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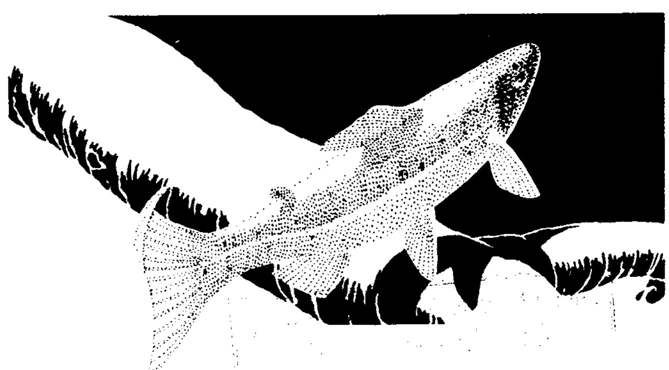
HYDROLOGY AND RECREATION ON THE COLD-WATER RIVERS OF MICHIGAN'S UPPER PENINSULA



Prepared by the United States Geological Survey in cooperation with the Michigan Geological Survey

1973

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HYDROLOGY AND RECREATION ON THE COLD-WATER RIVERS OF MICHIGAN'S UPPER PENINSULA

by G. E. Hendrickson

R. L. Knutilla

and C. J. Doonan

U. S. Geological Survey

artwork by Jim Campbell

Prepared by the
United States Geological Survey
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Michigan Geological Survey
Department of Natural Resources

1973

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SURVEY DIVISION

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HYDROLOGY AND RECREATION ON THE COLD-WATER RIVERS OF MICHIGAN'S UPPER PENINSULA

by: G. E. Hendrickson
R. L. Knutilla
C. J. Doonan

ABSTRACT

Recreational values of the cold-water rivers of Michigan's Upper Peninsula are dependent on streamflow characteristics, water-quality, and character of channel, bed, and banks. All recreational values are generally benefited by relatively uniform streamflow, clear water free from objectionable contaminants, and forested river banks protected from excessive erosion. Analyses of correlations of hydrologic parameters and trout populations in Upper Peninsula streams showed that trout populations may be limited by stream temperature, bottom vegetation, variability of streamflow, and discharge per unit drainage area. Preservation of recreational values of Upper Peninsula streams chiefly requires the control of man-made changes in the hydrologic environment.

INTRODUCTION

The cold-water rivers of Michigan provide outdoor recreation--trout fishing, boating, and camping--to rapidly growing numbers of vacationers. The Upper Peninsula, because of its distance from large metropolitan areas, has not as yet felt the full impact of increased recreational use of its cold-water streams, and many of its rivers are still relatively wild. The purpose of this report is to describe the relationships of hydrologic factors to recreational values so that these values can be protected from adverse changes in any watershed. The report includes data on most of the large cold-water rivers of the Upper Peninsula (fig. 1). A similar report on Michigan's Southern Peninsula has been published (Hendrickson and Doonan, 1972).

Acknowledgments

The hydrologic information presented here is chiefly the product of the continuing investigations of streamflow, groundwater conditions, and water quality made by the U.S. Geological Survey. Additional data on water quality, base flow of streams, and character of river channel, bed, and banks were obtained in 1971 and 1972 as part of the present study. Data on recreational use and potential of the streams were provided chiefly by various divisions of the Michigan Department of Natural Resources. These data include information on trout populations, fishing pressure, fishing success, and campgrounds attendance at river campgrounds.

Special thanks for help in this study go to Arthur E. Slaughter, State Geologist, Paul M. Brigham, Forest Recreation Manager, and David P. Borgeson, Cold-water Fish Specialist, all of the Michigan Department of Natural Resources. Assistance in the study also was obtained from colleagues of the U.S. Geological Survey. Streamflow, specific conductance, temperature, and dissolved oxygen were measured by Gordon C. Hulbert, Lauritz B. Hough, and John L. Oberg of the Escanaba subdistrict office.

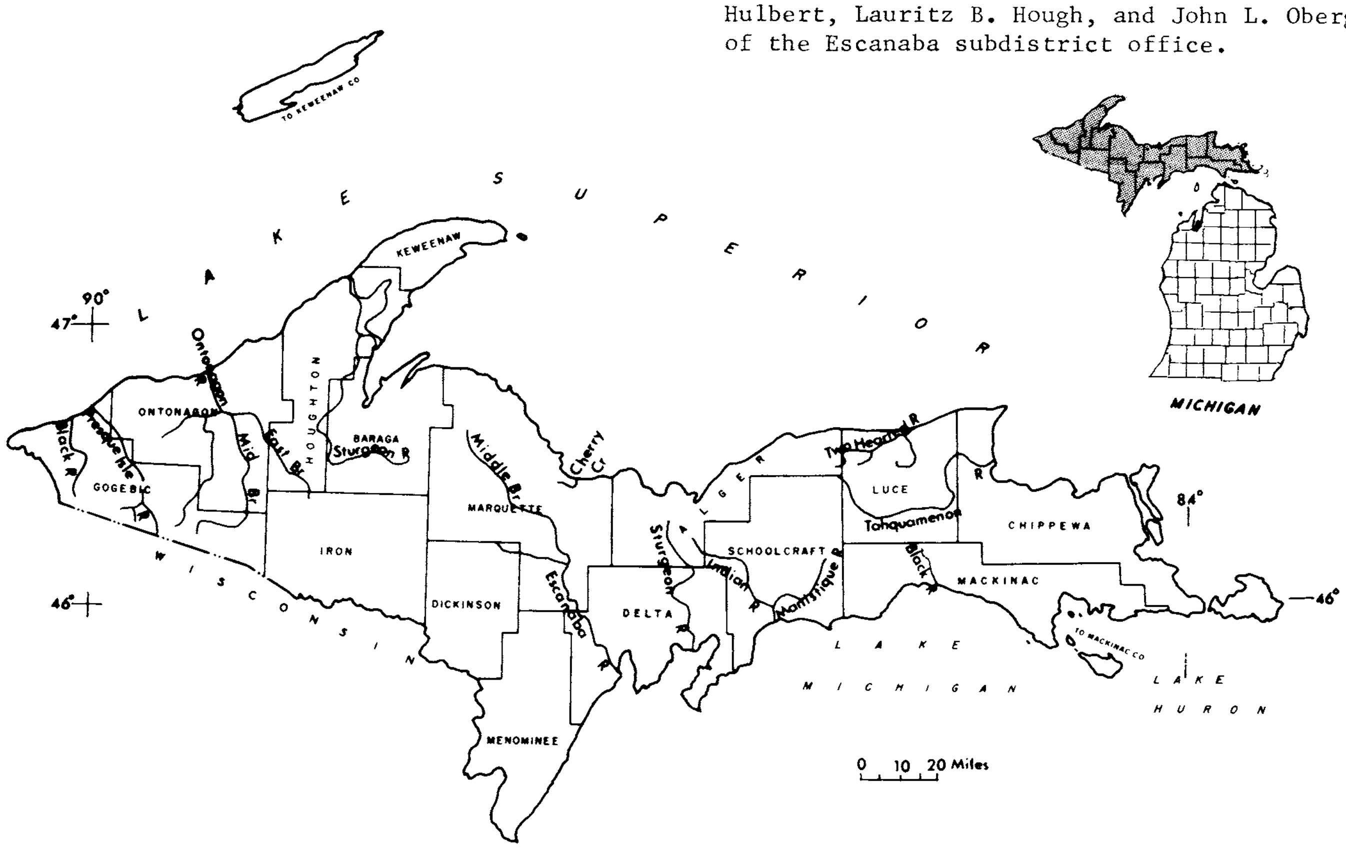


Figure 1.--Area of study includes many cold-water rivers in Michigan's Upper Peninsula.

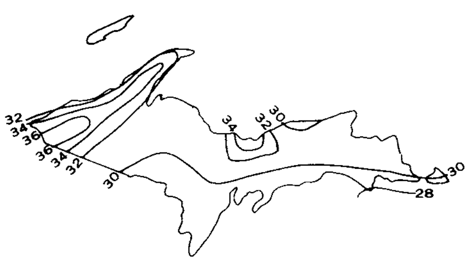
PHYSIOGRAPHY

Michigan's Upper Peninsula is bordered on the north by Lake Superior and on the south by Wisconsin, Lake Michigan, and Lake Huron. The uplands of the western Upper Peninsula are continuous with those of north-central Wisconsin. In the western part of the Upper Peninsula, the more rugged hills are areas of Precambrian bedrock outcrop; the rolling hills are glacial moraines. In the eastern part, glacial lake plains and till plains predominate, but morainal hills, such as the Munising Moraine near Munising, are conspicuous in places.

General Hydrology

Water falling on the watersheds of the Upper Peninsula flows over the surface of the land to streams (surface runoff), percolates down to the water table and flows through permeable materials to the streams (ground-water runoff), or is held in soil and plants until it is lost to the atmosphere (evapotranspiration). In general, the greater the amount of water that enters streams as ground-water discharge the more stable the flow and greater the drought flow of the streams.

Precipitation in the Upper Peninsula ranges from about 28 inches near Mackinac Straits to 36 inches per year near the west end of the Peninsula (fig. 2). Runoff ranges from 12 to 16 inches (fig. 3) and evapotranspiration from 14 to 20 inches (fig. 4). Ground-water discharge to streams ranges from about 25 to more than 90 percent of the total runoff.



AVERAGE ANNUAL PRECIPITATION, IN INCHES, 1931-60

Figure 2.--Average annual precipitation in the study area ranges from about 28 to 36 inches a year.

(Data from National Weather Service—NOAA)

AVERAGE ANNUAL RUNOFF, IN INCHES, 1951-60

Figure 3.--Average annual runoff ranges from about 12 to 16 inches a year.

AVERAGE ANNUAL EVAPORATION AND TRANSPIRATION, IN INCHES, 1951-60

Figure 4.--Average annual evaporation and transpiration range from about 14 to 20 inches a year.

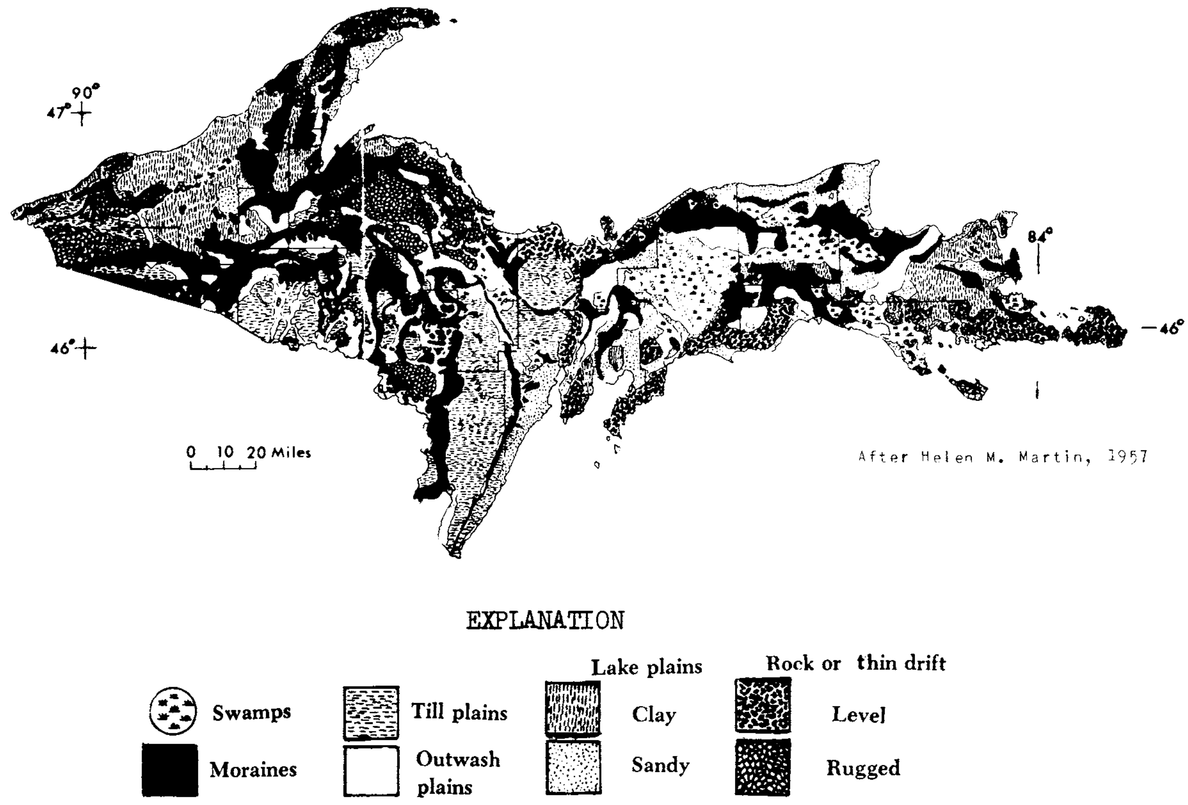
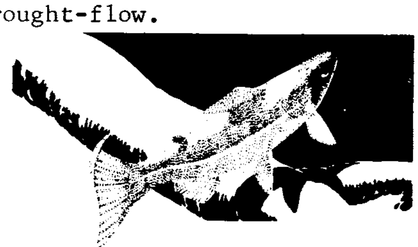


Figure 5.--Surficial geology influences streamflow.

Surface Geology

All the river basins in the Upper Peninsula have been glaciated, but the glacial deposits are thin or absent in large areas in the western part of the Peninsula and in smaller areas elsewhere. The surficial geology map of the Upper Peninsula (fig. 5) shows the general areas of glacial till, outwash, and lake bed deposits, as well as areas of bedrock outcrop and thin drift. Sandy lake beds and outwash deposits are relatively permeable and generally contribute to stable streamflow and high drought flow. Moraines, till plains, clay lake beds, and bedrock outcrop generally contribute to highly variable streamflow and low drought-flow. Moraine and till-plain deposits are sandy in places, however, and locally contribute to relatively stable streamflow and high drought-flow.



Bedrock Geology

Bedrock has a much greater influence on the hydrologic characteristics of streams in the Upper Peninsula than on streams in the Southern Peninsula. The rock formations are exposed or thinly mantled with drift over large areas of the Upper Peninsula, and the topography is controlled by bedrock in large areas in the western part. Bedrock, especially Precambrian bedrock, is generally less permeable than glacial drift. Consequently, areas of bedrock outcrop or thin drift are characterized by highly variable streamflow, low drought-flow, and high flood-flow.

Bedrock also influences the composition of the overlying glacial drift, inasmuch as the drift is derived from the rock. The carbonate Paleozoic rocks of the central and eastern Upper Peninsula generally contribute more soluble materials to the drift than the crystalline Precambrian rocks of the western part. This accounts in part for the slightly greater mineralization of water in streams of the central and eastern parts.

Topography and Drainage

The topography of the Upper Peninsula ranges from rugged hills, where Precambrian rocks crop out in the western part, to extensive plains underlain by glacial lake beds in the eastern part. Altitudes range from about 600 feet near the Great Lakes shorelines to nearly 2,000 feet in the western uplands. The highest peak in Michigan, Mt. Curwood in Baraga County, has an altitude of 1,980 feet. Most streams in the Upper Peninsula are short, and only a few drain more than 1,000 square miles. Streams draining to Lake Superior in the western part generally have steep gradients, many rapids, and some waterfalls (fig. 6). Streams draining to Lake Michigan in the western part generally have more moderate gradients and fewer rapids and waterfalls. Most streams in the eastern part have relatively moderate gradients and few rapids and falls. However, Tahquamenon Falls, the largest falls in Michigan, is in this area.

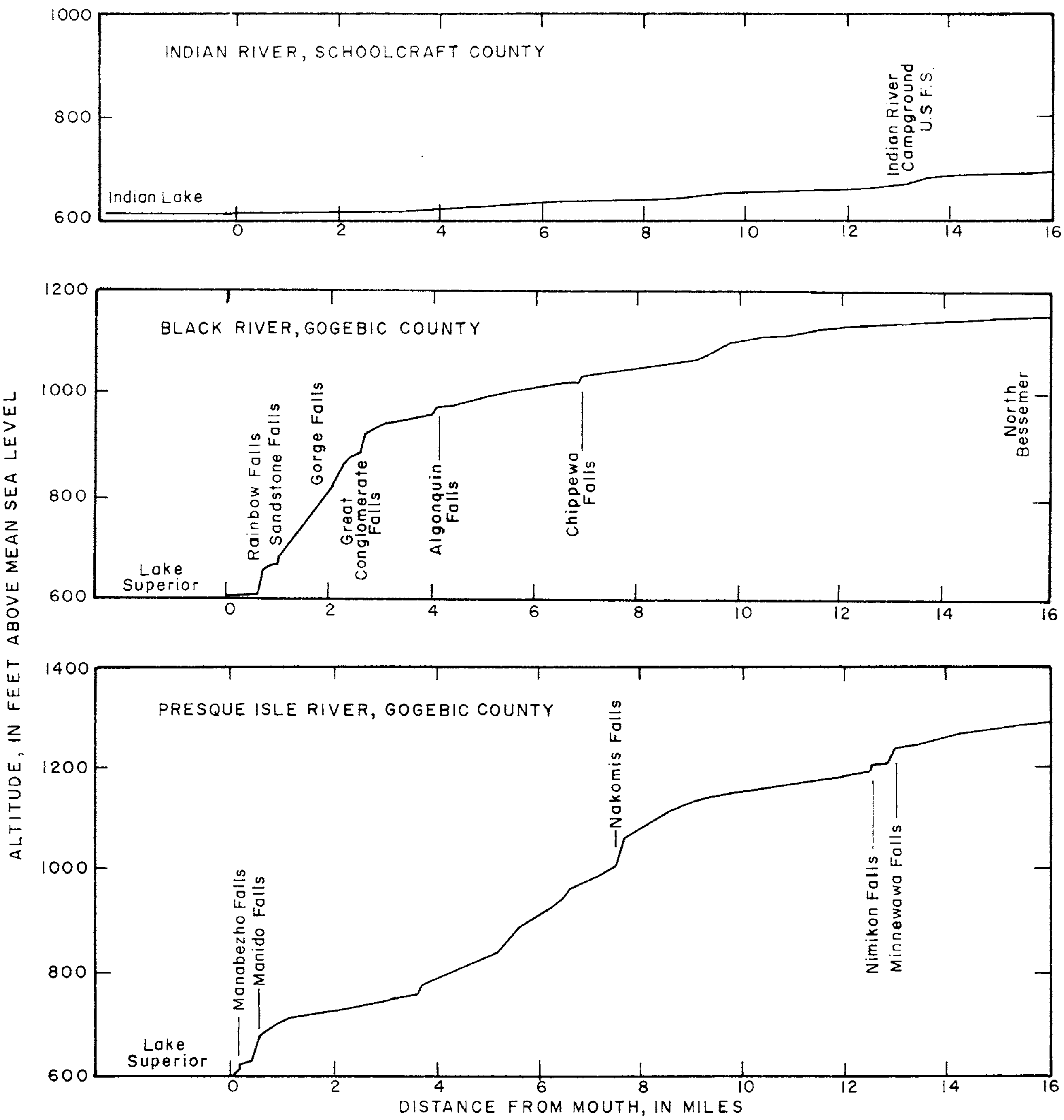


Figure 6.--Typical profiles of streams having rapids and falls and one that is more placid.

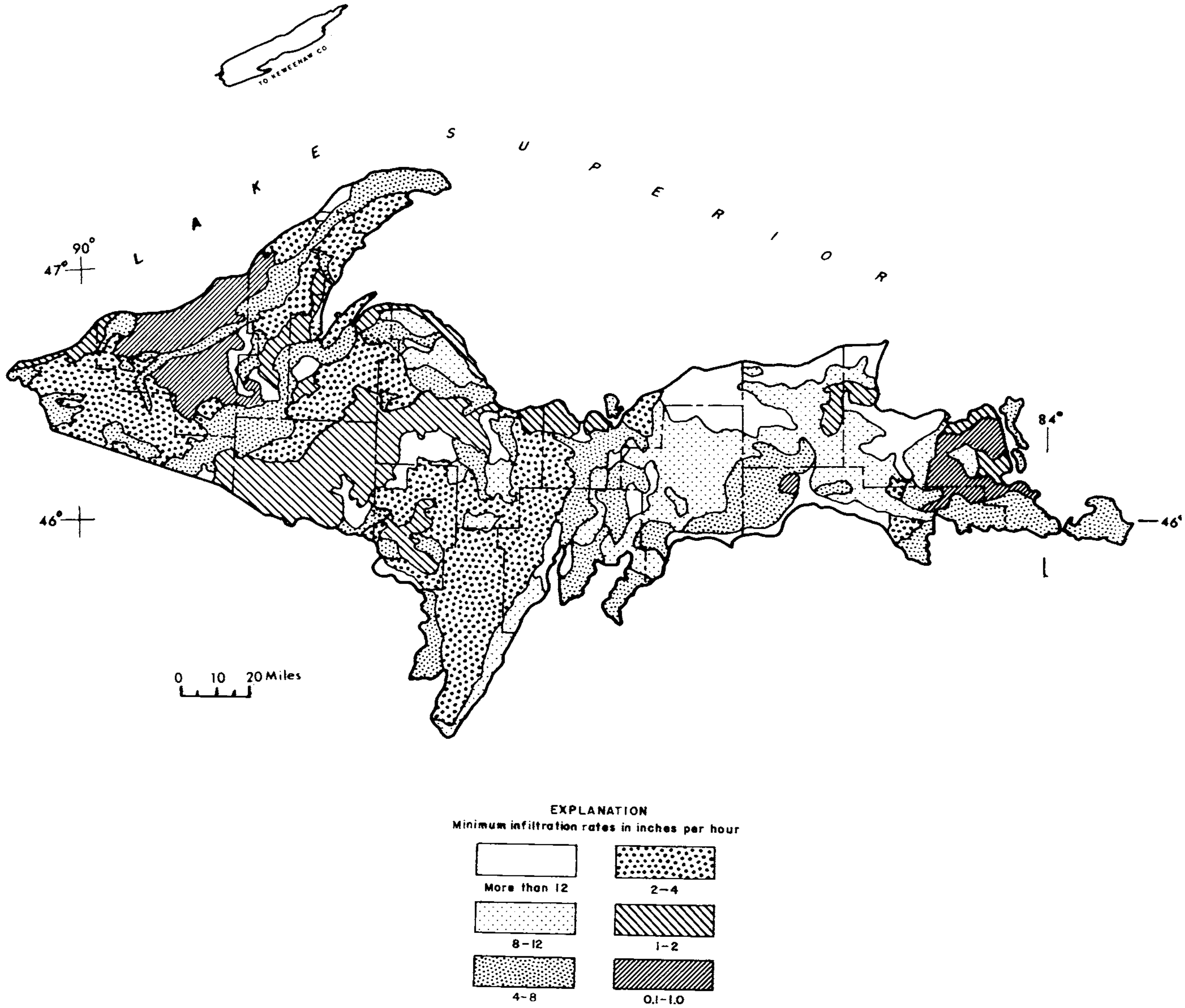
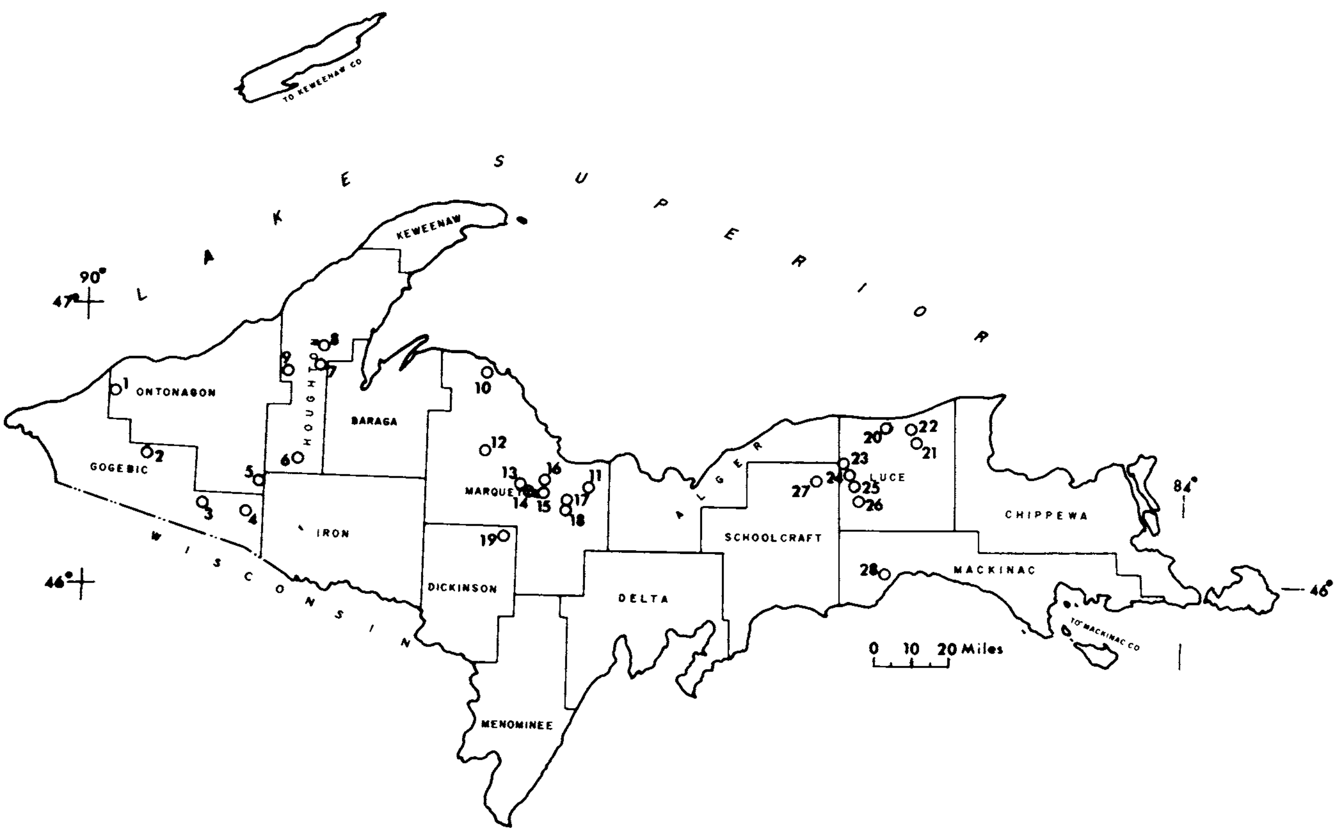


Figure 7.--Minimum infiltration rates of soils range from about 0.1 to 12 inches per hour (Schneider and Erickson, 1966).

Soils

Soils of the Upper Peninsula range from dense clay to permeable sand. The soils generally reflect the character of the underlying parent material. Soils overlying bedrock areas, clay lake beds, and clay till are chiefly composed of silt and clay of low permeability. Soils overlying sand lake beds, outwash, and sandy till are predominantly composed of permeable sand. Permeability of soils is indicated by minimum infiltration rates (fig. 7). Soils of most of the eastern half of the Upper Peninsula have higher infiltration rates than those of the western half. High infiltration rates are generally associated with high groundwater discharge and low surface runoff.

The character of river channel, bed, and banks of cold-water rivers are important to recreational values. Accordingly, a major effort of the present study was to obtain data on these features for many stream segments in the Upper Peninsula. A description of the character of the channel, bed, and banks, and other physiographic and hydrologic data on most major cold-water rivers in the Upper Peninsula, is given in table 1. Summaries of the results of mapping selected stream segments are given in tables 2 and 3. Locations of the segments mapped are shown on figure 8.



EXPLANATION

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Sampling point for channel characteristics, streamflow and water quality

Index numbers correspond to those used in tables 2, 3, 4-6

Figure 8.--Location of stream segments sampled for channel characteristics, streamflow, and water quality.

Table 1.--Hydrologic characteristics and recreation on 12 cold-water rivers of the Upper Peninsula.

Black River

Location: Gogebic County from U.S. Highway 2 near Bessemer to mouth at Lake Superior; about 22 river miles.

Width and Depth at Summer Low Flow: 25 to 100 feet wide; ½ to 2 feet deep in riffles and rapids, 2 to 4 feet deep in pools.

Streambed: Silt and sand in pools; gravel, boulders, and rock in riffles and rapids.

Banks: Mostly sand, silt, and muck, with some clay and rock; bank height varies from about 3 to more than 50 feet.

Flow Pattern: Riffles, rapids, and waterfalls predominate; some slower reaches.

Streamflow Characteristics: Variable flow; maximum discharge near Bessemer ranges from 1,500 to 3,000 cfs annually, exceeds 10,000 cfs occasionally; minimum, about 10 to 30 cfs; average annual range in stage about 9 feet.

Water Quality: Maximum summer temperatures near Bessemer usually range from 24° to 30°C (75° to 86°F); minimum temperatures, freezing point during winter months; dissolved oxygen near saturation; hardness ranges from about 20 to 50 mg/1; pH about 7.0 to 7.5.

Aesthetics: Rapids and waterfalls are the chief scenic attraction. U.S.F.S. trails lead to many scenic overlooks. Mostly hardwood forest with scattered conifers.

Fishing: Fair brook trout stream; migrant rainbow trout below Rainbow Falls; slippery rocks and fast water make wading dangerous in places.

Boating: Many falls, rapids, and boulders make the Black too dangerous for many but the expert canoeist. Even experts will have difficulty portaging around falls and rapids because of steep rocky banks.

Camping: One Campground now being built by U.S.F.S. just west of mouth of river. Camping is permitted on U.S.F.S. land not in campgrounds. No permits are required in Ottawa Nation Forest.

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Presque Isle River

Location: Gogebic County, from Michigan Highway 28 near Tula to mouth at Lake Superior, about 19 river miles.

Width and Depth at Summer Low Flow: 40 to 200 feet wide; 1 to 3 feet deep in riffles and rapids, 3 to 8 feet deep in pools.

Streambed: Silt and sand in pools; gravel, boulders, and rock in riffles and rapids.

Banks: Mostly sand, silt, and muck; bank height varies from 3 to 50 feet; high banks are generally rock.

Flow Pattern: Riffles, rapids and waterfalls.

Presque Isle River--Continued.

Streamflow Characteristics: Variable flow; maximum discharge near Tula usually ranges from 1,500 to 4,000 cfs; minimum, about 30 to 100 cfs; average annual range in stage is about 7 feet.

Water Quality: Maximum summer temperatures near Tula usually are about 23° to 25°C (73° to 77°F); minimum temperatures, freezing point during winter months; dissolved oxygen near saturation; hardness ranges from about 20 to 50 mg/1; pH about 7.0 to 7.5.

Aesthetics: Scenic attractions include waterfalls and rapids.

Fishing: Good brook trout stream; some migrant rainbow trout below Manabezho Falls. Difficult wading in places.

Boating: Similar to the Black. May be even more difficult because of vertical rock banks.

Camping: No developed campgrounds.

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Middle Branch Ontonagon River

Location: Gogebic and Ontonagon Counties, from U.S. Highway 2 about 6 miles west of Watersmeet to Bond Falls Reservoir, about 23 river miles.

Width and Depth at Summer Low Flow: 30 to 100 feet wide; 1 to 3 feet deep in riffles and rapids; 2 to 6 feet deep in pools.

Streambed: Mostly sand and silt in pools; gravel and boulders in riffles and rapids.

Banks: Mostly sand and muck, 2 to 10 feet high.

Flow Pattern: Pools and riffles, some rapids and one falls.

Streamflow Characteristics: Fairly steady flow; maximum discharge near Paulding usually ranges from 500 to 1,500 cfs; minimum, about 75 to 100 cfs; average annual range in stage about 5 feet.

Water Quality: Maximum summer temperatures near Paulding usually are about 20° to 23°C (68° to 73°F); minimum, freezing point during winter months; hardness generally ranges from 50 to 70 mg/1; pH about 7.3 to 7.5.

Aesthetics: Chief attraction is wilderness forest atmosphere, especially downstream from Watersmeet. Mixed forest cover, hardwood predominant. Few cabins.

Fishing: Good trout stream; mostly brook and rainbow.

Boating: Safe for novice if portages are made around fast-water reaches. Portages are few. Low-flow discharge usually enough to float loaded canoe. Upper two-thirds near roads; lower one-third more remote from roads.

Camping: About 1,700 camper days recorded in 1971 at Burned Dam Campground, U.S.F.S., near Watersmeet. Camping also permitted at State pulbic access site near Watersmeet.

Table 1.--Hydrologic characteristics and recreation on 12 cold-water rivers of the Upper Peninsula.--Continued.

Strugeon River

Location: Baraga and Houghton Counties, from U.S. Highway 41, 9 miles south of L'Anse to Pricket Dam; about 32 river miles.

Width and Depth at Summer Low Flow: Generally 50 to 100 feet wide; 1 to 3 feet deep in riffles and rapids, 2 to 6 feet deep in pools.

Streambed: Mostly bedrock, gravel, and boulders; some sand and silt.

Banks: Banks are rock, boulders, and glacial till; mostly 3 to 10 feet high; where river cuts against sides of gorge, banks are as much as 300 feet high.

Flow Pattern: Mostly rapids and falls; some pools and riffles.

Streamflow Characteristics: Variable flow; maximum near Sidnaw usually ranges from 1,000 to 4,000 cfs; minimum, about 15 to 30 cfs; average annual range in stage about 6 feet.

Water Quality: Maximum summer temperatures usually about 19° to 24°C (66° to 75°F); minimum, at freezing point during winter months; hardness about 75 mg/1; pH about 7.5.

Aesthetics: Rapids and waterfalls in Sturgeon River Gorge are chief attraction. Trails lead to scenic overlooks. Forest is mixed hardwood with some Hemlock. Wilderness atmosphere.

Fishing: Good brook trout stream; fair for rainbow and brown trout; fast water and rock bottom make difficult wading in places.

Boating: Falls and rapids make boating too dangerous for any but the expert. Shoals would ground loaded canoes at low flow.

Camping: About 2,500 camper days recorded in 1971 at Sturgeon River Campground, U.S.F.S., near Watton, Baraga County.

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Cherry Creek

Location: Near Harvey, Marquette County, from source above fish hatchery on County Highway 551 to mouth at Chocolay River, about 5 river miles.

Width and Depth at Summer Low Flow: 1 to 2 feet wide at source; 20 to 35 feet wide in lower reaches; generally less than 1 foot deep near source, up to 3 feet deep in lower reaches.

Streambed: Sand and gravel near source, mostly sand, in lower reaches.

Banks: Mostly sand 2 to 100 feet high near source; sand and muck, 1 to 6 feet high in lower reaches.

Flow Pattern: Mostly riffles and pools.

Streamflow Characteristics: Extremely steady flow; maximum discharge at gaging station 22 to 37 cfs during 5 years, 1966-70; minimum, 16 to 18 cfs; average annual range in stage about 1 foot.

Cherry Creek--Continued.

Water Quality: Maximum summer water temperature about 10° to 11°C (50° to 52°F); minimum, about 2°C (36°F); hardness about 100 mg/1, pH about 7.7.

Aesthetics: Chief attraction is the clarity of water in Cherry Creek and the steadiness of streamflow. Upstream reaches are forested; lower reaches are part wooded and part open grassland.

Fishing: Good brook trout stream; some large resident brown trout and migrant rainbow trout in lower reaches. Fishing pressure moderate most of year; heavy during spring and fall spawning runs; narrow channel and brushy banks make fly-casting difficult. Wading hampered by brush and drowned logs.

Boating: Generally too narrow and shallow for boating.

Camping: No campgrounds.

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Two Hearted River

Location: Luce County, from forks above High Bridge to mouth at Lake Superior; about 22 river miles.

Width and Depth at Summer Low Flow: 30 to 100 feet wide; 1 to 3 feet deep in upper reaches, 2 to 6 feet in lower.

Streambed: Mostly bedrock, gravel, and boulders from forks to High Bridge; mostly sand in lower reaches.

Banks: Mostly sand, some silt and muck; bank height generally varies from about 1 to 30 feet; in a few places banks are as much as 100 feet high.

Flow Pattern: Riffles, rapids, some low falls 1 to 2 feet high in upper part; pools and glides in lower part.

Streamflow Characteristics; Fairly steady flow; maximum discharge at High Bridge probably is 300 to 500 cfs most years; minimum, probably is 30 to 50 cfs; average annual range in stage estimated to be about 3 feet.

Water Quality: Maximum summer temperatures usually about 20° to 21°C (68° to 70°F); minimum, at freezing point many winter days; dissolved oxygen near saturation; hardness ranges from about 40 to 70 mg/1, pH from 7.3 to 7.7.

Aesthetics: Chief attraction is wilderness atmosphere; mixed hardwood and conifer forest in uplands; swamps are spruce and hemlock; scenic rapids from Forks to High Bridge.

Fishing: The Two Hearted is one of the best-known trout streams in the Upper Peninsula; good trout population: mostly brook and rainbow; good natural reproduction of trout. Heavily-fished during spring and fall spawning runs; fishing pressure is light remainder of season.

Boating: Experienced canoeists can traverse the river from High Bridge to the mouth; many portages around log jams. Enough water to float a loaded canoe during low-flow periods. One canoe livery at Newberry provides rental canoes.

Camping: About 19,000 camper days recorded in 1971 at three State Forest Campgrounds.

Tahquamenon River

Location: Luce and Chippewa Counties, from County Highway 442 northwest of McMillan to mouth at Lake Superior; about 60 river miles.

Width and Depth at Summer Low Flow: 30 to 100 feet wide and 2 to 6 feet deep above Newberry; below Newberry 100 to 350 feet wide and 3 to 12 feet deep.

Streambed: Some gravel in upper reaches upstream from McMillan; mostly sand, silt, and muck in lower reaches; rock at falls.

Banks: Mostly sand; some muck in swampy reaches; banks are 1 to 50 feet high.

Flow Pattern: Mostly placid except near falls.

Streamflow Characteristics: Fairly steady flow; maximum discharge near Tahquamenon Paradise usually is 2,500 to 5,000 cfs; minimum, about 200 to 250 cfs; average annual range in stage is about 5 feet.

Water Quality: Maximum summer temperatures about 19° to 20°C (66° to 72°F) in upper reaches; 25° to 30°C (77° to 86°F) in lower reaches (below McMillan); minimum dissolved oxygen near saturation; hardness about 70 to 100 mg/l; pH about 7.5 to 8.5.

Aesthetics: The falls are the major scenic attraction of the Tahquamenon; scenic overlooks at both Upper and Lower Falls; wilderness atmosphere; predominantly hardwood forest.

Fishing: Good brook trout stream in upper reaches above McMillan; river can be waded above McMillan, lower reaches mostly warm-water fishing except for spring and fall spawning runs. Fishing pressure is moderate.

Boating: Can be boated from McMillan to mouth, with portages around dam and falls; fast water immediately above falls; take-outs should be well upstream from both falls; low-flow discharge enough to float loaded canoe.

Camping: At Tahquamenon Falls State Park about 103,000 camper days were recorded in 1971 at the Lower Falls unit and about 58,000 camper days were recorded at the River Mouth unit. About 460 camper-days were recorded in 1971 at the 16-Creek State Forest Campground near Newberry.

Black River

Location: Mackinac County, from Black River Forest Campground to mouth at Lake Michigan, about 4 river miles.

Width and Depth at Summer Low Flow: 20 to 100 feet wide, ½ to 2 feet deep in riffles, 2 to 4 feet in pools.

Streambed: Mostly sand, some gravel and boulders.

Banks: Mostly sand; 3 to 6 feet high, occasionally higher.

Flow Pattern: Mostly placid; some riffles and rapids.

Streamflow Characteristics: Fairly steady flow; maximum discharge near Garnet usually is 200 to 400 cfs; minimum, about 8 to 10 cfs; average annual range in stage is about 3 feet.

Black River--Continued.

Water Quality: Maximum summer temperatures usually range from 16 to 19°C (61° to 66°F); minimum temperature, 0°C many winter days; hardness about 130 mg/l at low flow; pH about 8.0.

Aesthetics: Chief attraction is a clear, tranquil stream in hardwood forest. Few cabins except near U.S. Highway 2.

Fishing: Good spring and fall fishing for migrant rainbows; mostly brook trout and a few brown trout rest of season. Fishing pressure heavy during spawning runs; moderate to heavy remainder of season.

Boating: Too narrow and shallow for popular canoe trail; obstructed by fallen timber and log jams.

Camping: About 1,200 camper days were recorded at the Black River Forest Campground.

Manistique River

Location: Schoolcraft County, from Germfask to town of Manistique, about 75 river miles.

Width and Depth at Summer Low Flow: About 50 to 100 feet wide, 2 to 6 feet deep above Mead Creek Campground; 100 to 200 feet wide, 3 to 15 feet deep in lower reaches.

Streambed: Mostly sand, some gravel.

Banks: Mostly sand, some muck; banks generally are 2 to 10 feet high, some up to 30 feet high.

Flow Pattern: Mostly placid, few riffles.

Streamflow Characteristics: Relatively steady flow; maximum discharge at Germfask usually is 1,000 to 2,000 cfs; minimum, about 200 to 250 cfs; average annual range in stage is about 4 feet.

Water Quality: Maximum summer temperatures 20° to 24°C (66° to 75°F) most years; minimum, freezing point during winter months; hardness ranges from about 30 mg/l at high flows at about 70 mg/l at low flows; pH about 7.5.

Aesthetics: Wilderness forest, mostly hardwood, some pine and cedar; much of river is remote from roads.

Fishing: Good migrant trout and salmon fishing below dam at town of Manistique; northern pike and wall-eye fishing in most of river.

Boating: Wide and deep enough for outboard motor boats in some reaches. Can be canoed from Germfask to Manistique with few, if any portages or pullovers. Enough water at low-flow periods for loaded canoes and other light craft. Major challenge to canoeists are great distances between launching and take-out points.

Camping: About 4,700 camper days were recorded in 1971 at two State Forest Campgrounds (Mead Creek and Merwin Creek) on the Manistique.

Table 1.--Hydrologic characteristics and recreation on 12 cold-water rivers of the Upper Peninsula.--Continued.

Indian River

Location: Alger and Schoolcraft Counties, from Widewaters Campground to Indian Lake, about 34 river miles.

Width and Depth at Summer Low Flow: Generally 30 to 70 feet wide except in lakes and ponds where river widens to as much as several hundred feet. Braided channels in places; most of river is 1 to 3 feet deep except in lakes and ponds.

Streambed: Mostly sand, some gravel.

Banks: Mostly sand, some muck; 3 to 10 feet high most places, some lower than 3 feet and higher than 50 feet.

Flow Pattern: Mostly placid, some riffles, no rapids.

Streamflow Characteristics: Relatively steady flow; maximum discharge near Manistique usually 500 to 1,000 cfs; minimum, about 150 to 200 cfs; average annual range in stage about 2 feet.

Water Quality: Maximum summer temperature usually about 22° to 25°C (72° to 77°F); minimum, freezing point during winter months; hardness ranges from about 50 to 130 mg/1; pH about 7.4 to 7.8.

Aesthetics: Chief attraction of the Indian is crystal clear stream in wilderness forest; mostly hardwood with some conifer. High sandy banks provide many scenic overlooks.

Fishing: Good Brook trout stream, a few brown and rainbow; no migrant trout; heavily-fished all season; mostly wading fishing, some canoe-fishing.

Boating: Easy canoeing; no difficult rapids; major channel is marked in the braided channel "spreads" near Indian Lake; enough water at low-flow to float loaded canoes.

Camping: About 21,000 camper days recorded in 1971 at two U.S.F.S. campgrounds (Wide-Waters and Indian River).

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Sturgeon River

Location: Alger and Delta Counties, from 16-mile Lake to mouth at Lake Michigan; about 50 river miles.

Width and Depth at Summer Low Flow: 25 to 100 feet wide; mostly less than 3 feet deep, some holes 6 feet deep.

Streambed: Mostly sand in upper reaches; lower reaches bedrock, boulders, and gravel with some sand.

Flow Pattern: Mostly placid in upper reaches; riffles and rapids in lower reaches.

Streamflow Characteristics: Moderately variable flow. Maximum discharge near Nahma Junction usually 1,000 to 1,500 cfs; minimum, about 40 to 60 cfs; average annual range in stage about 5 feet.

Water Quality: Maximum summer temperatures usually about 19° to 24°C (66° to 75°F); minimum, freezing point on many winter months; hardness 70 to 100 mg/1; pH about 7.5 to 8.0.

Sturgeon River--Continued.

Aesthetics: Major attractions of the Sturgeon are riffles and rapids on clear-water stream in mixed hardwood and conifer forest. Bedrock outcrop on stream bottom in middle reaches.

Fishing: Good spring and fall run of rainbows; fair fishing for brooks, browns, and rainbows remainder of season; fishing pressure generally is moderate.

Boating: Most of stream not suitable for boating; too shallow in most reaches to float a loaded canoe especially during periods of low flow; many obstructions, including rock ledges, log jams, and fallen trees.

Camping: About 7,000 camper days recorded in 1971 at Flowing Well Campground, U.S.F.S.

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Escanaba River

Location: Marquette County, from Gwinn to Boney Falls reservoir, about 30 river miles.

Width and Depth: Mostly 100 to 150 feet wide, 1 to 3 feet deep; some holes more than 5 feet deep.

Streambed: Mostly bedrock and rock-rubble, some sand and gravel.

Banks: Mostly sand and muck; some rock; banks 2 to 10 feet high; higher banks in a few places.

Flow Pattern: Mostly riffles and rapids; some placid reaches.

Streamflow Characteristics: Variable flow, affected by regulation of powerplant near Princeton; maximum discharge most years is 2,000 to 4,000 cfs; minimum, is about 10 to 20 cfs; average annual range in stage is about 6 feet.

Water Quality: Maximum summer temperatures generally about 22° to 26°C (72° to 79°F); minimum, at freezing point many winter days; hardness ranges from 20 to 40 mg/1, pH about 7.3 to 7.6.

Aesthetics: Chief attraction is wilderness atmosphere. Much of river is remote from roads. Mostly forested swamplands, hardwood and conifer. River usually runs clear except at high flows.

Fishing: Although the Escanaba has brown trout and some brook trout, fishing success usually is not good; many shallow, unproductive reaches; only those fishermen who know the stream well can expect successful fishing.

Boating: Can be canoed from Gwinn to Boney Falls Reservoir; many rapids, some portages; canoes may be grounded in some reaches at low flow.

Camping: About 400 Camper days recorded in 1971 at Escanaba River State Forest Campground.

Table 2.--Summary of physiographic data on streams

Index number	Stream name	Stream segment Location	Length (feet)	Area (acres)	Average width (feet)	Average depth (feet)	Width-depth ratio	Volume (acre-feet)	Gradient (feet per mile)
1	Little Carp River	SE¼ sec.17, T.50 N., R.44 W.	450	0.25	24	0.7	34	0.18	200
2	Copps Creek	NW¼ sec.21, T.47 N., R.43 W.	150	.048	14	.7	20	.034	54
3	Middle Branch Ontonagon River	SE¼ sec.21, T.45 N., R.40 W.	500	.21	18	1.0	18	.21	10
4	do	NW¼ sec.27, T.45 N., R.39 W.	450	.42	41	1.6	26	.67	4.9
5	Deadman Creek	SE¼ sec.23, T.46 N., R.38 W.	200	.073	16	.7	23	.051	44
6	East Branch Ontonagon River	NW¼ sec.15, T.47 N., R.36 W.	500	.41	36	1.3	28	.53	40
7	West Branch Sturgeon River	SW¼ sec.12, T.50 N., R.36 W.	400	.31	34	1.3	26	.40	20
8	Bart Creek	NW¼ sec.14, T.52 N., R.35 W.	190	.061	14	1.2	12	.073	50
9	West Branch Otter River	NW¼ NE¼ sec.33, T.51 N., R.36 W.	540	.26	21	1.9	11	.49	15
10	Salmon Trout River	Sec.12, T.51 N., R. 28 W.	3,960	3.45	38	2.5	15	8.62	6.2
11	West Branch Chocolay River	NE¼ sec.22, T.46 N., R.24 W.	225	.13	25	1.4	18	.18	20
12	Middle Branch Escanaba River	Sec.7, T.47 N., R.28 W.	500	.30	26	1.8	14	.54	4.7
13	Green Creek	SE¼ NW¼ sec.19, T.46 N., R.26 W.	200	.064	14	1.3	11	.083	24
14	do	NE¼ sec.29, T.46 N., R.26 W.	350	.14	17	1.9	8.9	.27	9.8
15	do	SW¼ sec.35, T.46 N., R.26 W.	360	.11	13	1.4	9.3	.15	6.9
16	Goose Lake Outlet	SE¼ SE¼ sec.12, T.46 N., R.26 W.	700	.55	34	2.0	17	1.10	11
17	East Branch Escanaba River	NW¼ sec.4, T.45 N., R.25 W.	400	.50	54	2.4	22	1.20	5.2
18	do	NE¼ sec.21, T.45 N., R.25 W.	850	.90	46	1.9	24	1.71	6.6
19	West Branch Escanaba River	SW¼ NW¼ sec.24, T.44 N., R.28 W.	1,500	1.14	33	1.9	17	2.17	9.5
20	Two Hearted River	NE¼ sec.31, T.49 N., R.10 W.	2,400	2.81	51	1.8	28	5.06	24
21	East Branch Two Hearted River	NE¼ sec.5, T.48 N., R.9 W.	600	.47	34	1.4	24	.66	8.9
22	do	SE¼ sec.18, T.49 N., R.9 W.	300	.21	31	2.0	16	.42	7.4
23	Tahquamenon River	SW¼ sec.8, T.47 N., R.12 W.	200	.13	29	1.1	26	.14	--
24	do	SE¼ sec.21, T.47 N., R.12 W.	300	.32	46	2.3	20	.74	--
25	do	NW¼ sec.10, T.46 N., R.12 W.	400	.33	36	2.1	17	.69	--
26	do	NE¼ sec.22, T.46 N., R.12 W.	400	.28	30	3.0	10	.84	--
27	East Branch Fox River	SW¼ sec.16, T.47 N., R.13 W.	1,920	.93	21	1.6	13	1.49	--
28	Rock River	W½ sec.30, T.43 N., R.10 W.	1,000	.25	11	.9	12	.22	--

Table 3.--Summary of channel characteristics

Index number	Stream name	Stream segment	Channel character											
			Bed materials				Bottom vegetation (percent)	Fish cover (percent)	Average bank height (feet)	Predominant bank material	Bank vegetation			
		Location	Gravel (percent)	Sand (percent)	Muck (percent)	Other (percent)					Hardwood (percent)	Conifer (percent)	Brush (percent)	Grass (percent)
1	Little Carp River	SE¼ sec.17, T.50 N., R.44 W.	8	4	0	88	0	5	18	rock	38	62	0	0
2	Copps Creek	NW¼ sec.21, T.47 N., R.43 W.	78	11	3	8	1	8	4	muck	6	24	42	28
3	Middle Branch Ontonagon River	SE¼ sec.21, T.45 N., R.40 W.	0	30	70	0	25	17	3	do	0	0	92	8
4	do	NW¼ sec.27, T.45 N., R.39 W.,	53	22	7	0	29	4	6	do	9	3	43	43
5	Deadman Creek	SE¼ sec.23, T.46 N., R.38 W.	58	11	31	0	8	19	4	do	6	10	77	7
6	East Branch Ontonagon	NW¼ sec.15, T.47 N., R.36 W.	64	28	8	0	0	4	5	do	25	15	60	0
7	West Branch Sturgeon River	SW¼ sec.12, T.50 N., R.36 W.	60	36	4	0	0	1	8	sand	25	7	58	10
8	Bart Creek	NW¼ sec.14, T.52 N., R.35 W.	2	90	8	0	0	13	2	muck	28	17	55	0
9	West Branch Otter River	NW¼ NE¼ sec.33, T.51 N., R.36 W.	11	26	63	0	1	9	3	do	8	5	87	0
10	Salmon Trout River	Sec.12, T.51 N., R. 28 W.	40	43	6	10	0	6	16	sand	67	13	8	12
11	West Branch Chocolay River	NE¼ sec.22, T.46 N., R.24 W.	3	92	5	0	0	6	4	muck	2	0	98	0
12	Middle Branch Escanaba River	Sec.7, T.47 N., R.28 W.	69	16	15	0	3	5	10	do	40	0	35	25
13	Green Creek	SE¼ NW¼ sec.19, T.46 N., R.26 W.	1	55	44	0	20	10	2	do	0	0	100	0
14	do	NE¼ sec.29, T.46 N., R.26 W.	11	63	16	0	3	6	3	do	0	5	45	55
15	do	SW¼ sec.35, T.46 N., R.26 W.	19	44	37	0	12	14	2	do	0	0	100	0
16	Goose Lake Outlet	SE¼ SE¼ sec.12, T.46 N., R.26 W.	20	65	15	0	1	19	4	do	5	15	80	0
17	East Branch Escanaba River	NW¼ sec.4, T.45 N., R.25 W.	69	18	5	8	0	8	5	do	2	5	93	0
18	do	NE¼ sec.21, T.45 N., R.25 W.	93	6	1	0	0	2	12	sand	44	20	17	19
19	West Branch Escanaba River	SW¼ NW¼ sec.24, T.44 N., R.28 W.	35	50	15	0	0	7	4	muck	22	28	46	4
20	Two Hearted River	NE¼ sec.31, T.49 N., R.10 W.	45	24	1	30	1	8	17	sand	22	37	27	16
21	East Branch Two Hearted River	NE¼ sec.5, T.48 N., R.9 W.	2	21	0	77	3	3	7	do	8	12	80	0
22	do	SE¼ sec.18, T.49 N., R.9 W.	0	96	4	0	1	10	15	do	1	16	83	0
23	Tahquamenon River	SW¼ sec.8, T.47 N., R.12 W.	17	80	1	2	2	4	36	do	28	72	0	0
24	do	SE¼ sec.21, T.47 N., R.12 W.	3	87	10	1	1	1	1	do	0	44	56	0
25	do	NW¼ sec.10, T.46 N., R.12 W.	56	43	1	0	1	13	11	do	25	55	20	0
26	do	NE¼ sec.22, T.46 N., R.12 W.	2	96	2	0	0	30	1	muck	0	0	50	50
27	East Branch Fox River	SW¼ sec.16, T.47 N., R.13 W.	27	73	0	0	1	5	3	sand	0	8	92	0
28	Rock River	W½ sec.30, T.43 N., R.10 W.	8	65	25	2	54	12	1	do	1	15	64	20

The width and depth of channel generally increase downstream, but this increase is not uniform. Many Upper Peninsula streams have alternating pools and riffles, with the pools substantially deeper than the riffles. Typical cross-sections are shown in figure 9. Width and depth of channel are greater at high than at low flows, and erosion and deposition may alter the channel from one season to another.

River banks in the Upper Peninsula are chiefly composed of muck, sand, or rock (tables 1, 3). Clay banks occur on some streams but are not extensive. The lower banks are chiefly muck, whereas higher banks are sand or rock. Rock and muck banks generally contribute little sediment to the stream, but sand banks may contribute relatively large amounts. Bank height and material also influence bank vegetation. Low muck banks are predominantly brush-covered, whereas trees cover most of the high sand and rock banks.

River-bed materials in Upper Peninsula streams include sand, gravel, boulders, muck, and rock (tables 1, 3). Low-gradient stream channels (less than 20 feet per mile) are generally sand-bottomed in the pools and gravel- or rock-bottomed in the riffles. Gravel and rock bottoms usually predominate in the high-gradient streams. Muck bottoms generally are confined to the relatively slow moving water near the banks and in the deeper pools.

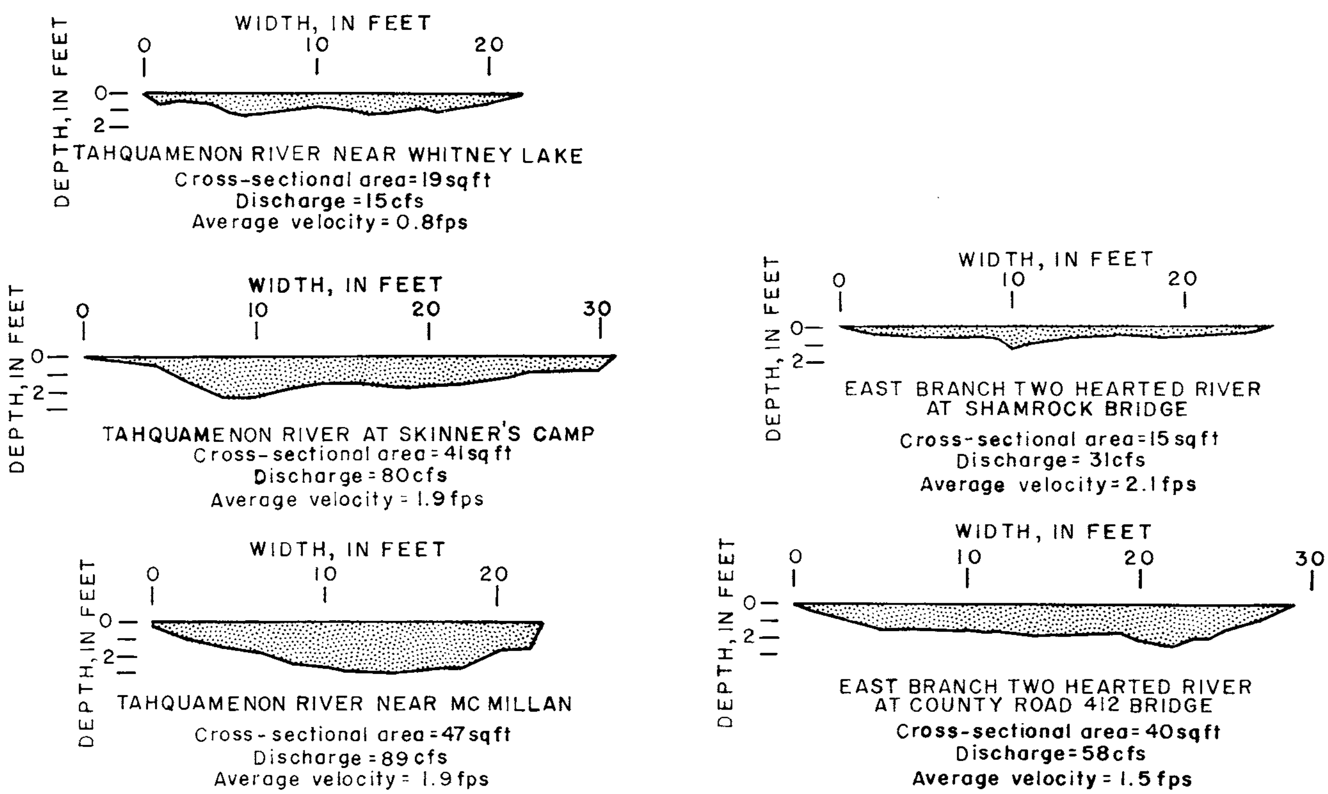


Figure 9.--Cross-sectional area and discharge of streams generally increase downstream.

Recreation and the River Channel, Bed, and Banks

Some Upper Peninsula cold-water streams have great recreational potential because their physical character is aesthetically attractive and favorable for fishing, boating, and camping. For example, the Indian River flows between sandy wooded banks in a wilderness atmosphere. It is wide and deep enough for easy canoeing and is a popular canoe trail and a productive trout stream. Its banks provide excellent campsites. Some rivers are best suited for only one or two recreational uses. The Black River in the western Upper Peninsula is of recreational value chiefly because of its falls and rapids. It is too dangerous to be a popular canoe trail and is only a fair trout stream. The physical character of several cold-water rivers and their major recreational values are included in table 1.

Aesthetic Considerations

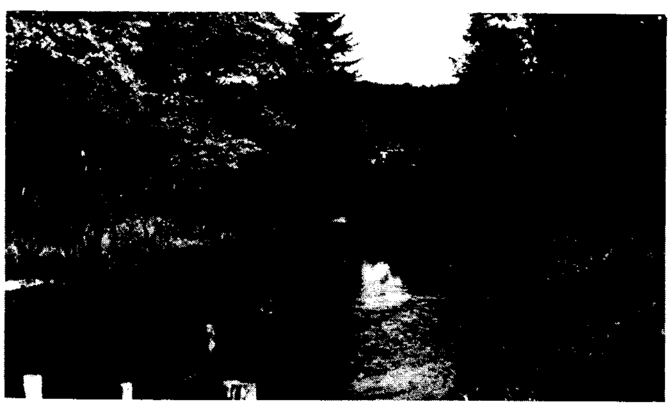
Although individual opinions differ, certain characteristics of river channel, bed, and banks are considered by most people to be more attractive than others. Moderately high sand or rock banks that provide a good view of the stream are generally preferred to low muck banks. Excessively eroded banks are generally objectionable. An open cover of trees is preferred to brush or weeds. A sand, gravel or rock streambed is more attractive than muck, silt, or mud. The width and depth of river channel are important considerations in aesthetic attractiveness, but individual preferences vary widely. Some prefer streams of great width and depth; others enjoy the smaller, shallower streams. Few rivers of the Upper Peninsula are as large as the larger rivers of the Southern Peninsula.

One quality that most Upper Peninsula rivers possess to a greater degree than most rivers of the Southern Peninsula is wildness, or wilderness atmosphere. Riverside cottages and homes are scarce on most of the rivers as yet, and distances between paved roads and bridges are greater than on streams of the Southern Peninsula. The State and Federal governments own about 40 percent of the land in the Upper Peninsula--land that is held for the public and generally retained in a wilderness state. Thus, boaters and hikers in the Upper Peninsula can find many miles of undeveloped river frontage.

The aesthetic attractiveness of several Upper Peninsula rivers is illustrated in the photographs showing typical river scenes (fig. 10).

Manido Falls, Presque Isle River
Gogebic County

Low Falls, West Branch Two Hearted River
Luce County



Indian River
Alger County

Tahquamenon River at Eagle's Nest
Luce County

Figure 10.--River scenes in the Upper Peninsula.

Fishing

Although many streams in the Upper Peninsula provide excellent trout fishing, there are no large streams with trout populations comparable with those of the Au Sable or Pere Marquette of the Southern Peninsula. The more productive trout streams are generally small and in remote areas and are not heavily fished. A few of the larger rivers, such as the lower Two Hearted, are heavily fished during spring and fall spawning runs but are moderately fished at other times (table 1).

The convenience and safety of the fisherman is influenced by the character of the bed materials, because wading is easier and safer on firm sand or gravel bottom than on slippery clay, boulders, or fractured bedrock. Wading is also easier and safer in a shallow channel than in a deep one if velocity is not too great. Many Upper Peninsula streams having steep gradients, such as the Black and Presque Isle Rivers, have some reaches where beds are composed of fractured rock that make wading difficult or dangerous (table 1). Most low-gradient streams have predominantly sand and gravel bottoms that usually provide a relatively firm footing. The Tahquamenon, Manistique, and Indian Rivers are mostly sand-bottomed, although the Tahquamenon has falls and rapids on bedrock. Streams having alternate reaches of moderate and steep gradients, such as the Middle Branch Escanaba River, generally have sand or gravel bottoms in the flatter reaches and boulders or bedrock in the steeper.

The width of channel and character of bank vegetation are important to the fly-fisherman, because fly-casting is easier on a broad, open stream than on a narrow channel with overhanging branches. Many excellent trout streams, such as Copps, Deadman, Bart, and Green Creeks (table 3) are too narrow and brushy for easy fly-casting. The wider, more open streams, such as the Ontonagon, Two Hearted, Tahquamenon, and Escanaba Rivers, provide easier fly-casting.

The river channel, bed, and banks also influence trout fishing indirectly by influencing the temperature and dissolved-oxygen content of the stream. Water in a well-shaded deep and narrow channel will not get as warm as water in a broad shallow and open channel, other conditions being equal. Cooler water normally retains a higher dissolved-oxygen content. Also, the reaeration of oxygen-depleted streams is influenced indirectly by stream gradient and bottom materials. High gradients and gravel or boulder streambeds are associated with riffles and rapids that promote aeration of the water.

The relationships of hydrologic factors, including character of bed and banks, to trout populations are discussed in greater detail in a later section of the report.

Boating

Boating on cold-water rivers of the Upper Peninsula is enjoyed by only a few. Experienced canoeists who enjoy the solitude of wilderness and the challenge of white water are attracted to these streams, but the novice finds many of them too dangerous or the numerous portages required too exhausting for enjoyable boating (table 1). Even the relatively easy canoe trails, such as the Indian River, have only minor canoe traffic in comparison with the more popular Southern Peninsula streams. The great distances from population centers, limited access, and scarcity of rental canoes make boating a minor recreational use of Upper Peninsula streams.

The narrow, shallow channels that characterize most Upper Peninsula rivers in their upper reaches will not float even light canoes or kayaks. The wide, deep channels in the lower reaches of some of the larger rivers, such as the Manistique, are traversed by motor boats as well as by canoes and other light craft. Streams with very steep gradients, such as the lower Black and Presque Isle Rivers, have numerous rapids and falls that make these rivers too dangerous for all but expert boaters (table 1). The predominantly sand beds of the Manistique and its tributaries are less hazardous, even in shoal water.

The height and vegetation of the river banks are important to the boater where portages are necessary. Low sandy banks with open grassland or scattered trees make portaging relatively easy. Steep, high banks or low banks with dense brush make portaging difficult. Most portages on Upper Peninsula streams require the canoe to be lifted over high rocky banks or carried through dense brush through mucky swamps, where footing is not firm.

Camping

Sandy banks of moderate height with open grassland or scattered trees make desirable campsites, providing good drainage and adequate sunlight to dry the tents and camping gear. Banks of Upper Peninsula streams are densely covered with brush or trees in most places and are generally too low and swampy or too high for the best campsites. Although they are not numerous, campsites that are desirable, or at least satisfactory, can be found in places along most of the rivers (table 1).

Public campgrounds have been developed along many Upper Peninsula streams in State and National Forests, and attendance at these campgrounds is increasing (fig. 11). State Park campgrounds are much more popular with campers than the State Forest campgrounds. Attendance at the two units of Tahquamenon Falls State Park in 1971 was about 161,000 camper days, or about 500 camper days per camp space. Attendance at five State Forest riverside campgrounds that year was about 20,000 camper days, or about 240 camper days per space. The greater popularity of the State Park campgrounds can probably be attributed to the facilities offered--running water, showers, and indoor toilets--and to their accessibility and the fact that almost all tourists know where the State Parks are located. Many do not know how to find the State Forest campgrounds.

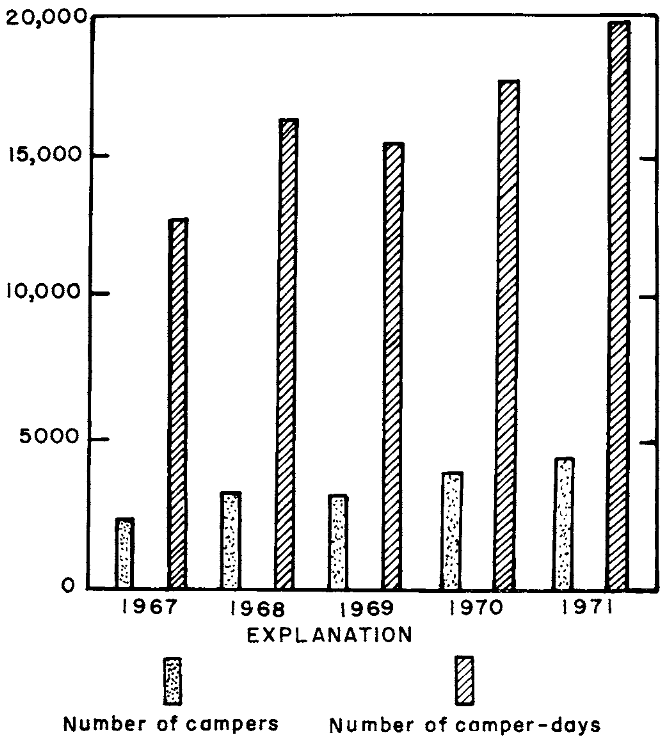


Figure 11.--Attendance at five State Forest campgrounds increased about 60 percent from 1967 to 1971. Attendance data from Michigan Natural Resources.

STREAMFLOW

Flow characteristics of Upper Peninsula streams vary widely. A few, such as Cherry Creek near Harvey, are remarkably steady, increasing only slightly in discharge in response to heavy rains and snowmelt. Others, such as the Black River near Bessemer, are extremely variable in discharge. These differences in flow characteristics influence the recreational potential of the rivers.

Streamflow characteristics can be described in terms of discharge, velocity, and stage. Discharge, in its simplest concept, means outflow. As used here, it is the volume of water moving past a given cross-section of the stream in a unit of time; velocity is the speed of water movement; stage is the height of the water surface above an established datum plane. A stream 100 feet wide and averaging 2 feet deep, having an average velocity of 1 foot per second, discharges 200 cfs (cubic feet per second)--1 cfs equals approximately 450 gallons per minute. When discharge increases, stage is higher, and velocity generally increases (fig. 12).

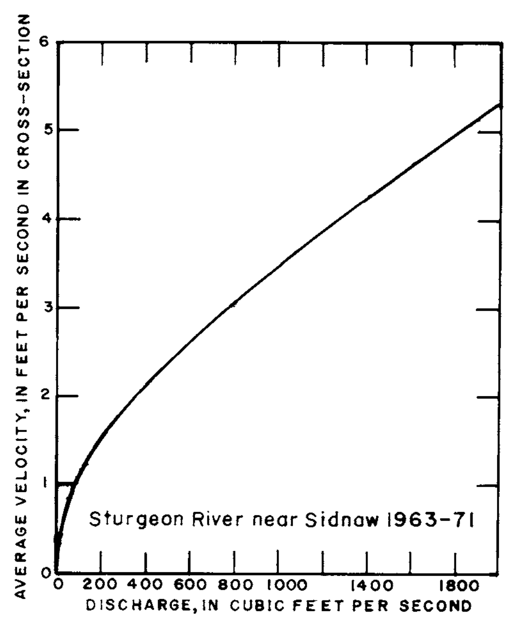


Figure 12.--Increasing discharge is marked by increasing velocity.

Discharge

Records of discharge of Michigan streams are published annually by the U.S. Geological Survey. Summaries of flow characteristics are compiled in two reports (Knutilla, 1967, 1970). The average discharge at a given station may be expressed in cubic feet per second (cfs), cubic feet per second per square mile (cfs per sq mi), or inches per year (depth of water on watershed above station). Annual runoff ranges from about 12 to 16 inches (fig. 3). In some of the smaller basins, such as Cherry Creek, annual runoff is as much as 56 inches, or about 24 inches more than the annual rainfall on this basin. This creek receives a substantial amount of ground-water inflow from an adjacent basin to the west.

Variations in discharge with time in an unregulated stream occur in response to variations in precipitation, snowmelt, and evapotranspiration. Highest discharge usually occurs during or shortly after the spring snowmelt (fig. 13); however, unusually heavy rains can cause high rates of discharge at any time. Discharge usually declines during the summer because growing plants transpire large quantities of water, and rising temperatures increase the rate of evaporation. Killing frosts in the fall reduce the transpiration of plants and usually cause a moderate increase in discharge. During the winter, most precipitation is in the form of snow, which does not reach the streams until the spring snowmelt. Consequently, discharge usually declines during the winter.

Seasonal variations in discharge are common to all Upper Peninsula streams, but the magnitude of variation differs widely (fig. 13). Streams maintained almost entirely by ground-water runoff, such as Cherry Creek, are unusually constant in discharge. Few, if any, streams in the United States have recorded discharge more constant than Cherry Creek. The Middle Branch Ontonagon River near Paulding is more representative of the relatively stable streams of the Upper Peninsula. Black River near Bessemer is representative of the more variable streams.

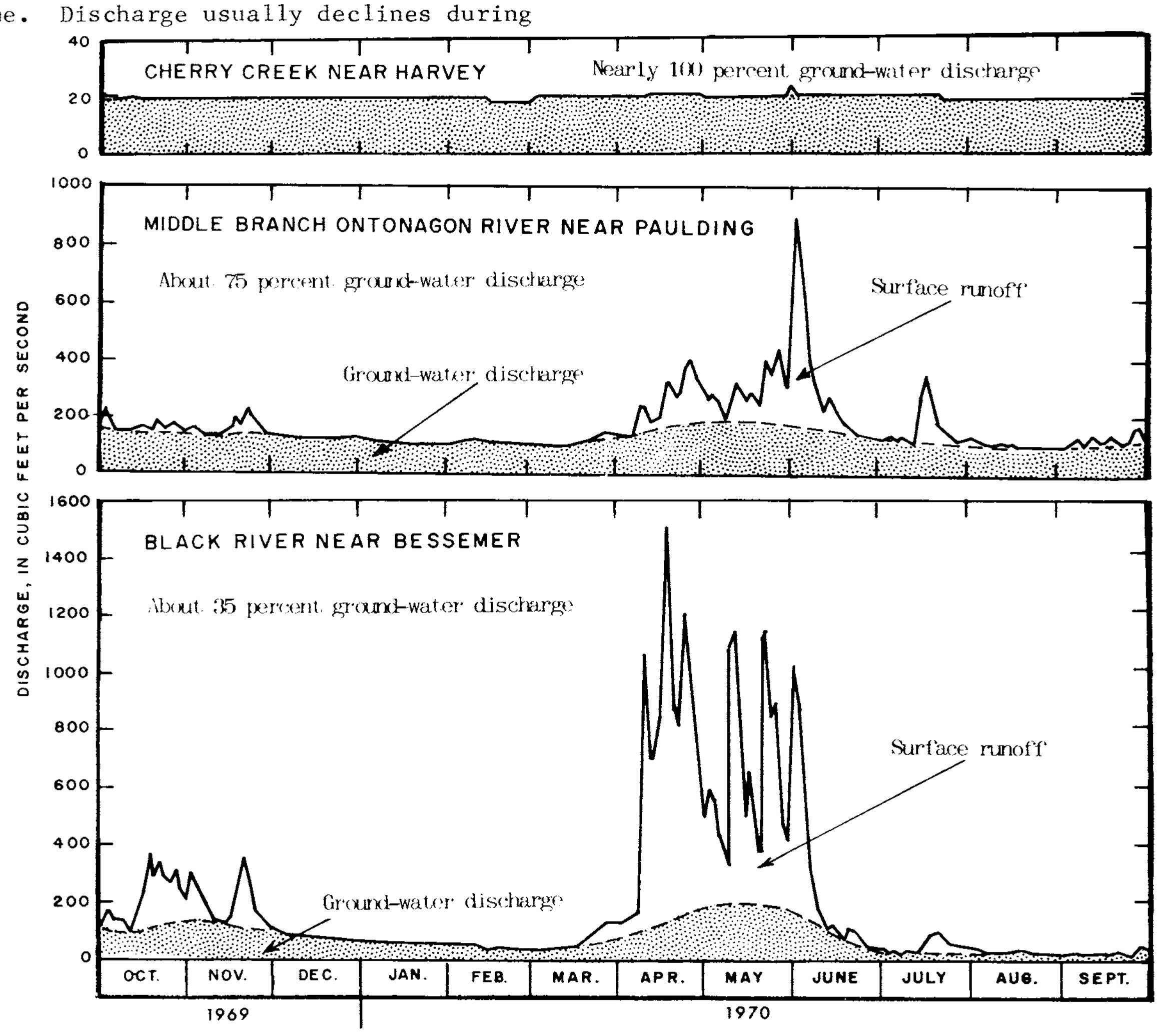


Figure 13.--The relative amounts of ground-water runoff and surface runoff varies between streams.

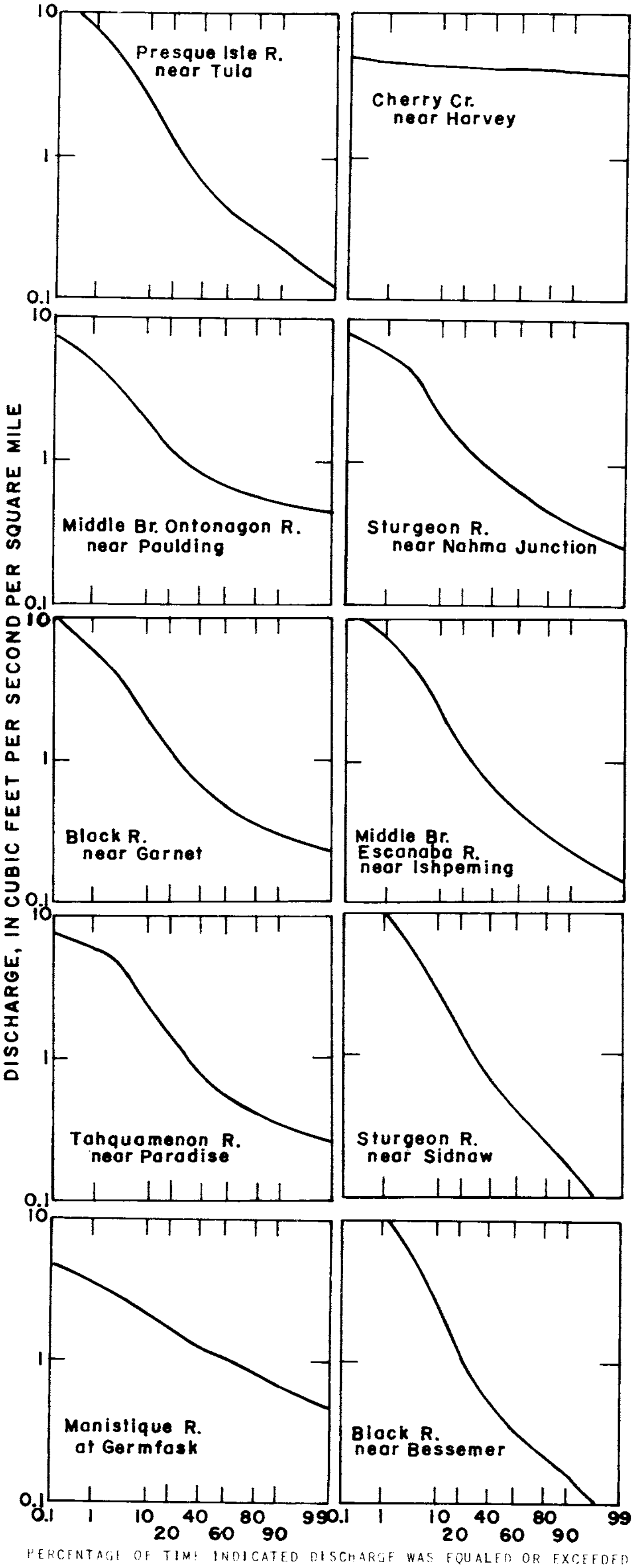


Figure 14.--Flow-duration curves show the percentage of time that specific discharges have been equaled or exceeded.

Flow-duration curves (fig. 14) show the percentage of time given discharges are equaled or exceeded on 10 Upper Peninsula streams. The curves in figure 14 are plotted in cubic feet per second per square mile to eliminate most of the effects of basin size. Cherry Creek stands out as having the most constant discharge, having a 10 percent duration discharge of about 4.4 cfsm and a 90 percent duration discharge of 4.1 cfsm. The next most constant is the Manistique River at Germfask, which has a 10 percent duration discharge of 2.15 cfsm and a 90 percent duration discharge of 0.67 cfsm. Most variable of the rivers plotted is the Black at Bessemer. Ten-percent duration discharge of the Black is 1.15 cfsm; 90 percent duration discharge is 0.15 cfsm. The 10 and 90 percent duration discharges and the ratio of the 90 percent to 10 percent duration discharge are shown by bar graphs in figure 15. The streams are arranged from left to right in order of decreasing stability of discharge.

Recreational uses of streams are usually diminished during periods of excessively low flow. Runoff during periods of low flow is predominantly ground-water discharge; unregulated streams draining permeable soils and glacial drift generally have greater low-flow discharge per unit drainage area than those draining relatively impermeable soils and drift. Frequency of low flow for 10 Upper Peninsula rivers are shown graphically on figure 16. The curves show the magnitude and frequency of recurrence of low flows for periods of 7 and 30 consecutive days during the 6 months from May through October. Steep curves and those with a wide gap between the 7-day and 30-day curves, such as those for the Sturgeon River near Sidnaw and the Black near Bessemer, usually indicate a stream with a small component of ground-water discharge. Closely spaced and flatter curves, such as those for the Middle Branch Ontonagon River near Paulding and the Manistique River near Germfask, indicate a relatively stable flow. The 7- and 30-day curves for Cherry Creek are virtually the same, indicating an extremely stable flow.

Flood flows on Upper Peninsula rivers may damage towns and villages, campgrounds, river-front cottages, and highway bridges and accelerate erosion of river banks. Floods may also make the rivers temporarily unsuitable for fishing or boating, but the flood season is usually over before the vacation season begins.

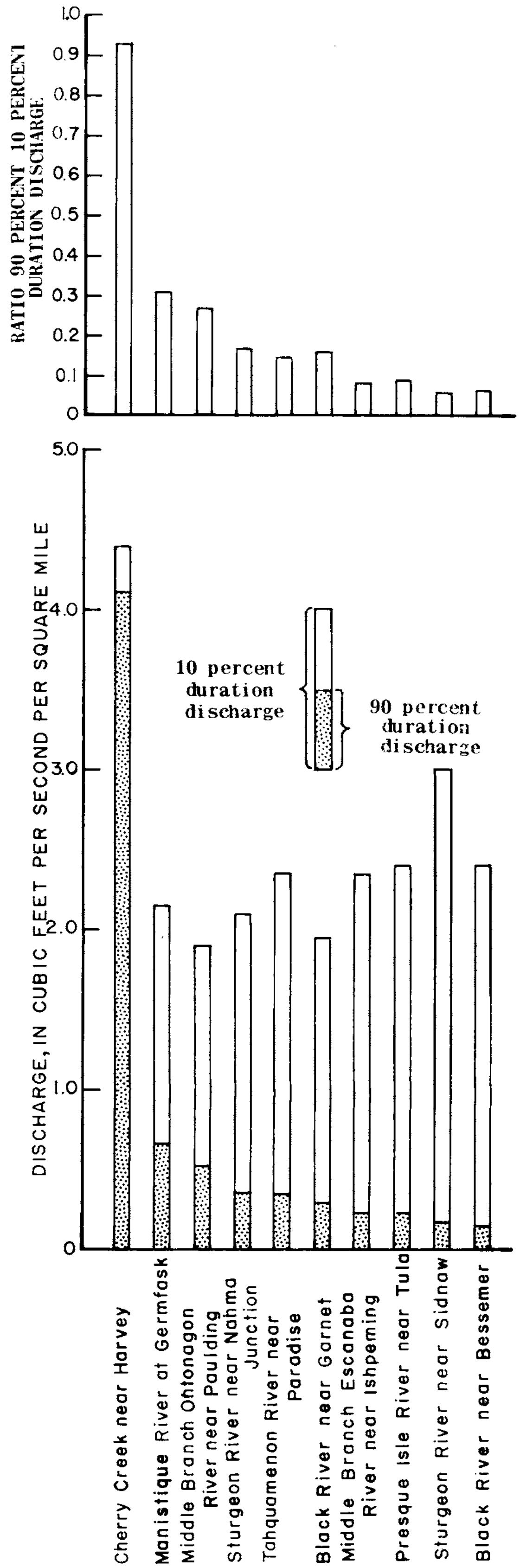


Figure 15.--Flow-duration characteristics reflect the relative amounts of ground-water runoff and surface runoff. Streams with relatively high values of 90-percent duration discharge have more ground-water discharge than streams with low values.

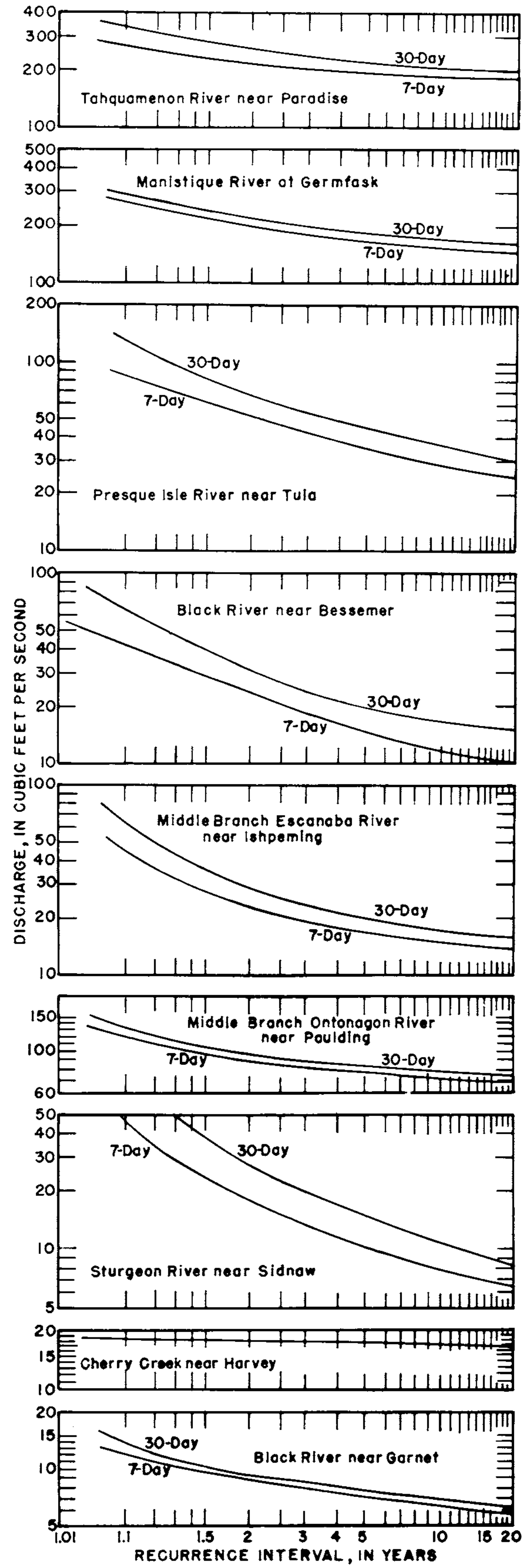


Figure 16.--Low-flow frequency curves define the character of streams during drought periods. Frequency of low-flow is of interest to recreationists because periods of excessively low-flow are generally unfavorable for recreational use.

Velocity

Velocities of Upper Peninsula rivers vary widely from stream to stream and in different reaches of the same stream. In general, steep gradients induce high velocities, but most streams descend in a series of steps rather than in a uniform slope, so slow-moving pools alternate with fast-moving riffles, rapids, and waterfalls. Velocities also vary in a given cross-section of the stream; the slower velocities are near the bed and banks, and the faster velocities near the midstream surface. Where the channel bends, the faster velocities are usually between mid-channel and the outer bank. Measured velocities on Upper Peninsula streams range from less than 1 foot per second (0.68 miles per hour) to more than 10 feet per second (6.8 mph). During the summer, average velocities are generally about 1 foot per second.

Velocities in a given cross-section usually increase with increasing discharge. The average velocity of the Sturgeon River near Sidnaw, for example, increases from about 1 foot per second at a discharge of 70 cfs to about 5 feet per second at a discharge of 1,800 cfs (fig. 12).

Stage

The stage, or water level, of a river rises with increased discharge. This rise is relatively large in reaches where the stream is narrow and banks are high, and relatively small where the stream is wide and banks are low. Ranges in stage on stable rivers, such as Cherry Creek, are only about 1 foot in an average year (fig. 17). "Flashy" rivers, such as the Black River at Bessemer, have an average annual range in stage of 9 feet or more. In general, rivers that discharge relatively large amounts of ground water have relatively small fluctuations in stage, whereas rivers that discharge relatively large amounts of surface runoff have relatively large fluctuations in stage.

Recreation and Streamflow

Rivers with relatively uniform discharge are generally more attractive, provide better fishing and boating, and are more desirable for camp and cabin sites than rivers with extremely variable flow. However, streamflow requirements of some recreational uses are less stringent than others. For example, the Black River below Bessemer, which has a highly variable discharge, has spectacular falls and rapids that make it one of the most attractive streams of the Upper Peninsula, even at low flows. On the other hand, the Black is only mediocre as a trout stream and is rarely used by boaters (table 1).

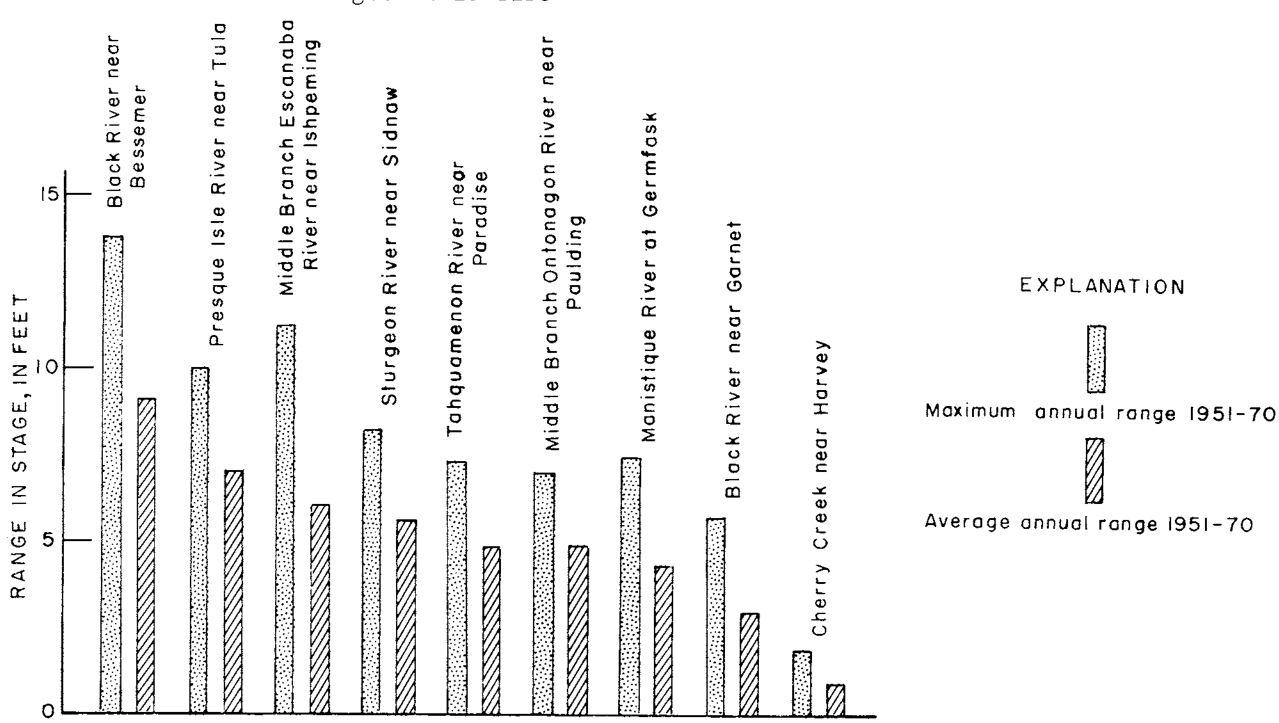


Figure 17.—Rivers in the Upper Peninsula have an average annual range in stage of about 1 to 9 feet.

Aesthetic Considerations

A fast-flowing stream with riffles and rapids is more attractive to most people than a sluggish stream. Streams with relatively stable flows are generally more attractive than streams that alternate between muddy flood-flows and a feeble trickle with intermittent stagnant pools. But, some streams are attractive in spite of highly variable flows, as described above. A relatively high discharge during rainless periods reduces odors that may result from decay of organic wastes.

Fishing

A relatively stable streamflow and a high rate of discharge per unit drainage area are generally favorable to trout populations, as will be shown in the section on Hydrology and Trout Populations. Most of the larger streams in the Upper Peninsula are more variable in discharge than the large streams in the northern part of the Southern Peninsula, and trout populations are generally smaller. Some of the smaller streams of the Upper Peninsula, such as Bart Creek and the West Branch Chocolay River, have relatively uniform discharge and large trout populations.

Velocity of streamflow may influence trout populations. The higher velocities are generally more favorable for trout. Mason and Wegner (1970) found that trout in the Pine and Popple Rivers of northern Wisconsin showed a preference for high-velocity reaches. They attributed this preference to better aeration, more food, better cover, and more favorable water temperatures. Velocity also influences the ease of wading the stream. Streams having high velocities and slippery beds are difficult or impossible to wade with safety.

Wide fluctuations in water level or stage are generally unfavorable for trout. Trout cover is reduced during low stages, and banks are eroded at high stages. Shallow water at low stages contributes to warming of the water. At high stages, wading may be difficult or impossible. Streams rising in stage may scour gravel beds in some reaches, but silt and sand may be deposited over gravel during falling stages.

Boating

Boating conditions on Upper Peninsula rivers vary widely with changes in discharge, stage, and velocity. Some streams are too shallow for boating during low stages, whereas at moderately high stages they are easily navigable. Other streams are relatively safe for novice boaters at low stages but are raging torrents too dangerous for any but the most expert at high stages. For example, the Escanaba River downstream from Gwinn has numerous shoals that may ground a heavily loaded canoe during low-water stages; at moderate stages these shoals do not obstruct boat traffic. On the other hand, the Middle Branch Ontonagon from Watersmeet to Bond Falls Reservoir is safe for the novice canoeist at low to moderate stages, if portages are made around rapids; at very high stages this river is too difficult for the inexperienced canoeist. Rivers having relatively uniform flow, such as the Indian and Manistique, are easily canoed at all times.

Camping and Cabin Living

Streamflow characteristics do not directly influence campers and cabin dwellers unless the river rises high enough to flood the camp or cabin site or to impede access to the campgrounds. Flow characteristics that make the river aesthetically attractive are important to the camper and cabin dweller. Inasmuch as many campers and cabin dwellers are fishermen and boaters, they are also influenced by flow characteristics favorable to fishing and boating. Thus, a relatively stable discharge is generally desirable.

WATER QUALITY

Water-quality characteristics that influence recreational values of rivers include dissolved solids and gases, suspended materials, and physical properties of the water. Characteristics most influential in determining recreational values of Upper Peninsula rivers are water temperature, dissolved oxygen, specific conductance, turbidity, nutrients, hardness, pH, and coliform bacteria.

Temperature

Maximum temperatures of Upper Peninsula rivers vary widely--some are among the warmest and some the coldest in Michigan. Flashy rivers, like the Black near Bessemer, have summer temperatures exceeding 25°C (77°F) most years (fig. 18). Relatively stable streams, like the Black River near Garnet, have maximum temperatures of about 17° to 18°C (63° to 64°F) most years. Cherry Creek, which has an extremely stable flow, has maximum summer temperatures of about 10°C (50°F) most years. No other stream in Michigan for which records have been obtained has such low summer water temperatures.

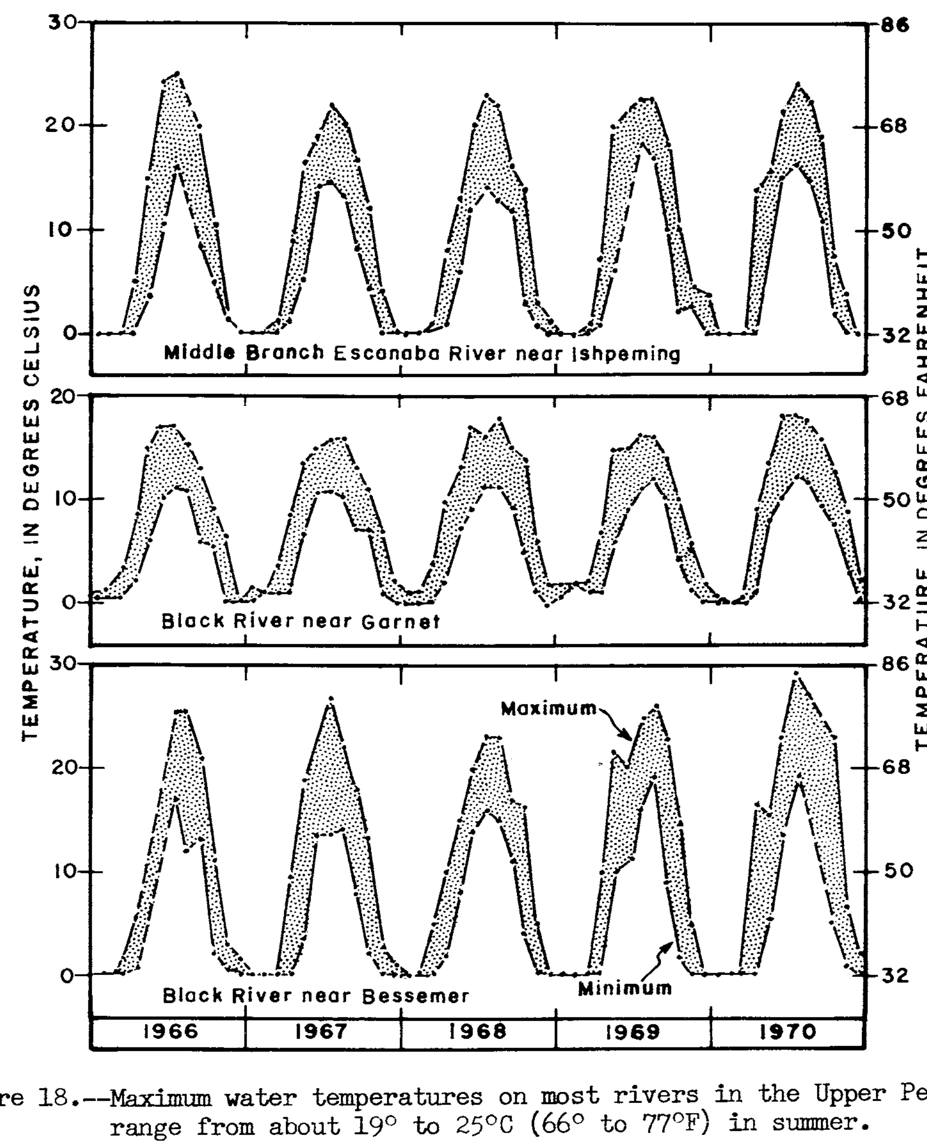


Figure 18.--Maximum water temperatures on most rivers in the Upper Peninsula range from about 19° to 25°C (66° to 77°F) in summer.

Daily variations in water temperature are usually less than variations in air temperature. In summer, the water usually is cooler than the air during most of the day and warmer than the air during most of the night (fig. 19). Daily variations in water temperature are usually greater in summer than in winter. In fact, water temperatures on many Upper Peninsula rivers are at or near the freezing point night and day during the winter (fig. 18).

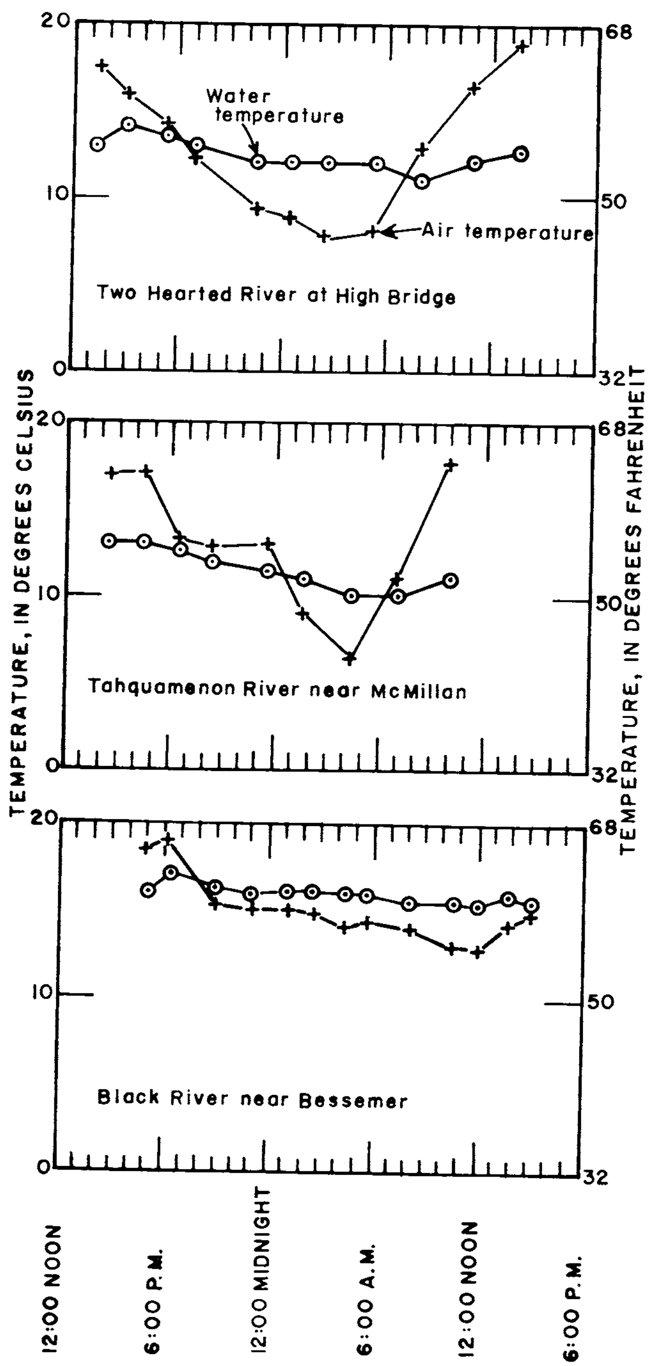


Figure 19.--In summer, daily variations in water temperatures usually are less than 5°C whereas air temperatures vary 10° to 15°C.

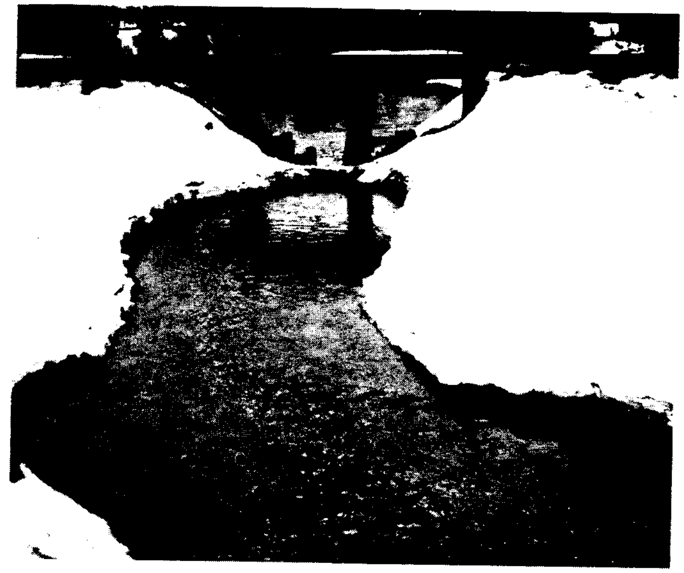


Figure 20.--Streams with a large component of ground-water inflow remain ice-free in winter.

Ground-water inflow, with a near-constant temperature of about 45°F (7°C), moderates the temperature of streams, cooling the stream in summer and warming it in winter. Streams with a large amount of ground-water inflow usually remain free of ice in their upper reaches and wherever ground-water contributions are large (fig. 20). In summer, streams with a large ground-water inflow, like Cherry Creek, are cooler than streams with relatively small ground-water inflow, like the Middle Branch Escanaba. In winter, streams with large ground-water inflow are warmer than streams with small inflow (fig. 21).

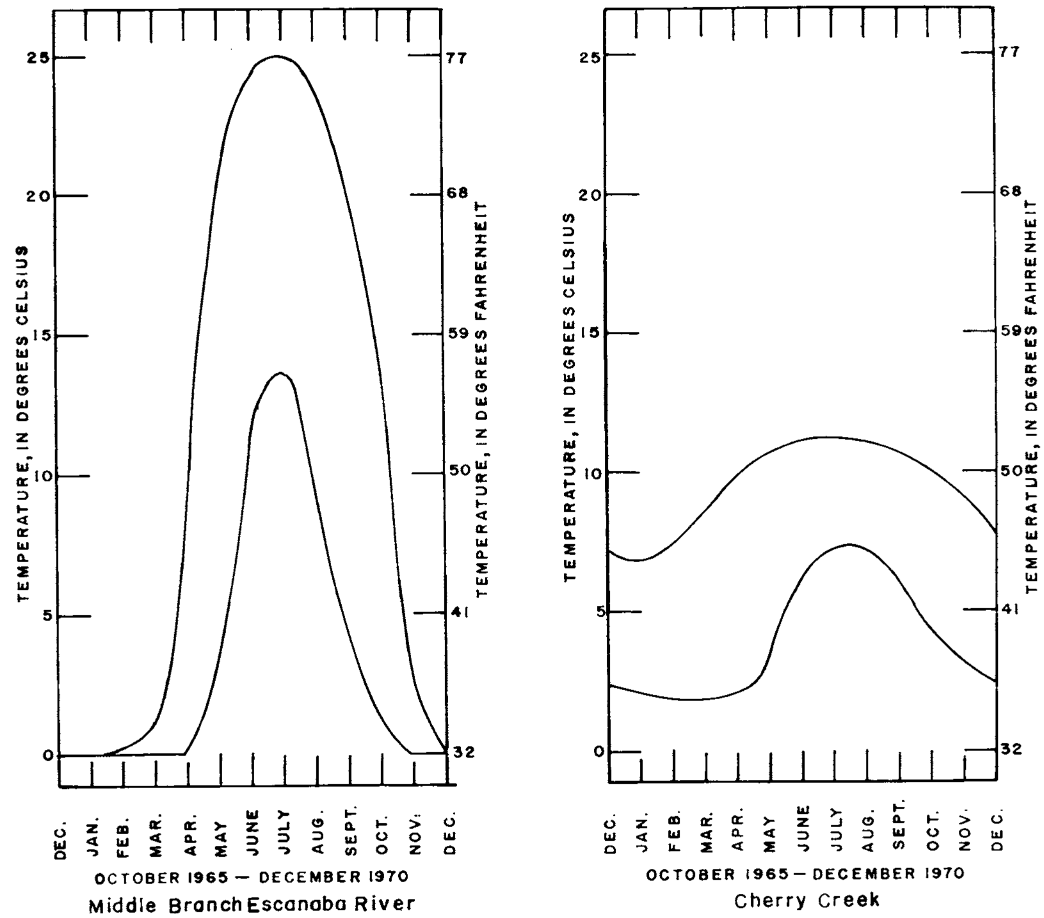


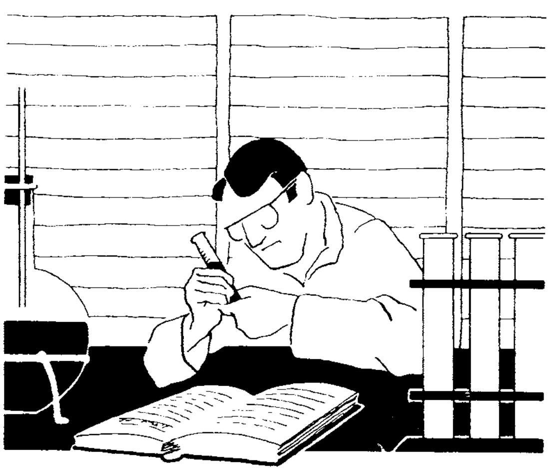
Figure 21.--Cherry Creek, with a large amount of ground-water flow, is cooler in summer and warmer in winter than nearby Middle Branch Escanaba River.

Sunlight warms the water, winter or summer, but in winter the warming influence of the sunlight is not sufficient to overcome the cooling influence of contact with the cold air or ice. The amount of sunlight reaching the stream surface varies with the width of stream and the amount of shade provided by high banks and by bank vegetation. In general, a stream segment oriented in a north-south direction is shaded more than one oriented in an east-west direction (Moore, 1967, p. K-17). Impoundments, by greatly increasing the area of exposure to sunlight and air, may warm the water. The effects of impoundments on stream temperature are complex, however, and water released at depth from deep reservoirs may cool the downstream summer temperatures. Broad, shallow impoundments with surface spillways generally warm downstream water during the summer.

Dissolved Oxygen

Most cold-water rivers of the Upper Peninsula are nearly saturated with oxygen at all times. The solubility of oxygen in water increases with decreasing temperature. Thus, at 70°F (21°C) water is saturated with about 9 mg/l (milligrams per liter) of oxygen; at 61°F (16°C) water is saturated with about 10 mg/l of oxygen. The relatively large diurnal variations in dissolved oxygen that are characteristic of cold-water rivers of the Southern Peninsula are generally not typical of Upper Peninsula streams (fig. 22). The relatively small variation in dissolved oxygen in Upper Peninsula streams can probably be attributed to the softer waters, which do not support an abundant growth of water plants. Plants growing in the water give off oxygen during daylight hours and consume oxygen at night. During the growing season this production and consumption of oxygen usually results in water that is supersaturated with respect to oxygen in the daytime and is less than saturated at night (fig. 22). Daily variations in dissolved oxygen in many Southern Peninsula streams are as much as 4 mg/l. In most Upper Peninsula streams, daily variations in dissolved oxygen are probably 1 to 2 mg/l (fig. 22).

Where streams are contaminated by organic wastes, dissolved oxygen is consumed by decaying organic matter. Elsewhere, the slow decay of natural vegetation and animal matter is compensated for by natural aeration of the water.



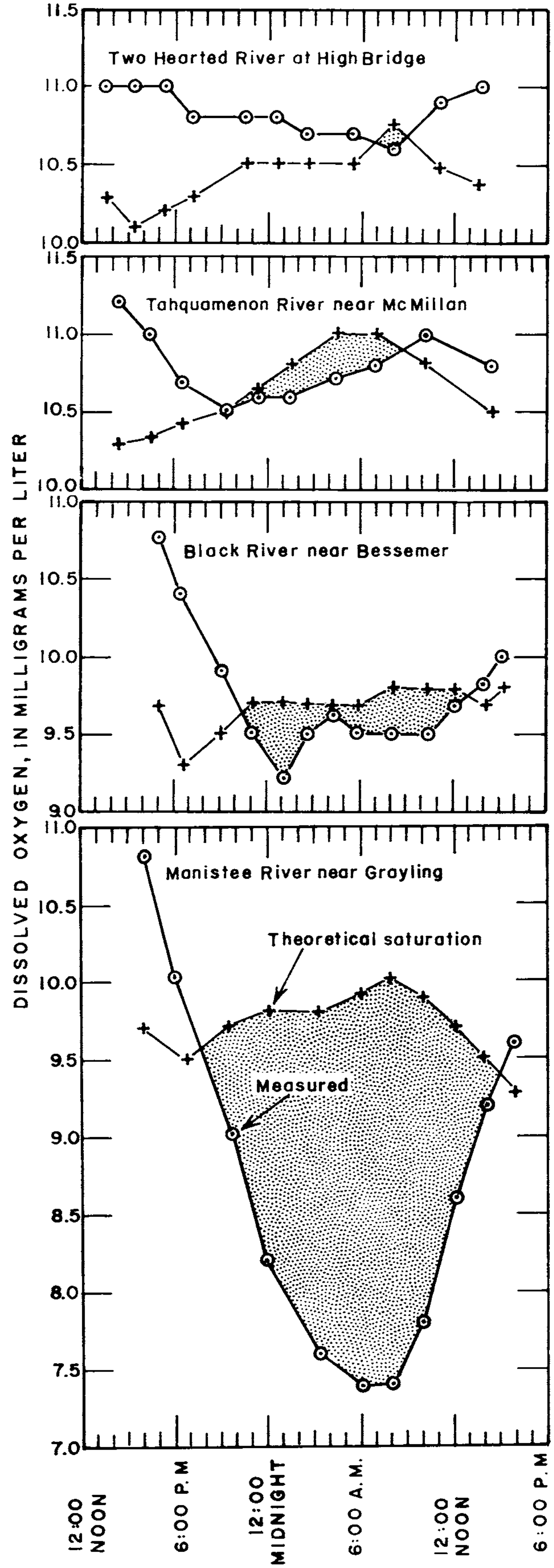


Figure 22.—Dissolved oxygen increases during daylight hours because of oxygen given off by plant photosynthesis. Diurnal variation in Upper Peninsula streams generally is smaller than in streams in the Southern Peninsula.

Hardness and pH

Water in Upper Peninsula streams is characteristically softer and lower in pH than water in Southern Peninsula streams. Water from most Upper Peninsula streams is soft, with hardness ranging from about 20 to 60 mg/l at high flows and from about 60 to 120 mg/l at low flows (fig. 23, Wood, 1970). The pH of most Upper Peninsula rivers, as an indicator of acidity or alkalinity, is 7.0 to 7.5, whereas the pH of most rivers of the Southern Peninsula is greater than 7.5.

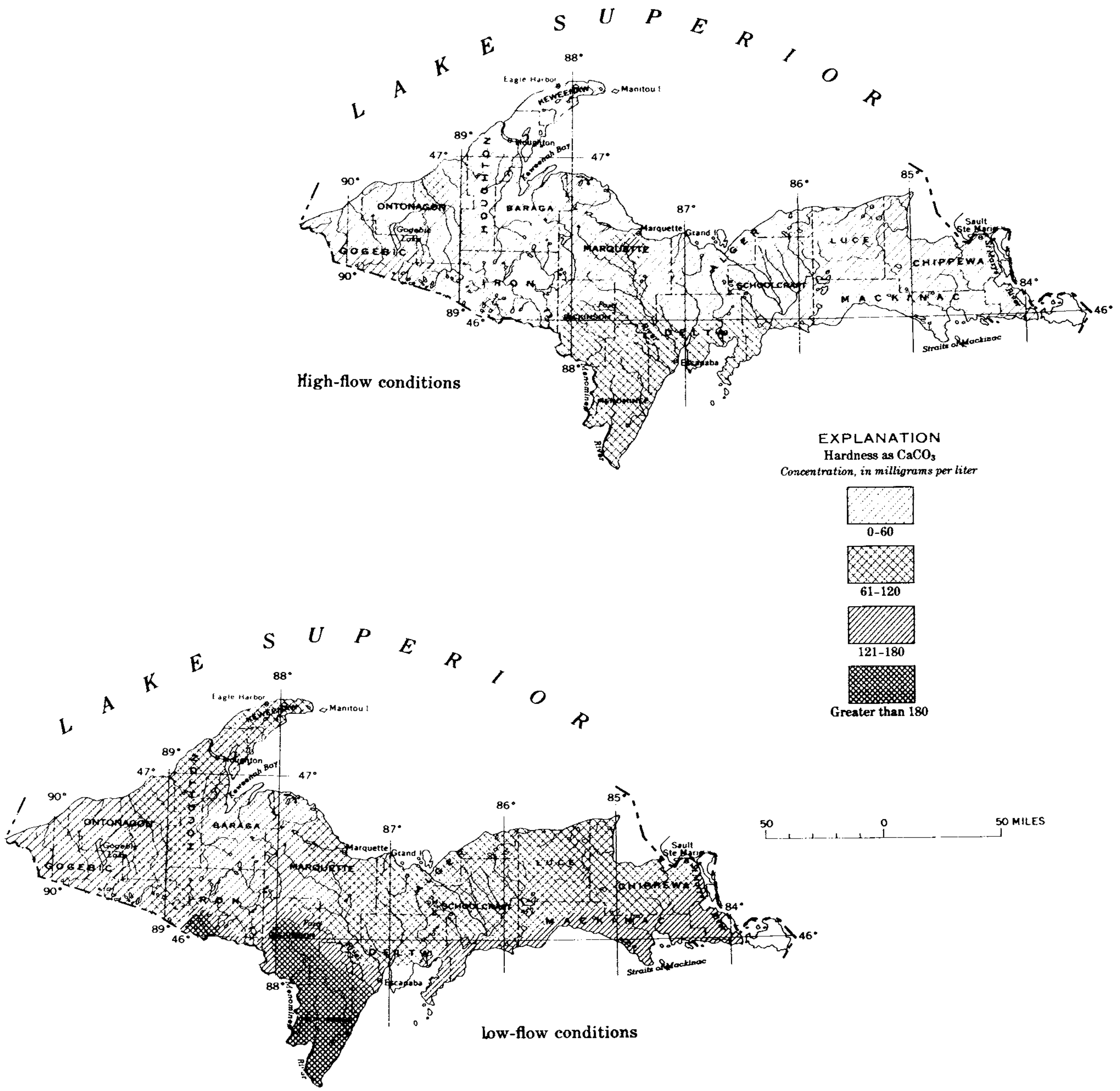


Figure 23.--Concentration of hardness in Upper Peninsula streams under high- and low-flow conditions (Wood, 1970).

Specific Conductance

Specific conductance is a measure of electrical conductivity of water. It is used as a convenient indicator of the dissolved-solids content of the water. In Upper Peninsula streams, a relatively high specific conductance is usually associated with relatively hard water. Specific conductance is generally lower in Upper Peninsula streams than in streams of the Southern Peninsula. Specific conductance values on most Upper Peninsula streams range from about 50 to 150 (micromhos at 25°C). Specific conductance is usually greater at low than at high flows (fig. 24).

Turbidity

Turbidity is a measure of the amount of light intercepted by suspended sediment in water. Turbidity of Upper Peninsula rivers

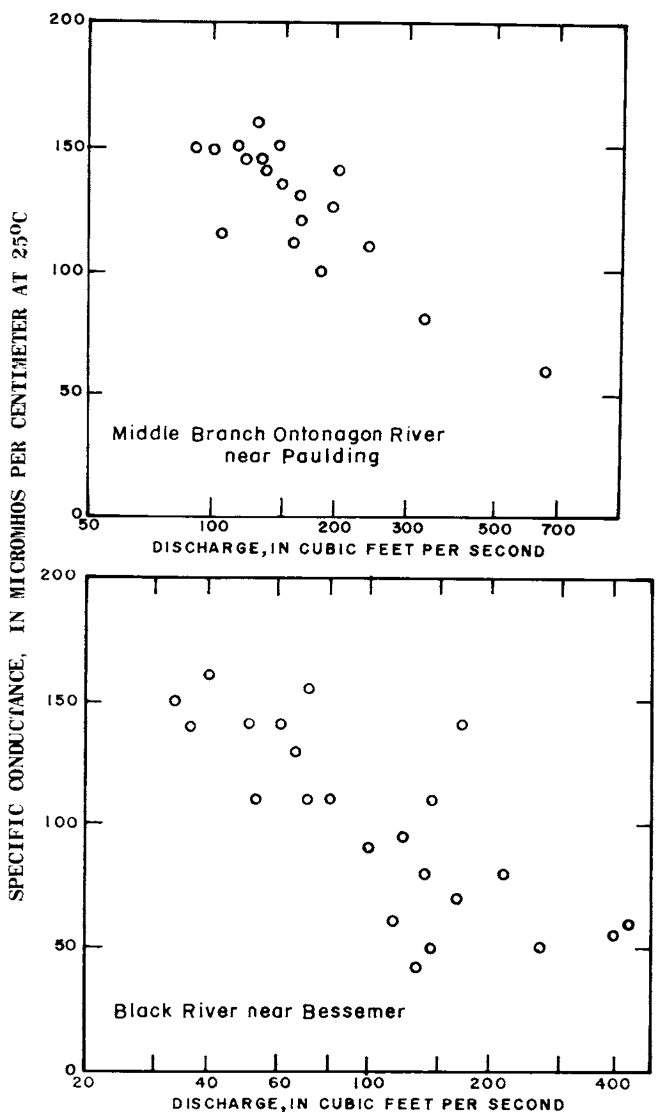


Figure 24.--Specific conductance usually declines with increased discharge.

was not measured as a part of this survey, but some of the rivers draining silt and clay soils, such as the lower reaches of the Ontonagon River and some of its tributaries, are noticeably turbid during high flows. Streams draining areas of sandy soils, such as the Upper Tahquamenon, are relatively clear.

Mining operations in parts of the Upper Peninsula may add some sediment to certain streams, but most of the sediment is removed in settling ponds.

Nutrients

Nutrients, which include nitrate, phosphate, and calcium, affect the productivity of plant and animal life. Upper Peninsula streams are relatively low in calcium, as indicated by the low values of hardness described above. Nitrate and phosphate also are low in most Upper Peninsula streams, as indicated by records of the Michigan Water Resources Commission. Most streams in undeveloped areas of the Upper Peninsula have nitrate and phosphate concentrations of less than 0.2 mg/l (Michigan Water Resources Commission, 1968). Where sources of pollution exist, such as population centers, nitrate and phosphate concentrations may exceed 1.0 mg/l.

Coliform Bacteria

Coliform bacteria enter the water where human or animal wastes are washed or discharged into a stream. Ground-water discharge usually does not add coliform bacteria to the stream, because sand and gravel aquifers act as filters. Where the river bed and banks are composed of fractured limestone, as in the lower Escanaba River, ground-water discharge may carry coliform bacteria into the stream, if a source of pollution exists. Criteria for interstate waters established January 1968 by the Michigan Water Resources Commission specify a maximum of 5,000 coliform organisms per 100 milliliters (geometric average of 10 consecutive samples) in waters where recreational use involves partial body contact, such as fishing or boating. Where recreational use includes swimming, the maximum is 1,000. Coliform organisms are generally less than 1,000 per 100 milliliters in streams in undeveloped parts of the Upper Peninsula. Streams in populated areas, such as the Montreal River downstream from Ironwood, have had coliform counts exceeding 90,000 per 100 milliliters in the past (Michigan Water Resources Commission, 1967 p. 51), but in recent years improvement in sewage treatment has reduced coliform counts on most of these streams.

Recreation and Water Quality

Water in most rivers of the Upper Peninsula is of excellent quality for all recreational uses, although some are too warm in summer for the best trout water. Objectionable contaminants in the past have included inadequately treated sewage and acid mine water, but these sources of contamination have been largely eliminated in recent years.

Aesthetic Considerations

The quality of water in most Upper Peninsula rivers is aesthetically pleasing. Unpleasant odor and color and objectionable floating materials are absent except in a few of the more highly populated areas. Nutrient levels in Upper Peninsula streams are generally too low to produce an objectionably rank growth of water vegetation. Suspended sediment and coloration due to decay of organic material detracts from the sparkling clarity of water in only a few stream segments.

Fishing

The most critical water-quality requirement for trout fishing is cool water. Most Upper Peninsula streams that are cool enough in summer for trout support some kind of a trout fishery. A correlation analysis of hydrologic characteristics and trout populations on Upper Peninsula streams showed a general relationship between average annual maximum water temperatures and trout populations--the higher populations occurring in the colder streams. Minimum temperatures also are important, as trout do not grow well in streams having very low temperatures during most of the year (Needham, 1969, p. 51). Only one stream in the Upper Peninsula is known to have summer temperatures lower than 13°C (55°F). That is Cherry Creek near Harvey. Growth of trout in Cherry Creek may be somewhat slower in summer than in some of the warmer streams. However, the relatively warm winter temperatures may provide more favorable conditions for trout in Cherry Creek than in other streams.

The dissolved oxygen content of most Upper Peninsula streams is near saturation, which is considered ideal for the trout fishery (Tarzwell, 1957). The Michigan Water Resources Commission has established a dissolved oxygen content of 6 mg/l as the minimum requirement for trout waters. A few segments of Upper Peninsula streams, such as the Menominee River in Menominee, have had dissolved oxygen content of less than 6 mg/l (Michigan Water Resources Commission, 1967), but these segments are generally not suitable trout waters for other reasons, such as excessively high water temperatures.

Nutrients, including nitrate, phosphate, and calcium, increase the production of trout. The relatively low trout populations of most Upper Peninsula streams, as compared with streams of the Southern Peninsula, are attributed to the softer (low calcium) waters of the Upper Peninsula (Hendrickson and Knutilla, 1972). Excessive amounts of nutrients, however, may stimulate a growth of water vegetation, so that the diurnal cycle of dissolved oxygen is exaggerated and night-time levels of dissolved oxygen may become critically low. A study by the Water Resources Commission (1966) on the Au Sable River of the Southern Peninsula showed a zone of deterioration in trout populations corresponding to a zone of dense vegetation and low night-time concentrations of dissolved oxygen.

Turbidity can lower the productivity of a trout stream by reducing the amount of sunlight that reaches the streambed and, consequently, the amount of fish-food organisms that are produced (Needham, 1969, p. 55). Turbidity may decrease productivity of a few Upper Peninsula rivers, such as parts of the Ontonagon and Manistique, but most rivers of the Upper Peninsula are relatively clear most of the time.

Acid water can seriously deplete the trout fishery. In their natural state Upper Peninsula rivers are nearly neutral or slightly alkaline. However, discharge of acid mine water into the Iron River in 1962 drastically reduced fish populations in the Iron and Brule Rivers (Galbraith, 1965). When discharge of acid mine water ceased in February 1963, fish life in the rivers recovered rapidly.

Boating

Water-quality is not especially important to boating, except that the water should be free of contaminants that are aesthetically displeasing or dangerous to the health of the boater. None of the rivers studied in the Upper Peninsula were contaminated to the extent that they would be unsuitable for boating.

Camping and Cabin Living

Water-quality considerations that influence the aesthetic attractiveness of rivers are most important to campers and boaters, as no one wants to camp or live on an unattractive river. The bacterial or sanitary quality of water is important if the river water is used for drinking. However, few campers or cabin-dwellers use untreated river water for this purpose.

HYDROLOGY AND TROUT POPULATIONS

Trout populations in rivers respond to a variety of environmental factors, most of which are related to the hydrology of the streams in which they live. To evaluate the relationships between hydrologic factors and trout populations, hydrologic data were determined for 28 stream segments in the Upper Peninsula for which trout-population data were available (table 2). Twenty-one of the segments (fig. 8) were used to test for possible relationships. Selection of the 21 segments was based entirely on accuracy and completeness of hydrologic data. In addition, eight segments of streams in northern Wisconsin, which are similar in character to Upper Peninsula streams and for which hydrologic and trout population data were available, were included in the analyses.

Hydrologic Parameters

Hydrologic parameters that were used in this study describe the character of a stream's channel, bed, and banks, its streamflow characteristics, and the quality of the stream's water. Data on streamflow were obtained from records of the U.S. Geological Survey and from discharge measurements made at the time of channel mapping. Data on water quality were obtained from records of State agencies and the U.S. Geological Survey.

Physiographic Data and Channel Character

Each stream segment was surveyed to determine its average width, depth, and surface area (table 2); the type of bed materials, as percentages of gravel, sand, or muck; and the percentage of stream bottom that had submerged vegetation (table 3). Also determined were the average bank height, bank material, and bank vegetation as percentage of hardwoods, conifers, brush, or grass. Finally, the percentage of stream bottom that would afford cover for trout, such as undercut banks, logs, boulders, and overhanging brush, was visually estimated.

Average stream gradients were determined from topographic maps. Each reported gradient is the average computed between topographic contours that cross above and below the measured stream segment. The actual gradient of the segment may differ from the value so obtained.

Streamflow Characteristics

For each stream segment, the average discharge, in cubic feet per second and cubic feet per second per square mile, and parameters of low flow and flow duration were determined (table 4). As an index of low flow, the median annual 7-day low-flow (7-day Q_2) was used. Flow-duration data included the discharges equaled or exceeded 10 and 90 percent of the time.

Characteristics of streamflow were determined from streamflow records at gaging stations or by correlating discharge measurements with records for gaging stations. In general, values for streamflow characteristics are probably accurate within about 30 percent.

The ratio of 10-percent and 90-percent duration discharges was used as an index of the variability of streamflow. As an index of the velocity of each stream segment, the median minimum 7-day discharge was divided by the cross-sectional area of the segment. The cross-sectional area, computed as the product of the average width and average mid-channel depth, is greater than the actual area because the mid-channel depth is usually greater than the average depth in the cross-section. Accordingly, the average velocities tabulated are low. However, velocities are representative and are probably comparable between streams.

Quality of Water

Because temperature has been shown to be one of the more significant water-quality parameters, thermometers that register maximum and minimum temperatures were installed in each stream segment unless adequate temperature records were available. Records of maximum and minimum temperatures were obtained for at least one summer month at almost all sites. These records were correlated with temperature records at gaging stations to obtain estimates of the mean annual maximum and mean July temperatures (table 5). For most sites these temperatures are probably accurate within 2°C (3°F).

Specific conductance, pH, and hardness of water were determined in the field during the summer of 1971, usually during base-flow conditions. Values of specific conductance are probably accurate within about 10 micromhos; values of pH are probably accurate to one-half pH unit; and values of hardness are probably accurate to about 20 mg/l. Appearance of the water (clear, colored, or turbid) was recorded, but numbers were not assigned to these parameters, and they were not included in this analysis.

Table 4.--Summary of data on streamflow characteristics

Index number	Stream name	Stream segment Location	Drainage area (square miles)	Mean discharge (cfs)	Mean discharge (cfs)	Median 7-day minimum discharge (cfs)	Median 7-day minimum discharge (cfsm)	10-percent duration discharge (cfs)	10-percent duration discharge (cfsm)	90-percent duration discharge (cfs)	90-percent duration discharge (cfsm)	Ratio 10/90 percent duration discharges	Ratio mean discharge to average 7 day minimum discharge	Velocity index
			Streamflow characteristics											
1	Little Carp River	SE¼ sec.17, T.50 N., R.44 W.	11.1	17	1.53	2.4	0.22	39	3.51	3.0	0.27	13.0	7.08	0.14
2	Copps Creek	NW¼ sec.21, T.47 N., R.43 W.	2.97	--	--	--	--	--	--	--	--	--	--	--
3	Middle Branch Ontonagon River	SE¼ sec.21, T.45 N., R.40 W.	14.4	10	.69	3.4	.24	21	1.46	3.6	.25	5.83	2.94	.19
4	do	NW¼ sec.27, T.45 N., R.39 W.	48.0	48	1.00	23	.48	81	1.69	24	.50	3.38	2.09	.35
5	Deadman Creek	SE¼ sec.23, T.46 N., R.38 W.	6.1	4.9	.80	2.5	.41	7.6	1.25	2.6	.43	2.92	1.96	.22
6	East Branch Ontonagon River	NW¼ sec.15, T.47 N., R.36 W.	22.3	37	1.66	20	.90	57	2.56	21	.94	2.71	1.85	.43
7	West Branch Sturgeon River	SW¼ sec.12, T.50 N., R.36 W.	42.8	44	1.03	11	.26	100	2.34	12	.28	8.33	4.00	.25
8	Bart Creek	NW¼ sec.14, T.52 N., R.35 W.	2.79	7.2	2.58	5.2	1.86	9.0	3.23	5.2	1.86	1.73	1.38	.31
9	West Branch Otter River	NW¼ NE¼ sec.33, T.51 N., R.36 W.	7.39	6.3	.85	2.0	.27	15	2.03	2.1	.28	7.14	3.15	.05
10	Salmon Trout River	Sec. 12, T.51 N., R. 28 W.	37.8	53	1.40	32	.85	65	1.72	35	.93	1.86	1.66	.34
11	West Branch Chocolay River	NE¼ sec.22, T.46 N., R.24 W.	10.2	32	3.14	20	1.96	44	4.31	21	2.06	2.10	1.60	.57
12	Middle Branch Escanaba River	Sec.7, T.47 N., R.28 W.	47.6	60	1.26	7.3	.15	135	2.84	9.5	.20	14.2	8.22	.16
13	Green Creek	SE¼ NW¼ sec.19, T.46 N., R.26 W.	8.42	9.0	1.07	1.6	.19	21	2.49	1.9	.23	11.1	5.62	.09
14	do	NE¼ sec.29, T.46 N., R.26 W.	11.8	11	.93	2.8	.24	22	1.86	3.1	.26	7.10	3.93	.09
15	do	SW¼ sec.35, T.46 N., R.26 W.	13.8	14	1.01	4.0	.29	26	1.88	4.5	.33	5.78	3.50	.22
16	Goose Lake Outlet	SE¼ SE¼ sec.12, T.46 N., R.26 W.	37.5	30	.80	8.6	.23	65	1.73	8.9	.24	7.30	3.49	.13
17	East Branch Escanaba River	NW¼ sec. 4, T.45 N., R.25 W.	111	90	.81	25	.23	190	1.71	25	.23	7.60	3.60	.19
18	do	NE¼ sec.21, T.45 N., R.25 W.	124	101	.81	29	.23	215	1.73	30	.24	7.17	3.48	.33
19	West Branch Escanaba River	SW¼ NW¼ sec.24, T.44 N., R.28 W.	54.5	47	.86	21	.39	72	1.32	23	.42	3.13	2.24	.33
20	Two Hearted River	NE¼ sec.31, T.49 N., R.10 W.	97	160	1.65	50	.52	310	3.20	55	.57	5.64	3.20	.54
21	East Branch Two Hearted River	NE¼ sec. 5, T.48 N., R.9 W.	42	46	1.10	18	.43	80	1.90	19	.45	4.21	2.56	.38
22	do	SE¼ sec.18, T.49 N., R.9 W.	55	81	1.47	31	.56	140	2.55	34	.62	4.12	2.61	.50
23	Tahquamenon River	SW¼ sec. 8, T.47 N., R.12 W.	11	20	1.82	6.0	.55	40	3.64	7.0	.64	5.71	3.33	.19
24	do	SE¼ sec.21, T.47 N., R.12 W.	28	65	2.32	20	.71	140	5.00	2.3	.82	6.09	3.25	.19
25	do	NW¼ sec.10, T.46 N., R.12 W.	42	110	2.62	30	.71	220	5.24	40	.95	5.50	3.67	.40
26	do	NE¼ sec.22, T.46 N., R.12 W.	48	180	3.75	55	1.15	370	7.71	64	1.33	5.78	3.27	.61
27	East Branch Fox River	SW¼ sec.16, T.47 N., R.13 W.	24	50	2.08	15	.62	85	3.54	17	.71	5.00	3.33	.45
28	Rock River	W½ sec. 30, T.43 N., R.10 W.	16	--	--	--	--	--	--	--	--	--	--	--

Table 5.--Summary of data on chemical quality of water.

Index number	Stream name	Stream segment *Location*	Chemical quality: Mean annual maximum temperature (°F)	Mean July temperature (°F)	Specific conductance (microhoms)	Hardness (mg/l)	pH (units)	Appearance
1	Little Carp River	SE¼ sec.17, T.50 N., R.44 W.	81	68	140	60	7.7	Colored
2	Copps Creek	NW¼ sec.21, T.47 N., R.43 W.	73	66	80	38	7.0	do
3	Middle Branch Ontonagon River	SE¼ sec.21, T.45 N., R.40 W.	73	66	130	66	7.5	do
4	do	NW¼ sec.27, T.45 N., R.39 W.	77	66	170	68	7.5	turbid
5	Deadman Creek	SE¼ sec.23, T.46 N., R.38 W.	67	61	130	70	7.2	colored
6	East Branch Ontonagon River	NW¼ sec.15, T.47 N., R.36 W.	68	61	110	68	7.4	do
7	West Branch Sturgeon River	SW¼ sec.12, T.50 N., R.36 W.	66	59	220	96	8.1	clear
8	Bart Creek	NW¼ sec.14, T.52 N., R.35 W.	62	54	180	102	7.8	do
9	West Branch Otter River	NW¼ NE¼ sec.33, T.51 N., R.36 W.	68	59	180	80	7.5	do
10	Salmon Trout River	Sec.12, T.51 N., R. 28 W.	73	60	130	62	7.6	do
11	West Branch Chocolay River	NE¼ sec.22, T.46 N., R.24 W.	67	59	200	100	7.6	turbid
12	Middle Branch Escanaba River	Sec.7, T.47 N., R.28 W.	77	64	115	68	7.1	do
13	Green Creek	SE¼ NW¼ sec.19, T.46 N., R.26 W.	75	65	215	92	7.5	clear
14	do	NE¼ sec.29, T.46 N., R.26 W.	75	65	205	78	6.9	do
15	do	SW¼ sec.35, T.46 N., R.26 W.	75	66	180	80	7.7	turbid
16	Goose Lake Outlet	SE¼ SE¼ sec.12, T.46 N., R.26 W.	67	61	155	90	7.4	clear
17	East Branch Escanaba River	NW¼ sec.4, T.45 N., R.25 W.	73	64	160	64	7.5	turbid
18	do	NE¼ sec.21, T.45 N., R.25 W.	74	65	150	59	7.6	clear
19	West Branch Escanaba River	SW¼ NW¼ sec.24, T.44 N., R.28 W.	72	63	230	114	7.1	colored
20	Two Hearted River	NE¼ sec.31, T.49 N., R.10 W.	68	61	140	68	7.7	clear
21	East Branch Two Hearted River	NE¼ sec.5, T.48 N., R.9 W.	64	57	120	68	7.4	colored
22	do	SE¼ sec.18, T.49 N., R.9 W.	64	57	125	68	7.4	do
23	Tahquamenon River	SW¼ sec.8, T.47 N., R.12 W.	79	69	130	68	8.5	clear
24	do	SE¼ sec.21, T.47 N., R.12 W.	72	64	140	68	8.5	do
25	do	NW¼ sec.10, T.46 N., R.12 W.	66	58	140	68	8.5	do
26	do	NE¼ sec.22, T.46 N., R.12 W.	64	56	120	68	7.6	do
27	East Branch Fox River	SW¼ sec.16, T.47 N., R.13 W.	65	56	130	68	7.6	do
28	Rock River	W½ sec.30, T.43 N., R.10 W.	62	52	360	190	7.4	do

Table 6.--Summary of data on fall trout populations.

Index number	Stream name	Stream segment	Fall trout populations						
		Location	Number in segment	Number per acre	Pounds in stream segment	Pounds per acre	Pounds per acre-foot	Number per mile	Pounds per mile
1	Little Carp River	SE¼ sec.17, T.50 N., R.44 W.	65	260	4.2	16.8	23.3	763	49
2	Copps Creek	NW¼ sec.21, T.47 N., R.43 W.	42	870	5.9	123.0	174	1,478	208
3	Middle Branch Ontonagon River	SE¼ sec.21, T.45 N., R.40 W.	90	430	6.0	29.0	28.6	950	63
4	do	NW¼ sec.27, T.45 N., R.39 W.	50	120	7.0	17.0	10.4	587	82
5	Deadman Creek	SE¼ sec.23, T.46 N., R.38 W.	38	520	2.2	30.0	43.1	1,003	58
6	East Branch Ontonagon River	NW¼ sec.15, T.47 N., R.36 W.	61	150	2.1	5.1	4.0	644	22
7	West Branch Sturgeon River	SW¼ sec.12, T.50 N., R.36 W.	366	1,180	15.5	50	38.8	4,831	205
8	Bart Creek	NW¼ sec.14, T.52 N., R.35 W.	120	1,960	6.2	102	84.9	3,335	172
9	West Branch Otter River	NW¼ NE¼ sec.33, T.51 N., R.36 W.	108	416	6.5	25	13.3	1,056	64
10	Salmon Trout River	Sec.12, T.51 N., R. 28W.	276	80	38.0	11	4.4	368	51
11	West Branch Chocolay River	NE¼ sec.22, T.46 N., R.24 W.	228	1,756	5.6	43	31.1	5,350	131
12	Middle Branch Escanaba River	Sec.7, T.47 N., R.28 W.	60	200	7.5	25	13.9	634	79
13	Green Creek	SE¼ NW¼ sec.19, T.46 N. R.26 W.	42	654	2.2	34	26.5	1,109	58
14	do	NE¼ sec.29, T.46 N., R.26 W.	112	800	4.3	31	15.9	1,690	65
15	do	SW¼ sec.35, T.46 N., R.26 W.	44	400	3.2	29	21.3	645	47
16	Goose Lake Outlet	SE¼ SE¼ sec.12, T.46 N., R.26 W.	152	276	9.4	17	8.5	1,147	71
17	East Branch Escanaba River	NW¼ sec.4, T.45 N., R.25 W.	25	50	1.0	2	.8	330	13
18	do	NE¼ sec.21, T.45 N., R.25 W.	180	200	18.0	2.0	10.5	1,118	112
19	West Branch Escanaba River	SW¼ NW¼ sec.24, T.44 N., R.28 W.	74	65	5.7	5	2.6	260	20
20	Two Hearted River	NE¼ sec.31, T.49 N., R.10 W.	632	225	14.0	5	2.8	1,390	31
21	East Branch Two Hearted River	NE¼ sec.5, T.48 N., R.9 W.	91	193	4.7	10	7.1	801	41
22	do	SE¼ sec.18, T.49 N., R.9 W.	--	--	--	--	--	--	--
23	Tahquamenon River	SW¼ sec.8, T.47 N., R.12 W.	6	50	1.0	8	7.1	158	26
24	do	SE¼ sec.21, T.47 N., R.12 W.	6	18	.3	1	.4	106	5
25	do	NW¼ sec.10, T.46 N., R.12 W.	172	520	13.9	42	20.1	2,270	183
26	do	NE¼ sec.22, T.46 N., R.12 W.	115	412	20.7	74	24.6	1,518	273
27	East Branch Fox River	SW¼ sec.16, T.47 N., R.13 W.	193	208	27.0	29	18.1	531	74
28	Rock River	W½ sec.30, T.43 N., R.10 W.	112	448	23.5	94	107	591	124

Trout Population Parameters

Trout population data were obtained from State fisheries agencies in Michigan and Wisconsin. The accuracy of these data varies widely because the purpose and method of inventory varied. The error in estimating populations may be 50 percent or more. However, it is believed by the authors that the errors are random and that the population estimates are not consistently high or low.

All trout populations surveys used in this study were made in late summer or early fall. Some of the streams sampled receive annual plantings of trout. No attempt was made to exclude hatchery trout in the population estimates. However, large trout that were obviously migratory spawners were excluded. Population data were defined as number in segment, number per acre, pounds in segment, pounds per acre, pounds per acre-foot, numbers per mile, and pounds per mile (table 6).

Results of Statistical Analyses

Statistical multiple-regression analyses were used to develop relationships between trout populations and hydrologic parameters. The analyses provided a mathematical equation of the relation between trout populations and selected hydrologic parameters. The analyses also provided a measure of the accuracy of the defined relationships and the level of significance of each hydrologic parameter in the relation.

Trout populations were correlated with hydrologic parameters of channel character, fish cover, streamflow characteristics, and water quality. For each combination of variables tested, the regression equation, multiple correlation coefficient, standard error of estimate, and the significance of each independent variable were calculated. Calculations were then repeated, eliminating the least significant hydrologic parameter each time, until only the most significant parameter remained. The procedure was repeated for many combinations of hydrologic parameters and trout populations.

A summary of trout populations and the more significant hydrologic parameters are listed in table 7. Shown in the table are the degrees of correlation between each of the parameters. None of the independent variables, by themselves, show a high degree of correlation with trout populations. The relationship between mean annual maximum stream temperature and trout, in pounds per mile, has the highest degree of correlation (-0.43).

Table 7.--Summary of correlation coefficients for hydrologic and trout population parameters. Values shown indicate the degree of correlation between each parameter, for example, the simple correlation coefficient between trout populations, in pounds per acre, and bottom vegetation is 0.25.

	Bottom vegetation (%)	Mean discharge (cfsm)	7-day Q2 (cfsm)	Ratio of 10/90% duration discharges	Velocity Index	Temperature (°F)
Pounds per acre	0.25	0.25	0.18	-0.01	-0.13	-0.40
Pounds per mile	-.06	.42	.25	.08	.02	-.43
Bottom vegetation	1.00	-.48	-.37	.08	-.22	.20
Mean discharge (cfsm)		1.00	.77	-.20	.42	-.30
7-day Q_2 (cfsm)			1.00	-.76	.61	-.48
10/90% duration ratio				1.00	-.54	.38
Velocity index					1.00	-.25
Temperature						1.00

Analyses of trout populations in pounds per acre and pounds per mile resulted in regression equations from which trout populations could be estimated with standard errors of 79 and 64 percent, respectively. The equations that provide the best relations and for which independent basin parameters are effective within 90 percent confidence are shown in table 8.

Table 8.--Summary of regression relations:

$$Y = aBV^{b1}\bar{Q}^{b2}Q_2^{\ b3}DR^{b4}V^{b5}T^{b6}T_2^{\ b7}$$

Trout population (Y)	Regression constant (a)	Regression coefficients for							Standard error (percent)	Multiple correlation coefficient
		% bottom vegetation (BV)	Mean discharge (cfsm) (Q)	7-day Q_2 (cfsm) (Q_2)	Ratio 10/90% duration discharge (DR)	Velocity index (V)	Mean annual maximum temperature (°F) (T)	T divided by 55 (T_2)		
		b_1	b_2	b_3	b_4	b_5	b_6	b_7		
Pounds per acre	1.7×10^{10}	0.34	0.98			-0.53	-5.14		79	0.683
Pounds per mile	5.1×10^{8}	.12		.80	1.03		-4.00		64	.642
Pounds per acre	19.36	.34	.98			-.53		-5.14	79	.683

Example.--Trout population in pounds per acre = 19.36 $(BV^{0.34})$ $(\bar{Q}^{\ 0.98})$ $(V^{0.53})$ $(T_2^{\ -5.14})$

Significant Relationships

Trout populations seem to be limited chiefly by stream temperature and discharge per unit drainage area. The relatively small correlation coefficients (less than 0.5) of single hydrologic parameters with trout populations (table 7) suggest that populations in a heterogeneous sampling of streams are not dominated by a single hydrologic characteristic.

Mean discharge per unit drainage area and values of 7-day low flow per unit drainage area significantly affected trout populations in several of the regression analyses. Streams having high discharge per unit drainage area during periods of base flow (high 7-day Q_2) are generally those that discharge relatively large amounts of ground water. These streams also generally have a more stable flow and are colder in the summer than those with a smaller low-flow discharge per unit drainage area.

Temperature of water was one of the most significant hydrologic parameters in almost all regression analyses in which it was included. Final regression analyses were run using annual maximum temperatures and annual maximum temperatures divided by 13°C (55°F). Using temperatures as a ratio to the selected lower limit for trout 13°C (55°F) does not change the accuracy in making population estimates from the regression equations but puts the equations into a more useable form.

PRESERVATION OF RECREATIONAL VALUES OF UPPER PENINSULA STREAMS

The relationships between hydrologic characteristics and recreational values described above, ideally, would be considered in managing the streams and watersheds to protect the recreational resource. The unique attraction of the Upper Peninsula streams is the wilderness atmosphere and the feeling of solitude that may be enjoyed on them. Some are without doubt among the wildest rivers, in the sense of being remote from crowds, in the midwest.

Channel, Bed, and Banks

Almost any alteration of river beds or banks, unless specifically designed otherwise, will impair recreational values. Riverfront cabins, which have encroached upon the wilderness atmosphere of many cold-water rivers in the Southern Peninsula, have not yet been built in any numbers in the Upper Peninsula. Acquisition of riverfront lands by local, State, or Federal governments, designation of State or Federal "wild" or "scenic" rivers, and "Green Belt" zoning designed to maintain a buffer zone of natural vegetation along river banks would help preserve the wilderness atmosphere.

Trail-bikes and "all terrain vehicles" (ATV's) are becoming increasingly popular in wilderness areas. Their potential for alteration of river banks and bank vegetation is very real. Because of the great popularity of these vehicles, however, restrictive regulations may be difficult to enact and even more difficult to enforce.

Dredging of river channels to fill lowland areas before cabin development or to provide inlets for boaters usually diminishes the attractiveness of natural channels. Impoundments also produce drastic alterations of natural channels. Although the newly formed lake may provide another kind of recreation, the free-flowing river cannot be restored.

Streamflow

The most obvious alterations in the flow of Upper Peninsula streams are caused by impoundments. Regulation of flow from impoundments can be designed to minimize impairment of recreational values or possibly to enhance them. But the primary purpose of most impoundments is to regulate flow to generate power or to provide water for public or industrial use. Inasmuch as public and industrial needs are usually considered paramount, protection of recreational values commonly involves the selection of the least harmful of several alternate plans.

Alterations in streamflow caused by changes in land use within the drainage basins of the Upper Peninsula are probably small, although other characteristics of streams, such as sediment load, may be substantially altered. In general, total runoff is greater from open grasslands, weeds, and brush than from forests, but low flows may be about the same (Ayer, 1968). Drastic changes in the watershed, such as stripping large areas of vegetation, would inevitably result in large changes in stream characteristics.

Water Quality

Man's activities may change the quality of water of streams. If streamside trees are cut, shade is reduced and water temperatures increase. Sewage wastes may consume essential dissolved oxygen and stimulate undesirable growth of water plants. Factories may discharge pollutants of many kinds. Clearcutting of forests accelerates erosion and increases sediment loads of streams.

Some activities of man may protect the quality of water. Construction of ponds to increase ground-water recharge and, consequently, the low flow of streams may reduce maximum summer temperature of streams and increase their dissolved oxygen content. Release of water from near the bottom of deep impoundments may also reduce summer water temperatures in places.

SUMMARY AND CONCLUSIONS

1. The recreational values of the cold-water rivers of Michigan's Upper Peninsula are strongly influenced by hydrologic characteristics of rivers and river basins. Activities of man may change hydrologic characteristics that influence recreational values. These changes may be favorable or unfavorable. Most cold-water rivers of the Upper Peninsula are relatively free from man-made changes that diminish the recreational resource.

2. Hydrologic characteristics that are usually favorable to recreational values are streamflow that is relatively uniform and sustained during dry seasons. Clear water free of pollutants and river banks well stabilized against erosion also are favorable.

3. Trout populations in Upper Peninsula streams seem to be limited chiefly by water temperature and discharge per unit drainage area.

4. Deterioration of recreational values can result from overdevelopment of river banks and from changes in hydrologic conditions in the river and river basin. Some of these changes may be irreversible.

5. Preservation and improvement of recreational values of Upper Peninsula streams may be accomplished by zoning to prevent overdevelopment and deterioration of river banks, management of water withdrawals, improvement of waste-disposal systems, restriction of impoundments, and prohibition of discharge of all damaging contaminants, including warm water and sediment.

6. Some streams lacking suitable conditions of streamflow, water temperature, and dissolved oxygen may be improved by augmenting streamflow with cool waters from surface impoundments or ground-water reservoirs.

7. The interrelationships of hydrologic characteristics and recreational values are so complex that "rules of thumb" for water management are not generally practicable. Management practices that alter one hydrologic characteristic to improve recreational values may alter another characteristic to diminish these values. Each stream and each reach of stream, ideally, would be carefully studied to determine results of proposed changes and results of actual changes would be monitored.

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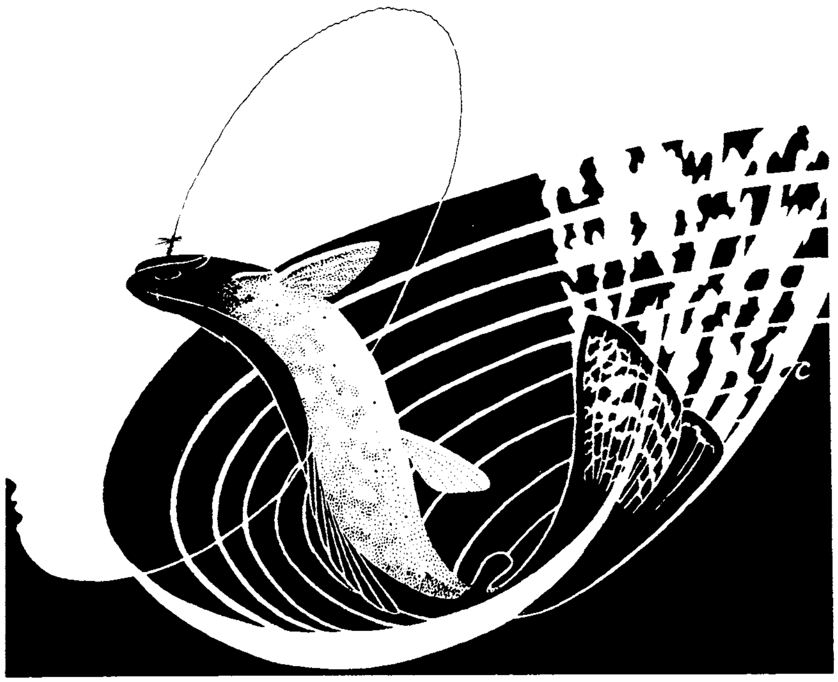

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