HYDROLOGY AND RECREATION OF SELECTED COLD-WATER RIVERS OF THE ST. LAWRENCE RIVER BASIN IN MICHIGAN, NEW YORK, AND WISCONSIN

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Cold-water rivers can be evaluated in terms of recreational potential and use. Recreation potential is chiefly dependent on hydrologic factors--streamflow, water quality, and character of bed and banks. Recreational use is dependent, in part, on hydrologic factors, but factors as accessibility and proximity to populated areas may be dominant. Recreational potential of 10 cold-water streams is described in terms of esthetic attractiveness, suitability for boating, camping and fishing opportunity.

Statistical analyses of 88 stream segments showed trout populations to be positively related to stability of streamflow and hardness of water and negatively related to maximum water temperatures. Other hydrologic factors influencing trout populations are streambed materials, low-flow characteristics, and stream velocity.

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ABSTRACT

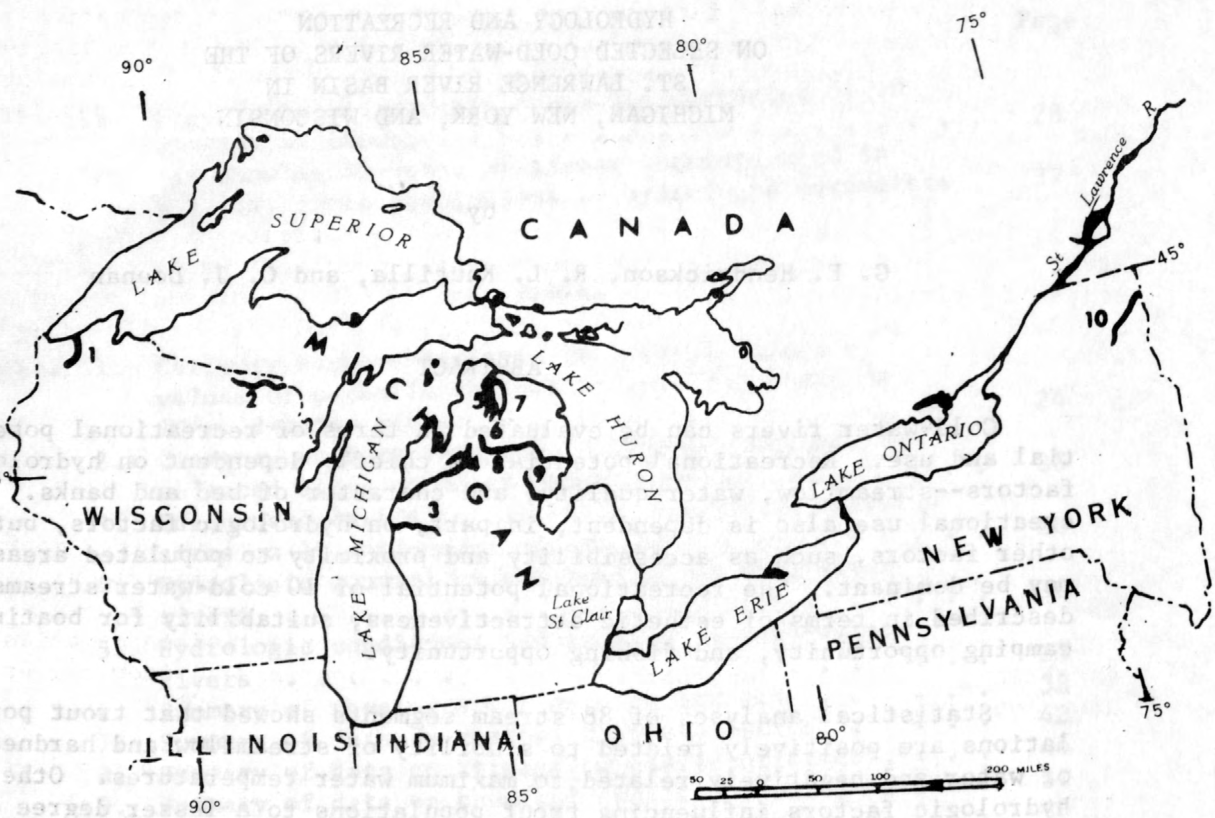
Cold-water rivers can be evaluated in terms of recreational potential and use. Recreational potential is chiefly dependent on hydrologic factors--streamflow, water quality, and character of bed and banks. Recreational use also is dependent, in part, on hydrologic factors, but other factors, such as accessibility and proximity to populated areas, may be dominant. The recreational potential of 10 cold-water streams is described in terms of esthetic attractiveness, suitability for boating, camping opportunity, and fishing opportunity.

Statistical analyses of 88 stream segments showed that trout populations are positively related to stability of streamflow and hardness of water and negatively related to maximum water temperatures. Other hydrologic factors influencing trout populations to a lesser degree are streambed materials, low-flow characteristics, and stream velocity.

INTRODUCTION

The cold-water rivers of the Great Lakes area are a valuable but fragile recreational resource. The recreational values of these rivers depend largely on their hydrologic characteristics--streamflow, water quality, and nature of bed and banks. The rivers can be protected by sound management based on knowledge of the relationships of hydrologic factors and recreational values. The purpose of this report is to contribute to this knowledge.

The river basins in the study area are chiefly mantled with glacial deposits, although bedrock crops out in places in some of them. The river environments range from near-wilderness, with limited road access, to highly developed, with paved roads and many houses or cabins. All the rivers support some river-based recreation, but the intensity of use varies widely. Ten rivers were selected for special emphasis in this study; they include the Bois Brule and Pine of Wisconsin, the Pere Marquette, Manistee, Sturgeon, Pigeon, Black, Au Sable, and Rifle of Michigan, and the West Branch Ausable of New York (fig. 1).



Key to Rivers

1 Bois Brule River, Wis.
2 Pine River, Wis.
3 Pere Marquette River, Mich.
4 Manistee River, Mich.
5 Sturgeon River, Mich.
6 Pigeon River, Mich.
7 Black River, Mich.
8 Au Sable River, Mich.
9 Rifle River, Mich.
10 West Branch Ausable River, N.Y.

Figure 1.--Map showing location of rivers studied.

Favorable hydrologic factors were examined in terms of recreational potential and use. The recreational potential of a stream is its inherent suitability for esthetic appeal, trout fishing, boating, and camping. Of all possible indicators of recreational potential, only trout populations, as one indicator of fishing potential, could be measured with sufficient confidence to justify statistical analysis. For this reason, a statistical analysis of the relationship of hydrologic factors to trout populations was a major component of the study. For this part of the study, data on 56 streams in Michigan and Wisconsin were used. Relationships of hydrologic factors to other indicators of recreational potential are described in nonquantitative terms. Recreational uses of the streams were determined by records of angler hours, density of boat traffic, and attendance at campgrounds.

ACKNOWLEDGMENTS

Many people contributed to the information presented in this report. Hydrologic data were contributed by U. S. Geological Survey personnel of the Wisconsin, Michigan, and New York districts; trout-population data were provided by fisheries personnel of State agencies; and information on camping and boating was obtained from State agencies and from campers and canoe-livery operators.

The authors are especially grateful for the data on trout populations furnished by Gaylord R. Alexander, David P. Borgeson, William H. Bullen, and Howard Gowing, of the Michigan Department of Natural Resources, and by Lloyd M. Andrews, Clifford Brynildson, Robert L. Hunt, John W. Mason and Thomas F. Thuemler, of the Wisconsin Department of Natural Resources. Martin H. Pfieffer and William E. Petty of the New York State Department of Environmental Conservation provided photographs and information on trout populations and recreational use of the West Branch Ausable River. Photographs of the Bois Brule and Pine Rivers of Wisconsin were contributed by the Wisconsin Department of Natural Resources.

THE STUDY AREA

The topography of the St. Lawrence River basin reflects chiefly the work of the latest (Wisconsin) glaciation, although the influence of the underlying bedrock is dominant in some areas. Rolling hills are composed of glacial till, and extensive plains are underlain by glacial outwash or glacial lake beds. The more rugged hills and mountains are underlain by resistant bedrock composed chiefly of Precambrian igneous and metamorphic rocks, and the glacial deposits in these areas are thin or absent. The cold-water rivers (trout streams) in the United States part of the basin are located chiefly in the northern part of the Great Lakes area and in the highlands of New York and New England.

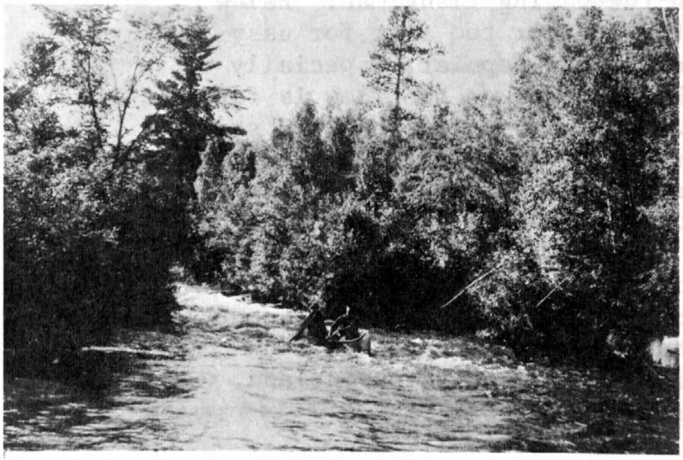
The characteristics of streamflow, water quality, and beds and banks of the rivers are strongly influenced by the geology. Rolling hills and plains underlain chiefly by thick deposits of permeable outwash and sandy till are characterized by relatively uniform streamflow, high drought flow, hard water, and sand and gravel beds and banks with many riffles but few rapids and no waterfalls. Most of the streams in the northern part of Michigan's Southern Peninsula are typical of these conditions. Rugged hills underlain by Precambrian rocks with a relatively thin mantle of glacial drift are characterized by greatly fluctuating streamflow, low drought flows, relatively soft water, rocky beds and banks, and many rapids and waterfalls. The West Branch Ausable in the Adirondack Mountains of New York is typical of such streams. River basins including both areas of permeable glacial deposits and areas of relatively impermeable drift and bedrock outcrop are drained by streams having characteristics of moderately fluctuating streamflow, soft to moderately hard water, and some rapids and waterfalls. The Pine River of northern Wisconsin is typical of streams draining such areas.

The 10 rivers described below are generally representative of the cold-water rivers of the St. Lawrence River basin. However, their selection was based chiefly on the availability of hydrologic and recreational-use data.

Bois Brule River, Wis.

The Bois Brule is one of Wisconsin's outstanding trout streams and is a popular canoe trail. It is especially popular with fishermen during the spring and fall, when large steelhead (rainbow) and brown trout ascend the river for spawning. Originating near Lake St. Croix in Douglas County in northwestern Wisconsin, the Brule flows generally northeast and north, about 40 miles, to Lake Superior. Cabin development on the river is sparse because most of the land is in public ownership. The river has four campgrounds. In addition, one small village--Brule, Wis.--provides accomodations for fishermen and canoeists. The river is crossed by U.S. Highway 2 at the village of Brule, and several paved State and county roads cross the river above and below the village.

The Bois Brule, from its origin to Stones Bridge (fig. 2), is narrow, generally less than 40 feet wide. For several miles downstream from Stones Bridge, it widens into a series of elongated ponds or lakes that are several hundred feet wide. Just upstream from Winneboujou Bridge it narrows to about 70 feet. From Winneboujou to Copper Range Campground it ranges in width from about 40 to 80 feet; it has an average width of about 60 feet. The Bois Brule, at normal summer flows, is generally less than 3 feet deep above the U.S. Highway 2 Bridge, but a few holes are 5 to 6 feet deep. Below Highway 2 it is 4 to 7 feet deep in the quiet reaches and less than 3 feet deep in the rapids.



"Little Joe" Rapids near Bois Brule Campground
Photograph by Wisconsin Department of Natural Resources

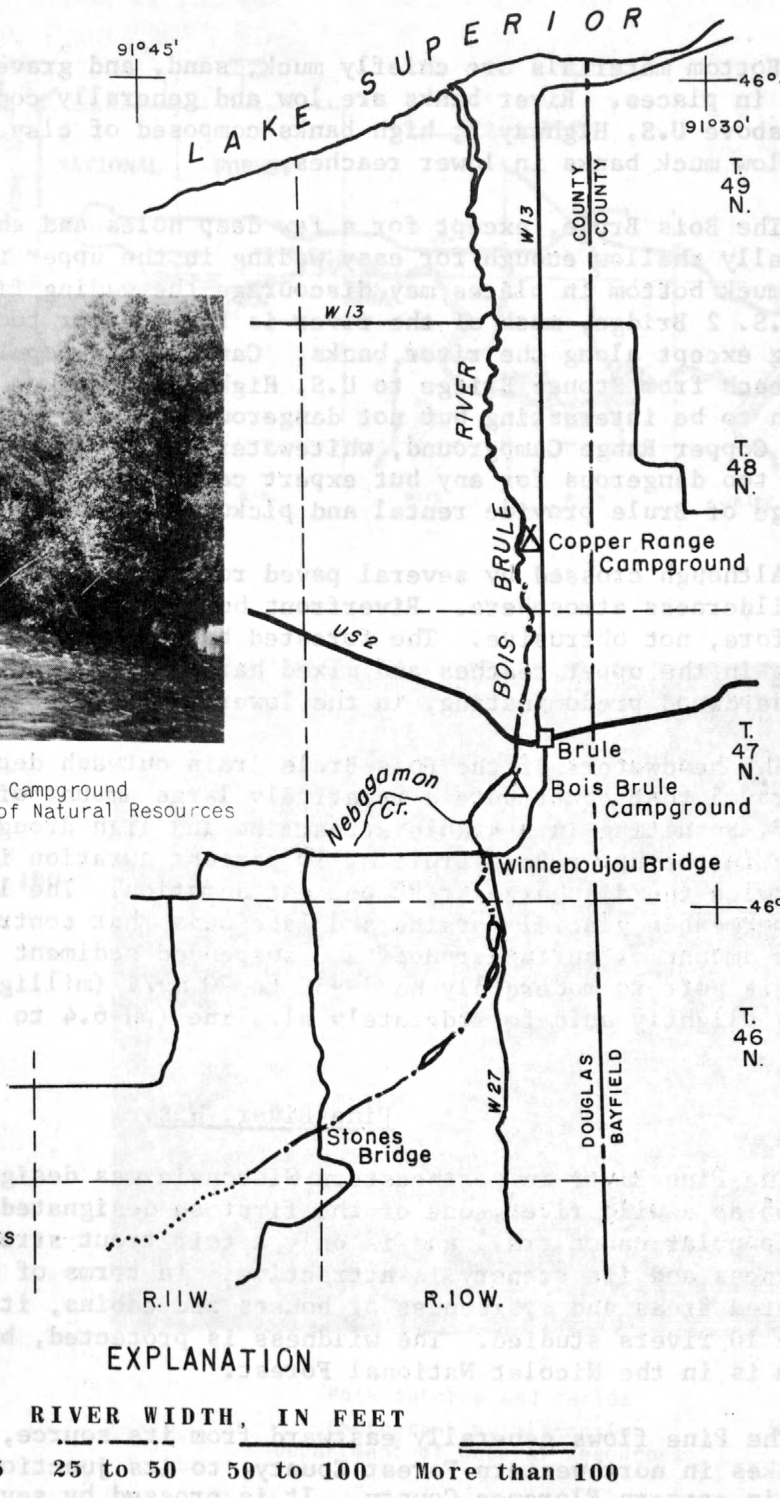


Figure 2.--Bois Brule River, Wis.

Bottom materials are chiefly muck, sand, and gravel, with rock outcrops in places. River banks are low and generally composed of muck and sand above U.S. Highway 2; high banks composed of clay and sand alternate with low muck banks in lower reaches.

The Bois Brule, except for a few deep holes and shallow rapids, is generally shallow enough for easy wading in the upper reaches, but the soft muck bottom in places may discourage the wading fisherman. Below the U.S. 2 Bridge, much of the river is too deep or too fast for easy wading except along the river banks. Canoeing is popular, especially in the reach from Stones Bridge to U.S. Highway 2 because the flow is fast enough to be interesting but not dangerous for canoers of moderate skill. Below Copper Range Campground, whitewater rapids and waterfalls make the river too dangerous for any but expert canoeists. Canoe liveries at the village of Brule provide rental and pickup service.

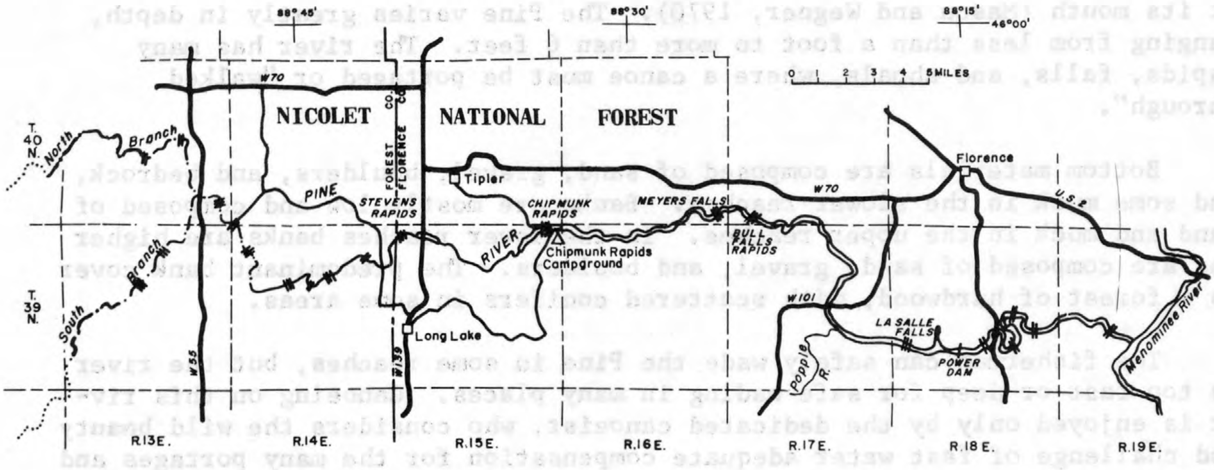
Although crossed by several paved roads the Bois Brule retains it's semiwilderness atmosphere. Riverfront homes and cabins are infrequent, therefore, not obtrusive. The forested banks are chiefly coniferous swamps in the upper reaches and mixed hardwood and coniferous upland, with hardwood predominating, in the lower reaches.

The headwaters of the Bois Brule drain outwash deposits of sand and gravel that contribute a relatively large amount of ground-water runoff, resulting in a stable streamflow and high drought flow. Discharge in the upper Bois Brule at 10 percent duration is slightly more than twice the discharge at 90 percent duration. The lower reaches drain less permeable glacial moraine and lake beds that contribute a relatively larger amount of surface runoff and suspended sediment to the river. The water is soft to moderately hard--50 to 70 mg/l (milligrams per liter)--and is slightly acid to moderately alkaline (pH 6.4 to 8.4).

Pine River, Wis.

The Pine River in northeastern Wisconsin was designated by the State in 1965 as a wild river, one of the first so designated. Although it is not a popular canoe trail and is only a fair trout stream, it is set in a wilderness and its scenery is attractive. In terms of remoteness from populated areas and sparseness of houses and cabins, it is the "wildest" of the 10 rivers studied. The wildness is protected, because much of the stream is in the Nicolet National Forest.

The Pine flows generally eastward from its source, extensive wetlands and lakes in northwestern Forest County, to its junction with the Menominee River in eastern Florence County. It is crossed by several paved and unpaved roads, but access points are several miles apart in some reaches (fig. 3). About 12 miles upstream from the mouth of the Pine River is a hydroelectric dam and power plant.

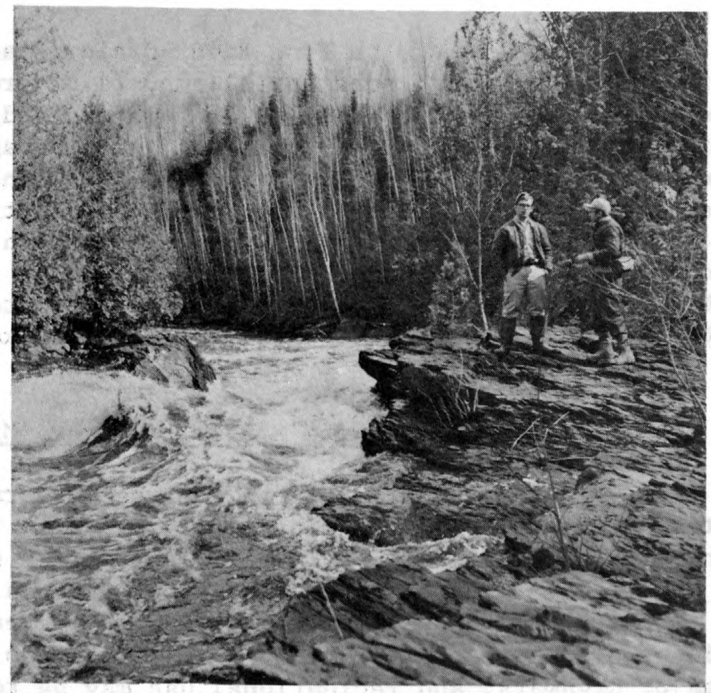


EXPLANATION

RIVER WIDTH, IN FEET

Less than 25 — 25 to 50

50 to 100 — More than 100



Rock outcrop and rapids

Photograph by Wisconsin Department of Natural Resources

Figure 3.--Pine River, Wis.

The river (including the North Branch) is about 65 miles long and increases in width from a few feet in the headwaters to about 200 feet at its mouth (Mason and Wegner, 1970). The Pine varies greatly in depth, ranging from less than a foot to more than 6 feet. The river has many rapids, falls, and shoals, where a canoe must be portaged or "walked through".

Bottom materials are composed of sand, gravel, boulders, and bedrock, and some muck in the slower reaches. Banks are mostly low and composed of sand and muck in the upper reaches. In the lower reaches banks are higher and are composed of sand, gravel, and boulders. The predominant bank cover is a forest of hardwood, with scattered conifers in some areas.

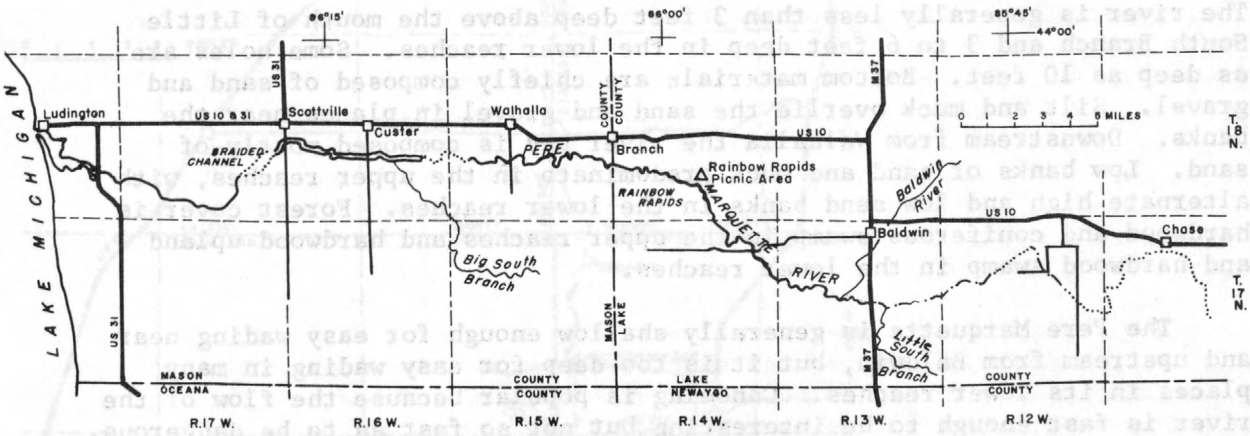
The fisherman can safely wade the Pine in some reaches, but the river is too fast or deep for safe wading in many places. Canoeing on this river is enjoyed only by the dedicated canoeist, who considers the wild beauty and challenge of fast water adequate compensation for the many portages and shoal areas encountered. The Pine has only one developed campground, but undeveloped sites suitable for camping are numerous. Perhaps mediocre fishing, scarcity of developed campgrounds, and difficult canoeing will help to keep this river "wild". Attraction of the Pine River is chiefly esthetic.

The headwaters of the Pine River drain areas of outwash and swamp deposits that contribute substantial amounts of ground-water runoff to the upper river. Extensive areas of Precambrian bedrock outcrop and till deposits in the lower (eastern) part of the drainage basin contribute relatively large amounts of surface runoff. The Pine has a relatively wide fluctuation in streamflow, with the discharge at 10 percent duration about six times as great as the discharge at 90 percent duration. It has the second largest variability of streamflow (after the West Branch Ausable of New York) of the 10 streams studied. The water is generally soft (20 to 60 mg/l) and is slightly acid to slightly alkaline (pH 6.6 to 7.8).

Pere Marquette River, Mich.

The Pere Marquette River, in the west-central part of Michigan's Southern Peninsula is a candidate for inclusion in the "National Wild and Scenic Rivers" system. The river is scenic, is an excellent trout stream, and is a popular canoe trail. The lower reaches are heavily fished during the spring and fall spawning runs. The upper reaches support an excellent resident fishery. However, the river may be too close to urban areas and to major highways, and recreational use may be too intensive for it to remain "wild".

The Pere Marquette flows generally westward about 75 miles from its source near Chase in southeastern Lake County to its mouth at Ludington on Lake Michigan. Only a few feet wide in the headwaters, it widens to about 60 feet near Baldwin and more than 100 feet in the lower reaches (fig. 4).

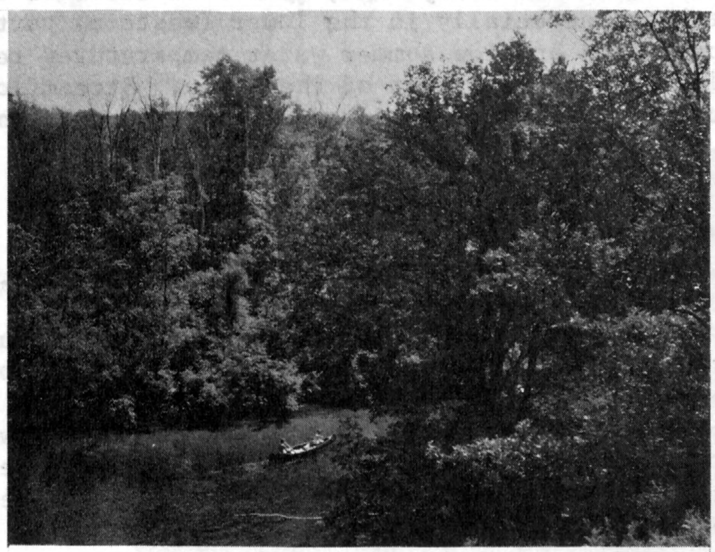


EXPLANATION

RIVER WIDTH, IN FEET

Less than 25   25 to 50

50 to 100   More than 100



Upstream from Rainbow Rapids

Figure 4.--Pere Marquette River, Mich.

The river is generally less than 3 feet deep above the mouth of Little South Branch and 3 to 6 feet deep in the lower reaches. Some holes are as deep as 10 feet. Bottom materials are chiefly composed of sand and gravel. Silt and muck overlie the sand and gravel in places near the banks. Downstream from Walhalla the river bed is composed mostly of sand. Low banks of sand and muck predominate in the upper reaches, with alternate high and low sand banks in the lower reaches. Forest cover is hardwood and coniferous swamp in the upper reaches and hardwood upland and hardwood swamp in the lower reaches.

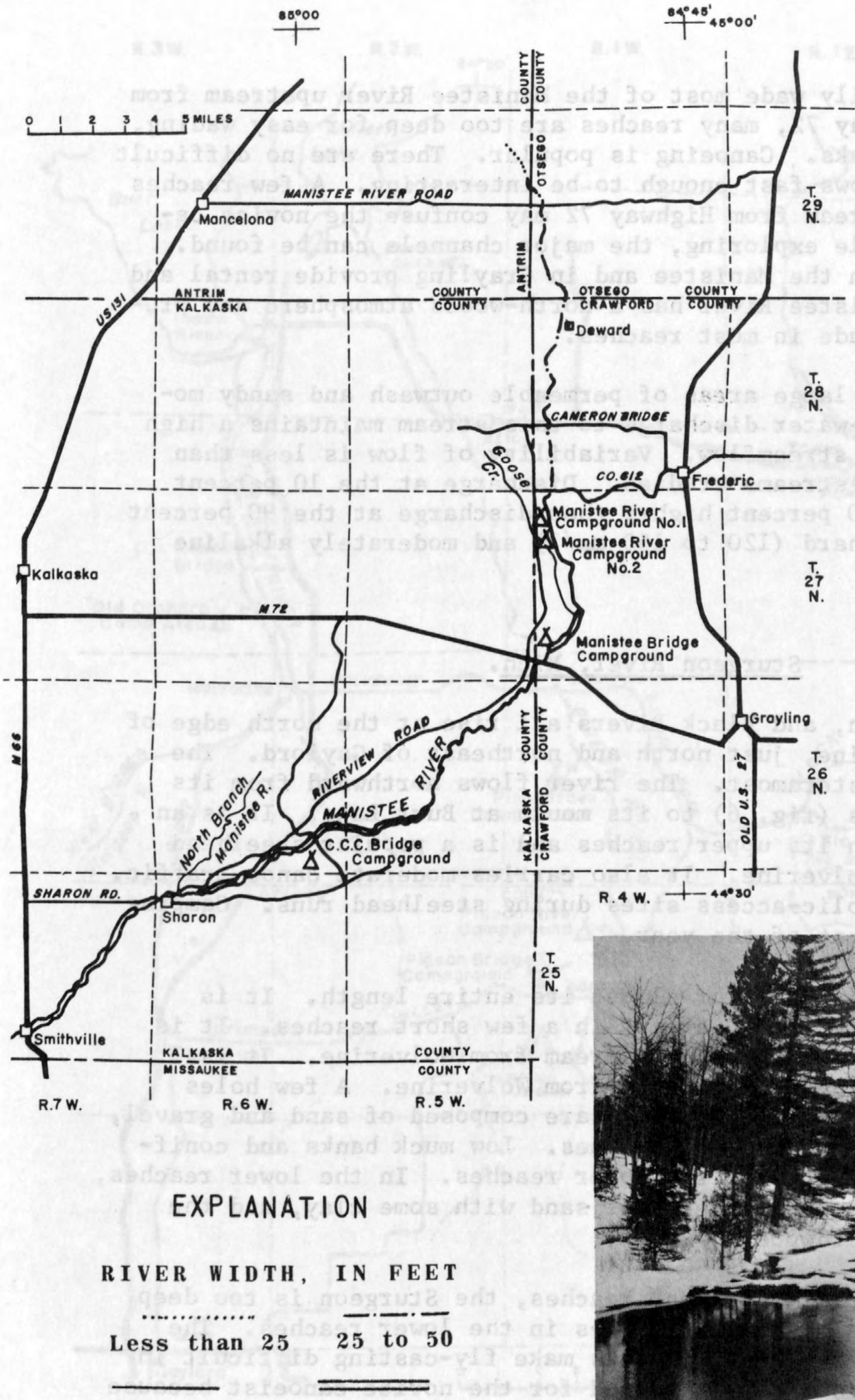
The Pere Marquette is generally shallow enough for easy wading near and upstream from Baldwin, but it is too deep for easy wading in many places in its lower reaches. Canoeing is popular because the flow of the river is fast enough to be interesting but not so fast as to be dangerous. Canoes are occasionally damaged on the rocks at Rainbow Rapids. Several canoe liveries provide rental and pickup service. The steep high banks between Baldwin and Walhalla provide numerous vantage points from which the natural beauty of the riverscape can be enjoyed. Camping is permitted at four public-access sites along the river. Cabin development is light to moderate, except near Baldwin, where riverside cabins and homes are numerous.

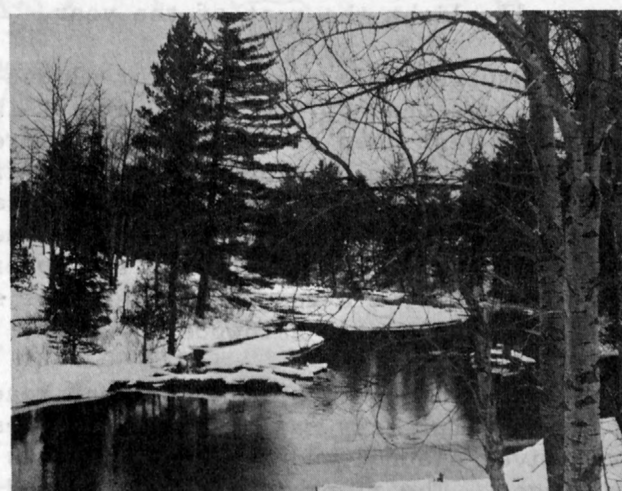
The river basin of the Pere Marquette is underlain chiefly by permeable outwash and sandy till, with some areas of less permeable till and lake beds, especially in the lower (western) part. The relatively high drought flow and low summer water temperatures reflect the permeable materials that underlie most of the basin. Streamflow is fairly uniform, with discharge at 10 percent duration slightly more than twice the discharge at the 90 percent duration. The water is hard (120 to 180 mg/l) and slightly alkaline (pH 7.4 to 8.0).

Manistee River, Mich.

Only the upper part of the Manistee River, upstream from the village of Smithville, was included in this study. One of Michigan's more popular canoe trails, the Manistee, is also a well known trout stream. The river is relatively wild in its upper reaches, with few cabins and access roads. Cabins are more numerous near State Highway 72 west of Grayling and at Sharon, but are sparse elsewhere. The upper river has four excellent campgrounds.

Only a few feet wide at Deward, the Manistee River widens to about 80 feet at State Highway 72 and 200 feet at State Highway 66 at Smithville (fig. 5). It is generally less than 3 feet deep upstream from Highway 72 and 3 to 6 feet deep, with some deeper holes, in the lower reaches. Bottom materials are composed of sand and gravel, with sand predominant. Banks are mostly low and composed of sand and muck in upper reaches; high sandy banks alternate with low muck banks in lower reaches.





Winter scene near Grayling

Figure 5.--Manistee River, Mich.

A fisherman can easily wade most of the Manistee River upstream from Highway 72. Below Highway 72, many reaches are too deep for easy wading, except near the river banks. Canoeing is popular. There are no difficult rapids, and the river flows fast enough to be interesting. A few reaches of braided channels upstream from Highway 72 may confuse the novice canoeist, but, with a little exploring, the major channels can be found. Several canoe liveries on the Manistee and in Grayling provide rental and pickup service. The Manistee River has a north-woods atmosphere and provides a measure of solitude in most reaches.

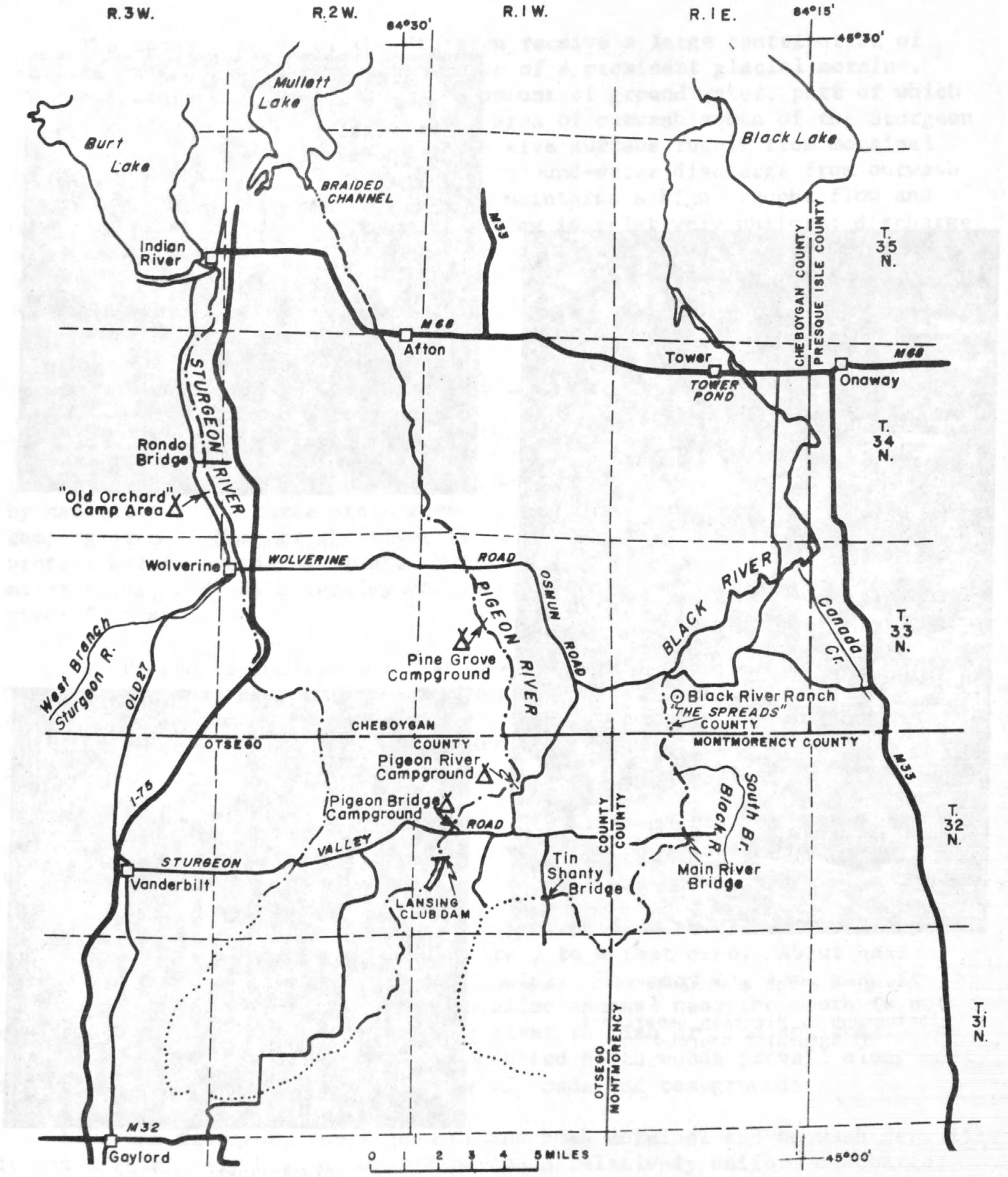
The Manistee drains large areas of permeable outwash and sandy moraine. The large ground-water discharge to this stream maintains a high drought flow and uniform streamflow. Variability of flow is less than that of any other of the streams studied. Discharge at the 10 percent duration is only about 30 percent higher than discharge at the 90 percent duration. The water is hard (120 to 150 mg/l) and moderately alkaline (pH 7.2 to 7.6).

Sturgeon River, Mich.

The Sturgeon, Pigeon, and Black Rivers all rise at the north edge of a prominent glacial moraine, just north and northeast of Gaylord. The Sturgeon River is the westernmost. The river flows northward from its source for about 37 miles (fig. 6) to its mouth at Burt Lake. It is an excellent trout stream in its upper reaches and is a popular steelhead stream downstream from Wolverine. It also carries moderate canoe traffic. Camping is popular at public-access sites during steelhead runs. Camping is generally light the rest of the year.

The Sturgeon flows swiftly for almost its entire length. It is generally less than 60 feet wide, except in a few short reaches. It is less than 3 feet deep at most places upstream from Wolverine. It is 3 to 6 feet deep in many places downstream from Wolverine. A few holes are deeper than 6 feet. Bottom materials are composed of sand and gravel, with sand predominating in the upper reaches. Low muck banks and coniferous swamp are characteristic of the upper reaches. In the lower reaches, banks are higher, are composed chiefly of sand with some clay, and the forest cover is mostly hardwoods.

Easy to wade in most of its upper reaches, the Sturgeon is too deep and too fast for easy wading in many places in the lower reaches. The narrow river channel and overhanging trees make fly-casting difficult in many places. The river is not well suited for the novice canoeist because the fast current, narrow channel, log jams, and occasional boulders require constant attention and much skill. Nevertheless, canoe liveries at the town of Indian River provide rental and pickup service, and the river supports a moderate amount of canoe traffic. The Sturgeon provides solitude and a near-wilderness atmosphere in some of the upstream reaches, but downstream from Wolverine it is generally close to major highways.

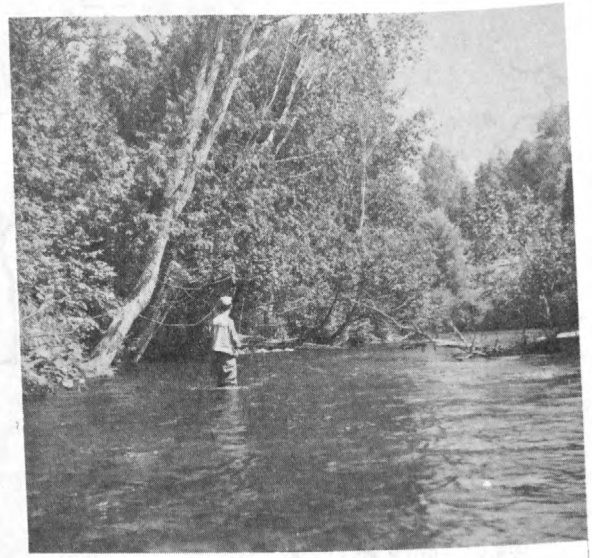


EXPLANATION

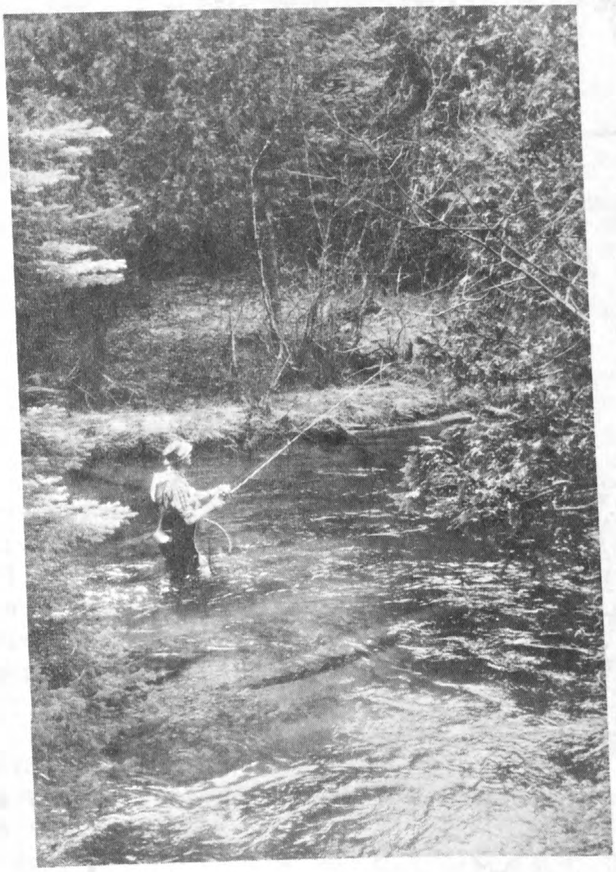
RIVER WIDTH, IN FEET

Less than 25   25 to 50   50 to 100   More than 100

Figure 6A.--Sturgeon, Pigeon, and Black Rivers, Mich.

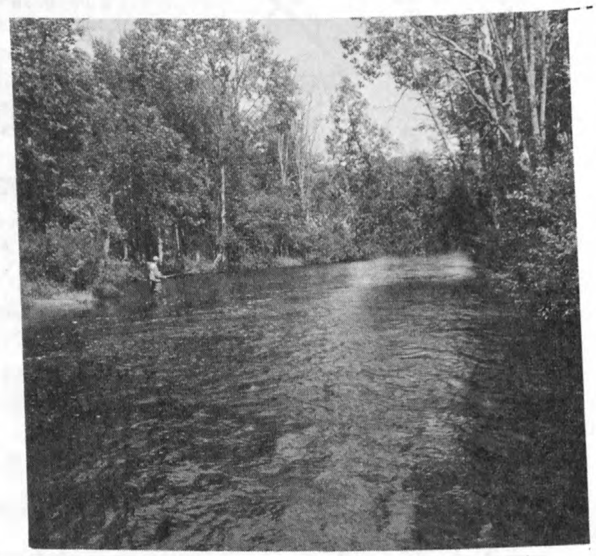


Pigeon River near Afton



Sturgeon River near Vanderbilt

Photograph by Michigan Department of Natural Resources



Black River near Tower

Figure 6B.--Sturgeon, Pigeon, and Black Rivers, Mich.

The upper reaches of the Sturgeon receive a large contribution of surface runoff from the northern slope of a prominent glacial moraine. The headwaters also receive a large amount of ground water, part of which is probably contributed by the broad area of outwash south of the Sturgeon watershed. The lower reaches also receive surface runoff from morainal hills and relatively large amounts of ground-water discharge from outwash deposits. The ground-water discharge maintains a high drought flow and low summer water temperature. Streamflow is relatively uniform; discharge at the 10 percent duration is about 75 percent greater than the discharge at the 90 percent duration. The water is hard (140 to 200 mg/l) and moderately alkaline (pH 7.3 to 8.2).

Pigeon River, Mich.

The Pigeon River rises in the same cedar swamp that supports the upper Sturgeon. It then flows generally northward for 43 miles to discharge into Mullet Lake (fig. 6). It is an excellent trout stream, but is little used by canoeists. The three State Forest Campgrounds on the river are popular camping areas. Much of the river is in State Forest land and, thus, is protected from overdevelopment. Most of its reach is fairly remote from major roads, and cabin development is sparse or absent on most of the river frontage.

The Pigeon is shallow and less than 50 feet wide upstream from Pine Grove Campground, except in the backwaters of Lansing Club Dam. It is 3 to 6 feet deep and as much as 80 feet wide in places in the lower river. The bottom material is composed of sand and gravel with silt and muck in places near the banks. Banks are generally low and composed of sand and muck for most of the river's length, but the lower river has a few high banks composed of sand and clay. Forest cover is mostly coniferous swamp in the upper reaches. Hardwood swamp and hardwood uplands predominate in the lower reaches.

The Pigeon River is easily waded upstream from the Pine Grove Campground, except in those reaches that are 3 to 6 feet deep. About half the lower river is too deep for easy wading. Its many log jams make it unpopular with most canoeists. The braided channel near the mouth is not canoeable. A few canoeists float the river to fish or find solitude. The solitude and quiet of the sparsely inhabited north woods prevail along most of the Pigeon, except in the vicinity of roads and campgrounds.

Like the Sturgeon, the Pigeon drains both morainal and outwash deposits. It has a relatively high drought flow and a relatively uniform discharge; discharge at 10 percent duration is about twice that at 90 percent duration. Its water is hard (160 to 220 mg/l) and moderately alkaline (pH 7.5 to 8.2).

Black River, Mich.

The Black River is the easternmost of the three rivers that rise on the north slope of the moraine near Gaylord. Only that part of the river above the village of Tower is included in this study. The Black is the most remote from well-travelled roads (fig. 6); because of this it is not overfished, and some of its brook trout are large. It is not a popular canoe trail, and very few people camp along it, although camping is permitted at two public access sites.

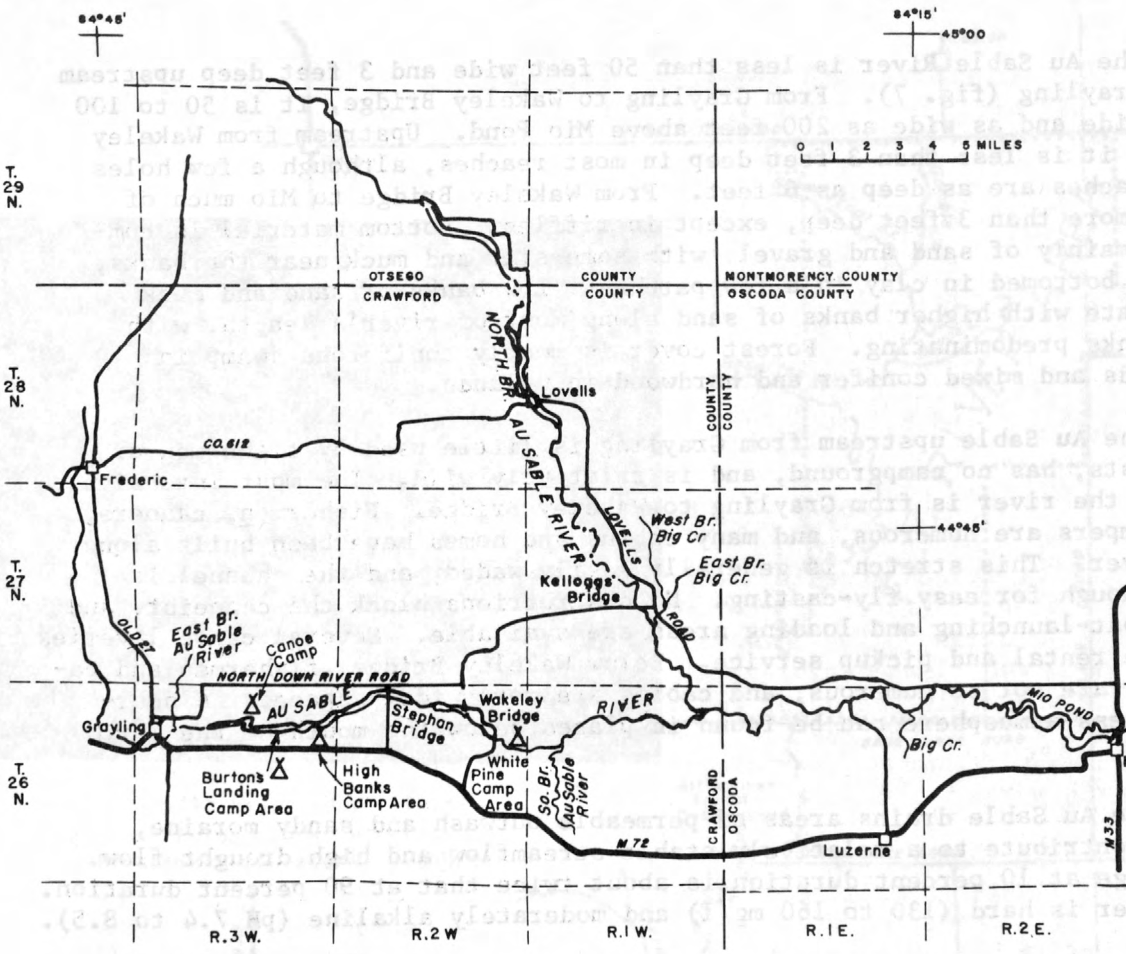
Upstream from Black River Ranch, the Black River is less than 50 feet wide and less than 3 feet deep in most places. In the lower reaches, between Black River Ranch and Tower Pond, it is as wide as 100 feet and as deep as 6 feet. Bottom materials are composed of sand and gravel. Banks are low and mucky along most of its length, but high sandy banks border the river on one or both sides in the reach between Tin Shanty Bridge and Main River Bridge. Clay banks bound the river in places south of the village of Tower. Forest cover is mostly coniferous swamp and coniferous uplands in the upper reaches, and it is mostly hardwood swamp in the lower reaches.

Fishermen wade the Black River with ease in most reaches upstream from Main River Bridge, but parts of the lower reaches are too deep for easy wading. Above Tin Shanty Bridge the narrow channel and overhanging brush make fly-casting difficult. The river is relatively open in the lower reaches, except for the braided channel known as "The spreads" at Black River Ranch. Many log jams, shoals, and beaver dams in the upper river obstruct canoe traffic and require frequent portages. "The spreads" cannot be canoed. Below Black River Ranch no portages are required, but rocky shoals may be troublesome at low stages. The upper reaches are quite wild. Cabin development is sparse, except for a few miles downstream from Tin Shanty Bridge and a few miles upstream from the village of Tower.

The Black River, like the Sturgeon and Pigeon, drains both morainal and outwash deposits. The Black also has a relatively high drought flow and a relatively uniform discharge; discharge at 10 percent duration is about twice that at 90 percent duration. Its water is hard (130 to 220 mg/1) and moderately alkaline (pH 7.8 to 8.4).

Au Sable River, Mich.

Michigan's Au Sable River flows generally southward and eastward from its source near Grayling to Lake Huron. That part of the river upstream from the town of Mio is included in this study. The Au Sable near Grayling is probably used by more people for outdoor recreation than any other of the 10 rivers. Despite intensive use, it still provides excellent trout fishing, canoeing, camping, and cabin-dwelling. The river has two State Forest campgrounds. Camping also is permitted at two public-access sites near Grayling.

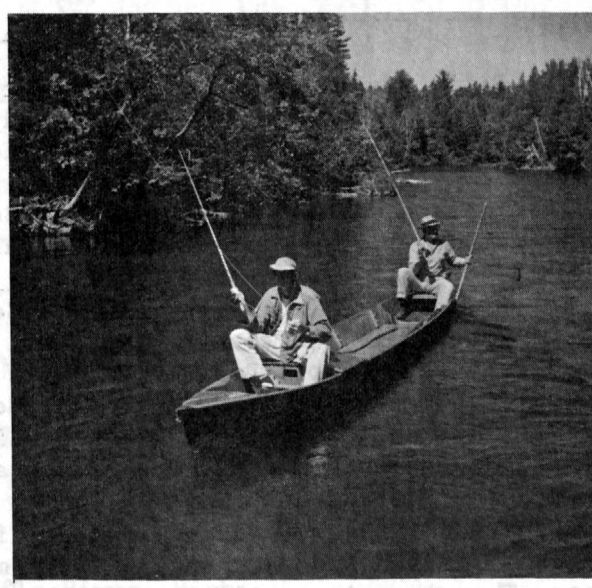


EXPLANATION

RIVER WIDTH, IN FEET

25 to 50

50 to 100 More than 100



"Au Sable River Boat"

Photograph by
Michigan Department
of Natural Resources

Figure 7.--Au Sable River, Mich.

The Au Sable River is less than 50 feet wide and 3 feet deep upstream from Grayling (fig. 7). From Grayling to Wakeley Bridge, it is 50 to 100 feet wide and as wide as 200 feet above Mio Pond. Upstream from Wakeley Bridge it is less than 3 feet deep in most reaches, although a few holes and reaches are as deep as 6 feet. From Wakeley Bridge to Mio much of it is more than 3 feet deep, except in riffles. Bottom material is composed mainly of sand and gravel, with some silt and muck near the banks, but is bottomed in clay in a few patches. Low banks of sand and muck alternate with higher banks of sand along most of river's length, with low banks predominating. Forest cover is mostly coniferous swamp in lowlands and mixed conifer and hardwood in uplands.

The Au Sable upstream from Grayling is little used by fishermen or canoeists, has no campground, and is relatively wild. The most intensive use of the river is from Grayling to Wakeley Bridge. Fishermen, canoers, and campers are numerous, and many cabins and homes have been built along the river. This stretch is generally easily waded, and the channel is wide enough for easy fly-casting. No obstructions block the canoeist, and many boat-launching and loading areas are available. Several canoe liveries provide rental and pickup service. Below Wakeley Bridge, fishermen and canoeists are not so numerous, and cabins are more widely spaced. A near-wilderness atmosphere can be found in places below the mouth of the North Branch.

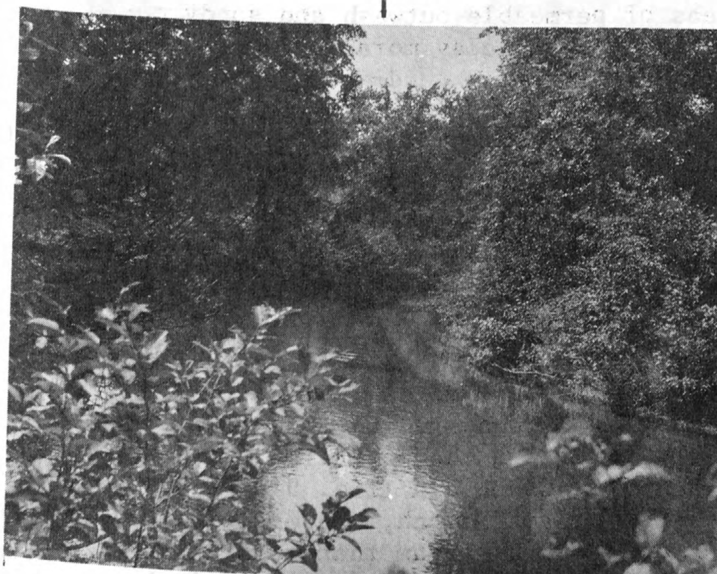
The Au Sable drains areas of permeable outwash and sandy moraine, which contribute to a relatively stable streamflow and high drought flow. Discharge at 10 percent duration is about twice that at 90 percent duration. Its water is hard (130 to 160 mg/l) and moderately alkaline (pH 7.4 to 8.5).

Rifle River, Mich.

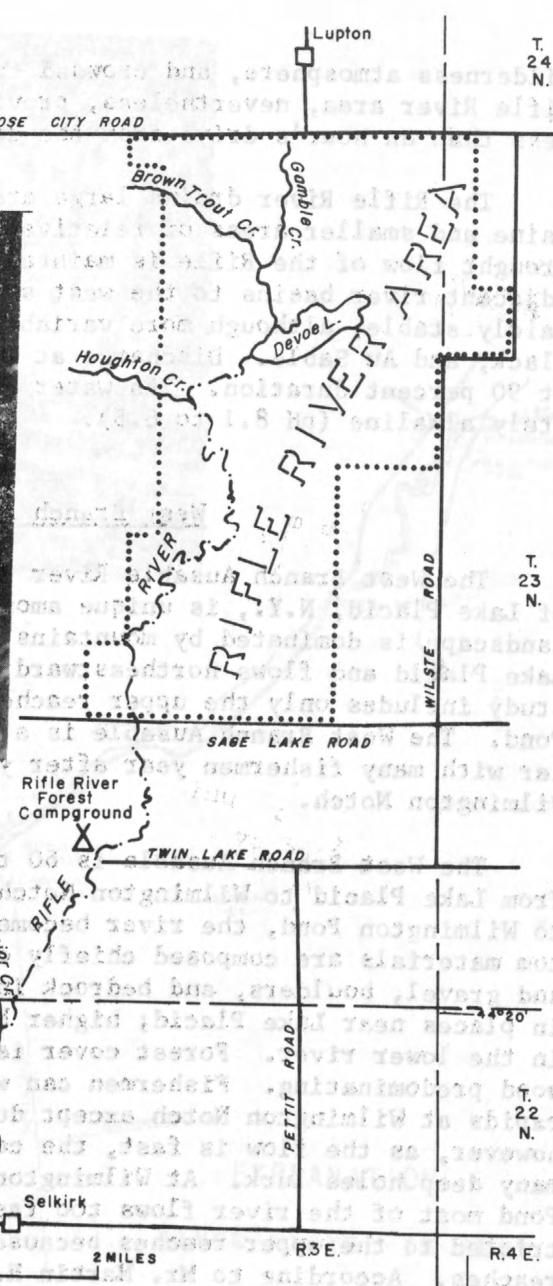
The Rifle River flows south and southeastward from Devoe Lake, in Ogemaw County, to Saginaw Bay. This study includes only the reaches above Selkirk (fig. 8). The Rifle is an excellent trout stream upstream from the village of Selkirk, but only fair in the downstream reaches. It supports a moderate canoe traffic--chiefly Boy Scouts and other youth groups. The two campgrounds on the river are usually crowded.

The Rifle River from Devoe Lake to Selkirk is small, 30 to 50 feet wide and generally less than 3 feet deep. Some of the river bends have holes 3 to 6 feet deep. Bottom materials are composed mostly of sand near Devoe Lake and gravel and boulders near Selkirk. Low banks of sand and muck alternate with high banks of sand. Forest cover is mostly hardwood swamp in the lowlands and mixed hardwood and conifer in the uplands.

Fishermen find easy wading in the Rifle River above Selkirk; however, the narrow channel and overhanging trees make fly-casting difficult in places. The river is easily canoed; there are no rapids or portages above Selkirk. Although paved roads and nearby cultivated fields detract from a



Rifle River near Selkirk
Photograph by Michigan
Department of Natural Resources



EXPLANATION

RIVER WIDTH, IN FEET

25 to 50 — 50 to 100

Figure 8.--Rifle River, Mich.

wilderness atmosphere, and crowded campgrounds offer little solitude, the Rifle River area, nevertheless, provides an attractive outdoor environment less than an hour's drive from the densely populated Saginaw-Bay City area.

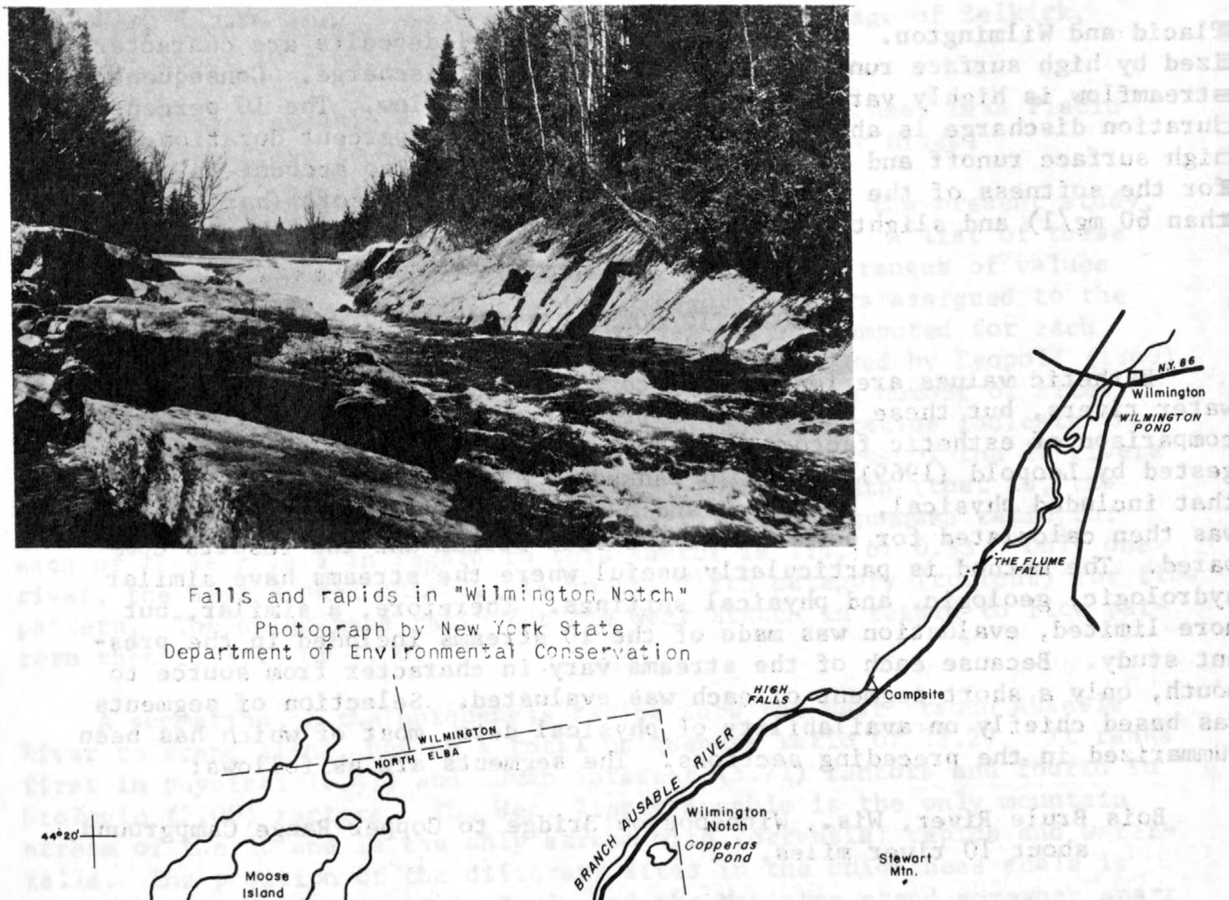
The Rifle River drains large areas of permeable outwash and sandy moraine and smaller areas of relatively impermeable clay moraine. The high drought flow of the Rifle is maintained in part by ground-water flow from adjacent river basins to the west and north. Discharge of the Rifle is fairly stable, although more variable than that of the Sturgeon, Pigeon, Black, and Au Sable. Discharge at 10 percent duration is 2.5 times that at 90 percent duration. Its water is hard (190 to 240 mg/l) and moderately alkaline (pH 8.1 to 8.5).

West Branch Ausable River, N.Y.

The West Branch Ausable River in the Adirondacks near the village of Lake Placid, N.Y., is unique among the 10 rivers studied in that the landscape is dominated by mountains. It begins in the mountains south of Lake Placid and flows northeastward into Lake Champlain (fig. 9). This study includes only the upper reaches of the West Branch, above Wilmington Pond. The West Branch Ausable is a classic trout stream that remains popular with many fishermen year after year. It has one State campground at Wilmington Notch.

The West Branch Ausable is 60 to 100 feet wide and 2 to 8 feet deep from Lake Placid to Wilmington Notch. From Wilmington Notch downstream to Wilmington Pond, the river becomes a series of rapids and falls. Bottom materials are composed chiefly of gravel and sand in the upper reaches and gravel, boulders, and bedrock in the lower. Low banks of silt occur in places near Lake Placid; higher banks of rocks and boulders predominate in the lower river. Forest cover is mixed hardwood and conifer, with hardwood predominating. Fishermen can wade most parts of the river above the rapids at Wilmington Notch except during high stages. Wading is not easy, however, as the flow is fast, the cobbles and boulders are slippery, and many deep holes lurk. At Wilmington Notch and downstream to Wilmington Pond most of the river flows too fast for safe wading. Canoeing is restricted to the upper reaches because of rapids and waterfalls in the lower reaches. According to Mr. Martin H. Pfeiffer (written commun., 1971), the most popular canoeing section is from the "Red Barn" to Monument Falls, about 4 miles. This reach is sometimes used for canoe and kayak racing. The river is too close to paved highways and populated areas to qualify as wilderness, but it provides a most attractive woods and mountains atmosphere. The falls and rapids are impressive in sight and sound.

Most of the drainage area of the West Branch Ausable is underlain by Precambrian bedrock thinly mantled with glacial till. Bedrock is exposed in many places in the stream channel and on the mountainsides. Deposits of sand and gravel occur in small areas along the river channel near Lake



Falls and rapids in "Wilmington Notch"
Photograph by New York State
Department of Environmental Conservation

Figure 9.--West Branch Ausable River, N.Y.

Placid and Wilmington. The bedrock and thin till deposits are characterized by high surface runoff and low ground-water discharge. Consequently, streamflow is highly variable, and drought flow is low. The 10 percent duration discharge is about 10 times that of the 90 percent duration. The high surface runoff and low ground-water discharge also account in part for the softness of the water. The water is generally soft (hardness less than 60 mg/l) and slightly acidic to slightly alkaline (pH 6.0 to 7.5).

ESTHETIC CONSIDERATIONS

Esthetic values are fundamental to all recreational uses of cold-water rivers, but these values are difficult to assess. A quantitative comparison of esthetic factors, based on relative uniqueness, was suggested by Leopold (1969). Leopold ranked 12 Idaho rivers on 46 factors that included physical, biologic, and human interest. Relative uniqueness was then calculated for each factor for each stream and the results compared. The method is particularly useful where the streams have similar hydrologic, geologic, and physical settings. Therefore, a similar, but more limited, evaluation was made of the 10 streams included in the present study. Because each of the streams vary in character from source to mouth, only a short segment of each was evaluated. Selection of segments was based chiefly on availability of physical data, most of which has been summarized in the preceding sections. The segments are as follows:

Bois Brule River, Wis., Winneboujou Bridge to Copper Range Campground, about 10 river miles.

Pine River, Wis., State Highway 139 downstream to Chipmunk Rapids Campground, about 7 river miles.

Pere Marquette River, Mich., Rainbow Rapids downstream to village of Branch, about 4 river miles.

Manistee River, Mich., County Highway 612 downstream to State Highway 72, about 9 river miles.

Sturgeon River, Mich., village of Wolverine downstream to Rondo Bridge, about 4 river miles.

Pigeon River, Mich., Lansing Club Dam downstream to Pigeon River Campground, about 5 river miles.

Black River, Mich., Tin Shanty Bridge downstream to Main River Bridge, about 8 river miles.

Au Sable River, Mich., "High Banks" camp area downstream to Wakeley Bridge, about 8 river miles.

Rifle River, Mich., Devoe Lake downstream to village of Selkirk, about 10 river miles.

West Branch Ausable River, N.Y., State Highway 73 near Lake Placid downstream to Wilmington pond, about 12 river miles.

Not all data included by Leopold were obtained in the present study, so the number of factors evaluated were reduced to 22. A list of these factors and category numbers corresponding to various ranges of values for each factor are shown in table 1. Category numbers assigned to the 22 factors are shown in table 2. Uniqueness ratios computed for each factor at the 10 sites are given in table 3. As defined by Leopold (1969), the uniqueness ratio is equal to the reciprocal of the number of sites sharing the size class of the parameter. Uniqueness ratios indicate the relative scarcity of a given factor. For example, three of the 10 rivers have category numbers of 2 for the factor of river width (that is, the three streams have widths of 25 to 50 feet). The uniqueness ratio for each of these rivers in regard to this factor is 1:3, or 0.33. Only one river, the West Branch Ausable, is in the fifth category (torrent) for flow pattern. The uniqueness ratio for the West Branch in regard to flow pattern then is 1:1, or 1.00.

A summation of the uniqueness ratios show the West Branch Ausable River to stand alone, having a total uniqueness ratio of 12.27. It ranks first in physical (6.47) and human interest (3.71) factors and fourth in biologic (2.09) factors. The West Branch Ausable is the only mountain stream of the 10 and is the only stream with torrential rapids and waterfalls. The position of the different sites in the uniqueness scale is shown in figure 10. The Bois Brule and the Manistee stand somewhat apart from the remaining seven because of their high position in physical and biologic factors and their low position in human-interest factors. The remaining seven sites are not distinguished by any outstanding characteristics.

Leopold (1969, p. 10) suggested that the grandeur or majesty of a stream depends to some extent on size and apparent speed of flow. A comparison of the 10 rivers, based on these characteristics, is shown on figure 11. Again, the West Branch Ausable stands well above the rest, with a rating of 4.8; a position that results from the prevalence of spectacular rapids and waterfalls on this stream. The Bois Brule and the Pine also have rapids and falls in places, but these are not the predominant character of the reaches used in this analysis. The Au Sable, Pere Marquette, and Manistee are relatively large rivers with abundant riffles but no real rapids. The Sturgeon is a relatively small stream with no spectacular rapids, but it is fast flowing with very few pools or "flat water". The Rifle, Pigeon, and Black are small streams in the selected reaches. They are at the bottom of the list at the "small and placid" side of the comparison.

Table 1.--Category numbers assigned to various ranges of values of esthetic factors at selected sites on 10 cold-water rivers.

Esthetic factors	Category numbers				
	1	2	3	4	5
PHYSICAL					
Width (feet)	25	25-50	50-100	100-150	More than 150
Depth (feet)	1	1-3	3-5	5-10	More than 10
Velocity (feet/second)	Less than 1.0	1.0-1.5	1.5-2.0	2.0-3.0	More than 3.0
Ratio 10/90 percent duration discharge	Less than 1.5	1.5-2.5	2.5-5.0	5.0-7.5	More than 7.5
Flow pattern	Sluggish	Glides	Riffles	Riffles & rapids	Torrent
Bed material	Clay & silt	Sand	Sand & gravel	Gravel	Cobbles & boulders
Bed slope (feet per mile)1/	75	5-10	10-20	20-40	40+
Bank material	Muck & silt	Muck & sand	Sand	Sand & gravel	Cobbles & boulders
Bank height (feet)	0-3	3-6	6-10	10-20	20+
BIOLOGIC AND QUALITY					
Color	Clear	--	--	--	Colored
Turbidity	Clear	--	--	--	Muddy
Floating solids	None	--	--	--	Much
Bottom vegetation (percent)	None	10	10-25	25-50	50+
Bank vegetation	Grass	Grass & trees	Hardwood	Conifer	Mixed
Pollutants2/	None	--	--	--	Much
HUMAN INTEREST					
Litter	None	--	--	--	Much
Accessibility	Wild	--	--	--	Much-paved
Scenery	Diverse	--	--	--	Restricted
Vistas	Open	--	--	--	Restricted
Land use	Wild	Forest	Forest recreation	Farm	Urban
Urbanization	None	--	--	--	Many houses
Recreation use	Little	--	--	--	Much

1/ Average for segment of river sampled
2/ Sewage wastes

Table 2.--Category numbers assigned to esthetic factors at selected sites on 10 cold-water rivers.

Esthetic factors	Bois Brule	Pine	Pere Marquette	Manistee	Sturgeon	Pigeon	Black	Au Sable	Rifle	West Branch Ausable
PHYSICAL										
Width	3	3	3	3	3	2	2	3	2	3
Depth	3	2	3	2	2	2	2	2	2	3
Velocity	4	3	3	2	3	2	2	2	2	5
Ratio 10/90 percent duration discharge	2	4	2	1	2	2	2	2	2	5
Flow pattern	4	3	3	3	3	3	3	3	3	5
Bed material	3	3	3	2	4	4	3	3	3	5
Bed slope	4	3	2	1	2	2	2	2	1	5
Bank material	2	2	2	2	3	2	2	2	2	5
Bank height	2	1	4	2	1	1	1	2	1	5
BIOLOGIC AND QUALITY										
Color	3	2	1	1	1	1	1	1	1	2
Turbidity	3	2	2	1	1	1	1	1	2	3
Floating solids	2	1	2	1	1	1	1	2	2	2
Bottom vegetation	2	2	2	3	2	2	2	4	3	2
Bank vegetation	3	3	3	4	2	5	5	5	3	5
Pollutants	2	1	2	1	2	1	1	3	2	3
HUMAN INTEREST										
Litter	2	1	3	3	2	2	1	5	3	3
Accessibility	3	1	3	2	4	2	1	4	3	4
Scenery	2	2	3	3	4	3	3	3	4	1
Vistas	3	3	2	4	3	4	4	3	4	1
Land use	3	2	3	3	3	3	2	3	3	3
Urbanization	2	1	3	2	3	2	2	5	2	1
Recreation use	4	1	4	4	2	3	1	5	4	5

Table 3.--Uniqueness ratios for esthetic factors at selected sites on 10 cold-water rivers.

Esthetic factors	Bois Brule	Pine	Pere Marquette	Manistee	Sturgeon	Pigeon	Black	Au Sable	Rifle	West Branch Ausable
PHYSICAL										
Width	0.14	0.14	0.14	0.14	0.14	0.33	0.33	0.14	0.33	0.14
Depth	.33	.14	.33	.14	.14	.14	.14	.14	.14	.33
Velocity	1.00	.33	.33	.20	.33	.20	.20	.20	.20	1.00
Ratio 10/90 percent duration discharge	.14	1.00	.14	1.00	.14	.14	.14	.14	.14	1.00
Flow pattern	.50	.14	.14	.14	.50	.14	.14	.14	.14	1.00
Bed material	.17	.17	.17	1.00	.50	.50	.17	.17	.17	1.00
Bed slope	1.00	1.00	.20	.50	.20	.20	.20	.20	.50	1.00
Bank material	.13	.13	.13	.13	1.00	.13	.13	.13	.13	1.00
Bank height	.33	.20	1.00	.33	.20	.20	.20	.33	.20	
Totals	3.74	3.61	2.58	3.58	2.79	1.98	1.65	1.59	1.95	6.47
BIOLOGIC AND QUALITY										
Color	1.00	.50	.14	.14	.14	.14	.14	.14	.14	.50
Turbidity	.50	.33	.33	.20	.20	.20	.20	.20	.33	.50
Floating solids	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Bottom vegetation	.14	.14	.14	.50	.14	.14	.14	1.00	.50	.14
Bank vegetation	.25	.25	.25	1.00	1.00	.25	.25	.25	.25	.25
Pollutant	.25	.25	.25	.25	.25	.25	.25	.50	.25	.50
Totals	2.34	1.67	1.31	2.29	1.93	1.18	1.18	2.29	1.67	2.09
HUMAN INTEREST										
Litter	.33	.50	.25	.25	.33	.33	.50	1.00	.25	.25
Accessibility	.33	.50	.33	.50	.33	.50	.50	.33	.33	.33
Scene	.50	.50	.20	.20	.50	.20	.20	.20	.50	1.00
Vistas	.25	.25	1.00	.25	.25	.25	.25	.25	.25	1.00
Land use	.13	.50	.13	.13	.13	.13	.50	.13	.13	.13
Urbanization	.20	.50	.50	.20	.50	.20	.20	1.00	.20	.50
Recreation use	.25	.50	.25	.25	1.00	1.00	.50	.50	.25	.50
Totals	1.99	3.25	2.66	1.78	3.04	2.61	2.65	3.41	1.91	3.71
Totals, all factors	8.07	8.53	6.66	7.65	7.76	5.77	5.48	7.29	5.53	12.27

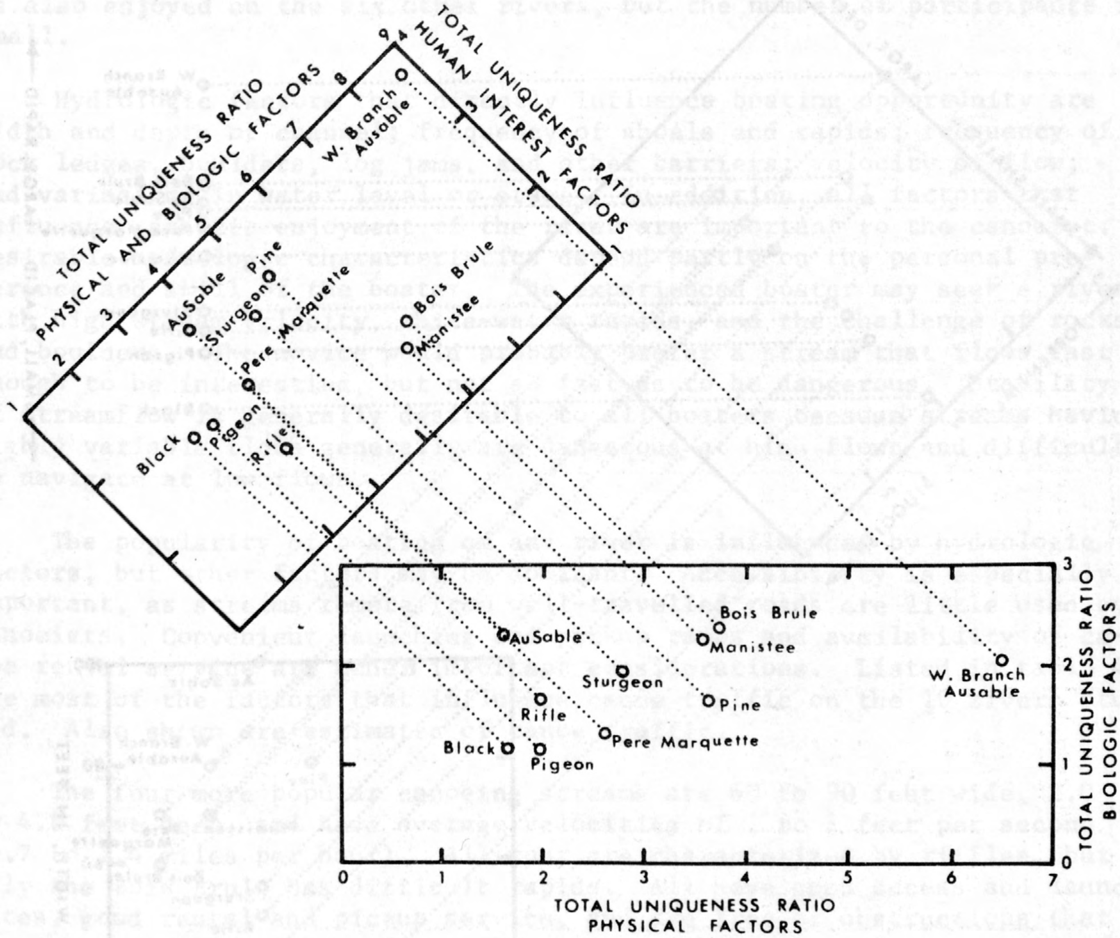


Figure 10.--Uniqueness ratios for 10 cold-water rivers.

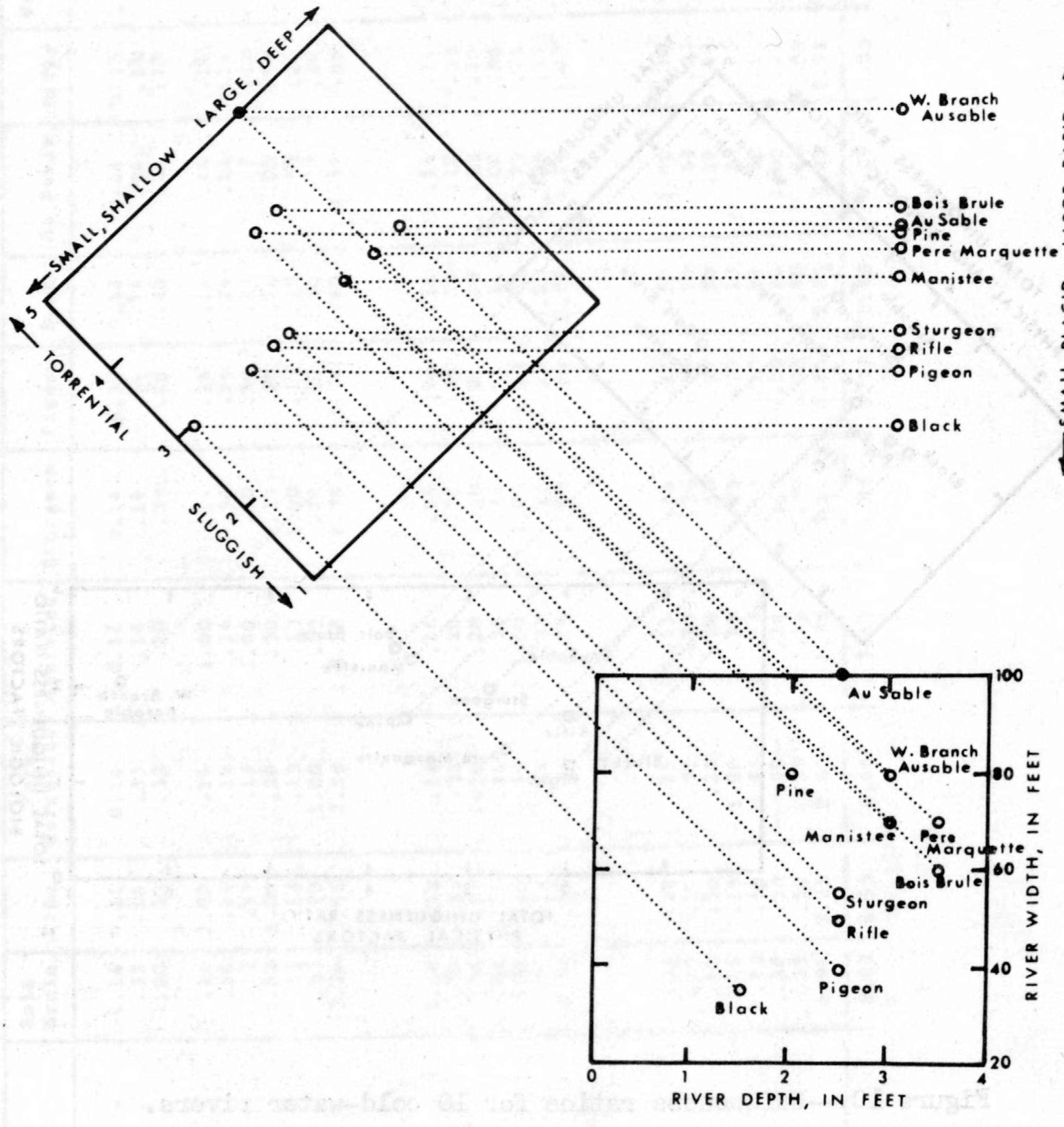


Figure 11.--Analysis of scenic character of 10 cold-water rivers.

BOATING

Boating and, especially, canoeing is a major recreation on four of the ten rivers studied. They are the Pere Marquette, Manistee, and Au Sable Rivers of Michigan, and the Bois Brule River of Wisconsin. Canoeing is also enjoyed on the six other rivers, but the number of participants is small.

Hydrologic factors that directly influence boating opportunity are width and depth of channel; frequency of shoals and rapids; frequency of rock ledges, boulders, log jams, and other barriers; velocity of flow; and variations in water level or stage. In addition, all factors that influence esthetic enjoyment of the river are important to the canoeist. Desirable hydrologic characteristics depend partly on the personal preference and skill of the boater. The experienced boater may seek a river with high stream velocity, white-water rapids, and the challenge of rocks and boulders. The novice would probably prefer a stream that flows fast enough to be interesting, but not so fast as to be dangerous. Stability of streamflow is generally desirable to all boaters because streams having highly variable flows generally are dangerous at high flows and difficult to navigate at low flows.

The popularity of boating on any river is influenced by hydrologic factors, but other factors may be dominant. Accessibility is especially important, as streams remote from well-travelled roads are little used by canoeists. Convenient launching and pickup ramps and availability of canoe rental service are other important considerations. Listed in table 4 are most of the factors that influence canoe traffic on the 10 rivers studied. Also shown are estimates of canoe traffic.

The four more popular canoeing streams are 60 to 90 feet wide, 2.0 to 4.0 feet deep, and have average velocities of 1 to 2 feet per second (0.7 to 1.4 miles per hour). All four are characterized by riffles, but only the Bois Brule has difficult rapids. All have good access and launch sites, good rental and pickup service, and are free of obstructions that require portaging. Four of the 10 streams are rated unsafe for the novice canoeist. Only one of these, the Bois Brule, carries heavy canoe traffic. Most of the traffic on the Bois Brule is generally restricted to the river upstream from the Copper Range Campground. This reach has several minor rapids, but the more difficult rapids are farther downstream.

The Au Sable River of Michigan, the most popular for canoeing of the 10 rivers, has easy access, frequent launch and take-out ramps, and is safe for the novice canoeist. The river has no obstructions or shoals requiring portages. Several canoe liveries at Grayling provide rental canoes and pickup service for trips ranging from a few hours to several days. Although the average velocity of the Au Sable is probably not more than 1 mile per hour, most canoeists believe it flows much faster than that.

Table 4.--Hydrologic conditions and boating on cold-water rivers.

River	Location	Width (ft)1/	Depth (ft)1/	Average Velocity ft/sec 1/	Variation in stage (ft)2/	Flow Pattern 3/	Shoals 4/	Other obstructions	Safety 5/	Cabins	Access	Launch sites	Rental & pick up	Number canoes season	Number people in canoes
Bois Brule Wisconsin	Stones River Bridge to U.S. Highway 2	60	2.0	2.0	2	Sl,Ri,Ra	None	None	Exp.	Few	Easy	Some	Many	5,500	9,100
Pine Wisconsin	Sec.12, T.39 N., R.14 E. to Chipmunk Rapids Camp	80	2.0	1.5	3	Sl,Ri,Ra	Many	None	Exp.	Few	Limited	Few	None	100	200
Pere Marquette Michigan	State Highway 37 to Scottville	90	4.0	1.5	3	Ri	None	None	Safe	Some	Easy	Many	Many	2,900	6,200
Manistee Michigan	State Highway 72 to Campground at "CCC" Bridge	80	4.0	1.5	1	Ri	None	None	Safe	Some	Limited	Some	Many	4,500	11,800
Sturgeon Michigan	Wolverine to Indian River	50	3.0	2.0	1	Ri,Ra	None	Few	Exp.	Few	Limited	Many	Few	500	1,200
Pigeon Michigan	Pigeon Bridge Campground to State Highway 68	70	2.5	1.0	3	Ri	None	Some	Safe	Few	Easy	Some	None	100	200
Black Michigan	Main River Bridge to Tower Pond	60	2.5	1.0	3	Ri	Many	Many	Safe	Few	Limited	Some	None	50	100
Au Sable Michigan	Grayling to Stephan Bridge	90	2.5	1.0	1	Ri	None	None	Safe	Many	Easy	Many	Many	17,000	40,000
Rifle Michigan	Devoe Lake to Selkirk	50	2.5	1.0	2	Ri	Few	None	Safe	Few	Easy	Some	Some	700	1,500
West Branch Ausable New York	State Highway 73 to "Monument Falls"	80	3.0	2.5	5	Ri,Ra	Some	One	Exp.	Few	Limited	Few	Some	500	1,200

1/ Except in lakes and ponds

2/ Approximate average annual variation. Does not include effects of ice jams.

3/ Sl = Sluggish
Ri = Riffles
Ra = Rapids

4/ Too shallow to float through at low water

5/ Safe = Generally safe for novice
Exp. = For experienced canoeist

The Bois Brule River of Wisconsin, the second most popular canoe trail, is very different in character from the Au Sable. Even in the reach from Stones Bridge to U.S. Highway 2 at Brule, the Bois Brule has several rapids that are too difficult for safe passage by inexperienced canoeists. In the lower reaches of the river, rapids and waterfalls challenge even the expert. Canoeists have easy access to the Bois Brule at several launching sites, and rental and pickup service is available at the town of Brule. Most canoe trips on the Bois Brule are short. It takes only half a day to travel from Stones Bridge to U.S. Highway 2. This is the most canoed section of the river. Travel time from U.S. Highway 2 to Copper Range Campground is less than half a day. Canoe traffic downstream from Copper Range Campground is generally moderate to light. There are no shoals or obstructions that require portages between Stones Bridge and Copper Range Campground, but several portages around falls and rapids are required on the lower river.

Third highest in canoe traffic, the Manistee River is similar to the Au Sable in hydrologic characteristics, but it is not as close to major highways, and it does not have as frequent launch and take-out sites. The Manistee is somewhat wilder than the Au Sable, with fewer cabins and other evidence of man.

The Pere Marquette is similar to the Au Sable and Manistee in character except that it has one stretch of fast water--Rainbow Rapids--that may sometimes damage canoes manned by inexperienced canoeists.

The Rifle is a small easily canoed stream above Selkirk. It was not heavily canoed in 1971, but a substantial increase is anticipated for 1972. Proposed regulations on canoeing on the Au Sable caused some youth groups to make reservations on other streams. The Rifle River, because of its proximity to populated areas, apparently was selected as second choice by many of these groups.

The remaining rivers are not so popular in terms of numbers of participants, but the relatively few canoeists using these trails may enjoy a very different kind of canoeing experience, with relative solitude an essential ingredient to their enjoyment. The Pine River of Wisconsin and the Pigeon and Black Rivers of Michigan provide this kind of canoeing experience. The frequent shoals and obstructions on these rivers limit the canoeists to those few who feel that the peace and quiet they enjoy is more than adequate compensation for the work involved. The Pine also offers the additional appeal of challenging white-water rapids.

The Sturgeon River is too close to major highways to provide the solitude that is characteristic of the Pine, Pigeon, and Black. However, the river is a narrow fast-water stream that offers some challenge to experienced canoeists.

Much of New York's West Branch Ausable is not canoeable because of torrential rapids and waterfalls. The section along Riverside Drive, from State Highway 73 to Monument Falls, is used for holiday canoe and kayak-racing events (Pfieffer, 1971). Except for these races, however, few canoeists float any part of the West Branch.

CAMPING

Camping on the banks of cold-water rivers is a fast-growing recreational use. Hydrologic factors that influence the esthetic attraction of a stream are probably important to all campers. Hydrologic factors directly involved in the convenience and comfort of campers are height and composition of river banks and type and density of bank vegetation. Most campers apparently prefer river banks that are low and sandy to those that are high and rocky or clayey, and most prefer a forest cover of mixed hardwoods and pines to one of hardwood or coniferous forests. Observations at several campgrounds during periods when more than half the available spaces were unoccupied showed that preferred sites are those that are open enough to permit grass to grow. Listed in table 5 are most of the hydrologic factors that influence camping on the 10 rivers studied and estimates of campground attendance on these streams.

The greatest number of campers and camper days for one campground were recorded at the Wilmington Notch Campgrounds on the West Branch Ausable near Lake Placid. This campground also logged the third largest number of camper days per camp space. The striking scenery of mountains, falls, and rapids, the good trout fishing, and the nearness to large population centers of the East combine to make this one of the most popular campgrounds of the study. According to Mr. Frank Dudley, Campground Supervisor (oral commun., 1971), at least half the campers of this campground are fishermen.

The Manistee Bridge Campground on the Manistee River near Grayling had the second highest attendance for a single campground and the fourth largest number of camper days per space. Although the scenery is not spectacular, this is an attractive campground, with sandy banks, mature pines, and a clear shallow stream with a gravel bottom. No record has been made of the number of campers who fish the Manistee, but observation of the campground over a period of 10 years suggests that much less than half, probably not more than a tenth, of the campers fish the river. About 10 percent of the campers are boaters; the remainder are interested chiefly in the camping experience in an attractive north-woods atmosphere. Two campgrounds, Manistee No. 1 and 2, upstream from the Manistee Bridge Campground, had the largest and second-largest number of camper days per space. These campgrounds are similar to the Manistee Bridge Campground in attractiveness, but the river bottoms are sand, and most of the campers are fishermen. A fourth campground, the CCC Bridge Campground, downstream from Manistee Bridge, is used chiefly by canoers and fishermen. Although remote

Table 5.--Hydrologic conditions and camping on cold-water rivers.

River	Campground	Width (feet)	Depth (feet)	Bottom material	Flow pattern	Appearance	Bank cover	Bank height (ft)	Bank material	Open river view	Miles from paved road	Number spaces	Facilities 1/	Estimated campground use 1970		Est. base 2/	Camper days per space
														Number Campers	Camper days 5/		
Bois Brule Wisconsin	Bois Brule	70	2	Gravel	Riffle	Clear to cloudy	Hardwood	3	Sand	No	0	20	Wa, To	--	6,072	R	304
	Copper Range	60	4	do	do	do	do	3	do	No	1.0	17	Wa, To	--	2,380	R	140
Pine Wisconsin	Chipmunk Rapids	100	3	Boulders	Rapids	Clear to cloudy	do	3	Gravel	Yes	4.0	6	Wa, To	700	2,000	S	333
Manistee Michigan	Manistee No. 1	50	3	Sand	Riffle	Clear	Conifer	5-6	Sand	Yes	2.0	8	Wa, To	1,700	6,400	R	800
do	Manistee No. 2	50	3	do	do	do	do	5-6	do	Yes	2.0	8	Wa, To	1,800	6,090	R	761
do	Manistee Bridge	80	3	Gravel	do	do	do	10-12	do	Yes	0	24	Wa, To	6,000	15,580	R	649
do	CCC Bridge	120	5	Sand	Glide	do	Hardwood	10-15	do	Yes	11.0	21	Wa, To	5,250	10,865	R	517
Sturgeon Michigan	Old Orchard	60	3	Gravel boulders	Riffle	do	Grass Hardwood	--	--	--	--	--	To	1,000	2,000	S	--
Pigeon Michigan	Pigeon Bridge	40	2	Gravel	do	Clear	Mixed	3-5	Sand	No	2.5	7	Wa, To	900	2,125	R	304
do	Pigeon River	40	2	do	do	do	Hardwood	3-5	do	No	5.5	22	Wa, To	1,325	6,245	R	284
do	Pine Grove	50	3	Sand	Glide	do	Mixed	3-5	do	No	12.0	8	Wa, To	500	1,495	R	187
Au Sable Michigan	Canoe Camp	100	4	do	do	Clear	Hardwood	3	Sand	Yes	2.0	18	Wa, To	2,450	6,780	R	377
do	Burton's Landing	100	2.5	Gravel	Riffle	do	Mixed	3-5	do	Yes	0.5	3/	To	--	5,140 4/	S	--
do	High Banks	100	2.5	do	do	do	do	3-20	do	Yes	0.7	3/	To	--	6,080 4/	S	--
do	White Pine	150	4	Sand	Glide	do	do	3-6	do	Yes	3.0	25	Wa, To	3,030	5,230	R	209
Rifle Michigan	Rifle River	50	2.5	Gravel	Riffle	Clear	Hardwood & grass	3-5	Sand	Yes	5.0	3/	Wa, To	1,670	4,520	R	--
West Branch Ausable New York	Wilmington Notch	80	4	Boulders	Falls Rapids	Clear to cloudy	Mixed	20-80	Bldrs. sand	No	0	55	Wa, To, Ba	13,376	35,792	R	651

1/ Facilities, Wa = Water, To = Toilets, Ba = Baths 2/ Estimates based on: R = Registration, S = Spot sampling 3/ No designated spaces 4/ Figures are for 1971
5/ Camper days = Number of campers times number of days in camp.

from paved roads, this campground is an important overnight stop for canoeists. Here the Manistee is deep and wide and is not really safe for families with small children. All campgrounds on the Manistee permit an open view of the river from the camp sites. The total campground attendance at the four campgrounds on the upper Manistee (above Sharon) was 38,935 camper days in 1970.

Total camper days at the four campgrounds on Michigan's Au Sable River in 1970 was about 23,000. The figures are not entirely compatible because estimates on two of the campgrounds were made in 1971 instead of 1970. The Canoe Camp and White Pine Campgrounds are used chiefly by canoers; whereas, the Burton's Landing and High Banks Campgrounds are used chiefly by fishermen. The Au Sable River at the Canoe Camp and White Pine Campground has a sand bottom, is about 4 feet deep, and is used for swimming. At Burton's Landing and High Banks, the river bottom is gravel, and the river is generally too shallow for swimming. All the Au Sable River campgrounds permit an open view of the river from the camp sites.

The three campgrounds on Michigan's Pigeon River accomodated 9,865 camper days in 1970. The Pigeon is a relatively narrow and shallow river, with a sand or gravel bottom at each of these sites. Banks are low and sandy, and bank cover is mixed or hardwood forest. Attendance at these campgrounds is probably limited chiefly by the number of spaces available and the distance from major roads. Probably about half the campers do some fishing, but the quiet and natural beauty of the area seem to be the major attractions.

Two campgrounds on the Bois Brule of Wisconsin accounted for 8,452 camper days in 1970. The Bois Brule is a fast-flowing gravel-bottom river at both camp sites. The Bois Brule is a clear-water stream at low flow but becomes cloudy and colored after heavy rains. Probably more than half the campers at these sites are fishermen or canoers. Other campgrounds on the Bois Brule that do not have road access are intended for canoers only. No records of attendance are maintained at these canoe camps.

At the Rifle River Campground, only 4,520 camper days were recorded in 1970, but in the following year 22,500 camper days were recorded. The great increase in camper days in 1971 was chiefly the result of longer stays for camper parties. The number of campers increased only moderately. The Rifle River Campground is on both sides of a shallow narrow river having a gravel bottom. Banks are sandy and are covered with hardwoods and open grasslands.

About 2,000 camper days were estimated for Old Orchard Campground on Michigan's Sturgeon River in 1970. Most camp use was in the spring during steelhead runs. The Sturgeon River is a fast-flowing stream here and not easy to wade. Banks are high, sandy, and mostly open grassland with scattered hardwood trees.

Chipmunk Rapids Campground is the only developed campground on Wisconsin's Pine River. Campground attendance at Chipmunk Rapids is estimated to be about the same as on the Sturgeon--2,000 camper days. At this campground, the Pine is a fast-flowing river about 100 feet wide and 3 feet deep, with a gravel and boulder bottom.

In summary, camping opportunity depends largely on the character of the river banks--the height and composition of the banks and the kind and density of bank vegetation. Most campers apparently prefer river banks 3 to 5 feet high, with an open stand of mixed hardwoods and conifers. Camping activity depends chiefly on the esthetic appeal of the camp site and on the availability and accessibility of developed campgrounds. Some campgrounds are so located that they are natural stopovers for canoe camping trips. However, almost all campgrounds having good road access seem to accomodate more car campers than canoe campers at all seasons. Nonhydrologic factors that influence camping activity are distance from population centers, accessibility by good roads, number of camping spaces available, and campground facilities.

FISHING

Cold-water rivers are probably best known as trout streams, for trout cannot survive in streams having consistently high summer water temperatures. Because trout populations are a measurable parameter, the relationship of hydrologic characteristics to trout populations can be studied by statistical analyses. Such a study was a major part of the present investigation. We do not suggest, however, that trout populations, in themselves, are the only important factor in the recreational value of fishing. The satisfaction of the trout fisherman depends on his enjoyment of the esthetic appeal of the stream, the challenge to his fishing skills, his convenience, his safety, as well as his success in taking fish. Nevertheless, there can be no trout fishing without trout, so we will first consider the influence of hydrologic parameters on trout populations.

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. Because trout populations are perhaps the one recreational aspect of cold-water rivers least affected by man's bias in choice of river use, greater effort was extended toward evaluating the relationships between populations and hydrology than that for other recreational uses. To obtain a sample large enough to be statistically significant, data were obtained from 50 streams not included in the rest of the study.

To evaluate the relationships between hydrologic factors and trout populations, hydrologic data were determined for 112 stream segments in

Michigan and Wisconsin for which trout-population data were available. These included segments of seven of the 10 rivers selected for this study and 50 other trout streams in Wisconsin and Michigan (fig. 12). Eighty-eight of the segments were used to test for possible relationships. Selection of the 88 segments was based entirely on accuracy and completeness of hydrologic data. For those streams on which data were available for many segments, some segments, generally alternate segments, were omitted from the analysis to avoid overemphasis of any particular stream. The analyses provided a basis for evaluating various combinations of trout population and hydrologic parameters as well as the relative importance of each hydrologic parameter on the populations. The selected parameters are described in the following section.

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. Most data on channel character were obtained by field mapping during the summer of 1971. Data on streamflow were obtained from records for stream gaging stations operated by the Geological Survey and from discharge measurements that were available or were made at the time of channel mapping. Data on water quality were obtained from records of State agencies, the Geological Survey, and from field analyses made at each stream segment.

Physiographic Data and Channel Character.--Each stream segment was surveyed to determine its average width, depth, and surface area; the type of bed materials, as percentages of gravel, sand, or muck; and the percentage of the stream bottom that had submerged vegetation. Also determined were the average bank height, bank material, and bank vegetation--as percentage of hardwoods, conifers, brush, or grass. Finally, the percentage of the stream bottom that would afford cover for trout, such as undercut banks, logs, boulders, and overhanging brush, was visually estimated. The summaries of these data for each stream segment are shown in tables 6 and 7.

Average gradients of stream segments 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 be higher or lower than the value so obtained.

Streamflow Character.--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 8). 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 for 10 and 90 percent of the time.

EXPLANATION

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Map numbers indicated on tables 6 to 10

Figure 12.--Locations of stream segments used in relating trout populations to hydrologic parameters.

Table 6.--Summary of physiographic data on streams.

Map 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)
	MICHIGAN (UPPER PENINSULA)								
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 6.--Summary of physiographic data on streams--continued.

Map 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)
	WISCONSIN								
29	Allen Creek tributary	NW¼ NW¼ sec.7, T.40 N., R.14 E.	600	.12	9	.4	22.5	--	--
30	West Branch Allen Creek	NW¼ NW¼ sec.5, T.40 N., R.14 E.	600	.10	7	.9	7.8	--	--
31	Woods Creek	NE¼ SE¼ sec.29 T.39 N., R.17 E.	1,500	1.2	35	1.2	29.1	--	--
32	North Branch Pike River	NW¼ sec.33, T.37 N., R.18 E.	2,040	1.5	36	1.7	21.1	--	--
33	do	Sec.33, T.36 N., R.20 E.	1,600	1.9	53	2.4	22.1	--	--
34	South Branch Pike River	SE¼ NE¼ sec.28, T.36 N., R.18 E.	2,000	1.1	23	1.8	12.8	--	--
35	do	SW¼ NE¼ sec.13, T.35 N., R.19 E.	1,200	1.1	40	2.4	16.7	--	--
36	Little South Branch Pike River	Sec.16, T.35 N., R.19 E.	1,000	.3	15	2.0	7.5	--	--
37	Mecan River	Secs.16, 21, T.18 N., R.9 E.	5,200	2.5	21	1.9	11.0	--	14
38	Lawrence Creek	Sec.36, T.17 N., R.7 E.	5,630	3.81	23	.8	28.7	--	16
39	do	Sec.31, T.17 N., R.8 E.	4,525	3.15	24	.8	30.0	--	16
40	Trout Creek	Sec.30, SW¼ sec.19, T.7 N., R.5 E.	7,390	2.5	15	1.9	7.9	--	25
41	do	NW¼ sec.30, T.7 N., R.5 E.	2,850	.9	12	1.7	--	--	--
42	do	SW¼ sec.19, T.7 N., R.5 E.	2,480	.8	14	1.7	8.2	--	17
43	do	Sec.19, T.7 N., R.5 E., sec.24, T.7 N., R.4 E.	9,240	3.0	14	1.7	--	--	--
44	do	SW¼ sec.13, NW¼ sec. 24, T.7 N., R.4 E.	5,200	1.6	13	1.5	8.1	--	10
	MICHIGAN (SOUTHERN PENINSULA)								
45	Little South Branch Pere Marquette River	SW¼ sec.31, T.17 N., R.12 W.	1,100	.88	35	2.4	15	2.11	5.7
46	do	SW¼ sec.26 T.17 N., R.13 W.	1,000	.80	35	2.4	15	1.92	5.4
47	do	NE¼ sec.22, T.17 N., R.13 W.	1,000	.78	34	2.2	15	1.72	5.5
48	Pere Marquette River	SE¼ sec.16, T.17 N., R.13 W.	2,460	3.05	54	1.9	28	5.80	6.7
49	Big Sable River	NE¼ sec.22, T.20 N., R.16 W.	300	.28	41	2.4	17	.67	7.1
50	Manistee River	NW¼ sec.30, T.28 N., R.4 W.	750	.88	51	3.3	15	2.90	4.8
51	do	SW¼ sec.31, T.28 N., R.4 W.	900	1.47	71	2.8	25	4.12	4.8
52	Pine River	NE¼ sec.3, T.19 N., R.11 W.	600	.69	50	2.1	24	1.45	11
53	do	SE¼ sec.13, T.20 N., R.12 W.	1,760	2.22	55	2.7	20	5.99	8.2
54	Poplar Creek	Sec.36, T.21 N., R. 12 W.	5,280	1.94	16	1.7	9.4	3.30	50
55	Silver Creek	SW¼ sec.18, T.20 N., R.11 W.	2,640	.61	10	1.0	10	.61	100

Table 6.--Summary of physiographic data on streams--continued.

Map 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)
	MICHIGAN (SOUTHERN PENINSULA)								
56	Little Manistee River	SE¼ sec.24, T.20 N., R.14 W.	400	.32	35	2.2	16	.70	6.9
57	do	NE¼ sec.16, T.20 N., R.14 W.	200	.17	38	3.2	12	.54	5.9
58	do	NW¼ sec.7, T.20 N., R.14 W.	200	.23	50	3.7	14	.85	5.6
59	North Branch Boardman River	SW¼ sec.35, T.27 N., R.9 W.	200	.18	40	2.6	15	.47	10
60	South Branch Boardman River	SW¼ sec.3, T.26 N., R.9 W.	200	.16	34	3.0	11	.48	19
61	Boardman River	SE¼ sec.4, T.26 N., R.9 W.	1,200	1.05	39	2.1	19	2.20	12
62	do	SE¼ sec.7, T.26 N., R.9 W.	1,000	1.12	49	1.9	26	2.13	8.7
63	do	NE¼ sec.13, T.26 N., R.10 W.	1,000	1.10	48	1.9	25	2.09	7.0
64	Betsie River	NE¼ sec.25, T.25 N., R.14 W.	650	.67	45	2.5	18	1.68	3.0
65	Little Betsie River	SW¼ sec.30, T.25 N., R.13 W.	840	.33	17	1.1	15	.36	7.1
66	Platte River	NW¼ sec.4, T.26 N., R.13 W.	1,500	1.38	40	1.5	27	2.07	25
67	do	SE¼ sec.12, T.26 N., R.14 W.	870	.80	40	2.4	17	1.92	14
68	do	SW¼ sec.15, T.26 N., R.14 W.	1,410	2.20	68	1.8	38	3.96	13
69	Sturgeon River	NE¼ sec.23, T.31 N., R.3 W.	155	.13	37	1.2	31	.16	20
70	do	SE¼ sec.31, T.32 N., R.2 W.	350	.21	26	2.3	11	.48	12
71	do	SE¼ sec.21, T.32 N., R.2 W.	965	.93	42	2.1	20	1.95	7.8
72	do	SW¼ sec.28, T.33 N., R.2 W.	740	.76	45	1.3	35	.99	22
73	do	NW¼ sec.7, T.33 N., R.2 W.	400	.35	38	1.9	20	.66	12
74	West Branch Sturgeon River	NW¼ sec.14, T.33 N., R.3 W.	400	.30	33	1.6	21	.48	13
75	do	NW¼ sec.7, T.33 N., R.2 W.	670	.49	32	1.5	21	.74	17
76	Sturgeon River	SW¼ sec.31, T.34 N., R.2 W.	250	.31	54	2.2	25	.68	12
77	do	NW¼ sec.13, T.34 N., R.3 W.	400	.49	53	2.2	24	1.08	13
78	do	NW¼ sec.1, T.34 N., R.3 W.	300	.37	53	2.8	19	1.04	13
79	Pigeon River	SW¼ sec.25, T.32 N., R.2 W.	300	.23	34	1.7	20	.39	7.4
80	do	SE¼ sec.19, T.32 N., R.1 W.	700	.61	38	1.7	22	1.04	8.5
81	do	SW¼ sec.17, T.32 N., R.1 W.	800	.73	40	2.0	20	1.46	8.5
82	do	SW¼ sec.9, T.32 N., R.1 W.	1,000	.76	33	2.3	14	1.75	11
83	do	SW¼ sec.10, T.32 N., R.1 W.	1,000	.90	39	2.1	19	1.89	9.1
84	do	NE¼ sec.28, T.33 N., R.1 W.	1,000	.92	40	1.8	22	1.66	6.9
85	do	NW¼ sec.8, T.33 N., R.1 W.	1,000	1.12	49	1.6	31	1.79	12

Table 6.--Summary of physiographic data on streams--continued.

Map 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)
	MICHIGAN (SOUTHERN PENINSULA)								
86	Little Pigeon River	SW¼ sec.1, T.33 N., R.2 W.	200	.12	26	1.5	17	.18	33
87	Pigeon River	NE¼ sec.24, T.34 N. R.2 W.	1,400	1.51	47	2.2	21	3.32	9.5
88	do	NE¼ sec.2, T.34 N., R.2 W.	1,500	1.58	46	1.4	33	2.21	20
89	Black River	NW¼ sec.35, T.32 N., R.1 W.	600	.48	35	1.2	29	.58	8.7
90	do	SE¼ sec.26, T.32 N., R.1 W.	450	.38	37	1.4	26	.53	8.7
91	do	NW¼ sec.21, T.32 N., R.1 E.	675	.56	36	1.6	22	.90	9.5
92	East Branch AuSable River	SW¼ sec.30, T.29 N., R.2 W.	600	.44	32	2.3	14	1.01	3.9
93	do	SE¼ sec.2, T.27 N., R.3 W.	370	.20	24	2.3	10	.46	3.9
94	do	SE¼ sec.29, T.27 N., R.3 W.	600	.34	25	1.8	14	.61	7.4
95	AuSable River	NE¼ sec.10, T.26 N., R.3 W.	800	1.93	105	3.9	27	7.53	3.2
96	do	NE¼ sec.12, T.26 N., R.3 W.	773	1.72	97	2.7	36	4.64	6.1
97	do	NW¼ sec.5, T.26 N., R.2 W.	700	1.56	97	2.4	40	3.74	7.7
98	South Branch AuSable River	SE¼ sec.21, T.25 N., R.2 W.	900	1.57	76	2.2	35	3.45	2.4
99	do	SE¼ sec.29, T.26 N., R.1 W.	900	1.84	89	2.2	40	4.05	5.1
100	North Branch AuSable River	NE¼ sec.21, T.29 N., R.2 W.	--	--	85	1.3	65	--	5.9
101	do	SW¼ sec.22, T.29 N., R.2 W.	1,500	3.09	90	1.0	90	3.09	5.9
102	do	SE¼ sec.1, T.28 N., R.2 W.	1,100	2.06	82	2.2	37	4.53	5.6
103	do	NE¼ sec.13, T.28 N., R.2 W.	1,200	3.34	125	1.7	74	5.68	7.0
104	do	SE¼ sec.5, T.27 N., R.1 W.	1,200	3.34	125	2.0	62	6.68	10
105	East Branch AuGres River	NE¼ sec.33, T.22 N., R.6 E.	1,080	.92	37	1.7	22	1.56	10
106	Gamble Creek	Sec.2, T.23 N., R.3 E.	4,010	2.30	25	1.3	19	2.99	10
107	Houghton Creek	NE¼ sec.31, T.24 N., R.3 E.	3,325	1.37	18	1.0	18	1.37	3.5
108	do	Secs.5, 8, T.23 N., R.3 E.	2,130	1.12	23	1.9	12	2.13	20
109	do	Sec.4, T.23 N., R.3 E.	1,580	1.12	31	2.8	11	3.14	7.1
110	Rifle River	Sec.11, T.23 N., R R.3 E.	2,840	3.06	47	1.7	28	5.20	5.9
111	do	Secs.11, 14, T.23 N., R.3 E.	11,750	12.95	48	2.6	18	33.67	3.1
112	do	Secs.14, 22, 23, T. 23 N., R.3 E.	9,300	10.25	48	2.4	20	24.60	3.1

Table 7.--Summary of data on channel characteristics.

Map number	Stream name	Stream segment Location	Channel character								Bank vegetation			
			Bed materials											
			Gravel (percent)	Sand (percent)	Muck (percent)	Other (percent)	Bottom vegetation (percent	Fish cover (percent)	Average bank height (feet)	Predominant bank material	Hardwood (percent)	Conifer (percent)	Brush (percent)	Grass (percent)
	MICHIGAN (UPPER PENINSULA)													
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 River	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

Table 7.--Summary of data on channel characteristics--continued.

Map number	Stream name	Stream segment: Location	Bed materials: Gravel (percent)	Bed materials: Sand (percent)	Bed materials: Muck (percent)	Bed materials: Other (percent)	Channel character: Bottom vegetation (percent	Channel character: Fish cover (percent)	Channel character: Average bank height (feet)	Channel character: Predominant bank material	Bank vegetation: Hardwood (percent)	Bank vegetation: Conifer (percent)	Bank vegetation: Brush (percent)	Bank vegetation: Grass (percent)
	WISCONSIN													
29	Allen Creek tributary	NW¼ NW¼ sec.7, T.40 N., R.14 E.	65	25	10	--	20	9	1	do	2	4	84	--
30	West Branch Allen Creek	NW¼ NW¼ sec.5, T.40 N., R.14 E.	46	37	17	--	9	36	1	do	--	--	90	10
31	Woods Creek	NE¼ SE¼ sec.29 T.39 N., R.17 E.	80	13	6	--	7	31	2	do	60	10	30	--
32	North Branch Pike River	NW¼ sec.33, T.37 N., R.18 E.	65	31	4	--	5	18	4	sand	40	10	50	--
33	do	Sec.33, T.36 N., R.20 E.	8	79	9	4	7	15	3	do	60	--	40	--
34	South Branch Pike River	SE¼ NE¼ sec.28, T.36 N., R.18 E.	22	58	20	--	28	13	3	do	20	3	30	47
35	do	SW¼ NE¼ sec.13, T.35 N., R.19 E.	36	56	5	3	1	25	5	do	75	6	14	5
36	Little South Branch Pike River	Sec.16, T.35 N., R.19 E.	4	65	31	--	48	25	2	muck	11	8	81	1
37	Mecan River	Secs.16, 21, T.18 N., R.9 E.	56	36	8	--	4	10	2	sand	35	--	60	5
38	Lawrence Creek	Sec.36, T.17 N., R.7 E.	5	49	47	--	35	25	1.5	muck	--	--	10	90
39	do	Sec.31, T.17 N., R.8 E.	12	51	37	--	35	6	20	silt	45	--	10	45
40	Trout Creek	Sec.30, SW¼ sec.19, T.7 N., R.5 E.	33	12	54	1	41	11	4	do	--	--	95	5
41	do	NW¼ sec.30, T.7 N., R.5 E.	18	34	48	--	23	7	4	do	--	--	95	5
42	do	SW¼ sec.19, T.7 N., R.5 E.	29	26	37	8	11	9	4	do	45	--	50	5
43	do	Sec.19, T.7 N., R.5 E., sec.24, T.7 N., R.4 E.	19	47	32	2	7	12	4	do	--	--	95	5
44	do	SW¼ sec.13, NW¼ sec. 24, T.7 N. R.4 E.	1	71	15	13	7	13	4	do	35	--	60	5
	MICHIGAN (SOUTHERN PENINSULA)													
45	Little South Branch Pere Marquette River	SW¼ sec.31, T.17 N., R.12 W.	57	29	14	0	8	18	8	muck	40	15	45	0
46	do	SW¼ sec.26 T.17 N., R.13 W.	42	43	6	9	2	2	5	sand	35	15	50	--
47	do	NE¼ sec.22, T.17 N., R.13 W.	80	17	3	0	0	8	4	do	40	10	50	--
48	Pere Marquette River	SE¼ sec.16, T.17 N., R.13 W.	72	23	5	0	11	9	5	do	40	15	50	--
49	Big Sable River	NE¼ sec.22, T.20 N., R.16 W.	65	22	9	4	7	10	6	sand	49	8	38	5
50	Manistee River	NW¼ sec.30, T.28 N., R.4 W.	11	78	11	0	14	17	1	muck	0	10	53	37
51	do	SW¼ sec.31, T.28 N., R.4 W.	4	81	15	0	14	20	17	sand	4	36	3	57
52	Pine River	NE¼ sec.3, T.19 N., R.11 W.	74	24	2	0	36	8	6	do	40	--	60	--
53	do	SE¼ sec.13, T.20 N., R.12 W.	63	26	1	10	24	9	16	do	40	20	40	--
54	Poplar Creek	Sec.36, T.21 N., R. 12 W.	26	50	1	23	1	31	15	muck	45	15	40	--
55	Silver Creek	SW¼ sec.18, T.20 N., R.11 W.	31	53	9	7	0	17	15	sand	50	40	10	--

Table 7.--Summary of data on channel characteristics--continued.

Map number	Stream name	Stream segment: Location	Channel character: Bed materials: Gravel (percent)	Sand (percent)	Muck (percent)	Other (percent)	Bottom vegetation (percent	Fish cover (percent)	Average bank height (feet)	Predominant bank material	Bank vegetation: Hardwood (percent)	Conifer (percent)	Brush (percent)	Grass (percent)
	MICHIGAN (SOUTHERN PENINSULA)													
56	Little Manistee River	SE¼ sec.24, T.20 N., R.14 W.	40	52	0	8	6	19	4	do	59	1	40	--
57	do	NE¼ sec.16, T.20 N., R.14 W.	3	87	9	1	9	15	2	muck	18	--	62	20
58	do	NW¼ sec.7, T.20 N., R.14 W.	9	77	14	0	12	21	2	sand	30	20	50	--
59	North Branch Boardman River	SW¼ sec.35, T.27 N., R.9 W.	51	40	9	0	3	10	4	sand	35	35	30	--
60	South Branch Boardman River	SW¼ sec.3, T.26 N., R.9 W.	57	33	10	0	22	18	2	muck	30	--	50	20
61	Boardman River	SE¼ sec.4, T.26 N., R.9 W.	65	31	4	0	3	19	4	sand	19	51	30	--
62	do	SE¼ sec.7, T.26 N., R.9 W.	62	30	8	0	20	17	1	do	7	12	80	1
63	do	NE¼ sec.13, T.26 N., R.10 W.	76	17	6	1	4	9	1	do	9	37	53	1
64	Betsie River	NE¼ sec.25, T.25 N., R.14 W.	19	69	12	0	4	16	6	do	58	2	25	15
65	Little Betsie River	SW¼ sec.30, T.25 N., R.13 W.	43	40	17	0	2	16	3	do	45	--	55	--
66	Platte River	NW¼ sec.4, T.26 N., R.13 W.	73	23	4	0	5	17	4	do	35	35	30	--
67	do	SE¼ sec.12, T.26 N., R.14 W.	72	21	7	0	13	19	2	muck	10	40	48	2
68	do	SW¼ sec.15, T.26 N., R.14 W.	72	16	12	0	32	16	2	do	25	40	30	5
69	Sturgeon River	NE¼ sec.23, T.31 N., R.3 W.	3	91	6	0	8	15	2	muck	7	64	11	18
70	do	SE¼ sec.31, T.32 N., R.2 W.	8	80	12	0	1	11	3	do	0	73	7	20
71	do	SE¼ sec.21, T.32 N., R.2 W.	0	78	22	0	16	7	2	do	2	52	37	9
72	do	SW¼ sec.28, T.33 N., R.2 W.	43	6	4	45	1	2	3	do	19	10	7	64
73	do	NW¼ sec.7, T.33 N., R.2 W.	81	13	6	0	0	4	3	do	13	1	86	0
74	West Branch Sturgeon River	NW¼ sec.14, T.33 N., R.3 W.	80	10	8	2	1	7	4	do	6	50	17	27
75	do	NW¼ sec.7, T.33 N., R.2 W.	92	6	2	0	1	3	3	do	14	23	12	51
76	Sturgeon River	SW¼ sec.31, T.34 N., R.2 W.	79	9	11	1	4	4	3	muck	63	0	37	0
77	do	NW¼ sec.13, T.34 N., R.3 W.	49	9	5	37	0	9	21	do	22	62	13	3
78	do	NW¼ sec.1, T.34 N., R.3 W.	68	30	2	0	1	6	4	do	20	28	44	8
79	Pigeon River	SW¼ sec.25, T.32 N., R.2 W.	71	12	17	0	0	11	4	do	13	13	57	17
80	do	SE¼ sec.19, T.32 N., R.1 W.	72	21	7	0	1	6	10	do	17	10	66	7
81	do	SW¼ sec.17, T.32 N., R.1 W.	84	10	6	0	2	6	3	do	17	34	49	0
82	do	SW¼ sec.9, T.32 N., R.1 W.	74	18	8	0	2	8	3	do	32	1	67	0
83	do	SW¼ sec.10, T.32 N., R.1 W.	67	18	15	0	0	8	4	do	34	1	65	0
84	do	NE¼ sec.28, T.33 N., R.1 W.	75	11	14	0	2	17	3	do	15	32	53	0
85	do	NW¼ sec.8, T.33 N., R.1 W.	72	23	5	0	1	5	6	do	32	41	27	0

Table 7.--Summary of data on channel characteristics--continued

Map number	Stream name	Stream segment	Channel character								Bank vegetation			
			Bed materials											
		Location	Gravel (percent)	Sand (percent)	Muck (percent)	Other (percent)	Bottom vegetation (percent	Fish cover (percent)	Average bank height (feet)	Predominant bank material	Hardwood (percent)	Conifer (percent)	Brush (percent)	Grass (percent)
	MICHIGAN (SOUTHERN PENINSULA)													
86	Little Pigeon River	SW¼ sec.1, T.33 N., R.2 W.	9	61	30	0	10	13	2	do	6	60	34	0
87	Pigeon River	NE¼ sec.24, T.34 N. R.2 W.	61	24	15	0	0	9	3	do	26	1	73	0
88	do	NE¼ sec.2, T.34 N., R.2 W.	86	9	3	2	0	4	4	do	22	13	58	7
89	Black River	NW¼ sec.35, T.32 N., R.1 W.	78	10	12	0	0	6	2	do	21	24	55	0
90	do	SE¼ sec.26, T.32 N., R.1 W.	56	13	31	0	3	10	2	do	6	1	93	0
91	do	NW¼ sec.21, T.32 N., R.1 E.	81	7	12	0	2	8	2	do	1	9	78	12
92	East Branch AuSable River	SW¼ sec.30, T.29 N., R.2 W.	19	30	51	0	41	10	2	do	35	20	40	5
93	do	SE¼ sec.2, T.27 N., R.3 W.	31	49	20	0	22	16	1	do	0	70	30	0
94	do	SE¼ sec.29, T.27 N., R.3 W.	73	16	11	0	11	16	2	do	30	20	45	5
95	AuSable River	NE¼ sec.10, T.26 N., R.3 W.	1	44	55	0	52	6	6	do	5	70	20	5
96	do	NE¼ sec.12, T.26 N., R.3 W.	60	25	15	0	29	10	3	do	15	70	15	--
97	do	NW¼ sec.5, T.26 N., R.2 W.	79	16	5	0	15	4	3	do	20	20	40	20
98	South Branch AuSable River	SE¼ sec.21, T.25 N., R.2 W.	75	19	6	0	4	5	3	do	45	10	40	5
99	do	SE¼ sec.29, T.26 N., R.1 W.	91	6	3	0	4	5	7	do	30	10	40	20
100	North Branch AuSable River	NE¼ sec.21, T.29 N., R.2 W.	93	1	6	0	5	5	3	do	50	1	48	1
101	do	SW¼ sec.22, T.29 N., R.2 W.	77	1	21	0	18	6	3	do	40	1	59	0
102	do	SE¼ sec.1, T.28 N., R.2 W.	56	35	9	0	20	5	4	do	45	5	45	5
103	do	NE¼ sec.13, T.28 N., R.2 W.	48	36	16	0	10	4	4	do	45	10	40	5
104	do	SE¼ sec.5, T.27 N., R.1 W.	75	13	12	0	14	4	4	do	30	15	35	20
105	East Branch AuGres River	NE¼ sec.33, T.22 N., R.6 E.	15	60	15	10	8	5	5	do	12	16	33	39
106	Gamble Creek	Sec.2, T.23 N., R.3 E.	37	46	17	0	2	14	2	do	5	53	41	1
107	Houghton Creek	NE¼ sec.31, T.24 N., R.3 E.	55	8	11	26	1	7	5	do	18	22	56	4
108	do	Secs.5, 8, T.23 N., R.3 E.	48	25	14	13	2	10	10	do	22	16	36	26
109	do	Sec.4, T.23 N., R.3 E.	10	51	30	9	8	8	3	do	15	9	24	52
110	Rifle River	Sec.11, T.23 N., R R.3 E.	15	45	40	0	4	8	2	do	19	38	35	8
111	do	Secs.11, 14, T.23 N., R.3 E.	16	66	18	0	6	6	2	do	33	9	43	15
112	do	Secs.14, 22, 23, T. 23 N., R.3 E.	21	62	17	0	3	5	2	do	46	3	47	4

Table 8.--Summary of data on streamflow characteristics

Map number	Stream name	Stream segment Location	Drainage area (square miles)	Mean discharge (cfs)	Mean discharge (cfsm)	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											
	MICHIGAN (UPPER PENINSULA)													
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 8.--Summary of data on streamflow characteristics--continued.

Map number	Stream name	Stream segment Location	Drainage area (square miles)	Mean discharge (cfs)	Mean discharge (cfsm)	Average 7-day minimum discharge (cfs)	Average 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											
	WISCONSIN													
29	Allen Creek tributary	NW¼ NW¼ sec.7, T.40 N., R.14 E.	3.5	3.0	.86	1.5	.43	5.0	1.43	1.6	.46	3.12	2.00	.42
30	West Branch Allen Creek	NW¼ NW¼ sec.5, T.40 N., R.14 E.	5.4	3.4	.63	1.7	.31	5.5	1.02	1.8	.33	3.06	2.00	.27
31	Woods Creek	NE¼ SE¼ sec.29 T.39 N., R.17 E.	42.3	30	.71	9.1	.22	65	1.54	11	.26	5.90	3.30	.22
32	North Branch Pike River	NW¼ sec.33, T.37 N., R.18 E.	37.2	45	1.20	18	.48	85	2.28	21	.56	4.05	2.50	.30
33	do	Sec.33, T.36 N., R.20 E.	129	135	1.05	50	.38	300	2.33	60	.46	5.00	2.70	.39
34	South Branch Pike River	SE¼ NE¼ sec.28, T.36 N., R.18 E.	52	40	.77	14	.27	90	1.73	16	.31	5.61	2.86	.34
35	do	SW¼ NE¼ sec.13, T.35 N., R.19 E.	85	60	.71	21	.25	130	1.53	25	.29	5.20	2.85	.22
36	Little South Branch Pike River	Sec.16, T.35 N., R.19 E.	10	12	1.20	4.1	.41	23	2.30	4.8	.48	4.80	2.93	.14
37	Mecan River	Secs.16, 21, T.18 N., R.9 E.	22.9	27	1.18	15	.65	40	1.75	16	.70	2.50	1.80	.37
38	Lawrence Creek	Sec.36, T.17 N., R.7 E.	7.8	10	1.28	9.5	1.22	11	1.41	9.5	1.22	1.16	1.06	.52
39	do	Sec.31, T.17 N., R.8 E.	8.3	13	1.57	12	1.45	15	1.81	12	1.45	1.25	1.08	.63
40	Trout Creek	Sec.30, SW¼ sec.19, T.7 N., R.5 E.	8.3	5.6	.68	3.2	.39	6.0	.72	3.2	.39	1.8	1.75	.11
41	do	NW¼ sec.30, T.7 N., R.5 E.	8.6	5.7	.66	3.3	--	6.0	--	3.3	--	--	--	--
42	do	SW¼ sec.19, T.7 N., R.5 E.	11.6	7.8	.67	4.4	.38	8.0	.69	4.5	.39	1.8	1.77	.19
43	do	Sec.19, T.7 N., R.5 E., sec.24, T.7 N., R.4 E.	12.9	8.7	.67	4.9	--	13	--	5.0	--	--	--	--
44	do	SW¼ sec.13, NW¼ sec. 24, T.7 N., R.4 E.	16.3	11	.67	6.2	.38	16	.98	6.3	.39	2.5	1.77	.32
	MICHIGAN (SOUTHERN PENINSULA)													
45	Little South Branch Pere Marquette River	SW¼ sec.31, T.17 N., R.12 W.	104	62	.60	39	.38	89	.86	41	.39	2.17	1.59	.46
46	do	SW¼ sec.26 T.17 N., R.13 W.	107	74	.69	46	.43	105	.98	49	.46	2.14	1.61	.55
47	do	NE¼ sec.22, T.17 N., R.13 W.	108	75	.69	46	.43	106	.98	49	.45	2.16	1.63	.61
48	Pere Marquette River	SE¼ sec.16, T.17 N., R.13 W.	165	155	.94	100	.61	225	1.36	105	.64	2.14	1.55	.97
49	Big Sable River	NE¼ sec.22, T.20 N., R.16 W.	114	120	1.05	80	.70	170	1.49	85	.75	2.00	1.50	.81
50	Manistee River	NW¼ sec.30, T.28 N., R.4 W.	64.3	100	1.56	88	1.37	115	1.79	90	1.40	1.28	1.14	.52
51	do	SW¼ sec.31, T.28 N., R.4 W.	71.4	115	1.61	97	1.36	130	1.82	100	1.40	1.30	1.19	.49
52	Pine River	NE¼ sec.3, T.19 N., R.11 W.	154	120	.78	77	.50	190	1.22	77	.50	2.47	1.56	.73
53	do	SE¼ sec.13, T.20 N., R.12 W.	198	185	.93	105	.53	290	1.46	115	.58	2.52	1.76	.71
54	Poplar Creek	Sec.36, T.21 N., R. 12 W.	15.1	15	.99	12	.79	19	1.26	12	.79	1.58	1.25	.44
55	Silver Creek	SW¼ sec.18, T.20 N., R.11 W.	4.94	4.7	.95	3.3	.67	6.5	1.32	3.5	.71	1.86	1.42	.33

Table 8. Summary of data on streamflow characteristics--continued.

Map number	Stream name	Stream segment: Location	Streamflow characteristics: Drainage area (square miles)	Mean discharge (cfs)	Mean discharge (cfsm)	Average 7-day minimum discharge (cfs)	Average 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
	MICHIGAN (SOUTHERN PENINSULA)													
56	Little Manistee River	SE¼ sec.24, T.20 N., R.14 W.	129	82	.64	63	.49	100	.78	65	.50	1.54	1.30	.82
57	do	NE¼ sec.16, T.20 N., R.14 W.	140	100	.71	78	.56	125	.89	80	.57	1.56	1.28	.64
58	do	NW¼ sec.7, T.20 N., R.14 W.	166	145	.87	100	.60	190	1.14	105	.63	1.81	1.45	.54
59	North Branch Boardman River	SW¼ sec.35, T.27 N., R.9 W.	73.3	62	.85	47	.64	85	1.16	48	.65	1.77	1.32	.45
60	South Branch Boardman River	SW¼ sec.3, T.26 N., R.9 W.	46.6	56	1.20	42	.90	76	1.63	42	.90	1.81	1.33	.41
61	Boardman River	SE¼ sec.4, T.26 N., R.9 W.	123	135	1.10	95	.77	180	1.46	100	.81	1.80	1.42	1.16
62	do	SE¼ sec.7, T.26 N., R.9 W.	128	140	1.09	100	.78	190	1.48	105	.82	1.81	1.40	1.07
63	do	NE¼ sec.13, T.26 N., R.10 W.	145	170	1.17	120	.83	230	1.59	125	.86	1.84	1.42	1.32
64	Betsie River	NE¼ sec.25, T.25 N., R.14 W.	95.4	76	.80	43	.45	115	1.21	48	.50	2.40	1.77	.38
65	Little Betsie River	SW¼ sec.30, T.25 N., R.13 W.	9.30	9.6	1.03	9.1	.98	11	1.18	9.2	.99	1.20	1.05	.49
66	Platte River	NW¼ sec.4, T.26 N., R.13 W.	66.2	44	.66	29	.44	60	.91	31	.47	1.94	1.52	.48
67	do	SE¼ sec.12, T.26 N., R.14 W.	91.9	77	.84	60	.65	92	1.00	63	.69	1.46	1.28	.62
68	do	SW¼ sec.15, T.26 N., R.14 W.	109	100	.92	74	.68	130	1.19	79	.72	1.65	1.35	.60
69	Sturgeon River	NE¼ sec.23, T.31 N., R.3 W.	7.51	26	3.46	18	2.40	34	4.53	19	2.53	1.79	1.44	.41
70	do	SE¼ sec.31, T.32 N., R.2 W.	29.1	41	1.41	29	1.00	54	1.86	31	1.07	1.74	1.41	.48
71	do	SE¼ sec.21, T.32 N., R.2 W.	40.2	48	1.19	34	.85	62	1.54	36	.90	1.72	1.41	.39
72	do	SW¼ sec.28, T.33 N., R.2 W.	75.9	96	1.26	67	.88	125	1.65	72	.95	1.74	1.43	1.15
73	do	NW¼ sec.7, T.33 N., R.2 W.	97.9	113	1.15	80	.82	150	1.53	86	.88	1.74	1.41	1.11
74	West Branch Sturgeon River	NW¼ sec.14, T.33 N., R.3 W.	86.0	68	.79	48	.56	89	1.03	50	.58	1.78	1.42	.91
75	do	NW¼ sec.7, T.33 N., R.2 W.	90	71	.79	50	.56	93	1.03	52	.58	1.79	1.42	1.04
76	Sturgeon River	SW¼ sec.31, T.34 N., R.2 W.	193	202	1.05	141	0.73	265	1.37	151	0.78	1.75	1.43	1.19
77	do	NW¼ sec.13, T.34 N., R.3 W.	201	210	1.04	145	.72	270	1.34	155	.77	1.74	1.45	1.24
78	do	NW¼ sec.1, T.34 N., R.3 W.	206	225	1.09	160	.78	290	1.41	170	.83	1.71	1.41	1.08
79	Pigeon River	SW¼ sec.25, T.32 N., R.2 W.	50.3	62	1.23	39	.78	87	1.73	43	.85	2.02	1.59	.67
80	do	SE¼ sec.19, T.32 N., R.1 W.	54.6	69	1.26	43	.79	95	1.74	49	.90	1.94	1.60	.67
81	do	SW¼ sec.17, T.32 N., R.1 W.	56.5	71	1.26	44	.78	100	1.77	50	.88	2.00	1.61	.55
82	do	SW¼ sec.9, T.32 N., R.1 W.	61.2	75	1.23	46	.75	104	1.70	52	.85	2.00	1.63	.61
83	do	SW¼ sec.10, T.32 N., R.1 W.	63.1	78	1.24	47	.74	110	1.74	53	.84	2.08	1.66	.57
84	do	NE¼ sec.28, T.33 N., R.1 W.	73.4	88	1.20	50	.68	120	1.63	57	.78	2.11	1.76	.69
85	do	NW¼ sec.8, T.33 N., R.1 W.	86.7	100	1.15	55	.63	140	1.61	61	.70	2.30	1.82	.70

Table 8.--Summary of data on streamflow characteristics--continued.

Map number	Stream name	Stream segment Location	Streamflow characteristics: Drainage area (square miles)	Mean discharge (cfs)	Mean discharge (cfsm)	Average 7-day minimum discharge (cfs)	Average 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
	MICHIGAN (SOUTHERN PENINSULA)													
86	Little Pigeon River	SW¼ sec.1, T.33 N., R.2 W.	22.3	21	.94	12	.54	29	1.30	14	.63	2.07	1.75	.31
87	Pigeon River	NE¼ sec.24, T.34 N. R.2 W.	128	135	1.05	70	.55	195	1.52	80	.62	2.44	1.93	.68
88	do	NE¼ sec.2, T.34 N., R.2 W.	136	141	1.04	72	.53	207	1.52	82	.60	2.52	1.96	1.12
89	Black River	NW¼ sec.35, T.32 N., R.1 W.	34.5	41	1.19	25	.72	57	1.65	28	.81	2.04	1.64	.60
90	do	SE¼ sec.26, T.32 N., R.1 W.	36.3	44	1.21	27	.74	61	1.68	30	.83	2.03	1.63	.52
91	do	NW¼ sec.21, T.32 N., R.1 E.	65.9	73	1.11	44	.67	100	1.52	50	.76	2.00	1.66	.76
92	East Branch AuSable River	SW¼ sec.30, T.29 N., R.2 W.	18.1	17	.94	15	.83	22	1.22	14	.77	1.57	1.13	.20
93	do	SE¼ sec.2, T.27 N., R.3 W.	25.8	23	.89	18	.70	29	1.12	19	.74	1.53	1.28	.33
94	do	SE¼ sec.29, T.27 N., R.3 W.	58.5	35	.60	24	.41	50	.85	23	.39	2.17	1.46	.53
95	AuSable River	NE¼ sec.10, T.26 N., R.3 W.	198	130	.66	85	.43	190	.96	85	.43	2.24	1.53	.21
96	do	NE¼ sec.12, T.26 N., R.3 W.	215	165	.77	110	.51	230	1.07	115	.53	2.00	1.50	.42
97	do	NW¼ sec.5, T.26 N., R.2 W.	224	175	.78	120	.54	250	1.12	128	.57	1.95	1.46	.52
98	South Branch AuSable River	SE¼ sec.21, T.25 N., R.2 W.	310	130	.42	66	.21	235	.76	73	.24	3.22	1.97	.39
99	do	SE¼ sec.29, T.26 N., R.1 W.	401	195	.49	102	.25	350	.87	110	.27	3.18	1.91	.52
100	North Branch AuSable River	NE¼ sec.21, T.29 N., R.2 W.	114	61	.54	45	.39	80	.70	47	.41	1.70	1.36	.41
101	do	SW¼ sec.22, T.29 N., R.2 W.	115	61	.53	45	.39	80	.70	47	.41	1.70	1.36	.50
102	do	SE¼ sec.1, T.28 N., R.2 W.	168	100	.60	85	.51	125	.74	90	.54	1.39	1.18	.47
103	do	NE¼ sec.13, T.28 N., R.2 W.	174	125	.72	100	.57	160	.92	100	.57	1.60	1.25	.47
104	do	SE¼ sec.5, T.27 N., R.1 W.	210	155	.74	125	.60	190	.90	125	.60	1.52	1.24	.50
105	East Branch AuGres River	NE¼ sec.33, T.22 N., R.6 E.	83	63	.76	31	.37	105	1.27	32	.39	3.28	2.03	.49
106	Gamble Creek	Sec.2, T.23 N., R.3 E.	14.1	23	1.63	15	1.06	31	2.20	16	1.13	1.94	1.53	.46
107	Houghton Creek	NE¼ sec.31, T.24 N., R.3 E.	11.6	12	1.03	7.6	.66	15	1.29	8.1	.70	1.85	1.58	.42
108	do	Secs.5, 8, T.23 N., R.3 E.	15.4	26	1.69	18	1.17	34	2.21	19	1.23	1.79	1.44	.41
109	do	Sec.4, T.23 N., R.3 E.	27.5	48	1.75	34	1.24	63	2.29	35	1.27	1.80	1.41	.39
110	Rifle River	Sec.11, T.23 N., R R.3 E.	26.4	38	1.44	24	.91	51	1.93	27	1.02	1.89	1.58	.30
111	do	Secs.11, 14, T.23 N., R.3 E.	62.1	98	1.58	60	.97	135	2.17	64	1.03	2.11	1.63	.48
112	do	Secs.14, 22, 23, T. 23 N., R.3 E.	71.0	110	1.55	60	.85	150	2.11	62	.87	2.42	1.83	.52

Characteristics of streamflow were determined from streamflow records at gaging stations or by correlating discharge measurements with records for gaging stations. Because most discharge measurements were made when streams were at base flow (streamflow consisting principally of ground-water runoff) estimates of low-flow parameters (median minimum 7-day and 90-percent duration) are more reliable than those of high flow (10 percent duration). Accuracy of streamflow parameters also varies with the number of streamflow measurements available and with the degree of correlation of the measurements with data 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 believed by the authors to be comparable between streams.

Quality of Water.--Because temperature has been shown to be one of the more significant water-quality parameters (Hendrickson and Doonan, 1971), thermometers that register maximum and minimum temperatures were installed in each of the stream segments unless adequate temperature records were available. Records of maximum and minimum temperatures were obtained for at least 1 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 9). For most sites these temperatures are probably accurate within 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 half a 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.

Another important water-quality characteristic is dissolved oxygen. One field analysis of dissolved oxygen was made at most stream segments. However, because of diurnal variation in dissolved oxygen, all values are not representative of the dissolved-oxygen content for each stream segment. Consequently, values of dissolved oxygen were not used in the regression analysis.

Table 9.--Summary of data on chemical quality of water.

Map number	Stream name	Stream segment Location	Chemical quality: Mean annual maximum temperature (°F)	Mean July temperature (°F)	Specific conductance (micromhos)	Hardness (mg/l)	pH (units)	Appearance
	MICHIGAN (UPPER PENINSULA)							
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 9.--Summary of data on chemical quality of water--continued.

Map number	Stream name	Stream segment Location	Chemical quality Mean annual maximum temperature (°F)	Mean July temperature (°F)	Specific conductance (micromhos)	Hardness (mg/l)	pH (units)	Appearance
	WISCONSIN							
29	Allen Creek tributary	NW¼ NW¼ sec.7, T.40 N., R.14 E.	76	67	160	100	7.5	Clear
30	West Branch Allen Creek	NW¼ NW¼ sec.5, T.40 N., R.14 E.	66	59	140	70	7.4	do
31	Woods Creek	NE¼ SE¼ sec.29 T.39 N., R.17 E.	71	65	230	140	7.9	colored
32	North Branch Pike River	NW¼ sec.33, T.37 N., R.18 E.	77	70	240	140	8.1	clear
33	do	Sec.33, T.36 N., R.20 E.	66	60	240	120	8.1	do
34	South Branch Pike River	SE¼ NE¼ sec.28, T.36 N., R.18 E.	75	66	240	120	8.0	colored
35	do	SW¼ NE¼ sec.13, T.35 N., R.19 E.	76	67	230	100	8.1	clear
36	Little South Branch Pike River	Sec.16, T.35 N., R.19 E.	64	59	210	100	7.7	do
37	Mecan River	Secs.16, 21, T.18 N., R.9 E.	72	64	345	220	8.5	do
38	Lawrence Creek	Sec.36, T.17 N., R.7 E.	73	59	300	170	8.0	do
39	do	Sec.31, T.17 N., R.8 E.	73	59	300	170	8.0	do
40	Trout Creek	Sec.30, SW¼ sec.19, T.7 N., R.5 E.	61	56	500	270	7.5	do
41	do	NW¼ sec.30, T.7 N., R.5 E.	64	58	500	270	7.5	do
42	do	SW¼ sec.19, T.7 N., R.5 E.	69	61	495	310	8.2	do
43	do	Sec.19, T.7 N., R.5 E., sec.24, T.7 N., R.4 E.	69	61	495	310	8.2	do
44	do	SW¼ sec.13, NW¼ sec. 24, T.7 N. R.4 E.	72	63	495	310	8.2	do
	MICHIGAN (SOUTHERN PENINSULA)							
45	Little South Branch Pere Marquette River	SW¼ sec.31, T.17 N., R.12 W.	67	60	310	170	8.4	do
46	do	SW¼ sec.26 T.17 N., R.13 W.	67	60	300	170	8.3	do
47	do	NE¼ sec.22, T.17 N., R.13 W.	67	60	300	190	8.4	do
48	Pere Marquette River	SE¼ sec.16, T.17 N., R.13 W.	68	61	300	190	8.4	do
49	Big Sable River	NE¼ sec.22, T.20 N., R.16 W.	73	64	300	155	8.5	do
50	Manistee River	NW¼ sec.30, T.28 N., R.4 W.	62	58	300	170	8.3	do
51	do	SW¼ sec.31, T.28 N., R.4 W.	64	61	300	170	8.4	do
52	Pine River	NE¼ sec.3, T.19 N., R.11 W.	68	60	320	190	8.2	do
53	do	SE¼ sec.13, T.20 N., R.12 W.	69	62	300	170	8.5	do
54	Poplar Creek	Sec.36, T.21 N., R. 12 W.	60	54	250	170	8.3	do
55	Silver Creek	SW¼ sec.18, T.20 N., R.11 W.	61	56	260	135	8.1	do

Table 9.--Summary of data on chemical quality of water--continued.

Map number	Stream name	Stream segment Location	Chemical quality: Mean annual maximum temperature (°F)	Mean July temperature (°F)	Specific conductance (micromhos)	Hardness (mg/l)	pH (units)	Appearance
	MICHIGAN (SOUTHERN PENINSULA)							
56	Little Manistee River	SE¼ sec.24, T.20 N., R.14 W.	71	62	280	155	8.2	Clear
57	do	NE¼ sec.16, T.20 N., R.14 W.	70	61	280	155	8.3	do
58	do	NW¼ sec.7, T.20 N., R.14 W.	70	61	280	170	8.4	do
59	North Branch Boardman River	SW¼ sec.35, T.27 N., R.9 W.	71	62	220	150	8.5	do
60	South Branch Boardman River	SW¼ sec.3, T.26 N., R.9 W.	64	58	250	150	8.3	do
61	Boardman River	SE¼ sec.4, T.26 N., R.9 W.	71	63	300	150	7.9	do
62	do	SE¼ sec.7, T.26 N., R.9 W.	68	60	300	150	8.1	do
63	do	NE¼ sec.13, T.26 N., R.10 W.	66	59	300	150	8.2	do
64	Betsie River	NE¼ sec.25, T.25 N., R.14 W.	81	72	280	190	8.5	do
65	Little Betsie River	SW¼ sec.30, T.25 N., R.13 W.	78	67	300	190	8.5	do
66	Platte River	NW¼ sec.4, T.26 N., R.13 W.	80	72	260	190	8.5	do
67	do	SE¼ sec.12, T.26 N., R.14 W.	72	64	280	170	8.3	do
68	do	SW¼ sec.15, T.26 N., R.14 W.	75	67	290	170	8.1	do
69	Sturgeon River	NE¼ sec.23, T.31 N., R.3 W.	64	55	410	255	8.0	do
70	do	SE¼ sec.31, T.32 N., R.2 W.	71	59	400	240	8.1	do
71	do	SE¼ sec.21, T.32 N., R.2 W.	66	58	380	220	8.2	do
72	do	SW¼ sec.28, T.33 N., R.2 W.	71	62	340	240	8.2	do
73	do	NW¼ sec.7, T.33 N., R.2 W.	72	62	325	220	8.2	do
74	West Branch Sturgeon River	NW¼ sec.14, T.33 N., R.3 W.	66	58	360	220	8.1	do
75	do	NW¼ sec.7, T.33 N., R.2 W.	67	59	370	220	8.1	do
76	Sturgeon River	SW¼ sec.31, T.34 N., R.2 W.	72	62	340	220	8.2	do
77	do	NW¼ sec.13, T.34 N., R.3 W.	71	62	380	220	8.2	do
78	do	NW¼ sec.1, T.34 N., R.3 W.	69	61	380	220	8.2	do
79	Pigeon River	SW¼ sec.25, T.32 N., R.2 W.	68	59	380	220	7.9	do
80	do	SE¼ sec.19, T.32 N., R.1 W.	77	67	380	205	8.2	do
81	do	SW¼ sec.17, T.32 N., R.1 W.	76	66	340	220	8.2	do
82	do	SW¼ sec.9, T.32 N., R.1 W.	77	66	370	220	8.2	do
83	do	SW¼ sec.10, T.32 N., R.1 W.	74	66	370	205	8.2	do
84	do	NE¼ sec.28, T.33 N., R.1 W.	73	63	370	220	8.2	do
85	do	NW¼ sec.8, T.33 N., R.1 W.	74	64	370	220	8.2	do

Table 9.--Summary of data on chemical quality of water--continued.

Map number	Stream name	Stream segment Location	Chemical quality: Mean annual maximum temperature (°F)	Mean July temperature (°F)	Specific conductance (micromhos)	Hardness (mg/l)	pH (units)	Appearance
	MICHIGAN (SOUTHERN PENINSULA)							
86	Little Pigeon River	SW¼ sec.1, T.33 N., R.2 W.	72	62	340	190	8.0	Clear
87	Pigeon River	NE¼ sec.24, T.34 N. R.2 W.	77	66	360	220	8.0	do
88	do	NE¼ sec.2, T.34 N., R.2 W.	77	68	360	205	8.2	do
89	Black River	NW¼ sec.35, T.32 N., R.1 W.	78	64	400	220	7.9	do
90	do	SE¼ sec.26, T.32 N., R.1 W.	77	65	385	220	7.9	do
91	do	NW¼ sec.21, T.32 N., R.1 E.	78	66	390	220	8.0	do
92	East Branch AuSable River	SW¼ sec.30, T.29 N., R.2 W.	81	69	270	170	7.9	do
93	do	SE¼ sec.2, T.27 N., R.3 W.	74	64	290	170	8.0	do
94	do	SE¼ sec.29, T.27 N., R.3 W.	74	63	300	170	8.3	do
95	AuSable River	NE¼ sec.10, T.26 N., R.3 W.	79	66	280	150	8.5	do
96	do	NE¼ sec.12, T.26 N., R.3 W.	73	63	285	150	8.0	do
97	do	NW¼ sec.5, T.26 N., R.2 W.	74	63	270	145	8.5	do
98	South Branch AuSable River	SE¼ sec.21, T.25 N., R.2 W.	75	68	260	140	7.9	turbid
99	do	SE¼ sec.29, T.26 N., R.1 W.	72	65	260	140	8.3	do
100	North Branch AuSable River	NE¼ sec.21, T.29 N., R.2 W.	82	70	270	145	7.9	clear
101	do	SW¼ sec.22, T.29 N., R.2 W.	82	70	265	140	8.0	do
102	do	SE¼ sec.1, T.28 N., R.2 W.	80	72	265	140	8.5	do
103	do	NE¼ sec.13, T.28 N., R.2 W.	80	69	300	145	8.5	do
104	do	SE¼ sec.5, T.27 N., R.1 W.	79	66	270	145	8.5	do
105	East Branch AuGres River	NE¼ sec.33, T.22 N., R.6 E.	73	64	355	205	7.9	do
106	Gamble Creek	Sec.2, T.23 N., R.3 E.	69	58	420	220	7.9	do
107	Houghton Creek	NE¼ sec.31, T.24 N., R.3 E.	65	56	365	205	8.1	turbid
108	do	Secs.5, 8, T.23 N., R.3 E.	70	58	350	190	8.0	do
109	do	Sec.4, T.23 N., R.3 E.	67	58	360	190	8.0	do
110	Rifle River	Sec.11, T.23 N., R R.3 E.	75	62	440	240	8.0	do
111	do	Secs.11, 14, T.23 N., R.3 E.	72	63	400	220	8.0	do
112	do	Secs.14, 22, 23, T. 23 N., R.3 E.	74	65	400	220	8.1	do

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. Estimates of trout population in 39 stream segments were obtained by the "mark and recapture" method. The accuracy of the results on these segments is probably within about 30 percent. Estimates of trout populations for other segments were obtained from one or more stream surveys. The error in estimating populations from these surveys may be 50 percent or more. However, the errors are probably random, and the population estimates are probably not consistently higher or lower than those obtained by "mark and recapture" survey.

All trout-population 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, number per mile, and pounds per mile (table 10).

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.

In the analyses it was assumed that the hydrologic parameters were logarithmically related to trout populations in the linear format. In each case this may not be entirely true. For example, Benson (1953) has shown that the condition and growth of brook trout in the Pigeon River (Michigan) were best when water temperatures ranged from 55 to 66°F. Also, as this and other studies have shown, trout populations tend to increase as hardness and specific conductance of water increase. However, it seems unlikely that excessively high levels of hardness or specific conductance

Table 10.--Summary of data on fall trout populations.

Map number	Stream name	Stream segment Location	Fall trout populations: Number in segment	Number per acre	Pounds in stream segment	Pounds per acre	Pounds per acre-foot	Number per mile	Pounds per mile
	MICHIGAN (UPPER PENINSULA)								
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. 28 W.	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	5.3
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

Table 10.--Summary of data on fall trout populations--continued.

Map number	Stream name	Stream segment: Location	Fall trout populations: Number in segment	Number per acre	Pounds in stream segment	Pounds per acre	Pounds per acre-foot	Number per mile	Pounds per mile
	WISCONSIN								
29	Allen Creek tributary	NW¼ NW¼ sec.7, T.40 N., R.14 E.	825	6,650	5.7	46.6	116	7,260	51
30	West Branch Allen Creek	NW¼ NW¼ sec.5, T.40 N., R.14 E.	120	1,254	3.0	30.5	39	1,056	25.7
31	Woods Creek	NE¼ SE¼ sec.29 T.39 N., R.17 E.	834	950	26.2	29.8	25	2,930	92
32	North Branch Pike River	NW¼ sec.33, T.37 N., R.18 E.	604	460	59.2	45.6	27	1,560	118
33	do	Sec.33, T.36 N., R.20 E.	279	215	24.8	19.1	7.9	920	63
34	South Branch Pike River	SE¼ NE¼ sec.28, T.36 N., R.18 E.	149	136	12.1	11.0	6.1	392	32
35	do	SW¼ NE¼ sec.13, T.35 N., R.19 E.	38	36	4.5	4.1	1.7	165	20
36	Little South Branch Pike River	Sec.16, T.35 N., R.19 E.	1,051	3,505	40.2	134	67	5,532	212
37	Mecan River	Secs.16, 21, T.18 N., R.9 E.	2,802	1,274	198.2	90.1	47	2,820	91
38	Lawrence Creek	Sec.36, T.17 N., R.7 E.	--	--	175	45.7	57	--	127
39	do	Sec.31, T.17 N., R.8 E.	--	--	181	57.5	72	--	168
40	Trout Creek	Sec.30, SW¼ sec.19, T.7 N., R.5 E.	3,100	1,240	313	125.2	66	2,210	224
41	do	NW¼ sec.30, T.7 N., R.5 E.	905	1,005	96.7	107.6	--	1,670	179
42	do	SW¼ sec.19, T.7 N., R.5 E.	475	593	54.9	68.5	40	1,010	117
43	do	Sec.19, T.7 N., R.5 E., sec.24, T.7 N., R.4 E.	696	232	116	38.8	--	397	66
44	do	SW¼ sec.13, NW¼ sec. 24, T.7 N., R.4 E.	154	96	38.9	24.3	16	98	40
	MICHIGAN (SOUTHERN PENINSULA)								
45	Little South Branch Pere Marquette River	SW¼ sec.31, T.17 N., R.12 W.	896	1,019	96	109	45	4,300	460
46	do	SW¼ sec.26 T.17 N., R.13 W.	230	287	68	85	35	1,205	360
47	do	NE¼ sec.22, T.17 N., R.13 W.	367	470	56	72	33	1,935	295
48	Pere Marquette River	SE¼ sec.16, T.17 N., R.13 W.	870	290	269	90	47	1,865	578
49	Big Sable River	NE¼ sec.22, T.20 N., R.16 W.	60	210	22	79	33	1,060	388
50	Manistee River	NW¼ sec.30, T.28 N., R.4 W.	535	610	28	32	10	3,780	197
51	do	SW¼ sec.31, T.28 N., R.4 W.	995	675	83	56	20	5,840	486
52	Pine River	NE¼ sec.3, T.19 N., R.11 W.	21	30	8	12	6	185	71
53	do	SE¼ sec.13, T.20 N., R.12 W.	244	110	64	29	11	722	192
54	Poplar Creek	Sec.36, T.21 N., R. 12 W.	2,970	1,526	179	92	54	2,970	179
55	Silver Creek	SW¼ sec.18, T.20 N., R.11 W.	1,120	1,836	41	68	67	2,240	82

Table 10.--Summary of data on fall trout populations--continued.

Map 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
	MICHIGAN (SOUTHERN PENINSULA)								
56	Little Manistee River	SE¼ sec.24, T.20 N., R.14 W.	96	300	24	75	34	1,270	316
57	do	NE¼ sec.16, T.20 N., R.14 W.	16	94	2.4	14	4.4	420	63
58	do	NW¼ sec.7, T.20 N., R.14 W.	10	44	7	30	8	260	185
59	North Branch Boardman River	SW¼ sec.35, T.27 N., R.9 W.	44	244	4.8	27	10	1,160	127
60	South Branch Boardman River	SW¼ sec.3, T.26 N., R.9 W.	100	624	15.8	99	33	2,640	415
61	Boardman River	SE¼ sec.4, T.26 N., R.9 W.	980	933	72.5	69	33	4,300	320
62	do	SE¼ sec.7, T.26 N., R.9 W.	790	703	56	50	26	4,170	296
63	do	NE¼ sec.13, T.26 N., R.10 W.	1,260	1,143	55	50	26	6,650	290
64	Betsie River	NE¼ sec.25, T.25 N., R.14 W.	28	42	6.0	9	3.6	228	49
65	Little Betsie River	SW¼ sec.30, T.25 N., R.13 W.	108	328	29	87	81	680	182
66	Platte River	NW¼ sec.4, T.26 N., R.13 W.	662	480	138	100	67	2,340	487
67	do	SE¼ sec.12, T.26 N., R.14 W.	276	344	84	105	44	1,700	520
68	do	SW¼ sec.15, T.26 N., R.14 W.	242	106	107	47	27	890	393
69	Sturgeon River	NE¼ sec.23, T.31 N., R.3 W.	160	1,230	21.5	165.0	13.4	5,440	731
70	do	SE¼ sec.31, T.32 N., R.2 W.	125	595	19.5	92.5	40.6	2,260	294
71	do	SE¼ sec.21, T.32 N., R.2 W.	185	200	50.0	53.5	25.6	1,010	273
72	do	SW¼ sec.28, T.33 N., R.2 W.	228	300	12.0	15.8	12.1	630	86
73	do	NW¼ sec.7, T.33 N., R.2 W.	63	172	7.0	20.0	10.6	830	92
74	West Branch Sturgeon River	NW¼ sec.14, T.33 N., R.3 W.	142	472	29.6	98.6	61.7	1,870	390
75	do	NW¼ sec.7, T.33 N., R.2 W.	108	220	14.4	29.4	19.5	850	232
76	Sturgeon River	SW¼ sec.31, T.34 N., R.2 W.	96	412	20.0	64.4	29.4	2,060	422
77	do	NW¼ sec.13, T.34 N., R.3 W.	80	164	14.0	28.4	13.0	1,052	184
78	do	NW¼ sec.1, T.34 N., R.3 W.	50	130	3.0	8.0	2.88	880	53
79	Pigeon River	SW¼ sec.25, T.32 N., R.2 W.	177	775	7.0	30.2	17.9	3,120	123
80	do	SE¼ sec.19, T.32 N., R.1 W.	3,311	592	149	26.1	143	3,311	149
81	do	SW¼ sec.17, T.32 N., R.1 W.	3,311	592	149	26.1	102	3,311	149
82	do	SW¼ sec.9, T.32 N., R.1 W.	4,920	910	240	38.5	137	4,490	218
83	do	SW¼ sec.10, T.32 N., R.1 W.	3,228	548	131	22.2	69.3	3,820	154
84	do	NE¼ sec.28, T.33 N., R.1 W.	423	460	45	48.3	27.1	2,280	238
85	do	NW¼ sec.8, T.33 N., R.1 W.	246	220	41	37.0	22.9	1,300	195

Table 10.--Summary of data on fall trout populations--continued.

Map 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
	MICHIGAN (SOUTHERN PENINSULA)								
86	Little Pigeon River	SW¼ sec.1, T.33 N., R.2 W.	118	980	8.0	67	44.4	3,115	211
87	Pigeon River	NE¼ sec.24, T.34 N. R.2 W.	73	50	26	17.3	7.83	275	97
88	do	NE¼ sec.2, T.34 N., R.2 W.	90	57	10.0	6.3	4.52	327	35
89	Black River	NW¼ sec.35, T.32 N., R.1 W.	193	404	27.0	54.3	46.5	1,700	238
90	do	SE¼ sec.26, T.32 N., R.1 W.	166	440	11.7	30.6	22.1	1,945	137
91	do	NW¼ sec.21, T.32 N., R.1 E.	130	232	11.7	21.0	13.0	1,140	103
92	East Branch AuSable River	SW¼ sec.30, T.29 N., R.2 W.	20	47	3.6	8.3	3.56	176	31
93	do	SE¼ sec.2, T.27 N., R.3 W.	350	1,830	19.3	96.5	42.0	4,860	268
94	do	SE¼ sec.29, T.27 N., R.3 W.	150	440	10.0	35.7	16.4	1,320	88
95	AuSable River	NE¼ sec.10, T.26 N., R.3 W.	22	11	8.0	4.0	1.06	145	53
96	do	NE¼ sec.12, T.26 N., R.3 W.	2,600	1,233	272	136.3	58.6	17,650	925
97	do	NW¼ sec.5, T.26 N., R.2 W.	3,300	2,114	340	217.9	90.9	24,500	1,645
98	South Branch AuSable River	SE¼ sec.21, T.25 N., R.2 W.	463	295	90	58.5	26.1	2,720	343
99	do	SE¼ sec.29, T.26 N., R.1 W.	1,035	553	67	37.1	16.5	6,080	218
100	North Branch AuSable River	NE¼ sec.21, T.29 N., R.2 W.	--	--	--	--	--	--	--
101	do	SW¼ sec.22, T.29 N., R.2 W.	3,780	1,227	168	54.3	54.4	13,300	191
102	do	SE¼ sec.1, T.28 N., R.2 W.	765	354	117	54.0	25.8	3,670	259
103	do	NE¼ sec.13, T.28 N., R.2 W.	4,760	1,427	260	76.0	45.8	6,280	334
104	do	SE¼ sec.5, T.27 N., R.1 W.	4,050	1,214	156	46.8	23.4	5,350	206
105	East Branch AuGres River	NE¼ sec.33, T.22 N., R.6 E.	1,300	1,413	16.2	17.6	10.4	6,900	86
106	Gamble Creek	Sec.2, T.23 N., R.3 E.	1,359	591	108	47	36.1	1,789	142
107	Houghton Creek	NE¼ sec.31, T.24 N., R.3 E.	1,963	1,433	178	130	130	3,117	283
108	do	Secs.5, 8, T.23 N., R.3 E.	909	812	98	88	46.0	2,253	243
109	do	Sec.4, T.23 N., R.3 E.	736	657	101	90	32.2	2,460	338
110	Rifle River	Sec.11, T.23 N., R R.3 E.	260	85	49	16	9.42	483	91
111	do	Secs.11, 14, T.23 N., R.3 E.	1,735	134	544	42	16.2	780	244
112	do	Secs.14, 22, 23, T. 23 N., R.3 E.	687	67	256	25	10.4	390	145

would be increasingly favorable to trout populations. Other hydrologic parameters also may have favorable ranges not yet demonstrated. However, any deviation from the straight-line relationship probably does not seriously affect the results of this study. Graphic plots of trout populations and independent variables did not reveal any divergence from the straight-line relationship. The probable reason for this is that values for most parameters are within the favorable range for trout. Also, values of many of the parameters evaluated in the study affect trout populations in only one direction from the favorable limits. For example, few of the streams sampled are too cold in summer for production of trout. Again, it is unlikely that any of the streams sampled have hardness or specific conductance greater than the optimum range for trout.

A summary of the hydrologic and trout population parameters for which data were obtained are listed in table 11. Shown in the table are the degrees of correlation between each of the parameters. This simple correlation matrix was used to aid in selecting independent variables--variables that did not exhibit a high degree of intercorrelation or interdependence--for regression analysis. For example, specific conductance and hardness were not used in the same regression analysis because of their high degree of correlation (0.97). Table 11 also shows the degree of correlation between the dependent variables (last five rows) and each of the independent variables. None of the independent variables, by themselves, show a high degree of correlation with trout populations for the units of population shown. The relation between pH and trout, in pounds per mile, has the highest degree of correlation (0.47).

Analyses of trout populations, in pounds per acre and pounds per mile, resulted in regression equations from which trout populations could be estimated with approximately the same standard error (89 to 84 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 12. Analyses of trout populations, in pounds per acre-foot, numbers per acre, and numbers per mile, with several combinations of independent variables, showed no strong correlation. In the analyses, the standard error of estimate was generally in excess of 110 percent (table 12).

To test the defined relationships for possible areal differences, the difference between observed and computed values, termed residuals, were calculated for each station analyzed. An analysis of the residuals showed that the regression equations were unbiased areally. Reaches of some streams and small local areas showed some differences, or bias, but they were too small to warrant separate analysis.

Table 11.--Simple correlation coefficients for hydrologic and trout-population parameters

	Area (acres)	Width (ft)	Depth (ft)	Gravel (%)	Sand (%)	Muck (%)	Bottom vegetation (%)	Cover (%)	Bank height (ft)	Hardwood (%)	Conifer (%)	Brush (%)	Grass (%)	Drainage area (sq. mi.)	Mean discharge (cfs)	Mean discharge (cfsm)
Area	1.00															
Width	.43	1.00														
Depth	.29	.54	1.00													
Gravel	.30	.27	.04	1.00												
Sand	-.17	-.17	.24	-.62	1.00											
Muck	-.06	-.17	.01	-.26	.10	1.00										
Bottom vegetation	.07	.23	.31	-.19	.13	.38	1.00									
Cover	-.16	-.30	.12	-.21	.33	.19	.27	1.00								
Bank height	.13	.01	-.17	.12	-.14	-.39	-.23	-.30	1.00							
Hardwood	.19	.22	.10	.44	-.17	-.28	-.15	-.16	.37	1.00						
Conifer	.20	.33	-.07	.11	-.10	-.12	-.13	-.07	.20	.08	1.00					
Brush	-.01	-.15	.11	.08	-.02	.27	.10	.09	-.58	-.29	-.47	1.00				
Grass	.18	.29	.24	-.07	-.04	.18	.16	-.11	-.02	-.19	-.01	-.12	1.00			
Drainage area	.39	.84	.66	.42	-.25	-.31	.18	-.20	-.01	.29	.12	.05	.18	1.00		
Mean Q (cfs)	.36	.85	.65	.34	-.14	-.40	.05	-.21	-.04	.19	.16	-.02	.23	.93	1.00	
Mean Q (cfsm)	-.17	-.17	-.17	-.30	.33	-.15	-.35	.03	-.09	-.32	.07	-.18	.08	-.42	-.06	1.00
7-day Q_2 (cfsm)	.05	.08	.14	-.10	.34	-.03	-.08	.25	-.30	-.08	.17	-.04	.07	-.14	.12	.66
10% (cfsm)	-.26	-.20	-.26	-.33	.26	-.18	-.40	-.10	.03	-.35	.02	-.19	.06	-.42	-.09	.91
90% (cfsm)	.04	.07	.12	-.10	.33	-.05	-.12	.24	-.29	-.10	.18	-.06	.07	-.15	.13	.71
10/90	-.26	-.24	-.33	-.18	-.10	-.11	.22	-.31	.29	-.20	-.15	-.10	-.02	-.21	-.19	.10
Mean Q/7-day Q_2	-.24	-.28	-.36	-.17	-.11	-.10	-.25	-.31	.30	-.22	-.16	-.13	-.02	-.25	-.21	.15
Velocity	.21	.43	.27	.39	-.15	-.41	-.10	-.02	-.18	.21	.06	.13	.05	.58	.65	.04
W/D	.27	.76	-.13	.28	-.38	-.21	.03	-.44	.14	.18	.45	-.26	.15	.48	.50	-.07
Slope	-.28	-.50	-.63	-.05	-.15	-.12	-.29	.09	.18	-.03	.12	-.15	-.27	-.56	-.53	.23
Max. temp.	.12	.30	-.05	.18	-.28	.12	.12	-.24	.04	.24	-.01	-.19	.03	.24	.16	-.26
July temp.	.15	.33	-.02	.20	-.26	.10	.19	-.17	.10	.23	-.02	-.18	.04	.31	.19	-.38
Spec. cond.	.36	.13	.23	.17	-.07	.28	.24	.13	-.33	.12	.04	.16	.07	.20	.12	-.22
Hardness	.34	.12	.26	.18	-.04	.24	.22	.20	-.33	.16	.03	.17	.03	.20	.13	-.21
pH	.27	.39	.39	.20	-.04	-.12	.25	.10	-.01	.38	.14	-.18	-.04	.44	.38	-.25
TROUT POPULATIONS: lbs/acre	-.02	-.14	-.04	.12	-.02	.03	.13	.29	-.27	.01	-.08	.11	-.08	-.09	-.11	-.03
TROUT POPULATIONS: lbs/ac-ft	-.01	-.30	-.34	.14	-.13	.02	-.02	.19	-.18	-.06	-.07	.09	-.13	-.29	-.29	.06
TROUT POPULATIONS: lbs/mile	.16	.32	.26	.23	-.09	-.06	.22	.17	-.26	.08	.11	.03	.04	.32	.32	-.06
TROUT POPULATIONS: No./mile	.10	.17	-.04	.23	-.16	-.06	-.06	.02	-.15	-.11	.14	.09	.13	.10	.13	.07
TROUT POPULATIONS: No./acre	-.07	-.24	-.29	.10	-.08	.04	-.13	.13	-.15	-.17	-.02	.15	.01	-.27	-.25	.12

Table 11.--Simple correlation coefficients for hydrologic and trout-population parameters.--continued.

		7-day[1/] Q_2 (cfsm)	10%[2/] duration discharge (cfsm)	90%[3/] duration discharge (cfsm)	Ratio 10/90	Ratio mean discharge to 7-day Q_2	Velocity index	Width-depth ratio	Slope (ft/mile)	Average annual maximum temperature (°F)	Average annual July temperature (°F)	Specific conductance (micromhos)	Hardness (mg/l)	pH (units)	Trout population				
															lbs/acre	lbs/ac-ft	lbs/mile	No./mile	No./acre
Area																			
Width																			
Depth																			
Gravel																			
Sand																			
Muck																			
Bottom vegetation																			
Cover																			
Bank height																			
Hardwood																			
Conifer																			
Brush																			
Grass																			
Drainage area																			
Mean Q (cfs)																			
Mean Q (cfsm)																			
7-day Q_2 (cfsm)		1.00																	
10% (cfsm)		.32	1.00																
90% (cfsm)		.99	.38	1.00															
10/90		-.67	.49	-.63	1.00														
Mean Q/7-day Q_2		-.65	.50	-.59	.98	1.00													
Velocity		.44	-.15	.44	-.54	-.54	1.00												
W/D		-.01	-.03	-.01	-.03	-.06	.29	1.00											
Slope		.04	.23	.05	.15	.18	-.22	-.10	1.00										
Max. temp.		-.32	-.16	-.30	.15	.16	-.06	.39	-.30	1.00									
July temp.		-.39	-.26	-.38	.14	.13	-.05	.40	-.30	.93	1.00								
Spec. cond.		.29	-.47	.27	-.65	-.61	-.35	-.03	-.16	.01	-.01	1.00							
Hardness		.34	-.48	.32	-.70	-.66	.41	-.06	-.15	-.01	-.01	.97	1.00						
pH		.27	-.43	.24	-.59	-.61	.49	.16	-.23	.13	.19	.57	.61	1.00					
lbs/acre	TROUT POPULATIONS	.22	-.17	.21	-.34	-.31	.12	-.14	.14	-.34	-.33	.35	.35	.32	1.00				
lbs/ac-ft		.18	-.05	.19	-.21	-.18	.05	-.08	.32	-.23	-.23	.28	.27	.18	.89	1.00			
lbs/mile		.29	-.22	.28	-.45	-.44	.36	.17	-.12	-.23	-.20	.41	.41	.47	.87	.69	1.00		
No./mile		.21	-.01	.21	-.21	-.21	.18	.23	.18	-.32	-.27	.19	.15	.16	.66	.66	.68	1.00	
No./acre		.16	.05	.16	-.11	-.10	-.02	-.06	.40	-.41	-.38	.13	.10	.01	.73	.78	.52	.90	1.00

1/ Average 7-day low flow for 2 year recurrence interval.
2/ Discharge equaled or exceeded 10 percent of the time.
3/ Discharge equaled or exceeded 90 percent of the time.

Table 12.--Summary of regression relations:

$$Y = aG^{b1}BV^{b2}\bar{Q}^{b3}Q_2^{b4}DR^{b5}V^{b6}WD^{b7}T^{b8}H^{b9}T_2^{b10}$$

Trout population	Regression constant						Regression coefficients for					Standard error (percent)	Multiple regression coefficient	Number of stream segments evaluated
		% gravel	% bottom vegetation	Mean discharge (cfsm)	7-day Q_2 (cfsm)	Ratio 10/90% duration discharge	Velocity index	Width-depth ratio	Annual maximum temperature (°F)	Hardness (mg/l)	T divided by 55			
Y	a	G	BV	$\bar{Q}$	Q_2	DR	V	WD	T	H	T_2			
Pounds per acre	85.7	0.14	0.18	2.14	-2.13	-1.91					-4.56	89	0.536	88
Pounds per mile	.60	.12	.13					0.64		0.84	-5.08	84	.615	88
Pounds per ac-ft	16.9			3.23	-3.54	-2.98		.59			-3.02	154	.359	88
Number per acre	923	.19									-6.20	135	.398	88
Number per mile	673	.20						.65			-7.47	113	.502	88
Pounds per acre (hardness 0-120)	$1.7x10^{10}$		.34	.98			-.53		-5.14			79	.683	27
Pounds per acre (hardness 120-160)	7.41	.63				-.68						51	.844	21
Pounds per acre (hardness >160)	$1.3x10^{11}$								-5.12			81	.462	44
Pounds per acre (hardness >120)	$3.2x10^{9}$	.31				-.88	-.38		-4.42			77	.559	62
Pounds per acre (temperature <68°F)	.37	.17			.67	.61		-.74		1.29		48	.812	26
Pounds per acre (temperature <72°F)	$2.1x10^{9}$							-.57	-4.96	.95		77	.604	47
Pounds per acre (temperature <75°F)	$1.9x10^{9}$		.16						-5.06	.69		83	.524	64
Pounds per acre (gravel >10%)	$3.7x10^{6}$	.48	.20			-.52	-.38		-3.83	.56		82	.624	72
Pounds per acre (gravel <10%)	87.9		.39	.18				-.79				57	.859	17
Pounds per acre (gravel >20%)	$1.5x10^{6}$	.74	.17			-.57	-.43		-3.90	.59		83	.626	62
Pounds per acre (gravel <20%)	$1.5x10^{7}$		.32	1.25				-.66	-2.87			60	.816	27
Pounds per acre (mark and recapture)	$1.3x10^{12}$	.44	.25	-.88	1.06				-6.01			65	.749	39
Pounds per acre (single survey)	$1.3x10^{6}$								-3.28	.68		95	.437	50

Example.--Trout populations in pounds per acre = $85.7\,(G^{0.14})(BV^{0.18})(\bar{Q}^{2.14})(Q_2^{-2.13})(DR^{-1.91})(T_2^{-4.56})$

Significant Relationships

Trout populations seem to be limited chiefly by stream temperature, hardness of water, bottom materials, bottom vegetation, variability of streamflow, and discharge per unit drainage area. The relatively small correlation coefficients (less than 0.5, table 11) of single hydrologic parameters with trout populations suggest that populations in a heterogeneous sampling of streams are not dominated by a single hydrologic characteristic. In general, where sample size was restricted to stream segments within certain limits of hardness, temperature, or percentage of gravel bottoms, improvement in the standard-error and multiple-correlation coefficients were obtained over that where the total sample was used (table 12). This improvement reflects a greater homogeneity of the restricted samples.

The differences in multiple correlation coefficients with different parameters of trout populations suggest that units of measurement of population in either pounds per acre or pounds per mile are preferred to pounds per acre foot or to numbers per acre or per mile. (The unit of pounds per acre foot is the unit of pounds per acre multiplied by depth of channel). Multiple-correlation coefficients for pounds per mile are slightly higher than those for pounds per acre, and the standard errors are slightly lower. Most individual hydrologic parameters were also found to be more highly correlated with pounds per mile than with pounds per acre. Possibly, a parameter of trout populations, combining both area and length, might show a higher correlation with hydrologic parameters than the units of trout populations used in these anslyses.

Variability of streamflow (expressed as the ratio of the 10 to 90 percent duration discharges, or as the ratio of the mean discharge to average minimum 7-day low-flow), was a significant factor in several of the regression analyses. The negative relationship of variability of streamflow to trout populations was expected, because it is generally recognized that "flashy" streams do not support large populations of trout. For these streams, available cover is greatly reduced at low stages, and shallow depths contribute to warming of the water. At high stages, erosion of banks is likely, and sediment deposition may become a problem.

A negative relationship between the ratio of the 10 to 90 percent duration discharges and specific conductance and hardness is indicated by their relatively high correlation coefficients (-0.65 and -0.70, respectively). This relationship may be explained, in part, by the fact that the more uniformly flowing streams discharge relatively large amounts of ground-water; whereas, the more flashy streams discharge relatively large amounts of surface runoff. Ground water in the study area is usually harder and higher in specific conductance than surface runoff.

Stream discharge per unit drainage areas significantly affected trout populations in several of the regression analyses. Populations were generally greater where 90 percent duration discharge or 7-day low-flow were large. Streams having high discharge per unit drainage area during periods of base flow are generally those that discharge relatively large amounts of ground water. These streams also generally have a more stable flow than those with a smaller discharge per unit drainage area. A negative relationship between the ratio of the 10 to 90 percent discharge and the 7-day low-flow, in cubic feet per second per square mile (-0.67), is shown in table 11.

Temperature of water was one of the most significant hydrologic parameters in almost all regression analyses in which it was included. The mean annual maximum temperature proved to be slightly more significant than the average July temperature. Final regression analyses were made by the use of annual maximum temperatures and annual maximum temperatures divided by 55°F. Using temperatures as a ratio to the selected lower limit for trout (55°F) does not change the accuracy in making population estimates from the regression equations but puts the equations into a more useable form. Earlier studies (Benson, 1953) have indicated that temperatures greater than 68°F are above the optimum for brook trout. When the regression analyses were restricted to the 26 stream segments having maximum temperatures of less than 68°F, temperatures did not significantly affect trout populations. However, when the regression analyses were restricted to the 47 stream segments having maximum temperatures of less than 72°F, temperature remained the second most important parameter (after hardness).

Hardness was a significant hydrologic parameter in most of the regression analyses except for those restricted to streams having specified ranges of hardness. When the regression was restricted to the 62 stream segments having hardness greater than 120 mg/l the parameters of hardness dropped out early in the regression. This suggests that, for hardness values greater than about 120 mg/l, trout populations may not increase as hardness increases. All the soft-water streams (streams having hardness of less than 120 mg/l) are in Michigan's Upper Peninsula and adjacent areas of northern Wisconsin. The generally smaller trout populations in the Upper Peninsula, in comparison to those in the Lower Peninsula, probably reflect, at least in part, this difference in hardness of the water.

The positive relationship of trout populations to specific conductance of water in five Pennsylvania streams was pointed out by McFadden and Cooper (1964). Specific conductance is highly related to hardness in most fresh-water streams.

Channel characteristics that seem to affect trout populations significantly are bottom materials, bottom vegetation, and width-to-depth ratio. Populations are generally greater in streams having higher percentages of gravel bottom and bottom vegetation. The relationship of width-to-depth ratios and trout populations is generally positive, where populations are expressed in pounds per mile, and negative, where populations are expressed in pounds per acre.

In almost all analyses, percentage of fish cover showed a surprisingly poor correlation with trout populations. This may be due in part to the subjectivity of estimates of fish cover. Also, it is possible that fish cover is generally adequate on almost all streams considered and that cover significantly influenced populations only in those short segments where great differences in cover and in populations may be typical of the stream in general.

Hydrologic Factors that Influence the Enjoyment, Convenience, and Safety of Fishermen

The satisfaction of the fisherman requires his conviction that there are fish to be caught in the stream where he fishes, but esthetic appreciation is probably equally essential to most fishermen. Dedicated trout fishermen usually appreciate the peace and quiet of the north-woods atmosphere typical of most trout streams. A measure of solitude also is preferred, but other fishermen are tolerated if they are quiet and not too numerous.

The convenience and safety of the fisherman are directly related to hydrologic characteristics. For example, the depth, velocity, and bottom materials determine the safety of wading fishermen. Assuming a firm sand or gravel bottom, a strong fisherman with long legs can wade a stream where the depth, in feet, multiplied by the velocity, in feet per second, is less than 10. A stream 3 feet deep, with a firm bottom and a velocity of 3 feet per second, could be waded by such a fisherman. If the bottom is slippery rocks or clay, wading may be unsafe at much smaller depths and velocities. In the West Branch Ausable, for example, the slippery cobbles make wading hazardous in places where depth times velocity is less than six. Regardless of velocity or bottom materials, the fisherman cannot comfortably and safely wade a stream that overtops his boots or waders.

Fly-casting on a broad open stream is relatively easy. A narrow channel with overhanging branches makes fly-casting difficult to impossible. The smaller streams appeal to some fishermen, however, because these streams provide a greater measure of solitude than larger rivers. Alternating pools and riffles provide a variety of fishing opportunities. Streams that are all riffle or all pool or "flat water" offer less variety to the fisherman.

A clear-water stream adds to the enjoyment of the fisherman, especially when fishing the dry fly, because he can see the trout approach and take the fly. Bottom vegetation provides cover for trout, but it can be a handicap to the wet-fly fisherman when it becomes so thick it fouls his hook.

Recreational Value of Fishing on 10 Rivers

All the rivers studied are trout streams. The true recreational value of fishing on these rivers cannot be measured because the intensity of enjoyment of individual fishermen is not a measurable quantity. Two quantities that can be measured, however, are fishing hours per acre of stream and fishing success, in pounds per hour. Acknowledging that these quantities do not tell the whole story, we can compare the fishing pressure and success on nine of the 10 streams, along with hydrologic and other characteristics that influence fishing (table 13).

The upper reaches of New York's West Branch Ausable and Michigan's Au Sable are similar in that both lack access for migratory or lake-run fish because of dams or falls. Both are classic trout streams, with brown trout predominating, but the natural reproduction and fall population of trout are much greater in Michigan's Au Sable than in New York's West Branch. Fishing pressure on the West Branch is more than double that on the Michigan stream, and fishing success is also higher on the West Branch. Most trout caught on the West Branch are hatchery fish, for this stream is stocked at an annual rate approaching 90 pounds per acre (Pfieffer, 1971). Michigan's Au Sable is not stocked in the study reach from Burton's Landing to Wakeley Bridge. Michigan's Au Sable is much easier to wade than New York's West Branch. Midstream velocities on the Michigan stream are slower and the bottom materials less slippery. The low fall population of trout on the West Branch (about 19 lbs per acre compared with about 150 lbs per acre on Michigan's Au Sable) is attributed to the warm summer water temperatures, the softness of the water, the great fishing pressure, and the variability of flow.

The Bois Brule, Pere Marquette, and Sturgeon Rivers are similar in that a large part of the fishery is based on migratory lake-run trout, chiefly steelhead (rainbow) in the Pere Marquette and Sturgeon, but including a good run of both rainbow and brown trout in the Bois Brule. Fishing pressure on these streams is concentrated during the spring and fall spawning runs and is relatively light the rest of the year. Much of the fishing during spawning runs is from the banks or from boats, so wading conditions are not generally so important. The upper reaches of each of these streams also support a good nonmigratory fishery consisting chiefly of brown trout and some brook and rainbow trout.

The Pigeon, Black, and Upper Rifle are small streams, with a moderate trout fishery that is chiefly nonmigratory. Fishing success on the Black, in numbers per hour, is higher than on any of the other streams, perhaps because most of the fish caught in the upper Black are brook trout, which are less wary than browns or rainbows. Brook trout also make up most of the catch on the Pigeon, but the larger fish are mostly browns. The Rifle River is mainly a brown trout stream, with relatively few brook or rainbow trout. Each of these streams is easily waded and open enough in some reaches for easy fly casting.

Table 13.--Hydrologic conditions and fishing on cold-water rivers.

River	Location	Ave. width (ft.)	Ave. depth (ft.)	Pred. bed mat.	Bottom vege.	Bank vege.	Fish cover	Ave. velocity ft./sec.	Public access sites	Wading	Boat fishing	Fly casting	Est. fish pressure hrs/acre	Fish success no./hr.
Bois Brule Wisconsin	Stones River Bridge to U.S. Highway 2	60*	2.0*	Sand gravel boulder	Sparse	Mixed	Moderate	2.0*	Few	Fair, except in rapids. Too deep in places.	Fair to good. No obstructions. Many rapids.	Good. Open enough for easy casting.	1/	1/
Pine Wisconsin	Sec.12, T.39 N., R.14 E. to Chipmunk Rapids Campground	80	2.0	Gravel boulder	Sparse	Hard-wood	Sparse	1.5	Few	Fair, except in rapids.	Many shoals and some rapids.	Good. Open for easy casting.	50	0.10
Pere Marquette Michigan	State Highway 37 to mouth.	90	4.0	Sand gravel	Moderate	Hard-wood	Moderate	1.5	Many	Good to fair. Firm bottom but too deep in lower reaches.	Good. No obstructions.	Good. Open for easy casting.	650	.28
Manistee Michigan	Deward to Smithville	70	3.5	Sand	Moderate	Mixed	Good	1.5	Many	Fair to good. Some soft sand bottom and too deep in many places.	Good. No obstructions.	Good to fair. Mostly open.	190	.34
Sturgeon Michigan	Source to mouth.	40	2.5	Sand gravel	Sparse	Hard-wood	Good	2.0	Many	Poor to fair. Too fast or deep in many places.	Poor. Too fast and narrow to fish from boat.	Too narrow for easy casting.	380	.34
Pigeon Michigan	Lansing Club dam to Pigeon River campsite	70	2.5	Sand gravel	Sparse	Mixed	Good	1.0	Many	Good in most of river.	Fair. Many obstructions.	Fair to good. Too narrow and brushy in places.	165	.21
Black Michigan	Source to Tower Pond	60	2.5	Sand gravel	Sparse	Mixed	Good	1.0	Few	Good. Mostly shallow and not too swift.	Poor to fair. Many obstructions.	Poor to fair. Too narrow and brushy many places.	125	.45
Au Sable Michigan	Burton's Landing to Wakely Bridge	95	2.5	Sand gravel	Dense	Mixed	Good	1.0	Many	Good. Shallow and firm bottom. Not too swift.	Good. No obstructions.	Excellent. Open enough for easy casting.	387	.17
Rifle Michigan	Devoe Lake to Selkirk	50	2.5	Sand gravel	Moderate	Hard-wood	Good	1.0	Many	Good. Shallow and not too swift.	Fair. Too narrow for easy boat fishing.	Fair. Too narrow and brushy in places	243	.14
West Branch Ausable New York	State Highway 73 to Monument Falls	80	3.0	Gravel boulder	Sparse	Mixed	Good	2.5	Many	Fair to poor. Too swift and slippery many places.	Fair to poor. Shoals in upper part. Too fast for good boat fishing.	Good. Open for easy casting	830	.32

1/ No recent data available
* Except in lakes and ponds

The Manistee is a big river, mostly sandy, with many holes too deep for wading. In the study area it supports a fair to good brown and brook trout fishery, with mostly nonmigratory fish. The lower reaches of the Manistee are well known for steelhead and salmon, but this part of the river was not included in the study.

The Pine River of Wisconsin supports a minor brown and brook trout fishery. The Pine is a most attractive stream in a remote northwoods setting, but it is lightly fished because it is remote from populated areas and because fishing success is relatively low.

The recreational values of trout streams can be described in terms of quantity and quality. Quantities that can be measured are trout populations, angler hours, and angler success. The satisfaction and enjoyment of fishermen depend, in part, on these quantities but also depend on qualities not easily measured--esthetic appeal, convenience and safety of the fisherman, and the "trophy value" of the fish. Trout populations are a convenient parameter for evaluation of trout streams because these populations also reflect characteristics of the streams that are important to esthetic values. Most streams having large trout populations sustained by natural reproduction are cool, clear, unpolluted, and have gravel riffles alternating with deeper pools. They are esthetically appealing. Naturally produced trout also have a higher "trophy value" than planted fish.

CONCLUSIONS

1. Relationships of hydrologic factors to esthetic appeal are not demonstrated conclusively. The 10 rivers were ranked as to relative uniqueness of hydrologic and other factors, as described by Leopold (1969). The West Branch Ausable of New York, the only stream with torrential rapids and waterfalls, stood alone among the 10 rivers. None of the other rivers ranked outstandingly high.

2. Hydrologic factors, such as width and depth of channel, bottom materials, and stream velocity, influence boating opportunity on cold-water rivers, but desirable characteristics depend partly on the personal preferences and the experience of the boater. High stream velocities, white-water rapids, and rocks and boulders provide a challenge to the experienced boater but may be a hazard to the novice. Stability of streamflow is important to all boaters, because streams having highly variable streamflow have variable boating quality, ranging from dangerous, during high flow, to impossible or difficult during low flow. The density of boat traffic, as a measure of recreational use, also is influenced by hydrologic factors, but the proximity to population centers, spacing of launching sites, and availability of rental canoes may be the dominant controls.

3. Camping opportunity on the rivers depends chiefly on the character of the river banks--the height of banks, bank materials, and bank vegetation. Probably most campers prefer sandy banks of moderate height, 3 to 5 feet. Most prefer a forest cover of mixed hardwoods and conifers, which is open enough to permit grass to grow. Camping activity depends chiefly on the attractiveness of the camp site and the availability and accessibility of developed campgrounds. Inasmuch as the number of campers is growing faster than developed camp space, the availability of campgrounds is becoming the limiting factor in most places.

4. Statistical analyses of relationships of hydrologic factors to trout populations indicated a positive relationship of populations to hardness of water and stability of streamflow and a negative relationship to summer water temperatures. Other hydrologic factors, such as percentage of river bottom that was gravel, bottom vegetation, percentage fish cover, low-flow characteristics, and stream velocity, also showed relationships to trout populations; however, the relationships were not as strong. Relationships of hydrologic factors to other indicators of fishing opportunity, such as wadability of a stream and ease of fly-casting, cannot be demonstrated by statistical analyses. However, cause and effect relationships can be identified. Wadability of a stream is influenced by depth, velocity of flow, and character of the river bed. Ease of fly-casting is influenced by width of stream and extent of overhanging vegetation. Recreational use, in angler hours per acre, and fishing success, in number of fish caught per hour, varied widely, but relationships to hydrologic factors were not conclusively demonstrated.

5. Recreational values of cold-water rivers can be described in terms of potential and use. Recreational potential is chiefly dependent on hydrologic factors--streamflow, water quality, and character of bed and banks. Recreational use also is dependent in part on hydrologic factors, but other factors, such as accessibility and proximity to populated areas, generally mask the hydrologic influence.

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