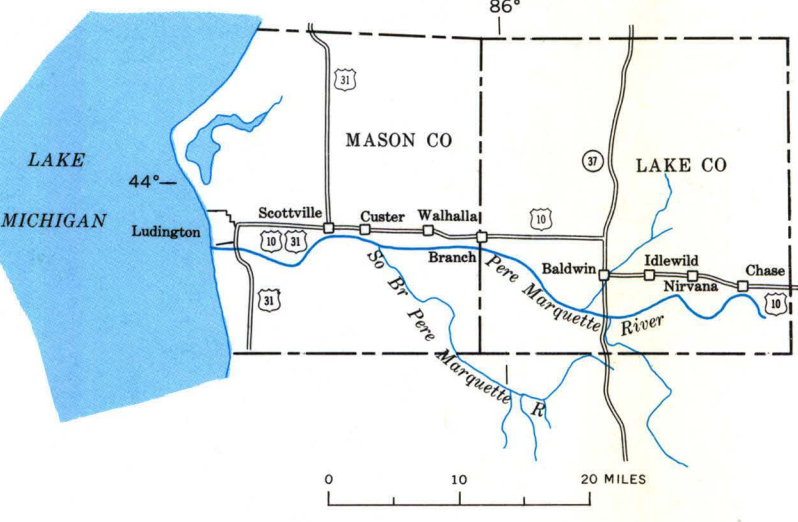


INTRODUCTION

The cold-water streams of the northern states provide unique recreational values to the American people (wilderness or semi-wilderness atmosphere, fast-water canoeing, and trout fishing) but the expanding recreational needs must be balanced against the growing demand of water for public and industrial supplies, for irrigation, and for the dilution of sewage and other wastes. In order to make intelligent decisions regarding use and management of the water resource for recreation and other demands, an analysis of the hydrologic factors related to recreational values is essential.

The Pere Marquette, an outstanding river for brown and steelhead trout fishing, is also a popular canoe trail. Larger boats, some equipped with motors, are common in the lower reaches where the river is wide and deep. Cabins are abundant on the river near Baldwin but are relatively sparse elsewhere. The broad swampy floodplain that borders most of the river between Wabasha and Ludington apparently offers few favorable cabin sites.

The Pere Marquette is located in the west-central part of the Southern Peninsula of Michigan, and flows westward from the headwaters near Chase in Lake County to the mouth at Ludington, in Mason County. The river is south of, and roughly parallel to, U.S. Highway 10 from Chase to Ludington.

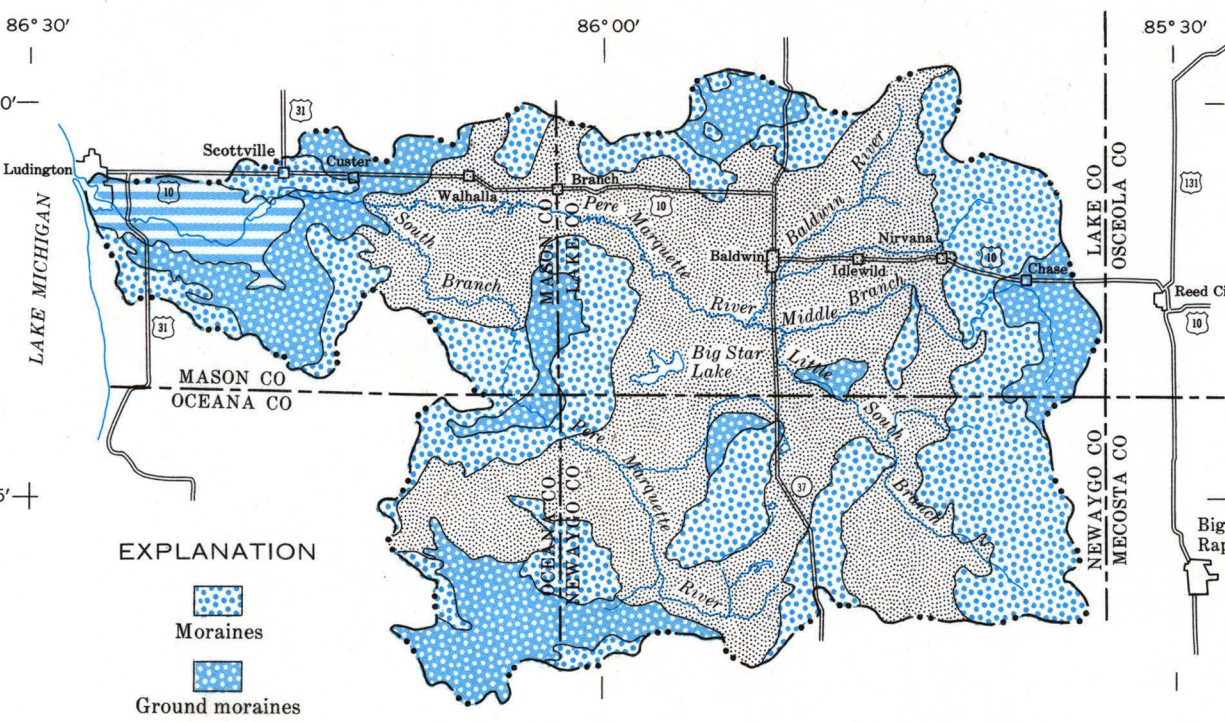


LOCATION MAP

GEOLOGIC SETTING

The Michigan Lobe of the Pleistocene glaciers deposited a series of moraines with associated ground moraines in the Pere Marquette River basin. These moraine areas form most of the boundary areas of the basin and isolated remnants within the basin. Between the moraine areas are broad areas of glacial outwash that cover more than half of the drainage basin. The moraine areas are relatively flat but dissected in places by streams and pitted with kettle holes formed by melting blocks of glacial ice. Some of the kettle holes are occupied by lakes. West of Scottville the river basin is a broad plain underlain by beds of sand deposited in a glacial lake. The Middle Branch of the Pere Marquette rises in the rolling hills of glacial moraine and ground moraine that form the eastern boundary of the drainage basin. West of this moraine area the river flows across a broad outwash plain that extends westward to Custer. The river crosses a belt

of ground moraine between Custer and Scottville and then crosses a sandy lake plain to the mouth at Ludington. The streamflow characteristics and temperature of the Pere Marquette are strongly influenced by the geology and topography of the basin. The more permeable materials in the basin, especially sand and gravel outwash, contribute a relatively large amount of ground-water discharge to the stream. This ground-water discharge maintains the flow of the stream during rainless periods and helps to keep the water cool during hot summer days. The less permeable materials that compose the moraines and ground moraines generally contribute more surface runoff and less ground-water discharge than is contributed by the outwash deposits. The relatively high drought flow and low summer water temperatures on the Pere Marquette reflect the permeable materials that underlie most of the basin.



SURFICIAL GEOLOGIC MAP

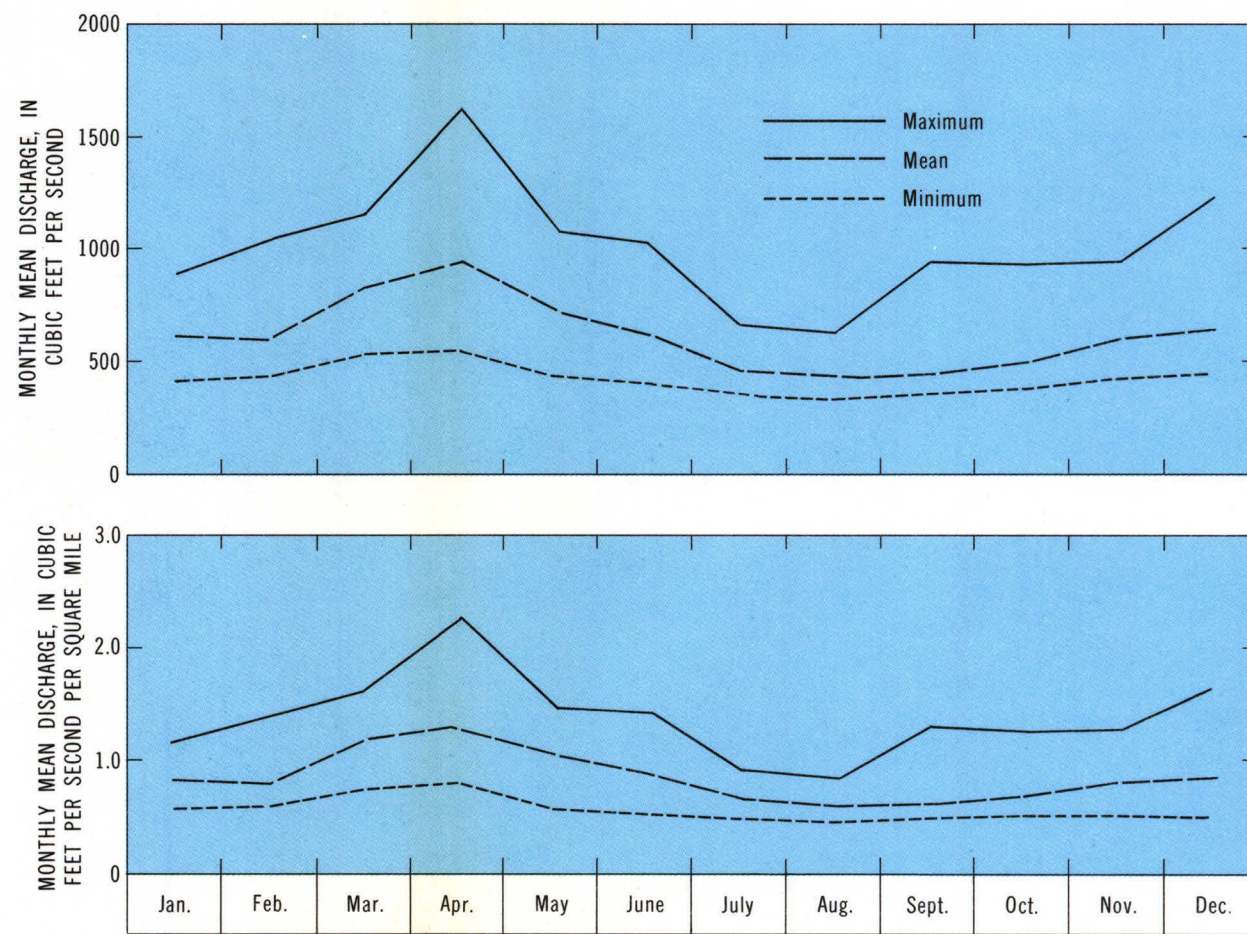
STREAMFLOW

INTRODUCTION

The flow of any uncontrolled river varies from day to day and from year to year. This variation may be measured in units of discharge (volume of water discharged per unit of time), velocity (speed of movement of water), and stage (elevation of water surface). These units are related— a high discharge results in high stages and, usually, in high velocities. Velocity also varies in different reaches of the river, the velocity generally being greater in reaches of steep fall than in the flatter reaches. The gradients of the reaches of the river are shown on the river profile (Sheet 2).

DISCHARGE

Daily discharge on the Pere Marquette is recorded at a gaging station at Scottville. Records of monthly mean discharge for the period October, 1951, through September, 1967, are shown below. Discharge is shown in cubic feet per second (cfs) and cubic feet per second per square mile (cfsm). The highest rates of discharge usually occur during the snowmelt season in April. Discharge generally declines through late spring and summer months and then increases somewhat in the fall when frost kills the vegetation and reduces the amount of evapotranspiration in the basin.



GRAPHS OF MEAN MONTHLY DISCHARGE

STREAMFLOW

To obtain information on the contribution of ground water in various reaches of the stream a series of discharge measurements were made at several stations on September 19, 1966, after a period of several days with little or no rain. Results of these measurements are tabulated below. The differences in discharge per unit drainage area reflect differences of ground-water contribution in the various reaches of the river. Locations of stations are shown on Map 1, Sheet 2.

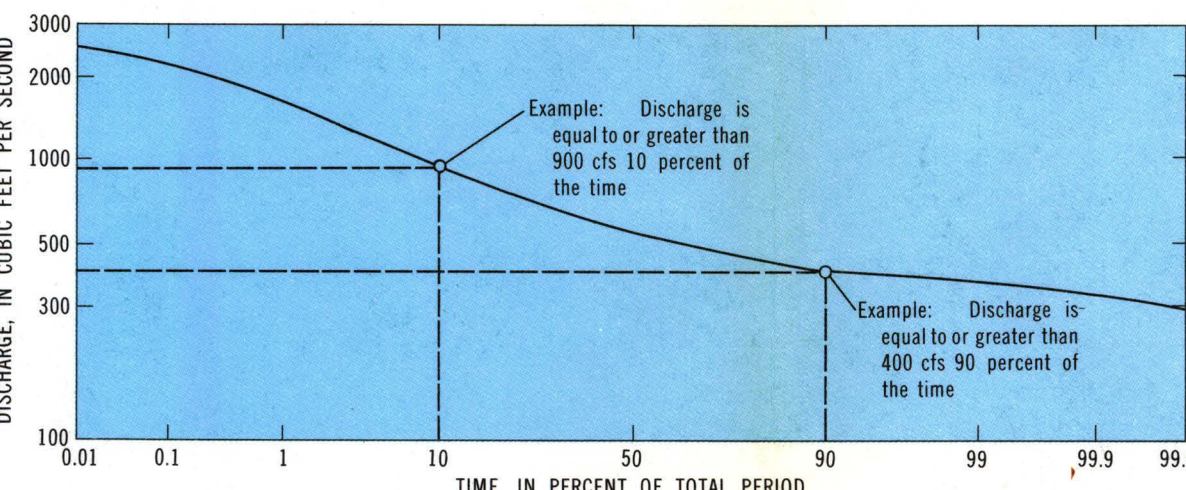
Stream	Location	Drainage area (sq. mi.)	Discharge (cfs)	Discharge (cfsm)
Middle Branch Pere Marquette River	Station 1 SE¼SE¼ sec. 10, T. 17 N., R. 12 W., at highway bridge 4½ miles southwest of Chase	30	15.6	0.52
Pere Marquette River	Station 2 SW¼SE¼ sec. 15, T. 17 N., R. 13 W., at fishing site 2.7 miles south of Baldwin	200	102	0.51
Pere Marquette River	Station 3 NW¼SW¼ sec. 27, T. 18 N., R. 14 W., ¾ miles southeast of Branch	320	210	0.66
Pere Marquette River	Station 4 SW¼SW¼ sec. 21, T. 18 N., R. 15 W., 1.4 miles south of Wabasha	380	257	0.68

The discharge per unit drainage area (cfsm) was greater at the two downstream stations than in the two upstream stations. This is attributed to the greater proportion of outwash in the drainage area contributing to the downstream stations.

STREAMFLOW

FLOW-DURATION

Discharge characteristics of streams can be illustrated graphically by flow-duration curves that show the percentage of time that specified discharges are equalled or exceeded. A flow-duration curve for the Pere Marquette at Scottville is shown below. The curve is based on record from 1940 to 1966.



FLOW-DURATION CURVE, PERE MARQUETTE AT SCOTTVILLE

The ratio of 90 percent to 10 percent discharge on Michigan streams varies from as great as 0.75 to less than 0.05. The higher ratios generally indicate a relatively large contribution of ground-water discharge to the stream. The Pere Marquette, with a ratio of 0.44, has a large contribution from ground-water, but not so great as some other rivers in the area, such as the Manistee.

VELOCITY

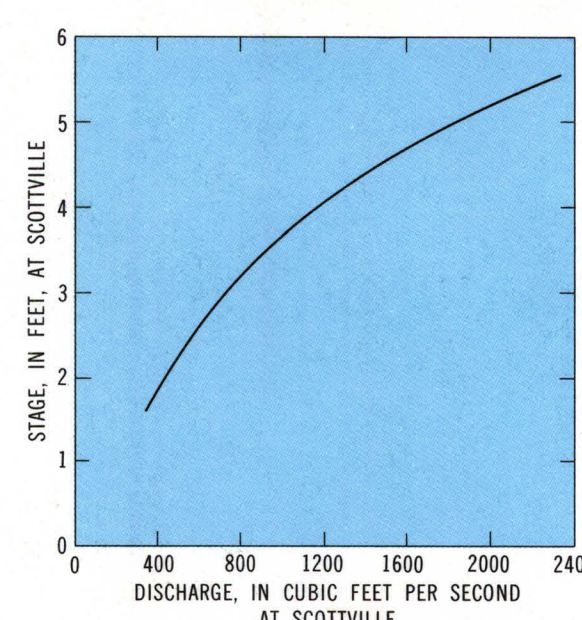
Velocity of flow on the Pere Marquette varies in time and place. Increased discharge generally is accompanied by increased velocity. Velocity normally is faster near the surface at mid-channel than near the bottom or banks of a river. Velocity in rapids and riffles is obviously faster than in deep pools. Measured velocities in the Pere Marquette ranged from less than 1 foot per second in the pools to more than 5 feet per second at Rainbow Rapids. The velocity and depth of a stream are limiting factors in safe wading. Generally it is not safe to wade a stream where the depth, in feet, multiplied

by velocity, in feet per second, is greater than 10. For example, if the velocity is 5 feet per second, the wader should not enter water more than 2 feet deep. This assumes a firm footing and a strong wader. If bottom material is slippery, even 1 foot may be too deep. Velocity is a limiting factor in safe wading on the Pere Marquette in the faster riffles and rapids. In most reaches wading is restricted chiefly by the velocity and depth of the water in relation to the wader's boots.

STREAMFLOW

STAGE

The stage, or water level, of the Pere Marquette fluctuates with discharge. The relation of stage to discharge is used to determine the discharge of the river between measurements. The relation between discharge and stage is shown on the graph at the right.



STAGE-DISCHARGE RELATION

The relation varies in different reaches of the river. In general, for a given change in discharge, fluctuations in stage are relatively large where the river channel is narrow and banks are high, and relatively small where the channel is broad and banks are low. Channel width and bank heights are shown on maps 1 and 3 on sheet 2.

Fluctuations in stage influence the amount of cover available to trout and the wadability of some reaches of the river. Extremely low stages make boating difficult in some shoal reaches, and extremely high stages may cause damage to cabins and campgrounds.

In a normal year, the stage of the Pere Marquette at the gaging station at Scottville fluctuates only about 3 to 4 feet. Stage is usually lowest in late summer and highest in early spring. Fluctuations in stage on the Pere Marquette usually are not abrupt, except during time of snowmelt or exceptionally heavy rains. At such times the changes in stage from day to day may be great enough to restrict wading in some reaches of the river.

STREAMFLOW

SUMMARY

The following table summarizes the streamflow characteristics of the Pere Marquette River and shows how these characteristics are related to recreational uses.

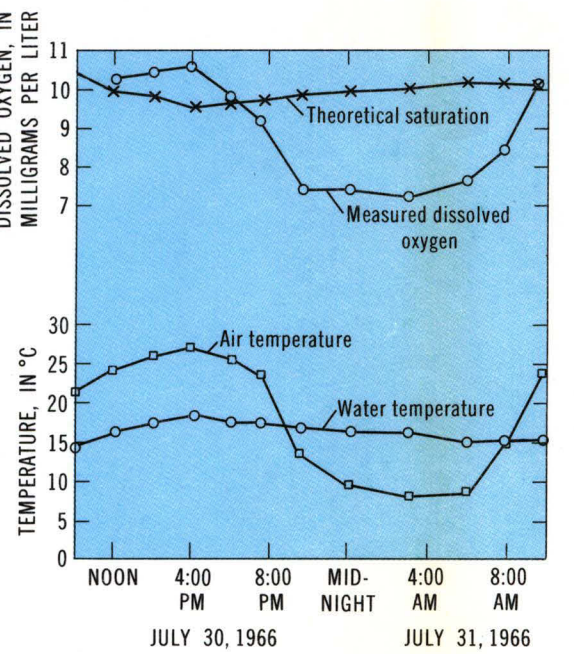
Recreational use	Relation of streamflow to recreational use (Prepared by the Michigan Department of Natural Resources)	Characteristics of Pere Marquette River
Trout fishing	High drought flow helps keep summer water temperature low. Excessive flood-flow removes cover and may cause erosion of banks. A variety of fast and slow reaches adds interest for fishermen. Excessively high velocities make wading dangerous. Abrupt and large increases in stage are a hazard to wading fishermen.	Drought flow of Pere Marquette is relatively high. Floodflows cause some bank erosion, but damage appears to be slight. Velocity varies in different reaches. Generally not too fast for safe wading except in a few of the larger rapids. Velocity at flood time may be too fast in much of river. Rise in stage may be great enough to make some reaches unwadable. Increases in stage generally are not abrupt. A rise of more than 1 foot in 24 hours is uncommon.
Boating	Boating season reduced by periods of flood and drought. A variety of fast and slow reaches adds interest for boaters. Small velocity makes upstream travel easier.	Flood season usually over before vacation season. Late summer drought flows may result in some boat damage caused by rocks and shoals. Alternating rapids and pools make boating interesting in upper river. Below Custer, rapids and riffles are rare. Velocity is slow enough to make upstream travel possible in most of river below Custer and in some reaches as far upstream as Baldwin.
Camping and cabin living	Streamflow characteristics favorable to fishing and boating also are generally favorable to camping and cabin living.	See descriptions above.

QUALITY OF WATER

DISSOLVED OXYGEN

Dissolved oxygen is another critical requirement of recreational rivers. The amount of dissolved oxygen in water is very small. At temperatures just above freezing, water saturated with dissolved oxygen contains about 14 mg/l (milligrams per liter) of oxygen. As water temperatures increase the capacity to retain oxygen decreases, and at water temperatures above 21.1°C (70°F) saturation is reached at concentrations less than 9 mg/l. In summer the effect of temperature may be masked by effects of photosynthesis and respiration of aquatic plants.

Dissolved oxygen was measured periodically for 24 hours at the campsite above Rainbow Rapids in the NW¼SW¼ Section 27, T. 18 N., R. 14 W. (see graph below). Dissolved oxygen was slightly above saturation during most of the daylight hours and dropped to 2 to 3 mg/l below saturation at night. Measured dissolved oxygen ranged from 12 to 10.4 mg/l. This is a normal range for an unpolluted cold-water stream with moderate bottom vegetation.



DISSOLVED OXYGEN AND TEMPERATURES PERE MARQUETTE ABOVE RAINBOW RAPIDS

QUALITY OF WATER

pH

The pH of water is an indicator of its acidity or alkalinity. Waters with a pH of 7 are said to be neutral. A pH lower than 7 indicates acid water; a pH higher than 7 indicates alkaline water. The water in the Pere Marquette is slightly alkaline with pH values ranging from 7.3 to 7.8.

SUSPENDED AND FLOATING SOLIDS

No direct measurements of suspended solids were in this study. Turbidity was apparently fairly low during most of the summer season, as the bottom was clearly visible most times at depths up to 3 feet. After heavy summer rains the water became slightly cloudy, and during the spring snowmelt the water appeared to be moderately turbid. Floating materials, such as organic trash, detergent foam, and oil slicks were not observed on the river.

SPECIFIC CONDUCTANCE

The specific conductance of water is an indicator of concentration of dissolved solids. It is useful in measuring gross changes in the dissolved load of a stream. During the period October, 1965, to May, 1966, the water from the Pere Marquette at the gaging station at Scottville fluctuated in specific conductance between 195 and 360 micromhos at 25°C. Specific conductance was generally low during very high flows and relatively high during base flow.

DISSOLVED SOLIDS

Chemical analyses of water from the Pere Marquette are listed below. (Locations of sampling sites are shown on Map 1, Sheet 2.) The water generally is moderately hard, of the calcium bicarbonate type, and dissolved constituents are in the normal range for an unpolluted stream in this area. Nitrates and phosphates were low in most samples, but a few showed relatively high phosphate content.

	Station 1 SE-SE sec. 10 T. 17 N., R. 12 W. 9-19-66	Station 2 SW-SW sec. 15 T. 17 N., R. 13 W. 9-19-66	Station 3 NW-SW sec. 27 T. 18 N., R. 14 W. 9-19-66	Station 4 SW-SW sec. 21 T. 18 N., R. 15 W. 9-19-66
Calcium (Ca) mg/l	42	42	42	42
Magnesium (Mg) mg/l	16	18	14	14
Sodium (Na) mg/l	2.5	5.8	6.1	7.9
Potassium (K) mg/l	.4	.3	.5	.4
Bicarbonate (HCO ₃) mg/l	206	197	172	174
Carbonate (CO ₃) mg/l	0	0	0	0
Sulfate (SO ₄) mg/l	9.2	12	24	23
Chloride (Cl) mg/l	1.0	8.0	8.5	14
Fluoride (F) mg/l	.1	.1	.1	.1
Nitrate (NO ₃) mg/l	.1	.2	0	0
Phosphorus as PO ₄ mg/l	.33	1.6	.07	.24
Dissolved Solids*, mg/l	182	193	187	195
Hardness as CaCO ₃ mg/l	171	179	163	168
Specific Conductance**	331	331	337	350
pH	7.5	7.5	7.4	7.5
Color	8	5	8	5

* Calculated

** micromhos at 25°C

QUALITY OF WATER

SUMMARY

The following table summarizes the quality of water characteristics of the Pere Marquette River and shows how these characteristics are related to recreational uses.

Recreational use	Relation of quality of water to recreational use	Quality of water in Pere Marquette River
Trout fishing	Temperature Criteria for intrastate waters, as established January, 1968, by the Water Resources Commission, Michigan Department of Natural Resources (1968) specify 21.1°C (70°F) as the maximum limit for intolerant fish (cold-water species).	Maximum temperatures in the upper reaches of the Pere Marquette probably exceed 21.1°C (70°F) only rarely. Maximum temperatures below Scottville probably exceed 21.1°C (70°F) a few days of most years.
	Dissolved Oxygen The Water Resources Commission (1968) specifies a minimum of 6 mg/l. At water temperatures above 20°C (68°F), Tarzwell (1957) indicates full air saturation is required for the full range of activity for brook trout.	Dissolved oxygen on the Pere Marquette above Scottville probably does not drop below 6 mg/l at any time. At night may drop 2 to 3 mg/l below saturation.
	Hydrogen Ion Concentration (pH) Water Resources Commission (1968) specifies limits of 6.5 and 8.5.	pH of the Pere Marquette generally ranges from 7.3 to 7.8.
	Nutrients (chiefly nitrates and phosphates) Water Resources Commission (1968) requires nutrients to be limited to the extent necessary to prevent stimulation of growths of algae, weeds, and slime, which are or may become injurious to the designated use. Because these nutrients are rather quickly taken up by plants, exact limits of desirable concentrations are difficult to determine.	Pere Marquette is generally free from undesirable weeds, algae, and slime. A few analyses indicate relatively high phosphate content.
Trout fishing, boating, camping, and cabin living	Floating, Settlesable, and Suspended Solids Water Resources Commission (1968) specifies no objectionable unnatural turbidity, color, or deposits sufficient to interfere with designated use; no floating solids, or evidence of residues of unnatural origin.	Pere Marquette appears to be generally free of floating weeds, algae, and residues of unnatural origin. Turbidity during spring flood flows may be moderately high.

OUTLOOK FOR THE FUTURE

The Pere Marquette at the present time (1969) is not overdeveloped, and is relatively free from pollution in all reaches upstream from Ludington. Fishing pressure no doubt will increase as migratory rainbow (steel head) trout recover from the predations of the lamprey. Migratory salmon also may use the Pere Marquette for spawning in the future. Continued development on river frontage is likely to increase considerably, as most frontage is privately owned. However, much of the frontage in the lower reaches of the river is too low and swampy for the best cabin sites. Canoe traffic will continue to grow, because

the Pere Marquette is well-suited to the novice canoeist—fast enough to be interesting but not dangerous. Campsites appear to be adequate for many more campers than are now using them—except for a few weekends at the height of the tourist season.

Two possible threats to the recreational values of the Pere Marquette are future contamination from increased waste disposal and pesticides, and degradation of the river banks by excessive cabin development. Degradation of river banks may include removal of cover, and may result in increased sediment load.

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RECONNAISSANCE OF THE PERE MARQUETTE RIVER, A COLD WATER RIVER
IN THE CENTRAL PART OF MICHIGAN'S SOUTHERN PENINSULA

By
G. E. Hendrickson and C. J. Doonan
1971