Fishing the Au Sable

by Ogden Pleissner

These two photos represent historic moments in the lives of the Au Sable and one of its earliest families. John Stephan, above, stands in the boat at right, netting a fish, around the turn of the century. That's the original Stephan's Bridge in the background. Below, John's son Lacey guides another Au Sable boat beneath the present Stephan's Bridge, at the same location, more than fifty years later.

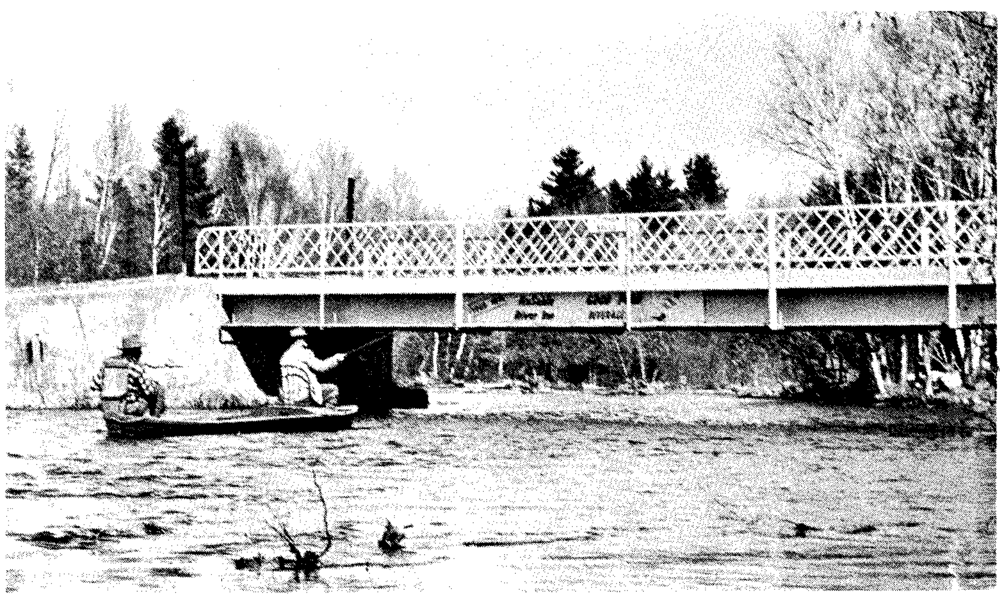
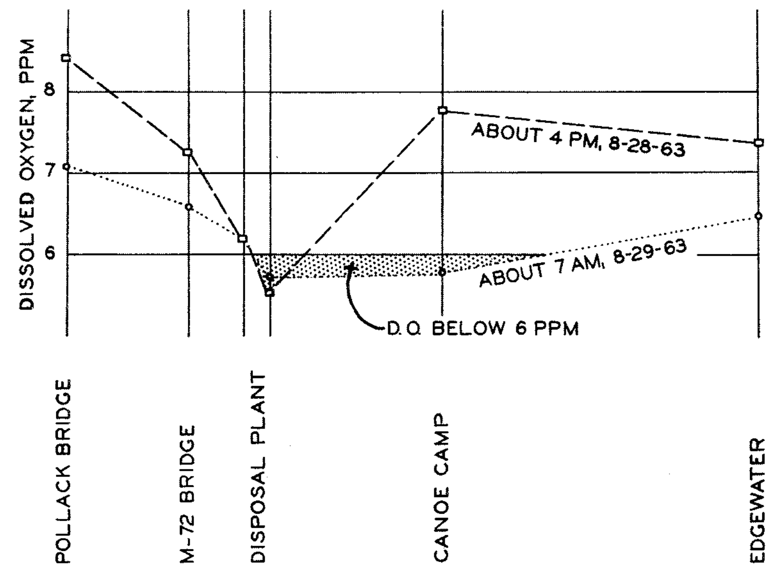


Figure 18. Dissolved oxygen drops perceptibly at Grayling disposal plant. (Note: values projected from two or more readings.)



oxygen again increases slowly during night and early morning, but quite rapidly during mid-day. The oxygen sag extends only a short distance below Grayling during daylight hours because photosynthesis restores the oxygen rather quickly. At night the oxygen sag extends further downstream.

The loss of 1.7 parts per million of dissolved oxygen between M-72 bridge and the collection point below the disposal plant may have been greater than usual on the afternoon of August 28, 1963. Samples taken the afternoon of September 5, 1963, showed a loss of only 1.4 parts per million. The oxygen sag at the plant depends mostly on the B.O.D. discharge which varies from day to day and hour to hour.

Another critical element of water quality for trout is temperature. The extreme temperature range of the Au Sable at Grayling during the period of October, 1957 to September, 1962 varies from about 32° F in winter to 82° F in the summer (fig. 19). The station at Grayling is not especially good for recording natural temperatures of the river because it is situated in a pond just upstream from a small dam at the Old U.S. 27 bridge. It is two and a half miles downstream from the power dam lake. A number of cottages are on the river at that point. A station more representative of natural conditions is located at Edgewater, just above Stephan's Bridge (fig. 20). Unfortunately, its record dates from August, 1963, and includes no prolonged hot spells. However, the record does indicate the temperature of the river to be generally lower in summer and higher in winter than at Grayling.

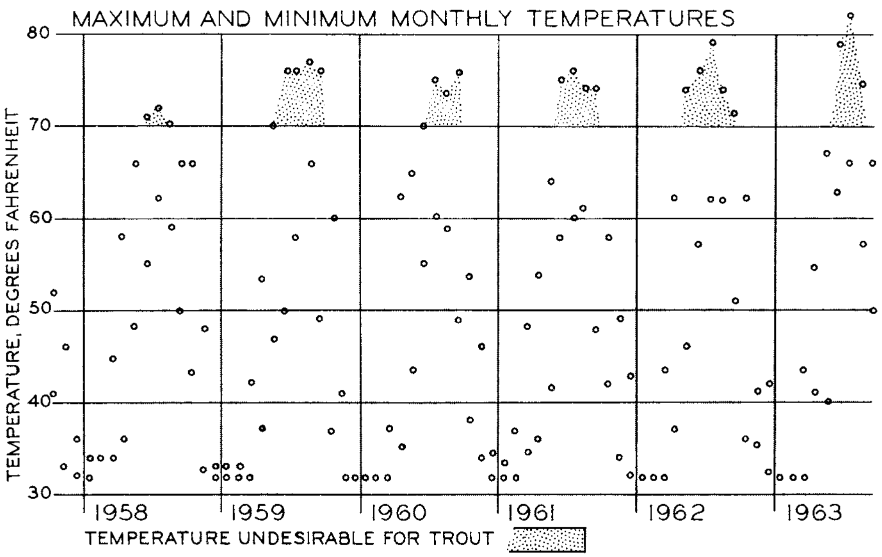


Figure 19. Water temperature of the Au Sable at Grayling occasionally rises higher than is desirable for trout.

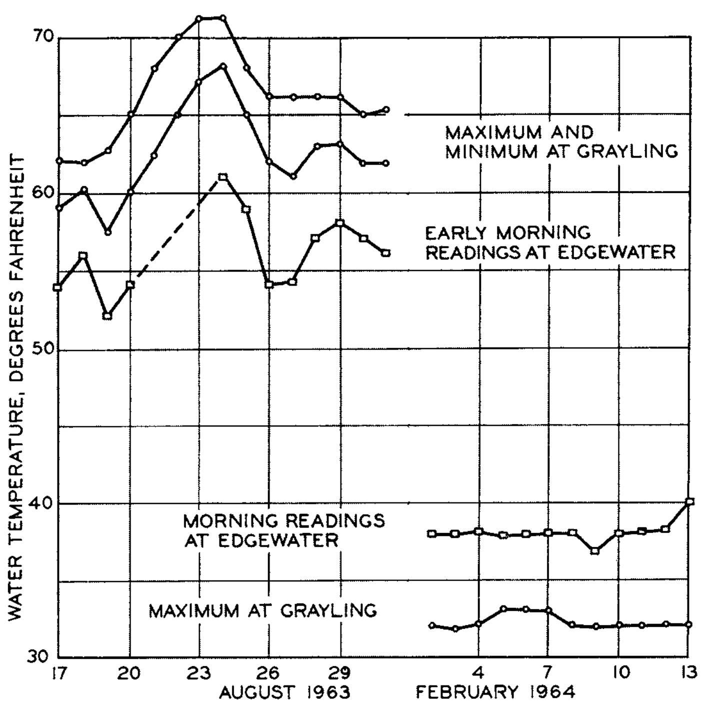


Figure 20. Water temperature at Edgewater is lower in summer and higher in winter than at Grayling.

Daily summertime warming of the waters in the upper reaches of the East Branch, North Branch and South Branch apparently is caused by lake outflow in these headwaters. The open areas in the "Meadows" of the East Branch and North Branch also allow the sun to warm the water (figs. 18 and 22). In downstream reaches, however, groundwater flowing in cools the streams. Temperature of shallow groundwater in the area averages about 48 F.

Suspended materials in the Au Sable river generally are very low. Measured turbidities in May, 1964, ranged from one to eight Jackson units, a measure of the depth of water to which a candle flame can be clearly distinguished. During low water of August, 1963, turbidities were generally lower than 2 ppm.

Dissolved nitrates can also affect fish population. Nitrates promote the growth of aquatic vegetation and thereby increase the daily fluctuation of dissolved oxygen in the water. More-than-usual amounts may also signal pollution. In seven out of ten samples collected from the Au Sable and tributaries on August 30, 1963, nitrates were less than one ppm. The three samples exceeding one ppm were collected below the Grayling sewage disposal plant, below the trout hatchery, and below Mio dam.

Other dissolved materials that may affect trout are detergents, pesticides, and industrial wastes. Detergent foam was observed a few days in August, 1963. Although unsightly, the foam was not extensive enough to affect trout. Oil slicks from outboard motor fuel or from leaky fuel storage tanks appear occasionally, but are very minor at present. Analyses for pesticides were not made. Other than a minor amount of sewage effluent and temperature loading, the river appears to be remarkably free of contaminants at this time.

Sport fishing demands a higher quality of water than any other recreation use. The canoeist, camper, and cabin-dweller seek clean, clear, water free of unpleasant odors. Water free of bacteriological contamination is certainly desirable, but not absolutely necessary. Water quality suitable for trout is invariably suitable for other recreational requirements — except that it usually is too cold for most swimmers.

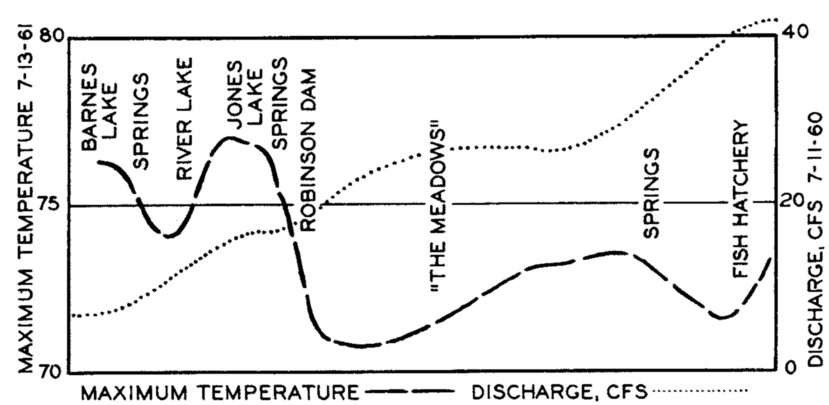


Figure 21. Water temperature in East Branch drops in vicinity of springs, and rises in lakes and meadows.

Figure 22a. Beaver dam below Frederic.

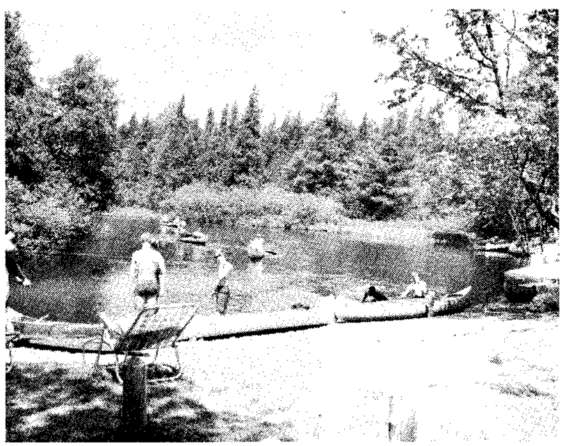


Figure 22b. Michigan Department of Conservation canoe camp below the "Pullover."

Figure 22c. Below Parmalee Bridge.

Bed and Banks

The gravel riffles, deep pools, cedar swamps, and pine-clad hills contribute to the beauty of the Au Sable. The character of bed and banks also influences trout habitat, quality of water, the flow, and suitability for recreation.

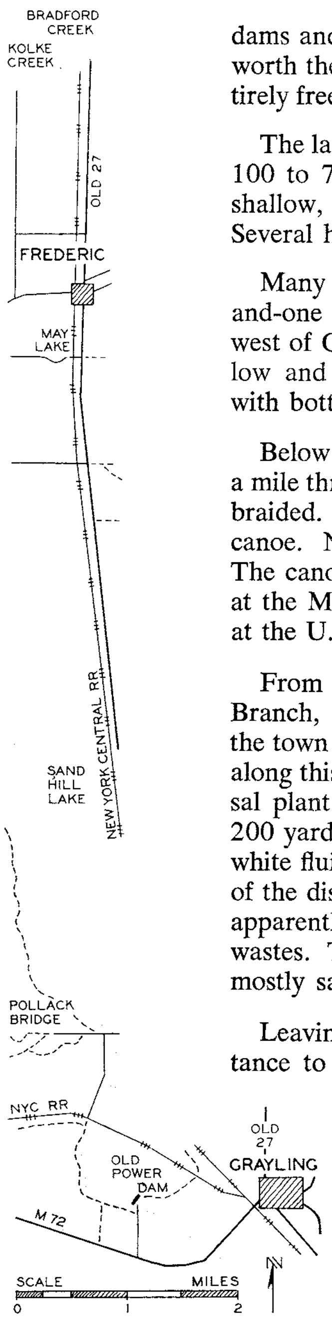
Gravel bottoms, alternating shallow riffles and deep pools, and adequate cover are desirable conditions for both trout and trout fishermen. The trout fisherman also likes shaded banks to keep the water cool, but too many low overhanging branches snag his line. A firm bottom and pools that can be waded are also a boon to fishermen. The canoeist enjoys long stretches of fast-water riffles; the slow-water pools are less interesting. Campers and cabin dwellers like high, dry banks with good landing spots and easy access to the water. Cabin-dwellers generally prefer sandy banks where chances of getting a groundwater supply are good. Sandy soil also drains better than clayey soil. Many, but not all, of those using the Au Sable prefer relatively isolated stretches to developed areas.

In general, the Au Sable's bed and banks satisfy recreational requirements. Some stretches of the river are more favorable than others. The depth, velocity, and even the width of the river varies with the season and the rainfall. In mid-August, 1963, I studied this river from a canoe. The river stage, or level, was about normal for that time of year. Mileages used in the following description are distances measured along the meandering course of the river — called river miles.

The Au Sable is born about two miles north of the town of Frederic at the junction of Kolke Creek and Bradford Creek. At Frederic the stream is 15 to 30 feet wide and varies in depth from a few inches to two feet. A canoe sometimes scrapes the gravel bottom, even in the deepest part of the channel. Velocity in the fastest parts is about one mile per hour. A few beer cans and wire fencing were encountered in this stretch.

The distance from Frederic to the backwaters of the old power dam above Grayling is about 15 river miles. The stream flows alternately between high sandy and gravelly banks and through broad flat cedar swamps. Where banks are high the river generally flows in a single channel with predominantly gravel bottom. In the swamps the flow is divided into braided channels with numerous grassy islands, and the bottom is generally sandy. Width is 20 to 40 feet, except at beaver dams and artificial ponds. Depth varies from one-half foot to three feet. Surface velocity probably averages less than one mile per hour.

Except for an occasional cabin, this stretch of river is lonely, and the feeling of isolation in nature is almost complete. Many deer and ducks were seen and also an occasional beaver. The canoe must be lifted over beaver



dams and many log jams, but the beauty and solitude is well worth the extra effort. As expected, this stretch is almost entirely free of litter.

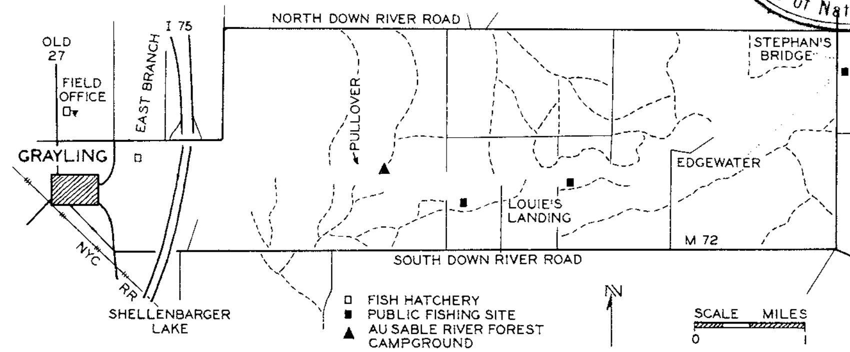
The lake behind the power dam is about two miles long and 100 to 700 feet wide. Depth at the upstream edge is very shallow, increasing to more than ten feet near the dam. Several homes and cottages are on the lake shore.

Many homes and cabins are situated along the next one-and-one half miles to the bridge on State Highway 72 southwest of Grayling. Banks are alternately high and sandy, and low and swampy. The sand and gravel bottom is littered with bottles and cans.

Below the M-72 bridge the river winds a little more than a mile through marsh. Bottom is mostly sand and the channel braided. In some places, the depth is too shallow to float a canoe. Not far from the river is an unsightly trash dump. The canoeist can bypass this stretch by taking his canoe out at the M-72 bridge and putting back in just below the dam at the U.S. 27 bridge (now business route for I-75).

From the old U.S.-27 bridge to the mouth of the East Branch, about one mile, the river is lined with dwellings in the town of Grayling. Also, several canoe liveries are located along this stretch. The treated effluent of the Grayling disposal plant empties into the stream near the left bank, about 200 yards above the mouth of the East Branch. The milky-white fluid is soon dissipated and the only other visible effect of the disposal plant is a greyish-brown slime on the bottom, apparently feeding on the nutrients provided by the sewage wastes. The bottom is mostly gravel, and the high banks are mostly sand. Width varies from 20 to 50 feet.

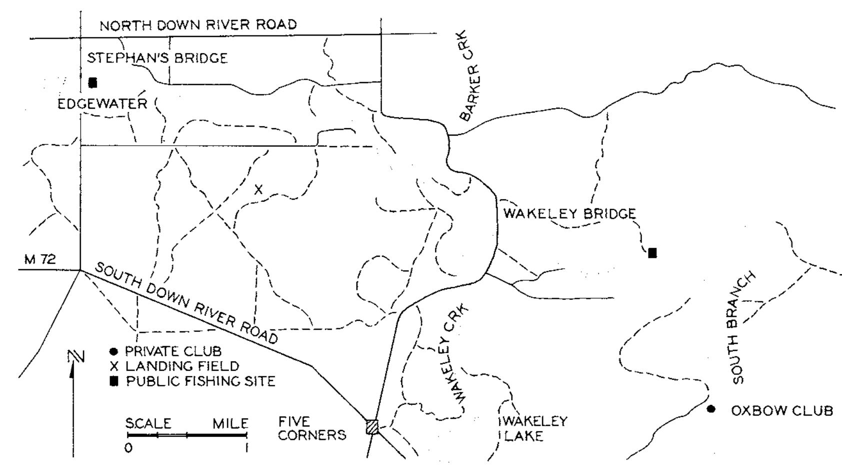
Leaving the mouth of the East Branch, the canoeing distance to the Au Sable River Forest Campground is about 6 miles. Here again the river flows alternately between high oak and pine-covered hills and low cedar swamps. Width varies from 30 to 70 feet and depth varies generally from one to six feet, though occasional deeper holes are found. In the high-bank areas the bottom may be sand or gravel, but in the swamps the bottom is mostly sand. Surface velocity of the river probably ranges from less than one-half mile per hour to a little over one mile per hour. Many cabins, palatial homes, and lodges are situated on high bank areas. The bed and banks in places are littered with bottles and cans.



Along this stretch is the broad swampy area extending north from Shellenbarger Lake. The river bottom has been dredged in places to provide fill for shore development. This modification of the stream cross-section has caused a marked reduction in the velocity of flow. In fact, during winter this section freezes over in extremely cold weather, thereby hampering winter canoe travel. On February 26, 1964, when the air temperature was about 23° F, the river was frozen over for about 200 yards here — the only area closed by ice between Grayling and Stephan's Bridge.

Below the Shellenbarger swamp, the river cuts into a high gravelly left bank and then makes a long oxbow meander through a swamp. The neck of this oxbow, opening to the south, is called the "Pullover" because canoeists sometimes pulled their canoes across here rather than paddle around the meander.

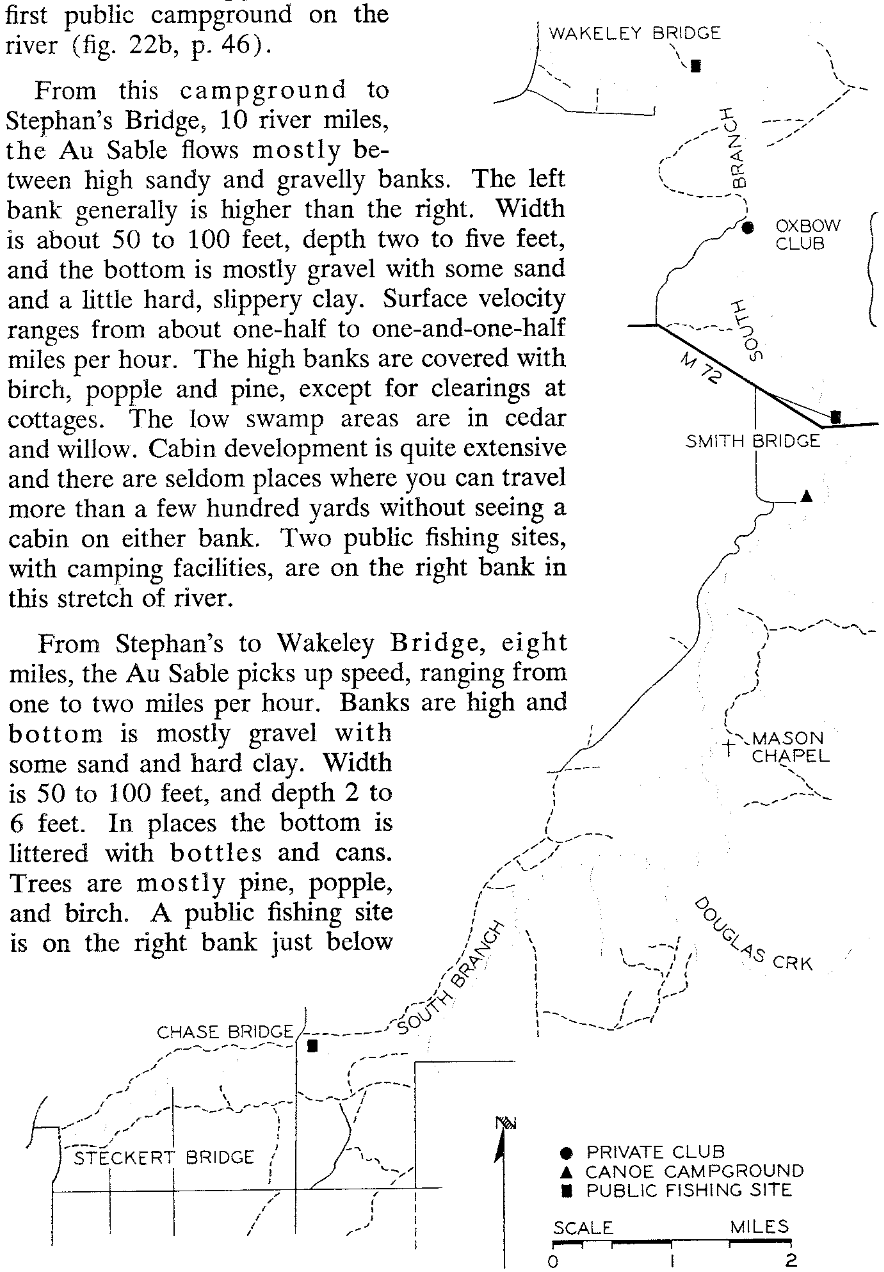
About 600 feet below the downstream end of the Pullover is the Au Sable

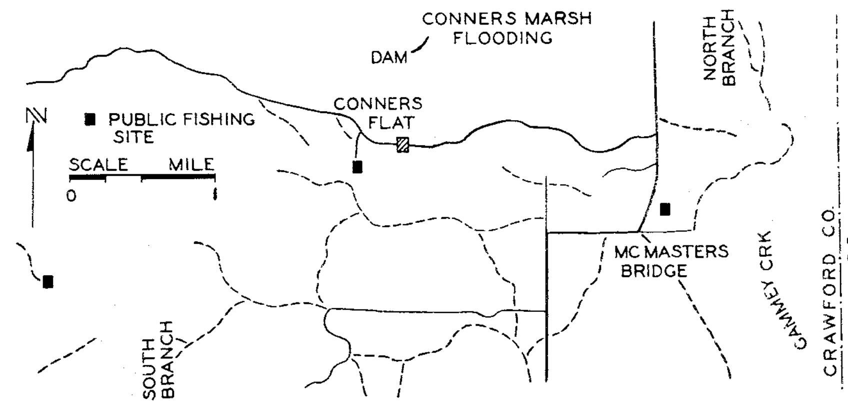


River Forest Campground—the first public campground on the river (fig. 22b, p. 46).

From this campground to Stephan's Bridge, 10 river miles, the Au Sable flows mostly between high sandy and gravelly banks. The left bank generally is higher than the right. Width is about 50 to 100 feet, depth two to five feet, and the bottom is mostly gravel with some sand and a little hard, slippery clay. Surface velocity ranges from about one-half to one-and-one-half miles per hour. The high banks are covered with birch, popple and pine, except for clearings at cottages. The low swamp areas are in cedar and willow. Cabin development is quite extensive and there are seldom places where you can travel more than a few hundred yards without seeing a cabin on either bank. Two public fishing sites, with camping facilities, are on the right bank in this stretch of river.

From Stephan's to Wakeley Bridge, eight miles, the Au Sable picks up speed, ranging from one to two miles per hour. Banks are high and bottom is mostly gravel with some sand and hard clay. Width is 50 to 100 feet, and depth 2 to 6 feet. In places the bottom is littered with bottles and cans. Trees are mostly pine, popple, and birch. A public fishing site is on the right bank just below

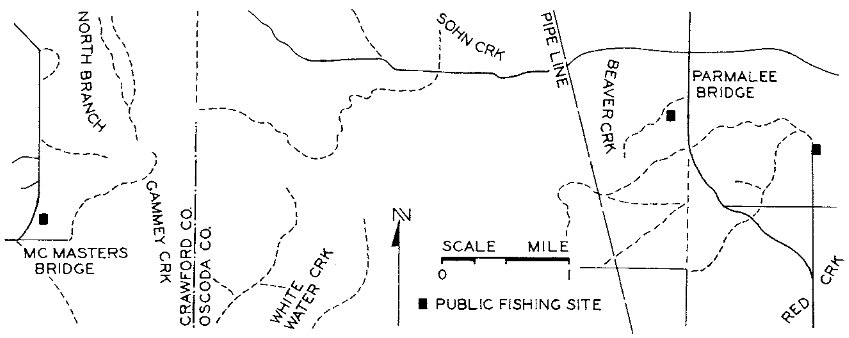




Stephan's Bridge, and many cabins line both banks, especially in the two miles above Wakeley Bridge. This is one of the most highly developed areas of the river.

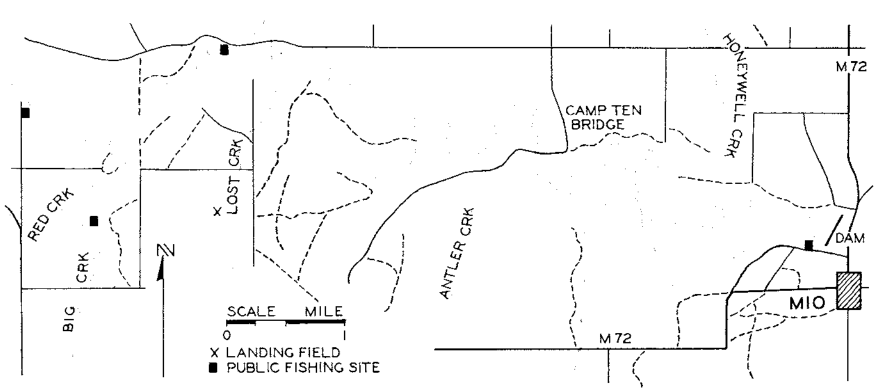
From Wakeley to McMaster's Bridge is a 15-mile stretch of extremely variable character. It begins with fast water, gravel bottom, and high banks, then flows slowly through the Stillwater where bottom material is mostly sand and clay, banks are low, and the river is relatively deep and wide — as much as 200 feet wide and more than six feet deep in places. The Stillwater is about 7 miles long. The surface velocity here is generally less than one-half mile per hour. The South Branch enters from the right in the upper part of the Stillwater. Below the Stillwater are 5 miles of relatively fast water with velocities as high as 2.5 miles per hour in the gravel riffles. There are many cottages, but not so closely spaced as just above Wakeley Bridge. Two public fishing sites are on the left bank, one just above and one just below the Stillwater.

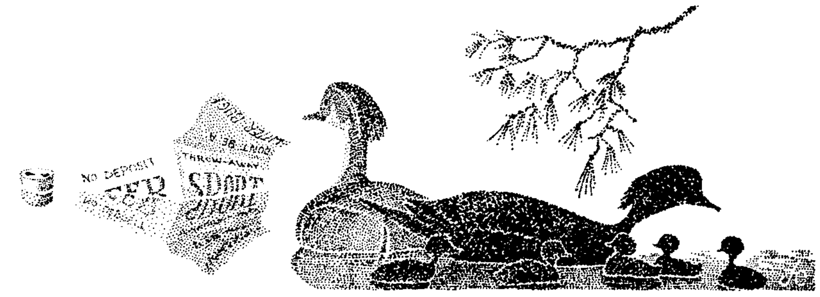
Below McMaster Bridge the Au Sable flows alternately in deep sandy pools and shallow gravelly riffles. The North Branch joins the stream on the left about two miles below McMaster's Bridge. After the first six miles the riffles become more widely spaced; then sandy deeps predominate for the remaining three miles to Parmalee Bridge. In places, the width exceeds 200 feet and the depth six feet. Velocity averages one to two miles per hour. For the first few miles below McMaster's Bridge cottages are numerous, but beyond that the river again recovers some of its wilderness aspects. The bottom and banks are generally free of litter except at unattended campsites. Though generally inaccessible by auto, these camps were littered with trash and garbage. A public access site is just below McMaster Bridge and another just above Parmalee Bridge.



A little more than a mile below Parmalee Bridge on the high right bank is an excellent campsite maintained by Luzerne Township. The river takes on a "big river" character here, being more than 250 feet wide in places and more than six feet deep (fig. 22c, p. 46). Cottages are few and the river appears relatively wild. Litter was apparent only at public access sites and campsites. Velocity averages one to two miles per hour. Width increases while velocity decreases about seven miles below Parmalee, where the backwater effect of Mio Dam is encountered. From this point to the Mio Dam, a distance of about six miles, the river becomes Mio Pond. It is generally a quarter of a mile wide and shallow, except for 20-foot depths in the drowned channel.

The bed and banks in the tributaries are similar to those of the main stem. Of special interest is the 14-mile stretch on the South Branch known as "Mason's Grant". In accordance with the donor's wishes, this tract is free from all development except for a simple log chapel (see p. 77) and one well-developed canoe campsite. Because it is an intensively travelled canoe area, however, even this stretch is not free of litter.





Chapter III

CHANGES ON THE AU SABLE

The Au Sable today is not the river it was 50 years ago, or even ten years ago. In the next ten years it can become either worse, or better. What are the present trends in population, water use, and land use in this watershed? What is happening to this river?

Population

The number of permanent residents in the Au Sable watershed is small but growing (fig. 23). The population of Crawford County increased one third from 1940 to 1960, the same rate as the total state population. About 90 percent of the county is included in the watershed. The population of Grayling declined about five percent in that period. The city of Roscommon increased its population 40 percent from 1940 to 1950; then population declined slightly during the next ten years. Growth in population of Gaylord was about 25 percent from 1940 to 1960.

The increase of residents in the Au Sable watershed above Mio is estimated at about 30 percent during the period 1940 to 1960. Full-time residents in the watershed at present total about 10,000. The summer population including cottage dwellers, campers, National Guardsmen, and guests of resorts, hotels, and motels, probably totals 30,000. Although National Guard headquarters is outside the watershed, the area of field operations is largely within.

Annual increase of full-time residents in the watershed is probably only two to three percent. The annual increase of summer residents, not including the National Guard, may possibly be as much as ten percent a year.

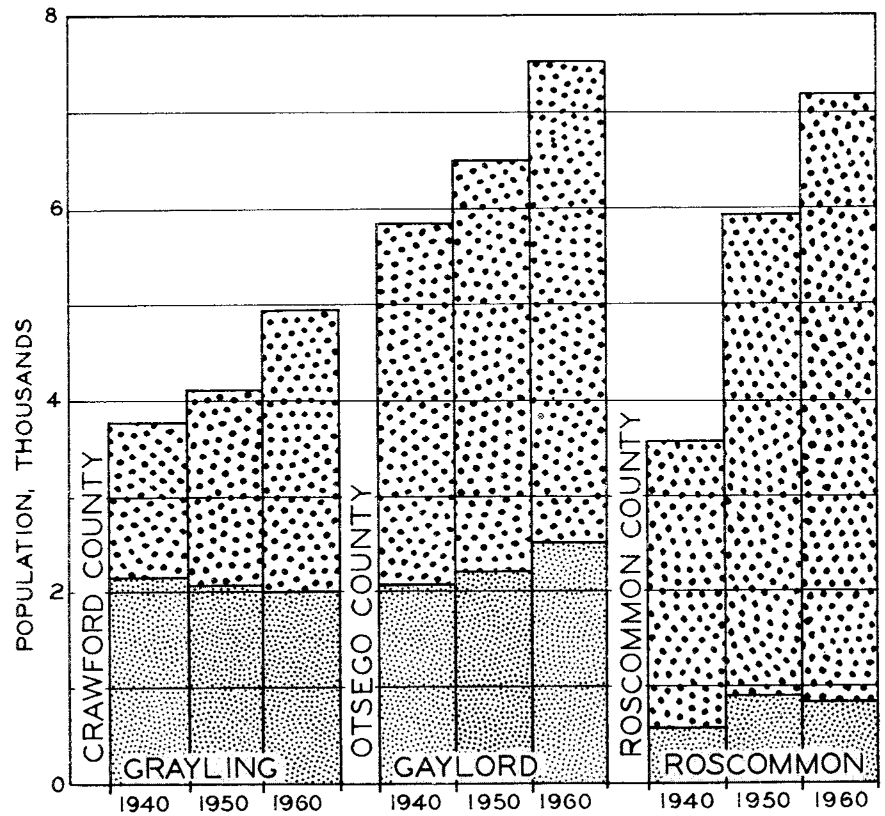


Figure 23. Total permanent population continues to expand.

Water Use

Water in the Au Sable watershed is used for municipal, domestic, and industrial purposes as well as recreation. Use for recreation seldom diminishes the supply, although it can decrease the quality. Use of water for municipal, domestic, and industrial supplies, however, can diminish the quantity although amounts currently being used for these purposes have no appreciable effect on recreation uses.

Records of municipal withdrawals suggest the per capita use of water is increasing. All municipal supplies and almost all industrial and domestic supplies are from wells. No records of withdrawals of water for individual domestic supplies are available, but domestic use is estimated to have grown at about the same rate as municipal use. Most industries in the watershed now use municipal supplies, but new industries may develop their own supplies.

The increasing population and increasing use of water is accompanied by increasing discharge of sewage wastes from municipal disposal plants and individual disposal systems. An increase in water use by industries may also bring added contaminants to the river, depending on the type of waste produced and the method of treatment and disposal.

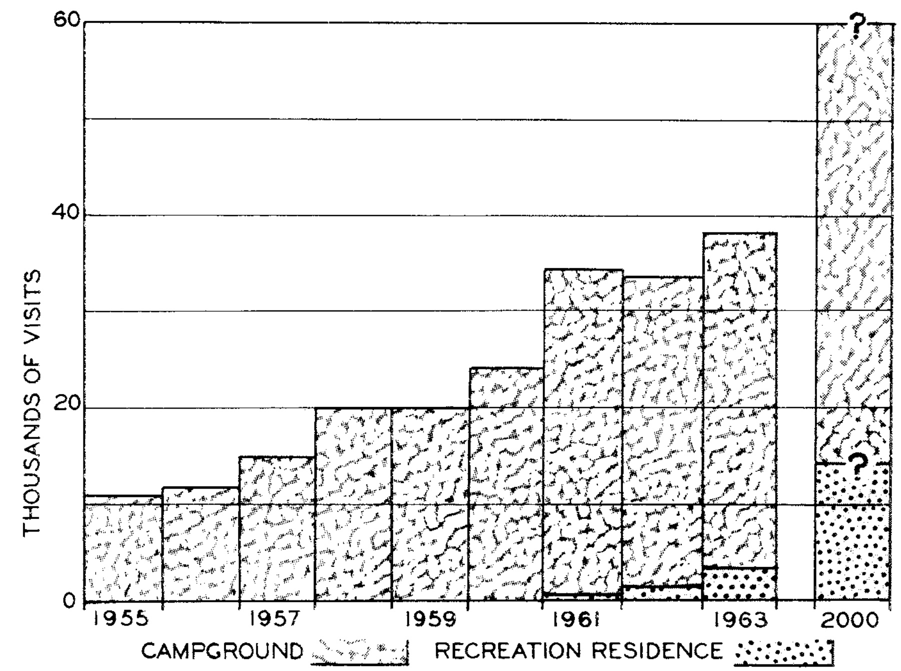


Figure 24. Increased recreation use of the national forests is anticipated by the Mio Ranger District.

Land Use

The use of land in the Au Sable watershed has changed radically in the past 70 years and it goes on changing. According to Mr. William Christenson, the country was stark and desolate in the 1890's after almost all marketable timber had been cut. He says it is much more attractive now that most of the watershed is reforested.

Following the lumber boom, sporadic attempts were made to farm parts of the area, but the sandy soils and relatively short growing season soon discouraged most farmers. In 1959, only 922 acres of land remained in cultivation in Crawford County, and the total value of all farm products sold was $32,663.

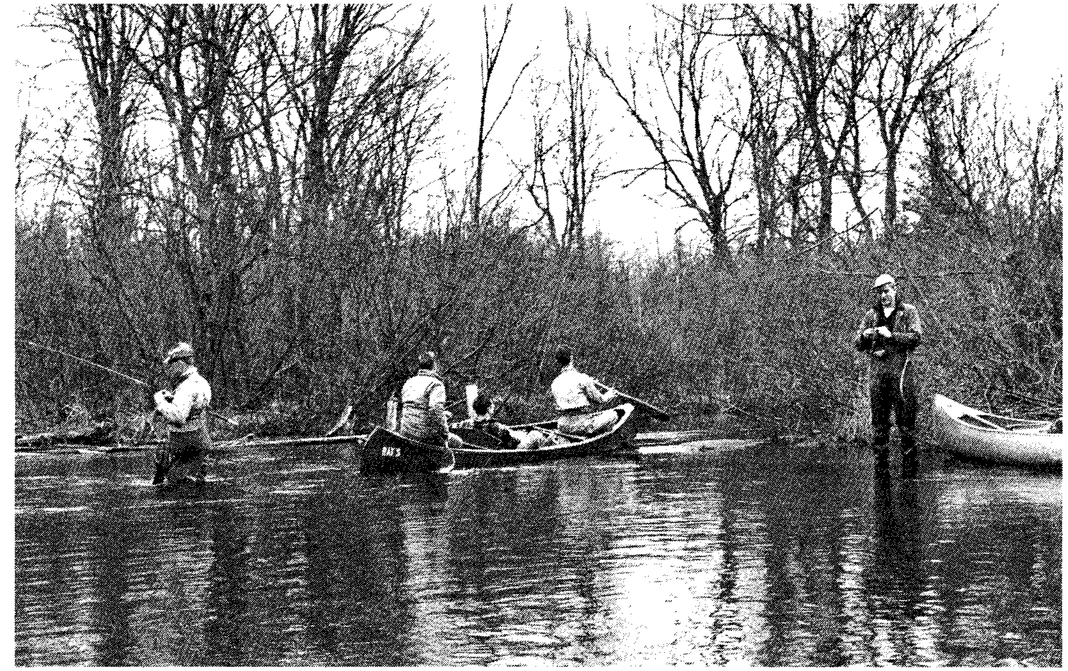
During the Depression of the 1930's much of the land reverted to the State for tax delinquency. About 75 percent of the watershed is now State and National Forests. With management, the forest cover has been renewed over most of these lands. One small area of virgin forest is preserved at Hartwick Pines State Park as a reminder of former grandeur. Most of the land in private ownership was also allowed to revert to woodlands, and the scarred landscape is recovering.

Having withstood attacks of lumbermen and farmers, the Au Sable watershed is now being exposed to a new threat — the postwar boom in outdoor recreation. With more money to spend, more leisure time to spend it, faster automobiles, and better roads, vacationers flocked to the Au Sable, crowding the campgrounds and river resorts, and buying up available river frontage for cabin development (fig. 24).

Crowding of campgrounds and resorts is a summer event, the effects of which are largely erased the next winter. But cabin construction is a more permanent alteration of the land. Trees at work sixty years rebuilding the forest are cut away to make room for cabins, roads are slashed through the pines, and bulldozers and dredges despoil the natural landscape and habitat. Cabin development is not restricted to the river banks. Large acreages away from the river have been subdivided into lots and sold for cabin sites.

The present rate of river-front cabin development is rather slow. The best estimate of R. M. Hayes of the Grayling Chamber of Commerce and L. Lovely, County Clerk of Crawford County, is that 20 cabins a year are built on the Au Sable and tributaries above Mio. However, some large river-front holdings are now being subdivided, and it appears that the rate of cabin development may increase sharply in the next ten years.

The growth in population, especially the summer population, the increased use of water and disposal of sewage, and the increase of developed frontage on the river are obvious threats to the river, especially to recreation. Deteriorating recreational values, however, are not inevitable, and it is the purpose of the next chapter to show how these may be preserved.



Canoeing on the Au Sable has grown rapidly as a recreation in recent years. Many liveries, such as this one, below, at Roscommon, are now operating, and provide both rentals and pick-up service.

Lightweight camping equipment has made many points along the river accessible for overnight fishing junkets. Two hours before this photo was taken, this family was in the heat and traffic of a southern Michigan city.

Chapter IV

TO PRESERVE RECREATION VALUES . . .

The Au Sable is still in good condition when compared to other streams, but it may not remain so if present trends continue. What must be done to preserve it, and how can this be accomplished?

The three essential attributes of any river are its streamflow, the quality of its water, and the condition of its bed and banks. Practices controlling one of these attributes may influence the others. Let us first consider water-management designed primarily to control streamflow.

Streamflow Controls

The components of streamflow are stage, velocity, and discharge. They are closely related, and modification of one generally results in change of the other two. When a favorable rate of discharge is maintained, favorable conditions of stage and velocity generally follow.

A combination of relatively high sustained discharge, stage, and velocity are desirable for recreation. One way to insure these desirable characteristics is to manage the watershed so the amount of water going underground to the water table is maintained and possibly increased. To do this, the amount of surface runoff must be decreased. The more water that reaches the river as ground-water discharge, the more stable the streamflow. How can this be accomplished?

Maintaining Ground-water Flow

Ground-water recharge, with consequent ground-water flow to the river, can be increased by intelligent management of vegetation in the watershed. Also, ground-water recharge can be increased by constructing recharge ponds to intercept surface runoff and divert it underground.

About 90 percent of the Au Sable watershed is now in forest cover consisting of trees and brushwood. Consequently, management of vegetation in-

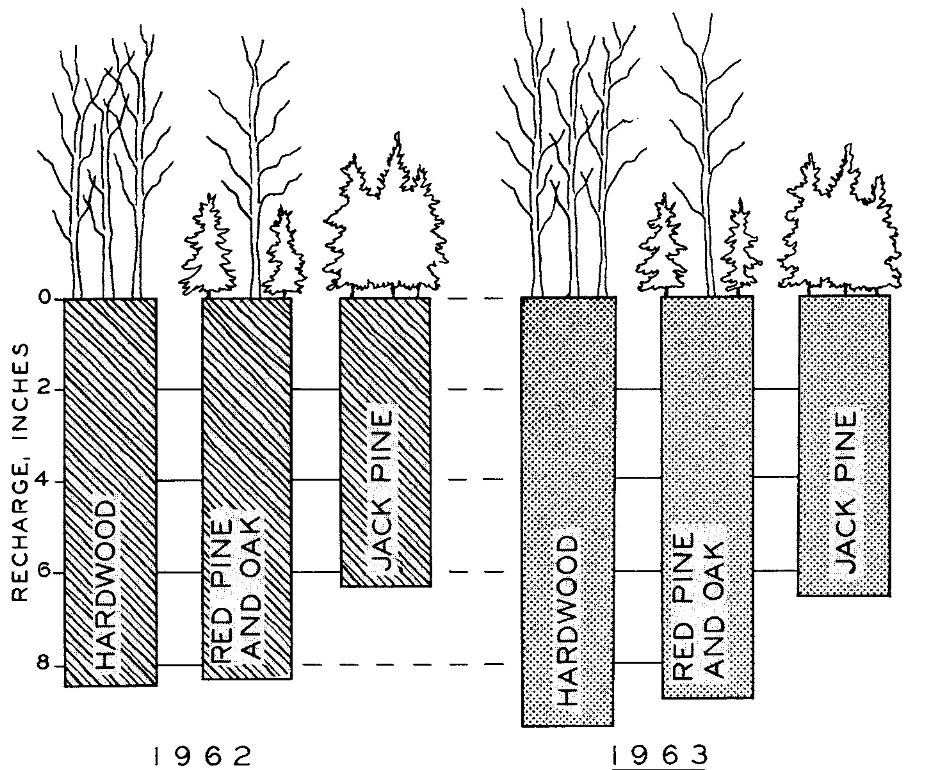


Figure 25. Snow period recharge is greater in hardwood and mixed stands than in pure jack pine (Udell Experimental Forest, U.S. Forest Service).

volves chiefly the management of forest lands. Defoliation, pruning, thinning, and clear-cutting, by reducing evapotranspiration, may increase ground-water recharge, but great care must be exercised in applying these practices because diverse climate, topography, and geology affect the results. A recent study made in 1965 by Dean Urie in the Udell Experimental Forest in Manistee County, Michigan, involves an area similar in most respects to the Au Sable watershed. Each plantation studied was in an area of sandy outwash. Conditions of soils and depth to water were similar in all cases. Possibly this study can be used in managing forests of the Au Sable area.

Urie found that the winter-season recharge of ground water in a hardwood

area was about five percent greater than in a mixed redpine-oak area, and about 30 percent greater than in a jack pine plantation. Results are summarized in figure 25.

Factors other than ground-water recharge must be considered in forest management decisions. Nevertheless, conservation of water resources should be an important consideration in forestry practises where recreational values are recognized as an important part of the forests' worth. If continued research bears out Mr. Uries' early findings, hardwood forests, or at least, mixed hardwoods and softwoods might be encouraged at the expense of pure stands of conifers, especially in new forest plantations. Mr. Urie (personal communication) makes the following additional suggestion: "The silvaculturists . . . . assure me that they can manage pine forests in such open conditions that both the aesthetic and water-yield qualities will be improved while still maintaining a desirable timber productivity. . . . In view of the sandy soils in most of the Au Sable basin, pine forests probably will remain the principal forest type. To a limited extent, these can be intermixed with hardwood in the planting program. The use of wider initial spacings and more frequent thinning, techniques which already are coming into use, will tend to reduce the unfavorable watershed aspects of pine forests."

Forest management practices that include defoliation, clear cutting, and other drastic alterations of forest cover to increase recharge may improve streamflow, but they depreciate the natural beauty of the forest.

Another method of increasing ground-water recharge is to construct recharge ponds which intercept and hold surface runoff and direct it underground. These ponds must be located in drainageways where water normally runs over the surface directly to the river, at least at some seasons. They should be underlain by highly permeable materials so that the water goes underground before much of it can be lost by evaporation. Also, impoundments should be far enough away from the river so that stored ground water does not discharge too rapidly to the river. And they should be located, if possible, in areas where the water table is beyond the reach of tree roots.

To increase spring seepage on a few stream development projects the Michigan Department of Conservation has constructed some experimental recharge ponds. Unfortunately, the effectiveness of these ponds has not been adequately demonstrated as yet. "Before and after" records of recharge and runoff are not available. Neither are there control areas, similar in all features, but without the recharge ponds, that can be used for comparison of recharge-runoff relationships.

Predominantly sandy soils underlain by permeable glacial drift leave few areas in the Au Sable watershed where substantial amounts of surface runoff reach the river. Even so, recharge ponds may be considered in the Au Sable watershed if other more natural means of inducing recharge prove ineffective or too expensive.

If future pumpage of ground water seriously decreases the flow of the river at critical times, recharge ponds in the vicinity of the pumped wells may be desirable. To be most effective, however, these ponds should intercept surface runoff that would otherwise contribute to the peaks on the discharge pattern (fig. 7). If diversions from the river are to be used to fill the recharge ponds, such diversions should be made only during periods of high flow.

Regulation by Dams

Another means of promoting desirable streamflow characteristics is by building dams that store the high flow of early spring for release during summer droughts.

On the main stem of the Au Sable between the Grayling airport and Mio are three dams. Only one of these, the power dam at Mio, is regulated at the present time (1964).

Prior to December 31, 1952, a powerplant southwest of the Grayling airport regulated the flow of the river to some extent. The dam was operated for the sole purpose of power production, and no attempt was made to increase the low flow of the river by releasing the stored water. Daily fluctuations in discharge were caused by operation of the power dam. The dam is still in place, but the flow no longer is regulated.

The second dam is located at the old U.S. Highway 27 bridge at Grayling. This dam has no control mechanism and has little effect on the streamflow except in the pond that extends a short distance upstream. The Grayling stream gage is located just above this dam.

The third dam is located at Mio. Velocity and discharge are affected to a minor extent upstream to the first riffle. The Mio Dam is regulated entirely for power production, except for regulation to provide water for the annual canoe race from Grayling to Lake Huron.

In addition to the three dams described above, a small fixed-crest concrete dam is located just below Frederic, and other small dams are in the upper reaches of the river and tributaries. None of these dams are regulated, and their effect on streamflow is slight.

None of the dams on the Au Sable above Mio control the streamflow for recreational purposes. The old power dam above Grayling probably could be regulated for this purpose, although it might impair recreational values of the existing pond. Several cottages and homes are located on its banks. Drastic lowering of the pond's water level to augment low flow would not be fair to these people. Undesirable effects of such pond level reduction were demonstrated in 1953, shortly after the power plant was abandoned. At that time, the pond was almost entirely drained.

Drastic reduction of pond above Grayling in 1953.

Streamflow could be controlled by dams at several sites on upper reaches of the river and its tributaries. None of these dams, however, could be constructed without sacrificing aesthetic values. Even if future water requirements indicate the need for such dams, none should be constructed before a thorough study of their potential effects on the hydrology and biology of the watershed has been made. An artificially-controlled stream is like a caged animal—it has lost the essential character of wildness.

Water Withdrawals

A third means of insuring desirable streamflow on the Au Sable is to control withdrawal of water from the river. Withdrawals are either direct, from the river itself, or indirect, from ground water that otherwise would be part of the river discharge.

The amount of direct withdrawal from the river is very small at the present time. In a few cases water is pumped directly from the river to water lawns. Although this pumpage is minor at present, it could become increasingly significant as dwellings line both banks. The lack of control over this kind of withdrawal is evident when sprinklers are left on all day, even when it is raining. Such withdrawal on rainy days, though probably having no effect on river flow, demonstrates a lack of concern over indiscriminate consumption of surface water.

Withdrawal of ground water in the Au Sable watershed is much greater than direct withdrawal from the river. The municipal water supplies of Grayling, Gaylord, and Roscommon are obtained from wells in the glacial drift. In addition, residents of the smaller communities of Frederic, Sigsbee, Lovell, Eldorado, Red Oak, and Luzerne as well as all rural residents and cottage owners, obtain their water from wells.

Most of the industries now in this watershed obtain their water from municipal supplies, but at least one new industry intends to develop its own supply.

Water pumpage from municipal wells at Grayling and Gaylord in 1963 is illustrated in figure 26. Part of the water pumped from these wells draws water away from the flow of the Au Sable. The river loses water either because pumpage reduces ground-water flow into the stream, or, as is probably the case at Grayling, because pumping removes water from the river.

Why is not *all* of the water pumped by wells at the expense of the flow of the river? Because much of the water pumped by wells is returned to the river as sewage waste; some gets back into the ground water; and some would have been lost anyway by evapotranspiration had not pumping lowered the water table in the vicinity of the pumped well. In July, 1963, nearly half of the 24 million gallons of water pumped by the Grayling city wells was returned to the river by the sewage plant. Much of the remainder probably was lost to evapotranspiration in lawn sprinkling, while some seeped down to the ground-water reservoir, or returned to the river via storm sewers. Consumptive use of water—that part of the water supply that is not returned to the river—probably averages only about 10 percent of the water pumped each year in Grayling. In midsummer, however, when much water is sprinkled on lawns, consumptive use may increase to 20 percent or more.

How does this withdrawal affect the flow of the river? Pumpage of ground water at Grayling in July, 1963, averaged about 530 gallons per minute, or 1.2 cubic feet per second. The average flow of the Au Sable at Grayling that month was about 66 cubic feet per second. In other words, pumpage at Grayling was less than two percent of the river discharge. Consumptive use of water, therefore, was probably only a few tenths of one percent of the river flow. The Grayling city wells are located very close to the river. Even though the water-bearing formation may be separated from the river by a layer of relatively impermeable clay, pumping the wells could affect streamflow rather quickly. For example, an increase in the rate of pumping may reduce the flow of the river a few days hence. However, most of the water pumped from wells is returned eventually to the river.

The Roscommon municipal wells are located near the South Branch of the Au Sable, and a small part of the water pumped from them reduces streamflow

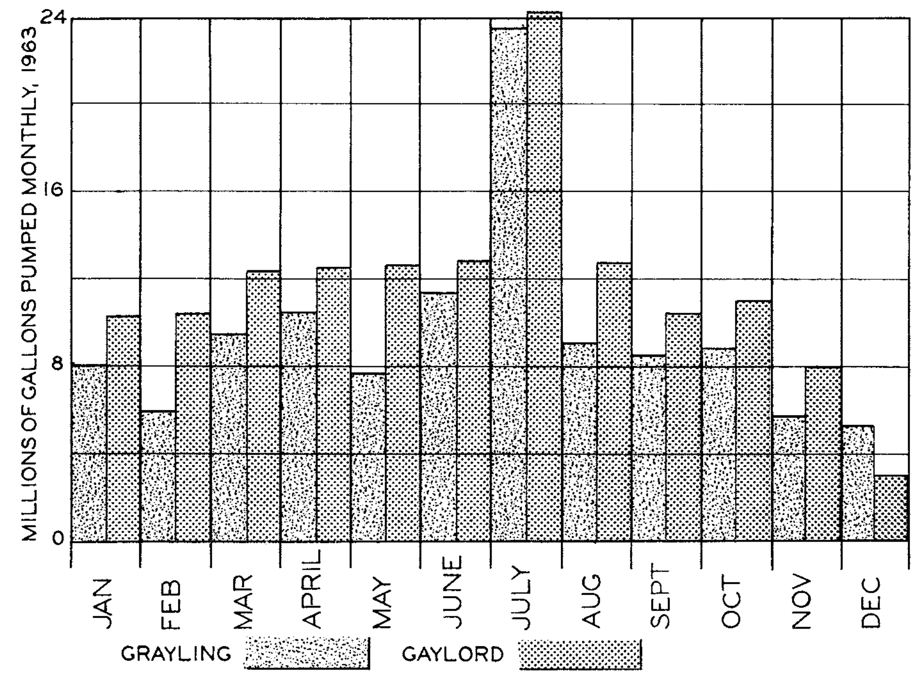


Figure 26. Pumpage of city wells is greatest during the warmest month.

in the South Branch. The estimated average pumpage of ground water from these wells in July, 1963, was about 90 gallons per minute, or about one fourth of one percent of the estimated flow of the South Branch at that time.

Unlike Grayling and Roscommon, the municipal wells at Gaylord are more than five miles from a main branch or tributary of the Au Sable system. The wells are only about two miles from the headwaters of the Sturgeon River to the north, but they are separated from the Sturgeon basin by a moraine less permeable than the outwash to the south. Pumpage of the Gaylord wells may cause a very slight reduction of the flow of both the Au Sable and the Sturgeon, but the relative amounts obtained from each system is unknown. The flow of the Manistee River to the southwest may also be very slightly affected.

Private wells in small communities and rural areas above Mio are estimated to pump an average of about 200 gallons per minute, or less than one-tenth of one percent of the average annual flow at Mio.

Pumpage of ground water at the present time is not threatening recreation on the Au Sable, but a large increase in consumptive use of water could seriously deplete the flow, especially during periods of drought. If a large increase in pumpage is needed to meet expanded demand, these additional withdrawals should be controlled to interfere as little as possible with desirable streamflow characteristics.

If wells were located farther from the river, they could be pumped without affecting the river level so rapidly. The water removed from the ground-water reservoir would lessen potential ground water discharge, but at least a part of this water would be replenished during the spring meltwater season, when streamflow is relatively high. One disadvantage of locating wells farther from the river may be increased costs of piping. Another disadvantage is increased pumping costs because of greater drawdown (lowering of water level) in the wells. In arriving at decisions, the advantages of improved streamflow conditions would have to be balanced against these increased costs.

An ideal arrangement would be to locate the wells at a distance from the river such that the effect of heavy pumping in the summer would not reach it until about nine months later during maximum streamflow. This distance can be worked out by determining the hydraulic characteristics of the aquifer.

Using recharge ponds, as described previously, is another means of augmenting public and industrial ground-water supplies.

Augmenting Low Flow

The low flow of the Au Sable probably could be increased to some extent by pumping water from wells and discharging the water into the river. Some of the water pumped by the wells would be diverted from the stream rather quickly. The net gain in low flow, therefore, would be less than the amount of water pumped by the wells. Nevertheless, the net gain in low flow would equal the amount of water removed from the ground-water reservoir during the low-flow season and replenished during the season of high flow. The greater the distance of the wells from the stream the greater the amount of water that could be removed from storage (fig. 27b). If water could be obtained from a deep aquifer separated from the river, by a layer of relatively impermeable clay, the net gain would be greater.

Channel Modification

The velocity of a river can be increased by making the stream channel smaller or by straightening the channel. Conversely, the river can be slowed by increasing the size or bend of a channel. Channel modification is generally undesirable because it destroys the natural beauty of a river. But if the natural beauty has already been destroyed by earlier modification, it can sometimes be restored to some extent.

For example, the Au Sable flows slowly through the dredged-out channel below Grayling, north of Shellenbarger Lake. In cold seasons, the water

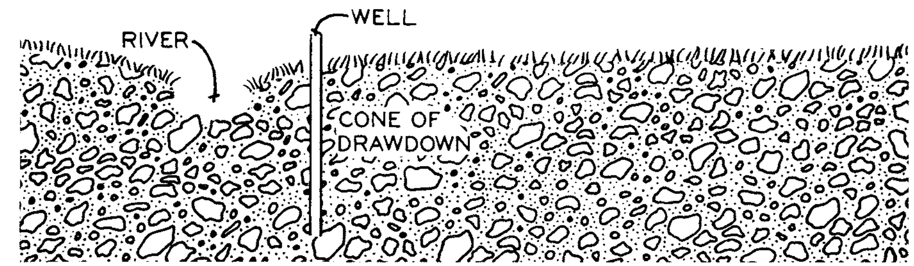


Figure 27a. Well near the bank draws water from the stream.

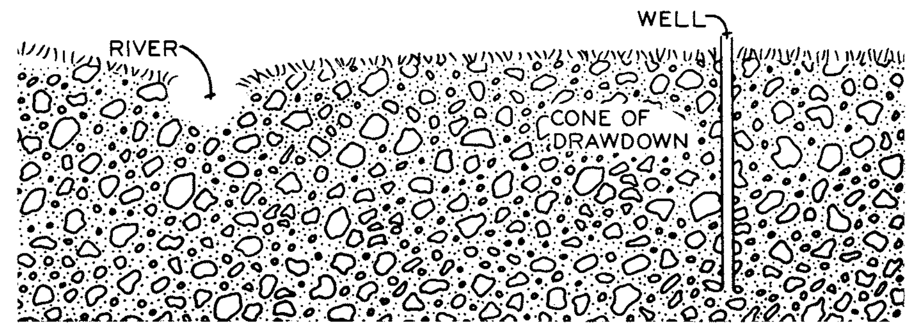


Figure 27b. Well located away from the river removes water from storage.

freezes here and doubtless the slow velocity causes higher water temperatures in summer. Velocity could be increased by constricting the channel here with sand or gravel. The advantage of such a further modification is questionable, however, because the natural relation of the stream to its channel never can be restored perfectly. As in most situations, prevention is generally superior to remedies.

In summary, the five methods of maintaining streamflow on the Au Sable are 1) to increase ground-water recharge, 2) to regulate by dams, 3) to control water withdrawals, 4) to pump ground water, and 5) to modify channels. The most natural and immediately desirable method appears to be control of forest cover for increasing ground-water recharge, although perhaps it is not the most effective in terms of quantity control. Other methods should be used only if more natural methods fail, and a thorough study insures that all effects are fully understood. Control, if not regulation, of water withdrawals will become increasingly important as water demands in the watershed increase.

Quality Controls

What can be done to keep the water of the Au Sable clear, cool, high in oxygen, attractive in appearance, and free of contaminants? Carry it further

—what can be done to improve the quality of the water for *all* uses?

The answer is to manage the flow, control the physical changes along the river bed and banks, and restrict contaminants that enter the stream.

Flow Characteristics

Management of the flow is needed because the quality of the water is strongly influenced by stage, velocity, and rate of discharge. A high sustained discharge or base flow during the warm season helps keep the water cool and high in dissolved oxygen. Benson found in 1953 that ground-water inflow, with attendant low summer water temperature, was the chief controlling factor in trout populations in the Pigeon River of Michigan. A high rate of sustained discharge also dilutes any sewage or other contaminants entering the stream. A relatively uniform level and velocity lowers turbidity because the river remains near equilibrium in its silt-carrying capacity. A minimum amount of surface runoff also reduces the silt load.

The same practices for maintaining the flow of the river are also desirable for quality control. High ground-water recharge with consequent high ground-water discharge to the river is especially desirable. The effect of ground-water discharge (spring flow) on water temperature is illustrated in figure 21.

Dams

Regulation of flow by dams can improve the quality of water by increasing the low flow to dilute waste. The only dam above Mio that could be used for this purpose is the abandoned power dam above Grayling. Regulation of this dam for quality control, however, would destroy the recreational value of the pond.

Construction of dams specifically for quality control does not appear necessary at this time.

Bed and Banks

A good tree cover on the banks of the river provides shade which lowers water temperatures and promotes a higher dissolved oxygen content. The rise in temperature of water on the East Branch (fig. 21, p. 45), as it flows through "The Meadows" demonstrates this effect. Wherever possible, trees and shrubs should be planted along the banks to help cool the stream. Tree cutting along the riverbanks should be discouraged. A cover of trees and shrubs also protects the banks from erosion and reduces turbidity of the river.

Bulldozing, scraping, dredging, and other rearrangement of the landscape increase the turbidity of the water and may cause silt and sand to be deposited over gravel beds. Widening the river increases the area of surface exposed to sunlight and may raise the temperature of the water. Reducing the width of the river by log jams or by fill may help cool the water, but these practices are aesthetically objectionable.

To maintain the quality of water in the Au Sable, the bed and banks should be kept in as natural a condition as possible. Where tree cutting and bank deterioration already has occurred, the quality of the water can be improved by planting trees and shrubs to control erosion and shade the river. Protecting the banks by rip-rap of logs, rock, and stumps should be limited to areas where more natural methods are not practicable.

Contaminants

The sewage effluent from Grayling and Roscommon causes a minor deterioration of the quality of water in the Au Sable (fig. 18, p. 43). Gaylord's effluent is disposed in a pond southeast of town several miles from the river, therefore has no effect on the quality of water of the Au Sable. Sewage effluent from cabins along the river also has little effect on water quality at present. Contaminants other than sewage wastes are not a serious problem on the Au Sable today.

State and local agencies have kept the water in the Au Sable of excellent quality for recreational use. But these public agencies need continuing public understanding and support.

A large expansion in city populations in the watershed, or unlimited cabin development along the banks could ruin the Au Sable as a recreational river. A new industry discharging toxic or noxious wastes could ruin it even more rapidly. Pesticide spraying of forests could kill the fish. Uncontrolled disposal of brines from a new oil field could make the water too salty for recreational use.

Increases in industry, urbanization, and cabin development are inevitable. The effects of such development on recreational resources must be understood, measured, and evaluated so that informed citizens can make wise choices among conflicting demands.

Before intelligent decisions can be made, it will be necessary to monitor the quality of water in the Au Sable at stations below Grayling and Roscommon, and at other stations on the river. Dissolved oxygen, turbidity, and temperature should be checked in particular. Chlorides, nitrates, phosphates, pH, detergents, and pesticides should be determined occasionally. Other determinations should be made if there is reason to suspect other contaminants. For example, determinations of phenols should be made if an industry discharging phenolic wastes should move into the watershed.

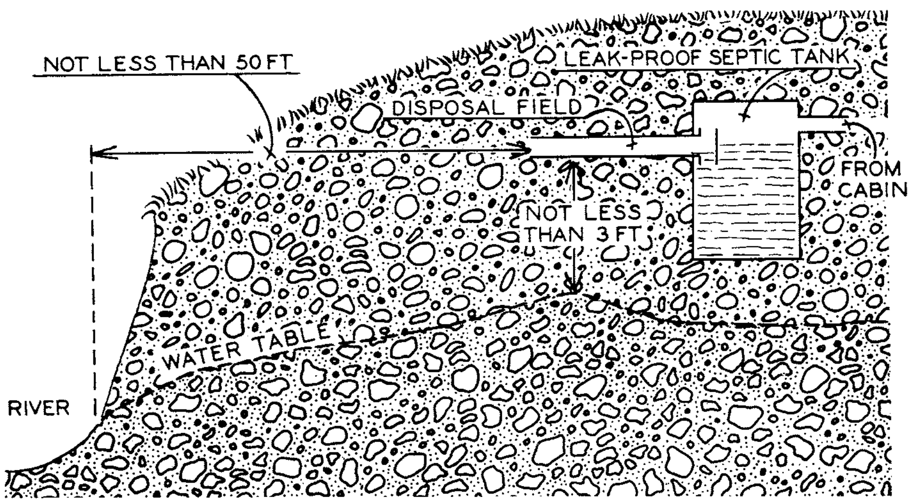


Figure 28. Disposal systems can be designed to reduce pollution. (Note mounding of water table beneath disposal field.)

Whenever any deterioration in quality of water is found, the cause should be identified at once. Suppose an increased discharge of effluent from the sewage disposal station at Grayling causes a decline in dissolved oxygen below the desired limits for a trout stream. A decision may be made to improve the dissolved oxygen content by carrying treatment of sewage a step further before releasing it into the stream. This would reduce the biochemical oxygen demand and temperature loading. Or, the sewage effluent might be diluted by increasing the low flow of the river. The feasibility of using a sewage lagoon for disposal may be investigated. State water agencies stand ready to assist local governments solve their pollution problems. Regardless of action taken, the quality of water must be monitored to demonstrate effectiveness of the remedy.

Primary treatment of sewage and chlorination of the effluent are practiced at both Grayling and Roscommon. The major reason for constructing these plants was to protect the sanitary quality of the water, but in reducing the B.O.D., fishing and other recreational uses are also benefited.

The Grayling disposal plant usually removes 35 to 50 percent of the B.O.D., depending chiefly on the amount of sewage and water going through the plant. Because part of the storm drainage from Grayling goes through the plant, heavy rains decrease its efficiency.

Addition of secondary treatment to these disposal plants probably could raise the efficiency of B.O.D. removal to as high as 90 percent.

Further investigation may show that a decline in dissolved oxygen is not caused by sewage effluent from a town, but is chiefly the result of increased septic tank effluent and temperature loading from cabins along the river. If

this is the case, then individual disposal systems should be checked to insure that dry wells and drain tiles are well above water table and are well removed from the river. A check should also be made to insure that sewage is not piped directly to the river.

The B.O.D. of septic tank effluent is quickly reduced in the zone of aeration (above the water table) as water percolates down to the water table. However, if the drain tiles or dry well are located below the water table, the B.O.D. is reduced very slowly because free air is not available to oxidize the wastes. Drain tiles and dry wells should be at least three feet above water table whenever possible (fig. 28).

As septic tank effluent moves toward the river in the zone of saturation below the water table, the filtering action of the glacial aquifers removes much of the bacteria from the water, and the water is cooled by heat exchange with the earth materials. B.O.D. is also reduced as the water moves through the aquifer, although very slowly. Drain tiles and dry wells should be at least 50 feet from the river.

In no instance should septic tank effluent be discharged directly to the river. Such direct and unsightly discharge is loaded with B.O.D. and coliform bacteria, is usually much warmer than the river water, and a menace to health.

If sewage disposal from riverside cabins does not meet requirements outlined above, every effort should be made to improve the individual systems. More important, all new cabin development should include adequate disposal systems. Possible restrictions and specifications are discussed later.

What about other contaminants that may show up by monitoring water? If the contaminant is a waste material from an industry, the amount of waste discharged, how and where it is discharged, and how it reaches the river must be determined. Next it should be determined whether the waste can be reduced or eliminated or disposed of in such a manner that it will not unduly degrade the quality of the water.

Correcting the errors leading to contamination is good, but avoiding the errors in the first place is much better. Mention has been made of restrictions on individual sewage disposal systems to protect the quality of water. Possibly firm plans should be devised to improve the treatment of municipal sewage as population increases. If a new industry plans to move into the watershed, the assistance of state water agencies should be called upon to look into the possible effect of its waste products. For example, when a large waste-producing industry recently proposed to locate in the headwaters area of the Au Sable, the Michigan Water Resources Commission cooperated with the industry in evaluating the waste problem. Controls needed to prevent unlawful pollution were identified. As a result, the industrial development to date has been entirely compatible with water resource values for recreation. Any future expansion must also comply with requirements of state laws as administered by this agency.

It is not easy to reject an industry that will provide much needed jobs, but we should make sure that the gain is worth the price we may have to pay in the deterioration of the river.

Bed and Bank Controls

In addition to water quality control, management of bed and banks is necessary to protect their appearance.

One of the most serious hindrances to enjoyment of the river is the huge quantity of litter on bed and banks. To quote R. M. Hayes of the Grayling Chamber of Commerce: "Twice each year it is necessary to clean the bottoms of the South Branch and Main Stream of the Au Sable in Crawford County. Our signs posted in various places and bridges, our free river litter bags and word-of-mouth caution from canoe livery operators does little to keep the trash in the canoes of the many thousand people who float these rivers each season." Not only is this corruption unpleasant to the eye, but is an unmitigated hazard to swimmers and wading fishermen; it also gouges the bottoms of passing canoes. Garbage from picnickers and campers decomposing in the water creates additional oxygen demands.

Littering must stop if recreational values of the river are to be preserved. It is moot how this can best be accomplished. It should be recognized, however, that effective control requires the cooperation of all who visit the river.

The same cottage dweller who rightly condemns the litterbug may also violently protest any implication that he, the cottage dweller, is guilty of harming recreational values of the river. Nevertheless, well-cared-for and beautifully-landscaped cabin grounds are not necessarily welcome sights to recreationists who are enthralled by the wonder of natural beauty. The manicured lawns, jutting boat docks, lawn chairs, and palatial houses all jar upon the sense of isolation in nature.

How to reconcile the desire for isolation of the nature-seeker with equally-valid wish of the cabin-dweller to enjoy the river? One possible solution is voluntary zoning of the river front to allow maximum enjoyment for all users. A strip 10 feet wide bordering each bank could be planted in trees or shrubs to partially screen cabin grounds from the river. This sylvan screen would also give the cabin-dweller some much-needed privacy from canoe traffic. To permit the cabin-dweller to view the river from his house, a gap in the screen 20 feet wide could be used. Boat docks could be limited to ten feet length along the banks and four feet protruding into the river. Covered boat docks might be prohibited. Buildings might be placed at least 50 feet from the river. The size of the cabin could be limited to ten square feet of floor space for every lineal foot of river frontage (fig. 29). These zoning regulations could not apply to already-constructed homes, but present cabin dwellers could be encouraged to plant a buffer zone of trees along the river. Regulations

would also be required to prohibit dredging and deepening of the river bottom, diverting or widening the river channel, removing logs or other natural cover, or altering bed and banks in any manner save for construction of a small boat dock.

Another desirable restriction, not easy to enforce, would prohibit bulldozing or rearrangement of the landscape in any way except for minimum excavation required to provide a substantial foundation for buildings.

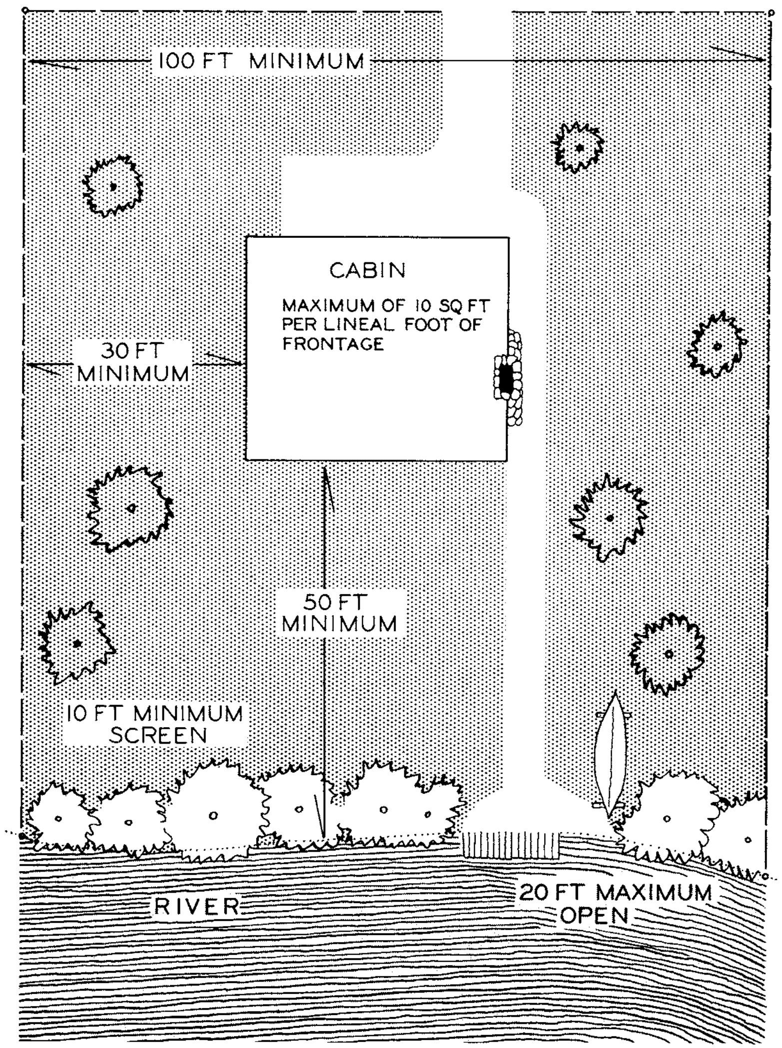


Figure 29. Zoning agreements can enhance the recreation value of a river for everyone.

An obvious solution to the problem of degradation through development of cabin sites is to obtain public ownership of all undeveloped river frontage. Because of the high and ever-increasing value of river frontage, it is unlikely that all undeveloped frontage can be acquired for public use. Possibly some undeveloped stretches could be purchased where large frontages are owned by private industries. Undeveloped frontage in swamp areas might be purchased at relatively low cost.

Of the 200 miles of river frontage (both sides) on the Au Sable and major tributaries above Mio, about 100 miles are owned by the Consumers Power Company of Michigan. These lands now are managed to permit maximum recreational benefits within the limits imposed by needs of the company. R. H. O'Neil, Company Forester, described conservation practices of the Company as follows (Written Communication, 1964):

"Our Company has practiced conservation of natural resources for many years, and this practice includes making reservoir and river lands available to those who enjoy the outdoors. Fishing, hunting, hiking, camping, winter sports and similar activities are publicly permitted insofar as may be consistent with the proper operation of our hydroelectric plants for water power and other public purposes.

"Most of these lands have remained in their natural state for many years and, therefore, afford excellent cover for wildlife. It has been estimated that thousands of deer hunters use the Company's lands during the hunting season. Many campers utilize these lands during canoe or boat trips down some of these rivers. The Company has been one of the co-sponsors of the Au Sable River Valley Canoe Race which is held annually on the Au Sable River. Boy Scout troops, church groups and youth organizations also make use of these lands for their activities.

"The Company also leases certain portions of its land to various groups and individuals. There are 61 sites along these rivers leased at a nominal rental to public agencies, such as the State Conservation Department, the State Highway Department, counties and townships for parks, fishing sites, camp sites, boat landings and picnic areas.

"Additionally, we also lease approximately 450 parcels of land to individuals for cabin sites and recreational purposes. Each site consists of about 20 acres and averages 600 feet of river frontage. The lessee is neither permitted to fence this land nor to exclude public hunting and fishing on these leased lands without the written consent of the Company, and each lease is made subject to the unobstructed use of the premises by the Company for any purpose in connection with its utility business.

"Starting in 1924, the Company undertook to bring all of these hydro-related lands under a forest management program. Forest cover for timber production is maintained. Wildlife and recreational resources and uses are recognized and co-ordinated. Open areas have been gradually planted to pine and other soft woods during the intervening years. Existing second

growth stands, and natural reproduction of hardwoods and conifers have been protected and managed for the immediate purpose of producing wood crops on a sustained yield basis. Of equal concern and interest to the Company, of course, were the other supplementary benefits of good forest management. Maintenance of forest cover on the lands has modifying influences on the regulation and stabilization of surface water runoff, and pond and soil water levels. Additionally, soil erosion was retarded and the effects of siltation in the ponds were minimized.

"We sell merchantable stumpage on the open market and thereby directly contribute to the economy of the State. Wood products find their way into the pulp and paper market, the saw log industry, the pole and piling industry and the Christmas tree market. Eventually we hope, of course, to harvest numerous red pine poles from our plantations for our own use.

"The Company budgets a modest amount of money to cover costs incurred for timber stand improvement and protection from fires, insects, and diseases."

Because of the size of these holdings the future of recreation on the Au Sable could easily depend to a large extent on the ultimate use or disposal of these lands. So long as present practices continue the bed and banks of a large part of the river will be preserved for public enjoyment.

Grants of frontage from public-spirited citizens also could be encouraged. Probably the most attractive stretch of river in the Au Sable watershed is that contained in Mason's Grant on the South Branch. Campsites and recreation areas could be named after the donors, and the wishes of donors regarding restrictions on use of the property should be strictly enforced.

A combination of responsible use, well-managed public frontage, and wise restrictions on private frontage could preserve the attractiveness of bed and banks of the Au Sable now and for future generations.

Key to the Future

Predictions of the future on the basis of present trends are by no means infallible, because the trends themselves are changeable and changing. Managed changes are needed. They could be brought about by government ownership of land, public laws, or private responsibility and cooperation.

Government ownership permits public agencies to manage water resources in accordance with hydrologic principles. Such practices can be instituted only with public approval. The high cost of frontage precludes public ownership of the entire Au Sable. Selected areas fronting the river, however, could be added to the public lands. Grants of lands from private donors, too, may be added.

Perhaps enactment of certain law, e.g., limiting the number or size of cabins per unit of river frontage, requiring adequate treatment of cabin wastes, restricting dredging of river bottoms and the cutting of trees along the bank would help slow down present trends. Here again, public awareness and support is absolutely necessary.

Finally, the key to the entire situation is private responsibility and cooperation. The Au Sable cannot be saved without it.

The future of the Au Sable is in the hands of those who love it. This paper, hopefully, will encourage citizens to take action — for themselves and for those who come after them. Those who have a stake in the future of other rivers should likewise examine that future in the light of the problems on the Au Sable.

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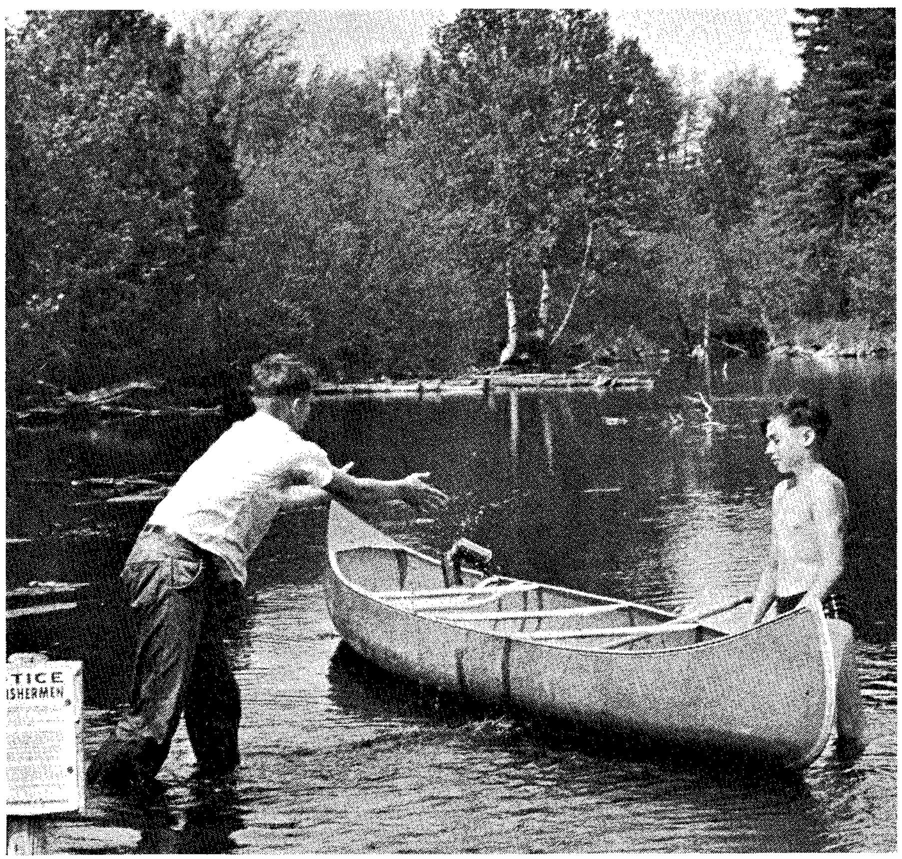
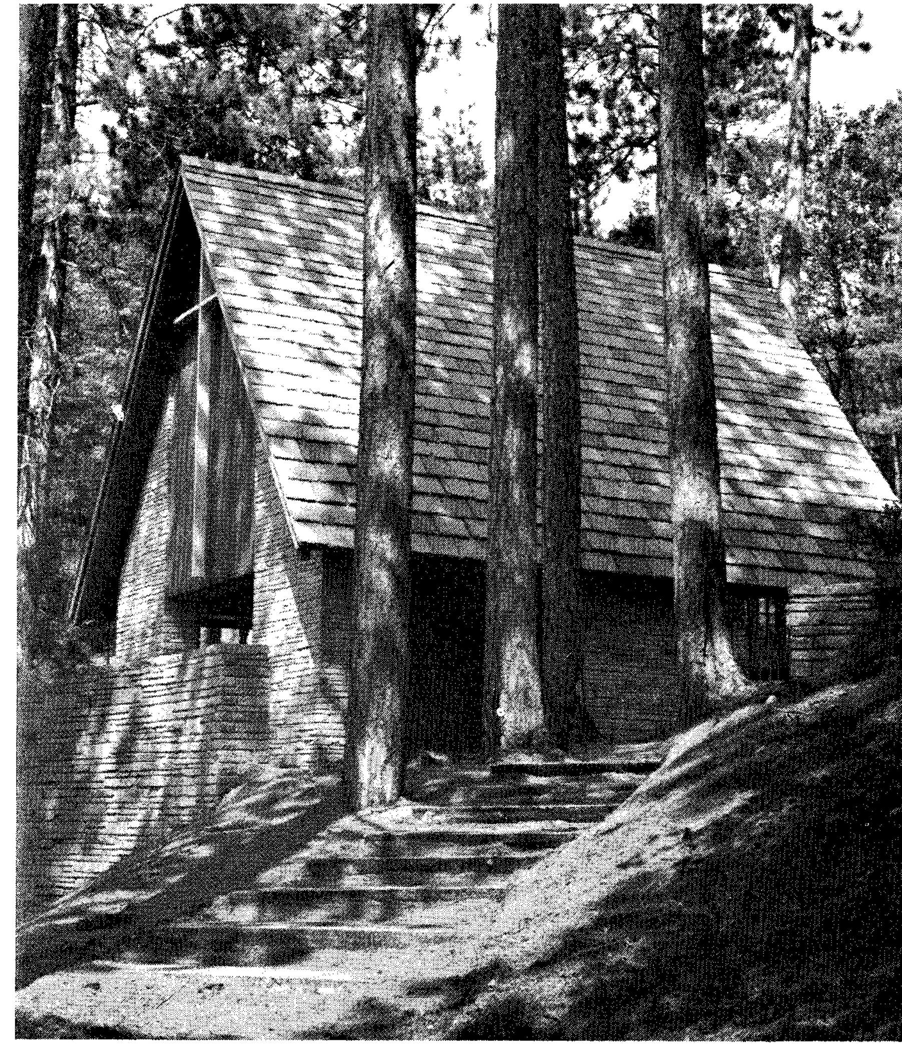
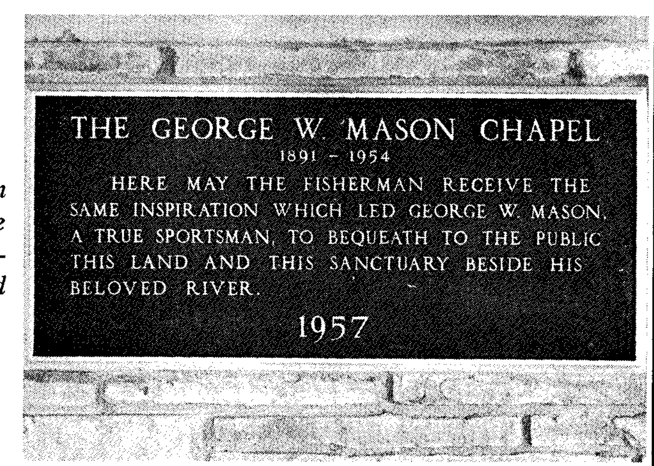


Clean-up projects along the river have become an annual necessity to keep the stream from becoming a junk-littered creek. Boy Scouts from Grayling, Roscommon, and other communities have turned out in recent years to carry on the litter-removal work. Here two scouts lift beer cans from a gravel bed in the river.





The well-known Mason Chapel on the South Branch of the Au Sable is visited annually by growing numbers of fishermen, canoeists, and passing campers.

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Glossary

NOTE: Definitions do not include all possible usages—only as used herein.

Aquifer — A water-bearing formation capable of storing water and allowing water to pass through it.

B.O.D. — Biochemical oxygen demand. The potential amount of oxygen that will be used up in oxidation of organic material.

Braided channels — Channels of a single stream that divide and reunite, resembling the strands of a braid.

Colorometric analysis — Analysis of dissolved material by measuring the intensity of color of a prepared solution.

Defoliation — Removing the leaves of trees and other plants.

Discharge — Rate of flow in volume per unit of time.

Drawdown — Lowering of the water table caused by pumping a well.

Drought flow — The flow of a stream during extended dry periods; low flow.

Evapotranspiration — Water returned to the air through direct evaporation or by transpiration of plants.

Fixed-crest dam — A dam having a spillway or overflow that is not adjustable; hence the water spills over a fixed crest.

Glacial drift — All materials deposited by glaciers, whether directly from the ice, or indirectly by meltwaters from the ice.

Ground moraine — Gently rolling hills underlain by till. Usually lack the ridge-like character of moraines.

Ground water — Water in permeable earth materials in the zone of saturation — below the water table.

Ground-water flow — Water that moves through the zone of saturation.

Headwaters — The upper reaches of stream courses; the source-area of streams.

Lake plains (glacial) — The bottom surface of abandoned lakes that were formed by glacial meltwaters. Usually underlain by layered deposits of sand, silt, and clay.

Moraine — Hills or ridges composed of glacial till.

Outwash — Sorted and bedded glacial drift deposited by meltwater streams beyond active glacial ice.

Overland flow — Water that runs over the land surface to a stream.

Oxygen sag — The decrease in dissolved oxygen content in a stream below the point of introduction of sewage or other organic material.

Permeable — Permeable materials allow water to pass through them.

pH — A measure of the intensity of acidity or alkalinity of water. A pH of 7 indicates water that is neutral — neither acid nor alkaline; pH above 7 indicates alkalinity, pH below 7 indicates acidity.

Recharge — Water that is added to the zone of saturation.

Riffle — A shallow extending across the bed of a river; a small rapid.

Sheer — The longitudinal upward curvature of the lines of a boat.

Sorted deposits — Sediments of relatively uniform grain size or weight.

Stage — Elevation of water surface above any chosen datum plane; water level; gage height.

Sweepers — Trees that have fallen across a river in such a way as to hinder or obstruct boat passage.

Till — Mixture of clay, silt, sand, gravel, and stones deposited directly by glacial ice with little or no sorting by meltwaters.

Titration — Analysis of dissolved material by adding a measured amount of a prepared solution to bring about a given reaction.

Turbidity — Cloudiness of water.

Watershed — The surface area contributing to the flow of a stream above a given point.

Water table — The upper surface of the zone of saturation.

Zone of aeration — Permeable earth materials above the water table. Pore spaces are not completely filled with water; hence they contain some air.

Zone of saturation — Permeable earth materials below the water table. Pore spaces are saturated with water.

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Abstract

The Au Sable River is one of Michigan's finest streams for fishing, canoeing, camping, and cabin living. Preservation of its recreational values depends upon practices such as: managing the forests to promote ground-water recharge, regulating withdrawals of water, protecting the river from harmful contaminants, and restricting alterations of bed and banks. Control of streamflow by artificial methods should be attempted only if more natural methods fail. Records should be kept of changes in streamflow characteristics, quality of water, and character of bed and banks to provide information needed for future water-management decisions.