnny darter				
							Iowa darter				
	COARSE FISHES						Least darter				
9	White sucker	10.5-16.0		1,3,5,6			Brook silversides				
	Lake chubsucker						Mottled sculpin				
	Redhorse						Brook stickleback				
	Black bullhead										
1	Brown bullhead	8.8		7		1	Silver lamprey	5.4		3	
	Yellow bullhead										

Fish identification by M. G. Galbraith, Jr. (I.F.R.)

(Fish names follow Amer. Fish. Soc. list, 1948, and revisions through 1953)

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

CONS. 8065
REV. 4/63

LAKE FISH COLLECTION AND AGE-GROWTH SUMMARY

Lake Torch Lake Canal

County Houghton T. 54,55N R. 32W Sec. 19,29,30,31,32,6 Date July 30, 1971

Weather Clear Air Temperature 70°F Water Temperature 67°F

Seine Acres Seined No. Hauls Snags

Nets Exp. gill nets Length 125' (total 1500') Mesh Exp. No. Sets 12 No. Lifts 1 per set

Other Gear

Species	2"	4"	6"	8"	10"	12"	14"	16"	18"	20"	22" +	Total No.	Total Wt.	Ave. Size	Per cent Catchable
Y. Perch			64	59	18	1						142	30.26	7.4"	29%
Alewife			31									31	3.69	6.7	-
Redhorse						6	4	1	2	2		15	22.44	17.3	-
Blk. bullhead					11	1						12	6.76	10.2	
P. seed		1	13									14	2.95	5.8	57
Smelt			1									1	0.06	6.1	
Rock bass				1								1	0.50	7.5	100
Cw. Sucker						2	4	1				7	6.88	13.7	-
Carp											1	1	6.75	23.5	-
Walleye								1	2	1	1	5	16.76	18.4	100
Sm. bass					1			1				2	2.82	12.9	100
Sauger									2	4		6	17.31	19.2	100
N. Pike							1	4	1		18	24	88.17	23.3	75
Totals........		1	109	60	30	10	9	8	7	7	19	261	204.85	-	82.6

Analysis and comments:

Fishing reports: Northern pike and yellow perch fishing success has been good in this area this summer.

Catchables: Bluegill and Pumpkinseeds, 6"; Crappie and Perch, 8"; Bass, 10"; Pike, 20".
Inch Groups: 2" Group 1.0-2.9; 4" Group 3.0-4.9; 6" Group 5.0-6.9, etc.

(Over)

Species	No.	Age Groups*										
		0	I	II	III	IV	V	VI	VII	VIII	IX	X
Bluegill		(2.1)	(2.9)	(4.3)	(5.5)	(6.5)	(7.3)	(7.8)	(8.0)	(8.5)	(8.5)	(9.2)
Pumpkinseed		(2.0)	(2.9)	(4.1)	(4.9)	(5.7)	(6.2)	(6.8)	(7.3)	(7.8)	(----)	(----)
Black Crappie		(---)	(----)	(5.9)	(8.0)	(9.0)	(9.9)	(10.7)	(11.3)	(11.6)	(----)	(----)
Yellow Perch		(2.5)	(4.2)	(5.8)	(6.8)	(7.9)	(8.8)	(9.8)	(10.4)	(10.8)	(11.4)	(12.2)
Largemouth Bass		(3.3)	(6.1)	(8.7)	(10.0)	(12.1)	(13.7)	(15.1)	(16.1)	(17.7)	(17.9)	(----)
Northern Pike		(7.9)	(15.5)	(19.4)	(22.2)	(23.4)	(25.4)	(27.7)	(32.5)	(37.1)	(34.8)	(44.4)

Fish Collection By R. Reichardt, N. Murphy Section Field Date of Collection July 30, 1971

Age Analysis By ____________ Section ____________

* Given in calendar years. State averages in parentheses. Enter mean length in age group columns.

C.O. Gussert

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

CONS. 8065
REV. 4/63

Lake Torch

LAKE FISH COLLECTION AND AGE-GROWTH SUMMARY

County Houghton T. 55N R. 32,33W Sec. Many Date August 2,3,1971

Weather Clear Air Temperature 68°F Water Temperature 68° at surf - 47° @ 100'

Seine Acres Seined No. Hauls Snags

Nets Gill nets Length 600' per mesh size Mesh $2\frac{1}{2}$", $3\frac{1}{2}$", $4\frac{1}{2}$" No. Sets 1 No. Lifts 1

Other Gear 1750' Exp. gill net fished over night (14 nets)

Species	2"	4"	6"	8"	10"	12"	14"	16"	18"	20"	22" +	Total No.	Total Wt.	Ave. Size	Per cent Catchable
Y.Perch			127	142	74	6						349	66.37	7.7"	43
Alewife				299								299	30.00	8.3"	-
Cw Sucker			2	3	11	52	24	2				94	73.02	12.2"	-
Smelt		1	35	17								53	5.00	6.6"	28
Bluegill			1									1	0.19	6.7"	100
Redhorse								1				1	1.50	15.0"	-
S.W. Cisco					2	2						4	2.57	11.0"	100
Coho									1			1	2.25	17.7"	100
Burbot							1					1	1.06	14.0"	100
Sm. Bass								1				1	2.31	15.0"	100
Rock bass				1								1	0.50	8.0"	100
Bl. bullhead					1	1						2	1.13	10.7"	100
Walleye									4	3		7	22.10	19.0"	100
Sauger							5	31	54	13	17	120	286.34	17.1"	100
N. Pike									2		10	12	58.28	25.3"	83
TOTALS		1	165	462	88	61	30	35	61	16	27	946	552.62		87.8%

Analysis and comments:

Total effort = 3550' gill net fished 24 hours.

Fishing reports:

Catchables: Bluegill and Pumpkinseeds, 6"; Crappie and Perch, 8"; Bass, 10"; Pike, 20".
Inch Groups: 2" Group 1.0-2.9; 4" Group 3.0-4.9; 6" Group 5.0-6.9, etc.

(Over)

Species	No.	Age Groups* 0	I	II	III	IV	V	VI	VII	VIII	IX	X	
Bluegill		(2.1)	(2.9)	(4.3)	(5.5)	(6.5)	(7.3)	(7.8)	(8.0)	(8.5)	(8.5)	(9.2)	
Pumpkinseed		(2.0)	(2.9)	(4.1)	(4.9)	(5.7)	(6.2)	(6.8)	(7.3)	(7.8)	(----)	(----)	
Black Crappie		(---)	(----)	(5.9)	(8.0)	(9.0)	(9.9)	(10.7)	(11.3)	(11.6)	(----)	(----)	
Yellow Perch		(2.5)	(4.2)	(5.8)	(6.8)	(7.9)	(8.8)	(9.8)	(10.4)	(10.8)	(11.4)	(12.2)	
Largemouth Bass		(3.3)	(6.1)	(8.7)	(10.0)	(12.1)	(13.7)	(15.1)	(16.1)	(17.7)	(17.9)	(----)	
Northern Pike		(7.9)	(15.5)	(19.4)	(22.2)	(23.4)	(25.4)	(27.7)	(32.5)	(37.1)	(34.8)	(44.4)	

Fish Collection By Raymond Juetten; R. Reichardt Section ____________ Date of Collection August 3, 1971

Age Analysis By N. Murphy, W. Petterson Section ____________

* Given in calendar years. State averages in parentheses. Enter mean length in age group columns. C.O. Gussert

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

CONS. 8070
9/60

FISH GROWTH ANALYSIS

Lake or stream: Torch Lake

County: Houghton   T. 55N   R. 32-33W   Sec. M

Date(s) fish were collected: 9/11-13/79   Collector: R.P. Juetten   Section:

Method(s) of collection: Gill net   Analyzed by: R.P. Juetten   Section:

Species *		Age Group**	Number of fish	Length range (inches)	Mean length (inches)	State avg. length	Growth index (by age group)	Mean growth index for species
Sauger	all males	IX	4	17.3-18.5	17.9			
Sauger	males	X	2	18.5-18.7	18.6			
Sauger	females	X	4	22.5-24.0	23.4			
Sauger	males	XI	1	18.8	18.8			
Sauger	females	XI	7	23.5-25.5	24.1			
Sauger	females	XII	1	22.5	22.5			
Sauger	male	XIV	1	19.5	19.5			
Walleye		II	1	11.5	11.5	13.3	-1.8	
"		III	2	13.9-14.7	14.3	15.2	-0.9	
"		IV	1	16.5	16.5	17.2	-0.7	
"		VII	10	18.0-19.5	19.0	19.6	-0.6	
"		IX	2	21.0-22.0	21.5	21.4	+0.1	
Northern pike		III	4	20.2-23.5	21.9	22.2	-0.3	
		V	2	28.0-28.2	28.1	26.5	+1.6	
		VI	4	30.0-30.5	30.1	28.9	+1.2	
		VII	1	32.5	32.5	32.7	-0.2	
		VIII	1	37.0	37.0	33.4	+3.6	

* Several species may be listed on one card

** Given in calendar years. Fish become one year older on January 1.

(over)

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

CONS. 8065
Rev. 4/63

LAKE FISH COLLECTION AND AGE-GROWTH SUMMARY

Lake: Torch
County: Houghton
T. 55N R. 32-33W Sec. Many
Date: 9/11-13/79

Weather: Rain Air Temperature: 50's Water Temperature: 55° surf.
Seine: Acres Seined: No. Hauls: Snags:
Nets: Gill nets Length: 600' per mesh size Mesh: 2 1/2" 3 1/2" 4 No. Sets: / No. Lifts: /
Other Gear: 1750' exp. gill net fished over night (14 nets)

Species	2"	4"	6"	8"	10"	12"	14"	16"	18"	20"	22" +	Total No.	Total Wt.	Ave. Size	Per cent Catchable
Walleye						1	2	1	3	3	13	23	81.6	19.8	87
Sauger									7	1	12	20	82.6	21.6	100
N. pike										1	11	12	75.7	27.9	100
Sm. bass					1		1		1			3	5.0	13.7	67
Cisco				1			1					2	0.8	10.8	100
Whitefish								1				1	1.0	15.0	100
Y. perch			136	72	12	2						222	31.3	6.9	14
R. bass			28	2	3							33	9.0	6.5	100
Rbw. trout			1		1	3						5	2.3	10.1	60
W. sucker			2	6	54	6						68	39.0	9.9	-
Alewife			62									62	3.1	6.0	-
Blk bullhd				1	5							6	2.2	9.7	83
Burbot										1	1	2	5.3	20.5	100
Sea lamprey				1								1	.1	8.3	-
Totals........			229	83	76	12	4	2	11	6	37	460	339.0	-	83

Analysis and comments: Total effort: 3550' gill net fished 24 hrs. All sauger were heavily infected by internal and external parasites.

Fishing reports: Poor for sauger.

Catchables: Bluegill and Pumpkinseeds, 6"; Crappie and Perch, 8"; Bass, 10"; Pike, 20".
Inch Groups: 2" Group 1.0-2.9; 4" Group 3.0-4.9; 6" Group 5.0-6.9, etc.

(Over)

Lake or Stream: Torch Lake

County: Houghton

MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

T 55N R 33 32 Sec. Many

Page 1

CONS. 8077
8/60

NOTES AND REFERENCES

Subject: Comparisons of 1971 and 1979 surveys

Walleye: Catch/unit effort increased 3 x's over the 1971 survey. % of catch by weight and number increased 6 x's over 1971 survey. Average length increased by 80 mm.

Sauger: Catch/unit effort declined 6 x's from 1971 survey. Catch composition % by weight and number significantly decreased since 1971 survey. Age data from 1971, 1974 and 1979 indicate little recruitment since late 1960's. Average length of 1971 saugers was 434 mm. In 1974 it was 490 mm and in 1979 it was 549 mm. All saugers were heavily infected by internal and external tumors.

Northern pike: Catch composition percentages by weight and number increased 2 x's since 1971 survey. Average length increased slightly. Catch/unit effort was the same as encountered in 1971.

Smallmouth bass: Too few collected in both surveys to compare. Trends indicate population is increasing.

Yellow Perch: Catch/unit effort declined slightly since 1971. Population appears stable. Slight increase in average lengths.

Rock Bass: Significant increase in numerical and weight percentages in catch composition. Catch/unit effort increased 33 x's over 1971.

W. Sucker: Slight decrease in catch composition percentage by weight, numerical percentages increased. Average lengths declined.

OVER

Prepared by Section Date

Copies to (check): Lansing ( ), Region ( ), District ( ), I.F.R. ( )

MICHIGAN DEPARTMENT OF CONSERVATION

FISH DIVISION

CONS. 8077
8/60

Lake or Stream........................

County.............................. Houghton

T 55N R 35 33 Sec. Many

NOTES AND REFERENCES

Subject:

Miscellaneous species: Rainbow trout, coho, whitefish, cisco, bluegill, burbot, alewife, smelt, redhorse, sea lamprey, and bullheads were collected in low numbers in 1971 and in this survey. Trends cannot be determined.

Summary: In 1971, 67% of biomass in collection was n. pike, walleye, sauger and sm. bass, with sauger comprising 51% of the collection biomass. In 1979 these species were 72% of the biomass in the collection, with saugers accounting for 24% of the survey biomass. It appears the total game fish biomass relation to other species has not changed but walleyes and n. pike are replacing saugers.

Prepared by R. Juetten Section Date 9-13-79

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Species	No.	Age Groups*										
		0	I	II	III	IV	V	VI	VII	VIII	IX	X
Bluegill		(2.3)	(3.4)	(4.4)	(5.5)	(6.4)	(7.0)	(7.5)	(7.9)	(8.6)	(7.9)	(8.8)
Pumpkinseed		(2.8)	(3.3)	(4.4)	(5.2)	(5.9)	(6.4)	(6.9)	(7.3)	(7.8)	(---)	(---)
Black Crappie		(3.6)	(5.1)	(6.8)	(8.2)	(9.0)	(9.5)	(10.6)	(10.9)	(11.8)	(12.2)	(---)
Yellow Perch		(3.1)	(4.6)	(6.1)	(7.0)	(8.0)	(9.0)	(9.9)	(10.7)	(11.3)	(11.8)	(12.3)
Largemouth Bass		(3.6)	(6.1)	(8.6)	(10.6)	(12.2)	(13.6)	(15.1)	(16.7)	(17.7)	(18.8)	(19.8)
Northern Pike		(10.2)	(15.6)	(19.4)	(22.2)	(24.6)	(26.5)	(28.9)	(32.7)	(33.4)	(38.7)	(39.6)

Fish Collection By R. Juetten Section Field Date of Collection 9/11-13/79

Age Analysis By ________ Section ________

*Give in calendar years. State averages in parentheses. Enter mean length in age group columns.

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MICHIGAN DEPARTMENT OF CONSERVATION
FISH DIVISION

CONS. 8065
REV. 4/63

LAKE FISH COLLECTION AND AGE-GROWTH SUMMARY

Lake Torch

County Houghton T. 55N R. 32-33W Sec. Many Date 7/23-24/80

Weather Clear, SW wind Air Temperature 20-25 C Water Temperature 20 C surf

Seine Acres Seined No. Hauls Snags

Nets Exp. gill net Length 125' ea. Mesh Exp. No. Sets 4 No. Lifts 1 per set

Other Gear Gill net: 300'-2 1/2; 300'-3 1/2; 300'-4 1/2

Species	2"	4"	6"	8"	10"	12"	14"	16"	18"	20"	22" +	Total No.	Total Wt.	Ave. Size	Per cent Catchable
MILLIMETERS	51	102	152	203	254	305	356	406	457	508	559		Kg	MM	
Perch			98	58	5	1						162	10.6	175	17
Walleye								1	4	9	27	41	72.0	544	100
Sm. bass							4	7	4	1		16	13.5	414	100
Sauger									2	1		3	3.2	457	100
North. pike									1		10	11	12.9	665	91
Lk.Sturgeon								1				1	-	419	0
Brk. trout				1						1		2	1.2	368	50
Rainbow trt.										1		1	1.4	508	100
Burbot											1	1	1.5	572	100
Alewife			1	1								2	-	178	-
Smelt		3	5	1								9	-	.4	-
W.sucker					4	41	9					54	29.0	310	-
Cisco				3	1	2	1					7	2.0	262	-
Totals........		3	104	64	10	44	14	9	11	13	38	310	147.3	-	-

Analysis and comments: Total effort: 1400 feet gill net fish 24 hours. Survey done at request of Water Quality Division to determine percentage of fish infected by tumors as a result of copper mining activities.

Fishing reports: Sites surveyed: 33, 38, 39, C/UE increase over 1979 due to survey sites used. This should not be classed as an inventory survey.

Catchables: Bluegill and Pumpkinseeds, 6"; Crappie and Perch, 8"; Bass, 10"; Pike, 20".
Inch Groups: 2" Group 1.0-2.9; 4" Group 3.0-4.9; 6" Group 5.0-6.9, etc.

(Over)

Species	No.	Age Groups*										
		0	I	II	III	IV	V	VI	VII	VIII	IX	X
Bluegill		(2.1)	(2.9)	(4.3)	(5.5)	(6.5)	(7.3)	(7.8)	(8.0)	(8.5)	(8.5)	(9.2)
Pumpkinseed		(2.0)	(2.9)	(4.1)	(4.9)	(5.7)	(6.2)	(6.8)	(7.3)	(7.8)	(----)	(----)
Black Crappie		(---)	(----)	(5.9)	(8.0)	(9.0)	(9.9)	(10.7)	(11.3)	(11.6)	(----)	(----)
Yellow Perch		(2.5)	(4.2)	(5.8)	(6.8)	(7.9)	(8.8)	(9.8)	(10.4)	(10.8)	(11.4)	(12.2)
Largemouth Bass		(3.3)	(6.1)	(8.7)	(10.0)	(12.1)	(13.7)	(15.1)	(16.1)	(17.7)	(17.9)	(----)
Northern Pike		(7.9)	(15.5)	(19.4)	(22.2)	(23.4)	(25.4)	(27.7)	(32.5)	(37.1)	(34.8)	(44.4)

Fish Collection By John Norcross Section Field Date of Collection 7-24-80

Age Analysis By ______ Section ______

* Given in calendar years. State averages in parentheses. Enter mean length in age group columns.

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